

Assessment of Natural Regeneration under Different Silvicultural Treatments in Bobiri Forest Reserve in Ghana

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Abstract

This study was conducted in Bobiri Forest Reserve in Ghana to assess natural regeneration under three (3) silvicultural treatments: The Tropical Shelterwood System (TSS), Post Exploitation System (PES) and Girth Limit Selection System (GLS). Data were collected on seedlings with height ≤ 30 cm in one-hectare plots under each silvicultural treatment. The k-tree sampling method was used to establish five (5) sub-sampling plots. 25 seedlings were enumerated in each sub-sampling plot making a total of 125 seedlings. 375 seedlings were enumerated per silvicultural treatment making a total of 1,125 seedlings in three (3) silvicultural treatments. Microsoft Excel was used for cleaning data and computing seedling relative density, and R software was used to compute seedling species abundance, diversity and richness indices. Statistical Package for Social Sciences version 25 was used to test for differences in seedling species abundance, diversity and richness between the three (3) silvicultural treatments using Games–Howell test. There was no significant difference in mean relative density of seedlings between TSS and PES ($P = 0.794$), TSS and GLS ($P = 0.603$), and PES and GLS ($P = 0.965$). The seedling species dominance in three (3) silvicultural treatments showed that *Nesogordonia papaverifera* had high relative density in TSS (17.6%) and PES (24.0%), and *Celtis mildbraedii* in GLS (19.2%). Seedling species abundance was statistically distinct between three (3) silvicultural treatments ($P = 0.023$), and between GLS and TSS ($P = 0.015$) but was not different between GLS and PES ($P = 0.553$). Seedling species richness differed significantly between three (3) silvicultural treatments ($P = 0.032$), and between TSS and GLS ($P = 0.04$) but not different between PES and GLS ($P = 0.778$). TSS needs to be emphasized to enhance biodiversity and natural regeneration in Bobiri Forest Reserve and similar tropical forest ecosystems. TSS proved effective in promoting natural regeneration. However, given the implications of treatment cost, this study recommends to adopt a more practical and cost-effective approaches such as pre and post-harvest tending operations to enhance regeneration and biodiversity.

Keywords: Seedlings, Silvicultural Treatment, Natural Regeneration, Species Abundance, Species Richness, Species Diversity, Species Relative Density

1. Introduction

Tropical forests play an important role in climate and water cycle regulation, the global carbon cycle, and

the world's terrestrial biodiversity [2, 48, 10]. For example, it is estimated that tropical forests support the needs of 1.5 billion people through the goods and services they provide [16]. Despite their critical importance, tropical forests are under severe threat, with approximately 13 million hectares lost to deforestation and 500 million hectares degraded annually [30]. Given their critical ecological, social and economic functions, reversing degradation and restoring tropical forests has become an urgent and growing priority globally [20, 30, 24]. Therefore, understanding forest regeneration is a crucial requirement for ensuring their long-term survival [26].

In many tropical forests, natural regeneration is the sole mechanism for restoration of degraded forest ecosystems [46, 5]. In regions where forests can regenerate naturally or with minimal help, natural regeneration is more cost-effective, ranging from US\$12 to US\$3,880 per hectare, compared to US\$105 to US\$25,830 per hectare for forest restoration in tropical and subtropical areas [36, 35, 47]. Although the role of artificial regeneration, enrichment planting and plantations is becoming more important [14]. Forestry in Ghana relies on natural regeneration as an important driver of timber source in its many forest reserves [45].

Natural regeneration is influenced by many biotic and abiotic factors and forest in turn can influence these factors through canopy opening and thus creating a different situation in terms of quantity and quality of light [27, 7]. The environmental conditions for tree growth on the site can be improved [21]. The question of the degree of canopy opening and the benefits and pitfalls going along with it, may be one of the most contentious discussions in forestry [13]. With regard to the biotic factors, several environmental and over-story factors affect natural regeneration and limit both species composition and diversity. For example, rainfall reduction affects regeneration of most plant species since most species are affected by environmental factors at the seedling level [13]. Hishe et al. [19] found that regeneration abundance was positively associated with soil quality ($P = 0.001$), canopy cover ($P = 0.04$), and precipitation ($P = 0.01$). Studies conducted on over-story structure looking at species distribution and canopy closure, show that canopy closure affects species diversity and composition (6, 19). Duah-Gyamfi et al. [11] demonstrated beneficial effects of logging disturbance on natural regeneration in a moist semi-deciduous tropical forest in Ghana's High Forest Zone. Duah-Gyamfi et al. [11] highlighted that logging disturbances such as skid trails and tree gaps, initially enhanced natural regeneration by increasing seedling recruitment, density, and growth rates, particularly for pioneer species. For example, seedlings densities peaked at 1.36 seedlings per square meter on secondary skid trails, compared to just 0.32 seedlings per square meter in unlogged areas, and canopy openness in logged areas reached 14.7% facilitating this process. However, the study also noted that these benefits diminished over time, emphasizing the need for sustainable management practices to maintain long-term regeneration success. Disturbances such as timber harvesting and pre or post-harvest interventions can stimulate generation and growth of tree species [25].

