Comparative ~~analysis~~ of woody vegetation population parameters in disturbed and undisturbed sites of a secondary montane forest

Comment [D. Kaseem1]: assessment

ABSTRACT

Secondary montane forests are created by disturbances either natural or artificial, causing open canopies. They are characterized by discontinuous canopy layers with short trees but dense understory. They are important resources in relation to economic and ecological values, however, they face over-exploitation. The objective of this study was to compare regeneration, forest structure and species diversity between disturbed and undisturbed sites of South-west (SW) Mau forest, Kenya. Nested research sampling design was used, whereby, plots of 500 by 500 m were laid down. In disturbed sites, 500 by 500 m plots were laid at 100 m from the forest edge and towards the interior for undisturbed sites in Itare, Maramara and Ndoinet blocks of the forest. In disturbed sites, a total of 41 canopy openings were randomly selected to constitute sample units. In undisturbed sites, 19 sample plots of 30 by 20 m were randomly nested. Regeneration was determined by tossing two quadrats; 1 by 1 (8 times) and 5 by 5 (4 times) m for seedlings and saplings respectively and population taken per sample unit. The diameter (dbh) was measured using diameter calliper (for small trees with dbh <65 cm) and diameter tape for trees with dbh > 65cm while height was measured using Suunto clinometer. Species diversity was determined using Shannon Weiner Diversity Index and Simpson's Diversity Index. Wilcoxon rank sum test with continuity correction was used to compare the three woody vegetation population parameters in disturbed and undisturbed sites of the forest. Results showed a significant difference in forest structure between disturbed and undisturbed sites of the forest (*P* = 0.01, *P value adjustment method*: *BH*). It was concluded that *Piper capensis, Ribes spp.* and ferns which invaded disturbed sites influenced woody vegetation population parameters through influencing microsite conditions. Enrichment planting was then recommended in disturbed sites to conserve biodiversity within the forest.

Keywords*: Canopy; Disturbances; Forest structure; Piper capensis; Regeneration; Species diversity; Understory*

1.0 INTRODUCTION

Tropical montane forests are important resources due to eco goods and services that accrues from them [1, 2]. Examples of the importance include; hydrological, biodiversity conservation, endemicity protection and carbon sequestration [3]. They are heterogeneous in forest structure and floristic composition of plant communities [2]. However, these forest type experience disturbances especially from anthropogenic origin [1, 2] creating another type of forest called secondary montane forests. Secondary montane forests are rapidly spreading around the globe [4] which is important as it help to alleviate the impacts of deforestation and contribute to forest conservation [5]. They are important resources in relation to economic and ecological values that they provide [6].

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Despite their importance, secondary montane forests are facing threats, hence, are characterized by discontinuous canopy layers with short trees (<15 m in height) but with dense understory. Other characteristics include; numerous lianas and bent trunks [7], increased species diversity triggered by coexistence of shade tolerant and shade intolerant species [4, 5, 8]. Such discontinued canopy favours invasion by alien species and herbs which may affect regeneration and succession by indigenous species [6]. Secondary montane forests regenerate mostly through natural processes (secondary succession) following disturbances of original forests [3]. However, successional development results into recovery of plant species that are affected by disturbances (artificial and human sources), consequently, influence on biodiversity [6]. Studies have been done to determine woody vegetation population parameters (regeneration, forest structure and species diversity) in disturbed sites of a secondary montane forest [9], however, a comparison with undisturbed sites has not been done specifically in SW Mau forest.

Nevertheless, secondary montane forests are driven by disturbances; natural or artificial. Natural disturbances are, however, a characteristics of all natural forest ecosystems. They can be defined as discrete events that alters forest structure and composition [8] and which are not from anthropogenic origin [10]. Examples entail; tree falls, landslides [4], wildfires, senescence, pests, snagging, diseases, droughts all resulting into tree mortality [11]. Artificial disturbances on the other hand are due to human activities which do not retain forest structural complexity, connectivity and landscape heterogeneity [10]. Artificial disturbances have resulted into loss of species diversity in natural forest ecosystems. This has often been linked to human population growth, agriculture [4], industries and construction, consequently, over-exploitation of the forests [1, 12]. Even though human disturbances, such as, deforestation is the major, there are other sporadic disturbances, such as, pollution [7, 2]. Disturbances have resulted into dwindling of forest resources, thus, open canopies. From the past decades, there has been increasing demand of forest resources in Kenya resulting into increased pressure on Mau forest in Kenya. Closed canopies have been converted into open canopies, hence, termed as disturbed in some parts of the forest [12].