The present study was carried out in Bobiri Forest Reserve (BFR), located in Ghana's Ashanti region. The focus was on assessing seedling species abundance, richness and diversity in an area where three different forest management regimes had been tested about 50 years earlier. The impact of the silvicultural treatments on forest structure and dynamics as a whole has been intensively researched in the study area by Foli [15].

1.1 Overall objective

The broad goal of this study is to contribute to sustainable management of tropical forests by assessing how silvicultural treatments influence natural regeneration and species composition in tropical moist forests in terms of seedling species abundance, diversity, and richness.

1.2 Specific objectives

1. To compare relative density of seedling species under the three (3) silvicultural treatments (TSS, PES, GLS).
2. To compare seedling species abundance, diversity, and richness under the three (3) silvicultural treatments (TSS, PES, GLS).
3. To evaluate effectiveness of the Tropical Shelterwood System (TSS) in enhancing seedling species diversity and richness relative to less intensive treatments (PES and GLS).

These objectives are premised on the following hypothesis:

1. It was hypothesized that the relative density of seedling species will be different under the three (3) silvicultural treatments (TSS, PES, GLS).
2. It was also assumed that seedling species abundance, diversity, and richness under the three (3) silvicultural treatments (TSS, PES, GLS) are distinct.
3. It was further hypothesized that treatments under the TSS will promote higher seedling species diversity and richness relative to PES and GLS.

All hypotheses were tested at a significance level 5%.

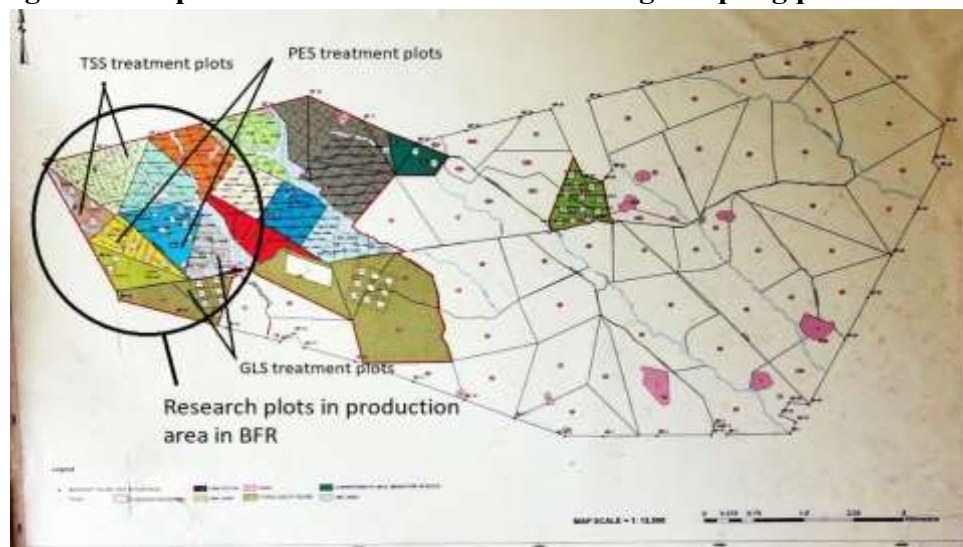
TSS, PES and GLS are Tropical Shelterwood System, Post-Exploitation System and Girth Limit Selection System, respectively.