Disturbances are the determinants of forest dynamics and biodiversity both at local and regional scale, therefore, crucial in creating natural communities in forest ecosystems [10]. Moderate disturbances are known to increase species diversity. This hypothesis is however, debated by other researchers who still doubt it [10]. Secondary montane forest species tend to resemble the initial species diversity before disturbances after 45 years of natural recovery, hence, stability in forests. Secondary montane forests are, therefore, highly resilient and recover fast after disturbances such as commercial logging. Such forests are, however, known to take a longer duration for trees to have large dbh as well as for saplings of shade-tolerant species to fully develop into large trees [8].

A previous study was done on a secondary montane forest and how canopy openings in disturbed sites influence regeneration, forest structure and species diversity in SW [9]. Nevertheless, there has not been a comparison with undisturbed sites. Other studies have also affirmed that understanding processes such as regeneration can be vital since disturbed forests are quick spreading [4].Therefore, comparison can help in deriving a conclusion on which site; disturbed or undisturbed conserve biodiversity as well as increase species diversity and improve forest structural development. This can go hand in hand with microsite conditions gradient in relation to canopy cover/openness as demonstrated by Ocholla *et al.* [13]. The study, therefore, focused to bridge the lacuna by comparing regeneration, forest structure and species diversity between disturbed and undisturbed parts of SW Mau forest which is a secondary montane forest in view of understanding the relationship between the two sites can help in biodiversity protection and conservation.

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2.0 MATERIALS AND METHODS

2.1 Site Description

The study was done in South-west (SW) Mau forest reserve (0˚15'S- 0˚47'S, 35˚28'E - 35˚69'E), one of the blocks of Mau forest in Kenya [14]. It is the largest remnant indigenous forest block of Mau and a home of the Ogiek community. It occupies an area of 60,000 ha and has an elevation of 2100-3300 m asl [15]. SW Mau forest has three blocks; Ndoinet, Maramara and Itare. Since 1997, the forest has been experiencing adverse human disturbances, such as, deforestation [12], consequently, resulted into its reduction from 84,000 ha to 60,000 ha in area [15, 16, 17].

2.2 Research and Sampling Design

Nested research sampling design was used, whereby, a plot of 500 by 500 m was demarcated in disturbed parts of Ndoinet, Itare and Maramara blocks at 100 m from the forest edge. Likewise, another plot of 500 by 500 m was laid towards the interior (undisturbed). In undisturbed sites, sub-sample plots of 30 by 20 m were randomly nested 19 times in the main plots; Itare 5, Maramara 6 and Ndoinet 8. In disturbed sites, a total of 41 canopy gaps (Itare 13, Maramara 11 and Ndoinet 17) were randomly selected to constitute the sample units.

Regeneration was determined by tossing two quadrats; 1 by 1 (8 times) and 5 by 5 (4 times) m for seedlings and saplings respectively, and population size taken per sample units. Trees with dbh >3 cm were considered for forest structure. The diameter (dbh) was measured using diameter calliper (for small trees with dbh <65 cm) and diameter tape (for large trees, dbh=>65 cm) while height was taken using Suunto clinometer. To determine the complexity of the forest structure, Holdridge's Complexity Index [18] was used;

$$HC = (Axdxnxh)/1500\, m^2 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

Where;

HC = Holdridge's Complexity Index, *A* = basal area (m^2), d = tree density/1500 m^2, *n*= number of species/1500 m^2, *h* = mean tree height in meters.

To determine species diversity, species from the two sites (disturbed and undisturbed) were identified and names inventoried. Two indices were used;

a) Simpson's Diversity Index (1-*D*) for species dominance [19];

$$D = \sum(\frac{n_i}{n})^2 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

b) Shannon-Weiner's Diversity Index (*H'*) for species diversity [20]

$$H' = \sum_{i=1}^{s}(P_i)ln(P_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

Where,

H`= Shannon-Wiener's Diversity Index, S= number of genera, Pi= ni/n; ni= total number of individuals of species i, n= total number of all the individuals, ln= natural $\log_{10}$ of Pi, *D*=Simpson's Diversity Index.