2. Materials and Methods

2.1 Study area

Bobiri Forest Reserve (BFR) is located 30 km East of Kumasi city in the Ashanti region of Ghana, between latitudes 6° 40' and 6° 45' N and longitudes 1° 15' and 1° 23' W. The forest covers an area of 5,450 ha [3, 9] in the moist semi-deciduous forest sub-type of Ghana [11, 9]. The altitude of BFR ranges from 183 m to 284 m above sea level [3]. Annual rainfall ranges from 1,200 mm to 1,750 mm with two rainy seasons from March to July and from September to November [32, 9]. BFR is managed by the Forestry Research Institute of Ghana (FORIG) [3, 4] and is divided into four (4) management areas: research, butterfly sanctuary, strict nature reserve and production area, where sustainable forest management takes place (Figure 1).

Figure 1: Map of Bobiri Forest Reserve showing sampling plots of one ha



2.2 Silvicultural treatments in the study area

In BFR different forest management systems were experimentally tested (Table 1) until about 1970 (Foli, pers. comm.) because the timber yields could not justify the high operation costs of TSS and PES regimes. Natural regeneration of the commercially valuable tree species that were targeted under these treatments was also assessed to be relatively too low to justify the high cost of the interventions [15]. Foli’s study [15] showed that 40 years after the silvicultural interventions, stem densities and basal areas were generally higher in the treated forest relative to unlogged forest and that advanced regeneration was better developed where more intensive treatments took place.

Table 1: Forest management regimes in Bobiri Forest Reserve

	Tropical Shelterwood System (TSS)	Post Exploitation System (PES)	Girth Limit Selection System (GLS)
Relevance for forest management in Ghana	Introduced as a modification of the Malaysian Uniform System, MUS [15]. Abandoned in 1970 due to insufficient regeneration as an effect of limited seed sources and exploitation [15].	Introduced as a variant of TSS but not continued [15].	Main forest management system [15, 11].
Differences in practice as applied in Ghana	<ul style="list-style-type: none"> • There was a gradual opening of the canopy from below to allow regeneration under the canopy of the “shelterwood” • Post-harvest operations such as climber cutting and removal of undesirable regenerating species were carried out 	<ul style="list-style-type: none"> • PES involved harvesting of the harvestable timber allowing regeneration to occur in the spaces created. • Post-harvest operations such as climber cutting and removal of undesirable regenerating species were carried out 	<ul style="list-style-type: none"> • Limited post-harvest operations to promote regeneration. • GLS entailed the selective harvesting of mature timber (2-3 trees per ha) allowing regeneration to take place. • Post-harvest operations were not carried out like in TSS and PES except for pre-harvest climber cutting.
Measures for improvement of regeneration	<ul style="list-style-type: none"> • Possibility for amount of light. • Thinning under controlled conditions reduces risk of encroachment. [15]. 	<ul style="list-style-type: none"> • Possibility for amount of light. • Thinning under controlled conditions reduces risk of encroachment. [15]. 	The low intensity logging ensured better regeneration [11].

2.3 Sampling method

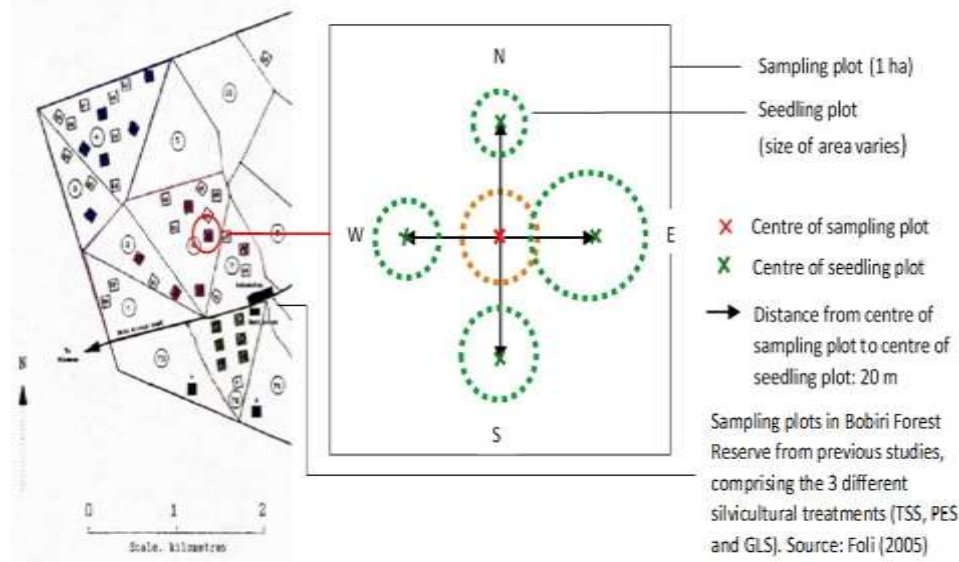
The sampling method applied for this study was k-tree sampling method, a variation of point-to-tree-distance techniques [39, 37] also known as plotless method [23, 33]. With k-tree sampling method, the size of each of the sampling plots was determined by the distance of the kth object to the sampling point. In general, feasibility and cost are the main reasons why the k-tree sampling method is increasingly applied [23, 40].

From the existing one (1) ha sampling plots per treatment that were used by Foli [15], three (3) sampling plots per treatment were selected for this study making a total of nine (9) sampling plots. In each sampling plot, five (5) sub-sampling plots were established making 15 sub-sampling plots per treatment. A total of 45 sub-sampling plots were established in all treatments (Table 2). In each sampling plot, the centre was located and the first sub-sampling plot was determined. The four (4) remaining sub-sampling plots were established in North, East, South and West directions at 20 m distance from the centre of the sampling plot (Figure 2).

Table 2: Number of sampling and sub-sampling plots

Silvicultural treatments	No. sampling plots per treatment	No. of sub-sampling plots per treatment	Total sample plots per treatment
Treatment 1 (TSS)	3	5	15
Treatment 2 (PES)	3	5	15
Treatment 3 (GLS)	3	5	15
Total	9	15	45

Figure 2: Sub-sampling plots established using k-tree sampling method



2.4 Seedling variables assessed

This study focused on assessing natural regeneration dynamics in Bobiri Forest Reserve, Ghana, under three (3) silvicultural treatments: The Tropical Shelterwood System (TSS), Post Exploitation System (PES), and Girth Limit Selection System (GLS). The study assessed relative density, seedling species abundance, diversity, and richness widely recognized as key indicators of forest regeneration dynamics

[42, 28, 31]. Seedling diversity was measured using Shannon-Wiener and Simpson diversity indices, with the reciprocal of Simpson's Dominance Index [22] improving interpretability. GLS recognized as the primary forest management system in Ghana [15] represented the control facilitating comparative analyses with TSS and PES.

2.5 Data collection

Data were collected in the Eastern part of BFR. For this study, k was fixed as 25 seedlings. This estimation was tested during the counting of the first five (5) sampling plots and confirmed to be appropriate, taking advantage of the k -tree-distance method. The fixed number of seedlings was reached in a short time and the size of the sub-sampling plots remained small. This was crucial in order to combine short time frames for field work with robust statistical analysis. In each one (1) ha treatment sampling plots, a starting point for seedling data collection was purposively selected to coincide with the centre of the plot. The centre of the plot was pegged using a stick and a red ribbon tied on the stick for visibility. The location was marked and coordinates were located using a GPS. A string was tied to the stick at the centre and used to “sweep” the study site. In each of the sub-sampling plots established, 25 seedlings with height ≤ 30 cm were identified (local and scientific names) assisted by two (2) botanists and the field guide from Hawthorne & Gyakari (2006). Counting started with the seedling nearest to the centre of the sub-sampling plot. Height of seedlings was taken with a calibrated stick within seedling height classes (0-10 cm, 11-20 cm and 21-30 cm). Once the first sub-sampling plot was finished, four (4) other sub-sampling plots were located in 20 m distance from the centre of sampling plot in North, East, South and West directions, respectively, using a compass (Figure 2). In each sub-sampling plot, canopy openness was estimated visually by two (2) team members independently and the average of the two estimates was recorded. Further, the slope in each sub-sampling plot was measured using a Suunto hypsometer. The K-tree sampling method optimized data collection precision and allowed for robust comparisons across treatments.

2.6 Sub-sampling plot computations

2.6.1 Seedlings density

The area of sub-sampling plots was calculated once the 25th seedling had been counted, taking the distance from the 25th seedling to the centre as the radius of the sampling plot. The size was calculated using the circle area formula (πr^2) to avoid over estimation bias that is associated with the k -tree sampling method since calculating with the smallest possible sample size area means to apply the largest expansion factor [23]. The following adjustment was made: The sampling area was calculated with the arithmetic mean of the two distances to the k and to the $(k + 1)$ object; k distance being the 25th seedling and $(k+1)$ the distance to the 26th seedling. The extension for calculating seedling density per hectare was done with the expansion factor (EF) = 10,000/sample plot area.