2.3 Data analysis

Data from this study was analyzed using RStudio and Microsoft excel. Results were displayed using descriptive statistics and inferential statistics to test hypotheses. Wilcoxon rank sum test with continuity correction was used to compare woody vegetation population parameters in disturbed and undisturbed sites of SW Mau forest.

$$W_c = \sum_{i=1}^{N} \delta_i R_{i+,} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

Where;

$W_{c=}$ Wilcoxon Rank Sum, *N*=*m*+*n* clusters in group 1 and 2, R_{i+}= total sum of rank in group i; $\sum_{j=1}^{z} R_{ij}$, δ_i=1 [21].

3.0 RESULTS AND DISCUSSION

3.1 Comparing regeneration between disturbed and undisturbed sites of SW Mau forest

Two growth levels were used to determine regeneration in the two study sites; seedlings and saplings. Disturbed sites recorded the highest frequency of regeneration (2035). Undisturbed sites on the other hand recorded (1163). Among the regenerating species, *Psydrax schimperiana* was the common species both in disturbed (428) and undisturbed (233) sites, *Tabernaemontana stapfiana* and *Macaranga kilimandscharica* then followed (Table 1).

Table 1: Frequency, percentage of species regeneration in disturbed and undisturbed sites of SW Mau forest.

Species	**Disturbed sites**	**Undisturbed sites**
Acacia lahai	2(0.10)	--------
Acacia mearnsii	24(1.18)	24(2.06)
Albizia gummifera	89(4.37)	36(3.10)
Allophylus abyssinicus	46(2.26)	151(12.98)
Dombeya torrida	--------	1(0.09)
Dovyalis abyssinica	3(0.15)	1(0.09)
Dracaena steudneri	13(0.64)	1(0.09)
Ehretia cymosa	13(0.64)	21(1.81)
Ekebergia capensis	1(0.05)	--------
Macaranga kilimandscharica	322(15.82)	171(14.70)
Maytenus ovatus	--------	2(0.17)
Maytenus rotudos	29(1.43)	-------
Maytenus undata	--------	5(0.43)
Millettia dura	20(0.98)	3(0.26)
Morella salicifora	15(0.73)	9(0.77)
Neoboutonia macrocalyx	128(6.29)	17(1.46)
Others	11(0.54)	20(1.72)
Pittosporum viridiflorum	4(0.20)	--------
Podocarpus latifolius	65(3.19)	12(1.03)
Polycias fulva	---------	4(0.34)
Polyscias capensis	2(0.10)	--------
Prunus africana	18(0.88)	-------
Psydrax schimperiana	428(21.03)	233(20.03)
Rapanea melanophloes	34(1.67)	45(3.90)
Schefflera abyssinica	3(0.15)	--------
Schefflera volkensii	3(0.15)	-------
Syzygium guineensii	261(12.83)	64(5.50)
Tabernaemontana stapfiana	339(16.66)	165(14.19)
Teclea nobilis	1(0.05)	7(0.60)
Trichilia emitica	99(4.86)	149(12.81)
Trichocladus elipticus	4(0.20)	--------
Vungueria madagascariensis	--------	5(0.43)
Xymalos monospora	13(0.64)	10(0.86)
Zanthoxyllum gilletii	45(2.21)	7(0.60)
Disturbed 29 **Undisturbed 25**	**2035(100.00)**	**1163(100.00)**

Values indicated in brackets represent the count %

However, there was no significant difference in regeneration between disturbed and undisturbed sites of SW Mau. Pairwise comparisons using Wilcoxon rank sum test with continuity correction reported that P=0.58 *P value adjustment method*: *BH*. Null hypothesis was, therefore, rejected.

Disturbed sites recorded higher number of seedlings and saplings compared with undisturbed sites. The study corroborated with other findings [6, 22] that disturbed sites avail resources, consequently favouring species regeneration. Disturbed sites are characterized by open canopies, hence, crucial for regeneration and this implies that open canopies promotes population growth [23, 24]. The study was again similar to other studies that open canopies found in disturbed sites are dominated by shade intolerant species [3] which in this case were *Piper capensis*, *Ribes spp.* and ferns which influenced colonization by climax species.