The effect of over estimation is illustrated by the following example:

(a) Expansion Factor (EF) based on size calculation without adjustment

For $k = 25$, seedling density per hectare is calculated as follows:

Distance from the sampling point to k^{th} (25th) seedling: 1.96 m

Radius (r) = 1.96 m

Sub-sampling plot area: $\pi r^2 = 12 \text{ m}^2$

Seedling density: $25/12 \text{ m}^2 = 2.08 \text{ per m}^2$

The Expansion Factor (EF) to 1 ha = $(10,000 \text{ m}^2/12 \text{ m}^2) = 833.3$

Seedling density per ha: $2.08 \times \text{EF} = 2.08 \times 833.3 = 1,733 \text{ seedlings per ha}$

(b) Expansion Factor (EF) based on size calculation with adjustment:

Distance from the sampling point to the kth (25th) seedling: 1.96 m

Distance from the sampling point to the kth + 1 seedling (26th): 2.16 m

Radius (r) = (1.96 m + 2.16 m)/2 = 2.06 m

Sub-sampling plot area: $\pi r^2 = 13.3 \text{ m}^2$

Seedling density: $25/13.3 \text{ m}^2 = 1,8797 \text{ per m}^2$

The Expansion Factor to 1 ha = $10,000 \text{ m}^2/13.3 \text{ m}^2 = 751.9$

Seedling density per ha: $1.8797 \times 751.9 = 1,413 \text{ seedlings per ha.}$

In this study, option (b) was applied to estimate seedling density per ha. The choice of option (b) over (a) was based on the need to minimize overestimation bias inherent in plotless sampling methods [23]. Taking the area defined by the distance to the kth seedling leads to the establishment of the smallest circular plot which in turn results in a larger expansion factor. When the radius is extended to the k + 1 seedling, it leads to a smaller expansion factor [23]. Specifically, the expansion factor was determined using the arithmetic mean of the distances to the kth and (k+1) seedlings, rather than relying solely on the distance to the kth seedling. This adjustment yields a more accurate estimate of the sampled area and reduces the likelihood of inflating seedling density values [23, 40, 37]. Averaging the distances provides greater statistical robustness and is considered the best practice in ecological field studies employing the k-tree sampling technique [23, 41].

2.6.2 Seedling species diversity and richness indices

Data were summarized using Microsoft Excel and R software was used to compute seedling species diversity and richness.

Shannon-Weiner diversity index (H) [34].

$$H = - \sum P_i \ln P_i \tag{1}$$

$$P_i = \frac{S}{N}$$

Where;

P_i = proportion of the species, S = number of individuals of one species; N = total number of all individuals in the site and ln = logarithm to base e.

Simpson's diversity index [21].

$$D = \sum \left[\frac{n(n-1)}{N(N-1)} \right] \tag{2}$$

Alternatively, it can be written as:

$$D = 1 - \left[\sum \left[\frac{n(n-1)}{N(N-1)} \right] \right] \tag{3}$$

Simpson's index of diversity = 1 – D

Where; n = number of individuals of species, N = total number of individuals in the sample and D = Dominance index.

2.7 Data analysis

Microsoft Excel was used to clean data and compute species relative density of seedlings. R software was used to compute species abundance, diversity, and richness of seedlings. Statistical Package for Social Sciences (SPSS) version 25 was used to carry out Univariate Analysis of Variance. Tests of Between-Subjects Effects were used to test the significant difference between the three (3) silvicultural treatments. Games–Howell test was used to compare seedling species in terms of relative density, abundance,

diversity and richness under the three (3) silvicultural treatments ensuring statistical precision. This provided a high-impact, replicable framework for studying the influence of silvicultural practices on natural regeneration. It was considered that there was a significant difference between silvicultural treatments if the p-value from the Tests of Between-Subjects Effects and Games–Howell test was less than the significance level 5%.

3. Results

3.1 Number of seedling species and relative density

A total of 125 seedlings were enumerated in each one (1) ha plot making 375 seedlings per silvicultural treatment and 1,125 seedlings in three (3) silvicultural treatments. A total of 54 different seedling species were enumerated during the study. The mean relative density for seedling species in three (3) silvicultural treatments was compared using Games-Howell test. This test did not provide sufficient evidence of differences between TSS and PES ($P = 0.794$), TSS and GLS ($P = 0.603$), or PES and GLS ($P = 0.965$). In terms of seedling species dominance in three (3) silvicultural treatments, *Nesogordonia papaverifera* had high relative density in TSS (17.3%) and PES (24.0%). *Celtis mildbraedii* exhibited high relative density in GLS (19.2%), followed by *Nesogordonia papaverifera* (16.0%). *Funtumia africana* was dominant in GLS (14.7%) whereas *Cleidon gabonicum* was dominant in PES (13.1%) (Appendices 1, 2, 3 & 4).

3.2 Seedling species abundance, richness and diversity

The results of species abundance, diversity and richness of seedling were presented using Boxplots. The seedling species abundance is expressed as a number of seedlings per ha. The highest mean of seedling abundance was recorded in GLS treatment ($\bar{x} = 3.84$ per ha) followed by PES ($\bar{x} = 3.83$ per ha) and TSS ($\bar{x} = 3.64$ per ha). These values differed significantly between three (3) silvicultural treatments ($P = 0.023$). Comparing seedling species abundance between GLS and other silvicultural treatments, there was significant difference between GLS and TSS ($P = 0.015$). The difference in seedling species abundance between GLS and PES was not significant ($P = 0.553$) (Figure 3). Seedling species richness varied between the three (3) silvicultural treatments ($P = 0.032$), with TSS showing the highest seedling species richness (0.875) followed by PES (0.725) and GLS (0.70). The difference in seedling species richness between TSS and GLS was statistically significant ($P = 0.04$) but no significant difference in mean species richness between PES and GLS ($P = 0.778$) (Figure 4). TSS had the highest seedling species diversity (0.95) followed by PES (0.825) and GLS (0.775). The differences in these values were significant between the three (3) silvicultural treatments ($P = 0.022$). The differences in mean seedling species diversity was significant between TSS and GLS ($P = 0.027$) but not between PES and GLS ($P = 0.723$) (Figure 5).