Increased rate of regeneration in disturbed sites were attributed to the availability of microsite conditions, such as, light [13] which could be used by the seedlings for photosynthesis, thus, increased seed germination, growth and establishment [25]. Similar results were demonstrated by Ronoh *et al.* [26] that grazing in SW Mau resulted into increased regeneration due to nutrients availed in form of manure [7]. However, this study was contrary to that reported by Tinya *et al.* [27] that disturbed sites are represented by scanty regeneration due to harsh environmental conditions, such as, extreme temperatures.

However, there was no significant difference in regeneration between disturbed and undisturbed sites of SW Mau. This could be because, sprouting seedlings in disturbed sites could have been affected by incessant disturbances such as animal trampling as reported by Ronoh *et al.* [26] and Zhang and Yi [22]. In addition, disturbed sites were invaded by *Piper capensis,* a light demanding species [19] utilizing resources which could have been used by woody species to regenerate. Disturbed sites usually report low regeneration due to unfavorable environmental conditions such as low moisture availability and increased temperatures Tinya *et al.* [27]. Also, undisturbed sites are known to have low microsite conditions such as light due to shading, hence, reduced regeneration [23].

3.2 Comparing forest structure between disturbed and undisturbed sites of SW Mau forest

Height and dbh were used as a measure of forest structure. Seedling was the highest growth level in disturbed sites (1511) compared with undisturbed sites (849) (Table 2). However, emergent layer was recorded least in relation to frequency in the two sites.

Table 2: Growth levels of woody vegetation in SW Mau Forest

Level	**Diameter (%)**	**Height (%)**
Seedlings	63.49(**58.03**)	63.49(**58.03**)
Sapling	20.80(**21.60**)	20.80(**21.60**)
U. canopy	2.73(**2.94**)	2.73(**2.94**)
M. canopy	10.92(**13.47**)	10.92(**13.47**)
E. layer	2.06(**3.96**)	2.06(**3.96**)
Total	100.00 **100.00**	100.00 **100.00**

Bolded values represent undisturbed while unbolded represent disturbed sites. U. represent Under, M. represent Main While E. represent Emergent.

Undisturbed sites, however, recorded higher mean in tree diameter (24.9 cm) and height (26.3 m) compared with disturbed sites (24.1 cm and 23.9 m) (Figure 1**)**.

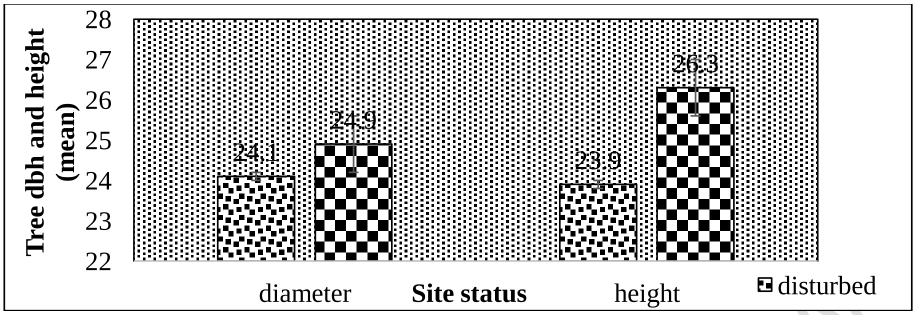

Figure 1: Physiognomic appearance of the forest (dbh and height) (%) in SW Mau Forest. Dbh was measured in cm while height was done in m.

Pairwise comparisons using Wilcoxon rank sum test with continuity correction was used to test for significant difference in the forest structure between disturbed and undisturbed sites of SW: *P* = 0.01, *P value adjustment method*: *BH*. Forest structure between disturbed and undisturbed sites of SW Mau was not the same, null hypothesis was, thus, rejected.

Disturbed sites recorded a complex structure than undisturbed sites. Seedlings and saplings growth levels were higher in disturbed sites than in undisturbed sites, hence, congruent with other studies [28]. However, undisturbed sites exhibited increased mean in tree height and dbh. Similar results were reported by Huang *et al.* [29] and demonstrated that this could be due to gradient in resources between the two sites, thus, variation in tree growth and development [13]. Structurally, disturbed sites were again dominated by *Piper capensis* which formed a generally uniform canopy layer, hence, congruent with previous studies [3]. Variations in tree growth results in vegetation layering due to difference in tree heights and species diversity [30].

Main canopy and emergent layers were also high in undisturbed sites, consequently, closed canopy yet less seedlings [28]. This could be related to competition for light among other resources, therefore, trees invest more in height rather than crown development [31]. Disturbed sites on the other hand recorded low stem and height mean. This could be related to less light competition due to open canopies, hence, more investment in lateral branches [6] [31]. Canopy openings in disturbed sites influences microsite conditions which affect forest structure [32]. The openings allow for light penetration which facilitates growth rate of seedlings and saplings. The study was, however, contrary to the demonstration of Tinya *et al.* [28] who reported increased dbh and height in disturbed sites.

The study reported a significant difference in forest structure in disturbed and undisturbed sites of SW. This could be related to invasion of the forest by *Piper capensis:* an invasive species suppressing seedlings of woody species in disturbed sites, therefore, similar to other findings [29]. However, the results were against the demonstrations by Tinya *et al.* [28] who reported an insignificant difference in forest structure between clear-cut and closed canopies.

3.3 ~~Species~~ Floristic composition and diversity in disturbed and undisturbed sites of SW Mau Forest

A total of 29 families, 31 genera and 34 species were recorded in disturbed sites while 24 families, 26 genera and 27 species were reported in undisturbed sites. However,11 species were reported in disturbed sites but absent in undisturbed sites (Table 3). Also, 4 species were present in undisturbed sites but not in disturbed sites. The species included; *Vangueria madagascariensis, Maytenus undata, Cassipourea malosana* and *Olea capensis.*

Table 3: Species diversity in SW Mau Forest.

Family	**Genus**	**Species**	**Disturbed**	**Undisturbed**
Alariaceae	*Polyscias*	*P. capensis*	+	-
Alariaceae	*Polyscias*	*P. fulva*	+	+
Apocynaceae	*Tabernaemontana*	*T. stapfiana*	+	+
Araliaceae	*Schefflera*	*S. volkensii*	+	-
Asparagaceae	*Dracaena*	*D. steudneri*	+	+
Boraginaceae	*Ehretia*	*E. cymosa*	+	+
Celastraceae	*Maytenus*	*M. rotudos*	+	-
Celastraceae	*Maytenus*	*M. ovatus*	+	+
Celastraceae	*Maytenus*	*M. undata*	-	+
Ebenaceae	*Diospyros*	*D. abyssinica*	+	-
Euphorbiaceae	*Macaranga*	*M. kilimandscharica*	+	**+**
Euphorbiaceae	*Neoboutonia*	*N. macrocalyx*	+	+
Fabaceae	*Millettia*	*M. dura*	+	+
Fabaceae	*Acacia*	*A. lahai*	+	-
Fabaceae	*Acacia*	*A. mearnsii*	+	+
Flacourtiaceae	*Dovyalis*	*D. abyssinica*	+	+
Flacourtiaceae	*Dovyalis*	*D. macrocalyx*	+	-
Hamamelidaceae	*Trichocladus*	*T. ellipticus*	+	-
Meliaceae	*Trichilia*	*T. emitica*	+	+
Meliaceae	*Ekebergia*	*E. capensis*	+	-
Mimosaceae	*Albizia*	*A. gummifera*	+	+
Monimiaceae	*Xymalos*	*X. monospora*	+	+
Myricaceae	*Morella*	*M. salicifora*	+	+
Myrtaceae	*Syzygium*	*S. guineensii*	+	+
Oleaceae	*Olea*	*O. capensis*	-	+
Others	*Others*	*Others*	+	+
Pittosporaceae	*Pittosporum*	*P. viridiflorum*	+	-
Podocarpaceae	*Podocarpus*	*P. latifolius*	+	+
Primulaceae	*Rapanea*	*R. melanophloes*	+	+
Rhamnaceae	*Rhamnus*	*R. prinoides*	+	-
Rhizophoraceae	*Cassipourea*	*C. malosana*	-	+
Rosaceae	*Prunus*	*P. africana*	+	-
Rubiaceae	*Psydrax*	*P. schimperianas*	+	+
Rubiaceae	*Vangueria*	*V. madagascariensis*	-	+
Rutaceae	*Zanthoxyllum*	*Z. gilletii*	+	+
Rutaceae	*Teclea*	*T. nobilis*	+	+
Sapindaceae	*Allophylus*	*A. abyssinicus*	+	+
Sterculiaceae	*Dombeya*	*D. torrida*	+	+
29	31	34		
24	**26**	**27**		