Figure 3: Seedling species abundance under three silvicultural treatments

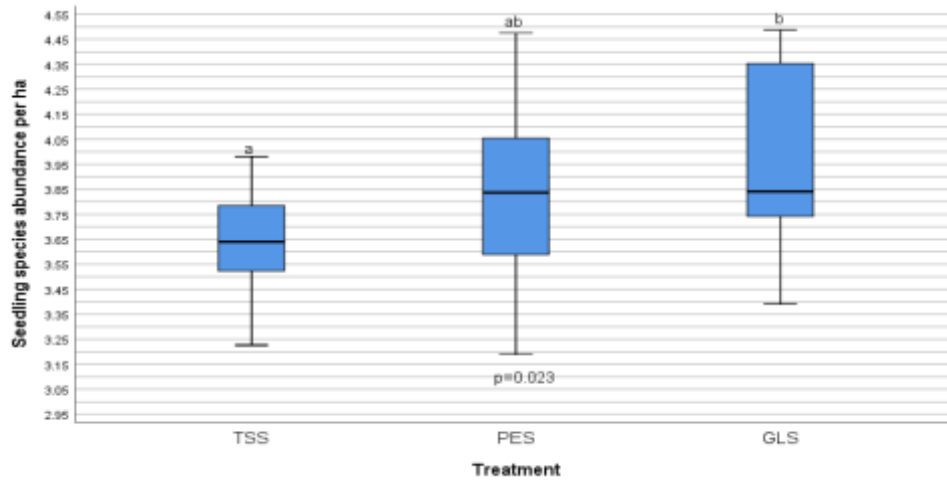


Figure 4: Seedling species richness under three silvicultural treatments

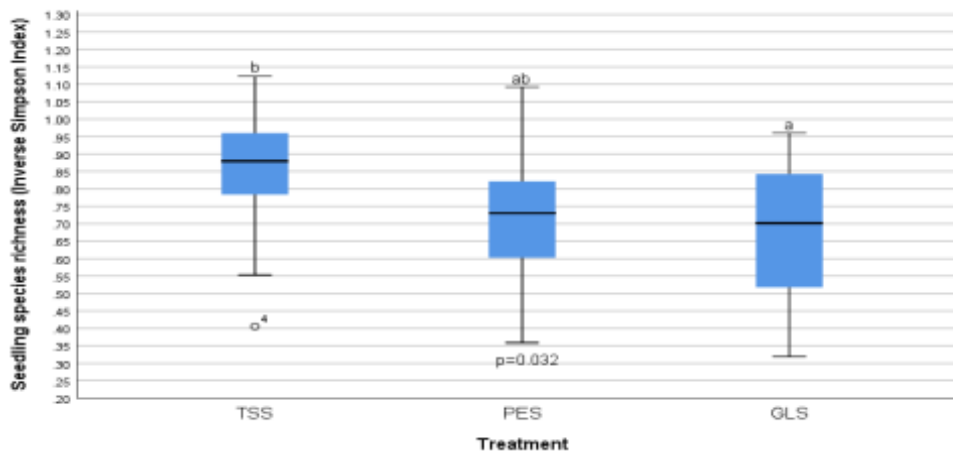
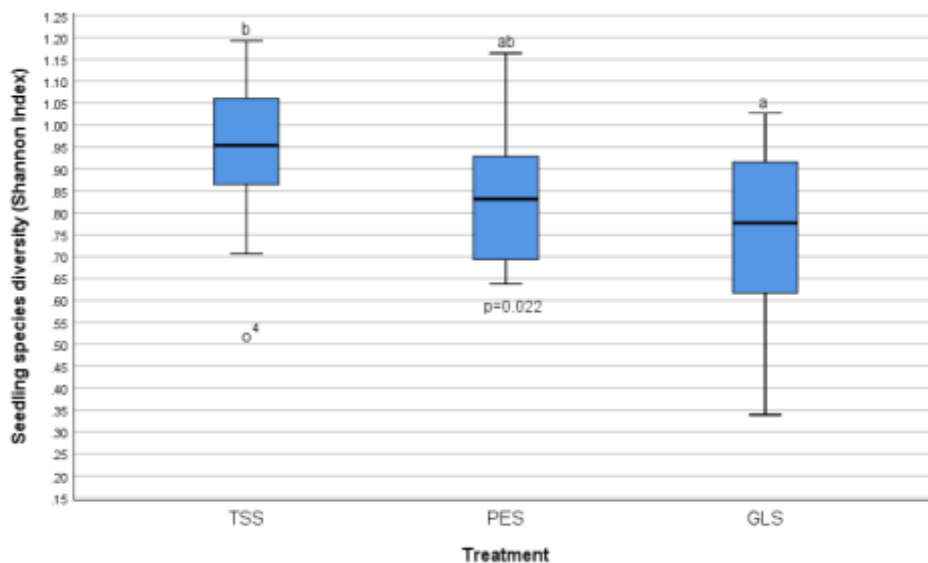


Figure 5: Seedling species diversity under three silvicultural treatments



4. Discussion

4.1 Number of seedling species and relative density

Several studies show that seedling growth is favoured by canopy openness, soil disturbance and logging intensity [38, 11, 19]. For the study area this has been corroborated by Foli [15]. The observation that the GLS plot in BFR had numerous fallen mature trees creating gaps in the sampling plots supports this view of changing seedling dynamics. Large numbers of shade tolerant non-pioneers such as *Nesogordonia papaverifera* in both TSS and PES, and *Celtis midbraedii* in GLS in this study suggest that they benefit from these conditions. Duah-Gyamfi et al. [11] reported that the relative density of non-pioneers was higher in moist semi-deciduous tropical forest in the High Forest Zone of Ghana than with pioneers. Similar effects for recruitment, mortality and plant density have been reported before in natural and artificial gaps [12, 8]. The results of this study show that the relative density of non-pioneers was higher relative to that of pioneers, and this agrees with the findings of the study conducted by Duah-Gyamfi et al. [11]. The observed variation arises from the sub-sampling plot area, which was used to compute the relative density of seedling species. Similar effects for recruitment, mortality, and plant density have been reported earlier studies in natural and artificial gaps [12, 8].