+ represent present while - represent absent. Others represent tree species whose identity are not known

Disturbed sites recorded a high species diversity using Shannon Weiner Diversity Index (H`=2.71) followed by undisturbed sites ($H$`=2.55) (Figure 2). However, Shannon Equitability Index was equal in the two sites (HE=0.77). Simpson'S species dominance was also high in

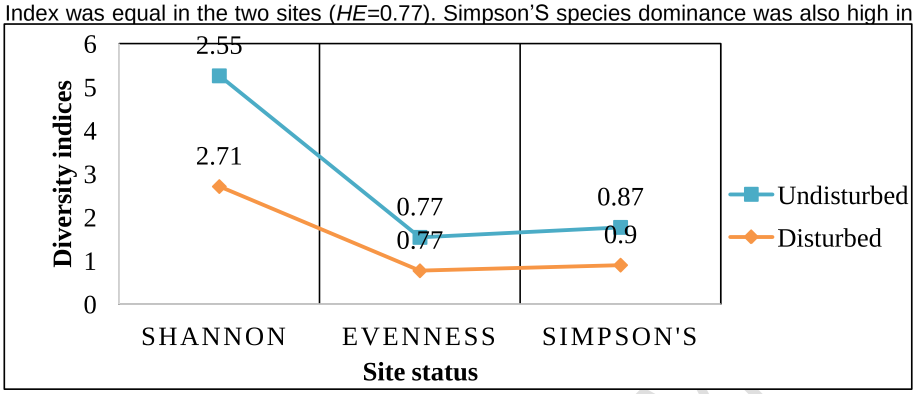

Figure 2: Species diversity, evenness and dominance in SW Mau Forest

Pairwise comparisons using Wilcoxon rank sum test with continuity correction gave a *P* value of 0.62 using *P value adjustment method*: *BH*. This was above 0.05, hence, null hypothesis failed to be rejected. It was concluded that there was no significant difference in species between disturbed and undisturbed sites of SW Mau forest.

Higher species diversity was reported in disturbed sites. This was similar to the findings of Kovács *et al.* [33] who reported that disturbed sites are characterized by canopy gaps which avail resources such as sunlight to tree species, consequently, promote species diversity. Light in the gaps is known to sieve species influencing species colonization. Species diversity in disturbed sites could also be high due to easiness in seed dispersal without obstruction. Additionally, species whose mother plants were not spotted could also be found in disturbed sites [34]. This was also related to light seed dispersion, such as by wind, thereby, high species diversity, therefore, congruent with the findings by Tinya *et al.* [28]. Undisturbed sites on the other hand reported low species diversity which could be related to low regeneration. This could be linked to shading by the closed canopy which could have affected light penetration [29]. Furthermore, closed canopy results into debris accumulation on the forest floor hindering seed settlement reducing seed germination [35].

There was a non-significant difference in species diversity between disturbed and undisturbed sites of SW Mau forest. This was attributed to *Piper capensis* which utilize canopy gap opportunity to grow fast adversely affecting species colonization, hence, similar to other studies [3, 36, 29]. These results were also similar to the findings from SW Mau, whereby, herbaceous plants resulted into low number of regeneration due to closed canopy [5, 13]. This, therefore, made no difference since both disturbed and undisturbed sites had closed canopies [29]. The invasive species created a uniform canopy cover in disturbed sites, consequently reducing species colonization just as in undisturbed sites [22].

4.0 CONCLUSION

Results from disturbed and undisturbed sites, showed that forest structure was significantly different in the two sites. This could be due to canopy ruggedness in undisturbed sites but an almost uniform canopy in disturbed sites due to the invasion by *Piper capensis* in the open spaces of disturbed sites. On the other hand, there was no significant difference in regeneration and species diversity between the two sites. This was attributed to dense canopy cover formed by *Piper capensis* and other invasive species which closed canopy openings in disturbed sites. This could have deprived species important resources for growth and development. Enrichment planting is, therefore, recommended in disturbed sites for biodiversity conservation.

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