4.2 Seedling species abundance, diversity and richness

The findings of this study confirm a clear distinction between TSS and PES, which represent the more intensive silvicultural treatments, and GLS which serves as the low-intensity control. Seedling abundance (n/ha) was highest in GLS exceeding that observed in both PES and TSS. Furthermore, the difference in seedling abundance between GLS and TSS was statistically significant. The relatively higher seedling abundance in GLS than in the more intensive treatments, contrasts with the prevailing understanding that higher levels of silvicultural intervention generally enhance regeneration. This outcome, which contrasts with the expectation that intensive treatments foster greater regeneration, may reflect temporal changes in seedling dynamics and density fluctuations [11]. The most dominant species recorded were *Nesogordonia papaverifera* in the TSS and PES plots. Interestingly, this differs from a survey conducted by FORIG in 2009 which identified *Funtumia elastica* as the most dominant species in the Bobiri Forest Reserve, followed by *Cleidon gabonicum* [1]. However, the findings of this study revealed that *Nesogordonia papaverifera*, *Celtis mildbraedii*, *Funtumia africana*, and *Cleidon gabonicum* ranked among the most abundant species. These results may reflect a response to changes in the microclimatic conditions within the forest reserve over time.

It was observed that 50 years after initial treatments highlight the ecological dynamics in stands with no further silvicultural interventions. Species diversity and richness were highest in TSS, clearly distinguishing it from the less intensive PES and GLS treatments. While GLS and PES showed similar diversity and richness, these were notably lower than in TSS. Given that PES differs from TSS only in post-harvest operations, the reason for this variation remains unclear. The higher diversity and richness in TSS support the view that intermediate logging disturbances can enhance regeneration, aligning with the intermediate disturbance hypothesis [43, 29].

The findings align with the intermediate disturbance hypothesis, which suggests that moderate disturbances maximize biodiversity by minimizing competitive exclusion [15, 11]. However, lack of statistically significant differences between high and low intensity treatments for some measures suggest the complexity of long-term ecological dynamics. Post-harvest interventions in PES might have disrupted regeneration, potentially due to soil compaction and microhabitat alteration from machinery use as

suggested by Duah-Gyamfi et al. [11]. These findings emphasize that careful consideration is needed when evaluating the ecological impacts of silvicultural practices over extended periods.

Finally, it can be stated that the findings of this study are positive with the view to recovering of forest ecosystems after logging. The onset of Foli's study [15] was the premise that a forest ecosystem does recover after intensive logging. This is consistent with the results of this study that shows that despite the relatively drastic measure of removal of species that were not commercially valuable, seedlings recovered and there was high species diversity and richness in the intensively logged shelterwood system. This may be attributed to the fact that the intended post-harvest interventions aimed at removing undesirable non-economic tree species was not followed through in subsequent years as originally planned.

5. Conclusions

The relative density of *Nesogordonia papaverifera* showed high relative density in TSS and PES. *Celtis mildbraedii* dominated in GLS. It was revealed that there was no significant difference in mean relative density of seedling species between TSS, PES and GLS leading to rejection of the hypothesis 1. Seedling abundance, diversity, and richness differed significantly among three (3) silvicultural treatments, with consistent significant differences between TSS and GLS leading to acceptance of the hypothesis 2. However, the differences were not significant between PES and GLS.

Silvicultural treatments differed significantly in their influence on natural regeneration. The Tropical Shelterwood System (TSS) enhanced seedling species diversity and richness more effectively than PES and GLS. The TSS treatment results in higher seedling species diversity and richness compared to PES and GLS leading to acceptance of the hypothesis 3. TSS recorded the highest diversity and richness values, indicating that moderate canopy opening and pre-harvest tending operations created favourable microhabitats for diverse seedlings recruitment.

Overall, the findings demonstrate that more intensive but ecologically moderated interventions such as TSS treatment can promote higher biodiversity and strong regeneration dynamics over long periods. This underscores the ecological value of TSS treatment practices for balancing biodiversity conservation with sustainable forest management in Ghana's moist semi-deciduous forests.

6. Recommendations

There is a need to conduct research to explore ecological factors such as soil properties, herbivory, and microclimatic variations to enhance forest regeneration strategies in Bobiri Forest Reserve contributing to sustainable forest management. The findings of this study suggest forest recovery after disturbance does not adversely affect regeneration and species richness. It is therefore, recommended that silvicultural operations such as climber cutting, selective harvesting of competing stems, and controlled canopy opening should be adopted as standard management procedures in tropical moist forests.

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