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Research Article

Tree seedlings ecology in the undisturbed and disturbed Takamanda Rainforest of south west region, Cameroon

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Abstract

Knowledge of the seedling population is paramount for the understanding of forest dynamics. Data were collected for undisturbed and disturbed sites of the forest. A total of 106 species, representing 38 families and 89 genera were recorded as seedlings. 87 species representing 83 genera were recorded in the undisturbed site and 48 species representing 40 genera were recorded in the disturbed site. The families with the highest number of species were Euphorbiaceae and Rubiaceae (11 species each) in the undisturbed site while in the disturbed site Fabaceae (9 species) was the highest. *Microdemis puburula* (32 quadrats) was the most frequently occurring individual in the undisturbed site while in the disturbed site *Anglocalyx pyneartii* (15 quadrats). Species richness was higher in undisturbed than the disturbed site. The total seedling density in the undisturbed site was 20073.53 seedlings ha^{-1} while 15039.06 seedlings ha^{-1} in the disturbed site. The relationship of seedling and mature tree densities were significantly ($P < 0.05$) different for both sites but the magnitude were generally low ($R^2 < 50\%$) in both sites. The different seedling population recorded clumped, uniform and random dispersion pattern. Consequently, measures such as natural regeneration inside and outside the National Park should be encouraged.

Keywords: Seedling, population; Diversity; distribution, composition; management

Introduction

Tropical forest, a storehouse of biodiversity, accounts for 52% of the total forest area of the world, of which 42% is dry forest, 33% is moist forest and 25% is wet and rainforest (Khurana and Singh, 2001). The rainforest of Cameroon is estimated to be approximately 20 million hectares, and most of the forests are moist forests, namely, tropical rainforests intermixed with semi-deciduous forest patches (Ichikawa, 2006). These rainforests have rich mammal faunas, in particular of primates and ungulates, and are well known for being habitats to endangered species such as gorillas and chimpanzees. These forests are also noted for their high diversity in plant species which play a different roles in ecosystem functioning and structuring (Ichikwa, 2006).

The Takamanda rainforest which is one of the remaining lowland rainforest of the Guinoe-Congolean forest is a biodiversity hotspot and it is home to vast population of endemic and threatened floras and faunas in the region (Zapfact *et al*., 2001; Sunderland *et al*., 2003). However, the rich expands of forest is rapidly shrinking as a result of increasing growth in population. Knowledge and ready markets for these forest products have increased their exploitation (Sunderland *et al*., 2002; Sunderland 2003). However, forest clearance for the establishment of plantation crop (cocoa and oil palm) and logging of timber (Ndah *et al*., 2013b). Furthermore, the large household which are strongly dependent on remaining forest stands for livelihoods, and this, coupled with the high demand for fuel wood, has exerted more pressure on the remaining forest stands.

Generally, such high pressures exerted by mainly anthropogenic activities and slightly by natural phenomena are likely to cause changes in the physiognomic formulae of the forest sites, spatial distribution of species, distortion of the size class distribution and above all the recruitment of the harvested tree species (Newbery and Gartlan 1996).

Seedlings of shrubs and trees play an important role in forest regeneration, as their survival and distribution affect the structure and maintenance of plant diversity in tropical and temperate forests (Harper, 1977; Denslow, 1991; Dalling *et al*., 1998). In tropical forests, the seedling community is composed of a large number of individuals and species which belong to different ecological groups (Humbell *et al*., 1999; Comita *et al*., 2007). Knowledge on germination and seedling establishment is of pivotal importance for the understanding of plant community processes as plant recruitment and succession and for the management of plant populations.

The challenges involved in ensuring that forests are managed sustainably can only be met if necessary parameters are put in position to maintain the remaining forests, while restoring deforested and degraded areas. Therefore, it is imperative to understand the processes of natural regeneration, distribution of seedlings, examine the build-up of future forest structure and composition (Pare *et al*., 2009). Many factors influence the processes of natural regeneration. Some of these processes include: wind direction, seed quality, seed viability, seed dispersal, moisture content, canopy cover, light, moisture content, predation etc ((Bebber *et al*., 2002)). Distribution patterns of tree seedlings within the ecosystem often followed natural patterns. However, these patterns are often distorted by human disturbance and some times by natural disasters. Competition for nutrients, water, light and space are paramount for survival, growth and distribution of seedlings. The quantity of the recruited and their spatial distribution determines the richness and the population structure of future forest site (Bebber *et al*., 2002). They are three main distribution patterns in nature; these include uniform, clumped and random. Clumped distribution pattern is the most common type recorded in the tropics ((Bebber *et al*., 2002).

Nevertheless, documentation of the processes of regeneration such as seed germination, seedling establishment and spatial patterns generated by seedlings during establishment are not known or limited. Information on anthropogenic pressure on seedling-sapling establishment, population and their spatial distribution compared with naturally protected site are poorly documented. This reference information is essential to know the state of the forest (richness, density, frequency and spatial distribution) when planning management and restoration strategies (Bationo *et al*., 2005).

Therefore, this study examined the species composition, density, frequency and spatial distribution of seedlings in relation to undisturbed and disturbed sites.

Materials and Methods

Study sites

This study was conducted in the undisturbed and disturbed sites of the southern part of Takamanda rainforest. The area extends 2° N to 13° N latitude and between 8° 25' E and 16° 20' W longitude. The Takamanda Rainforest is located in Akwaya subdivision of the South West Region of Cameroon (Figure 1.). The National Park is part of the Guineo-Congolean forest, which encompasses approximately 2.8 million km^2 mostly below 600 m, except where Precambrian highlands such as the Joss Plateau of Nigeria and the Cameroon Highlands rise above 1000m (Lawson 1996). The highest point is Mount Cameroon at 4,100m.

In general, the region has two distinct seasons (rainy and dry) with most rainfall occurring from April to November (Figure 2). The annual rainfall is about 4,500 mm per year. From November to April, the climate is mainly dry. Some months, usually January and February, may little or no rain at all. The mean annual temperature is 27°C. Normally, the temperatures are cooler in the rainy season than in the dry season (Figure 2). These favourable climatic conditions in this area give rise to a variety of vegetation floristic regions. The region also contains 84% of known African primates, 68% of known African passerine birds, and 66% of known African butterflies (Groom Bridge; Jenkins, 2000; Ndah *et al*., 2012). For this reason, the Guineo-Congolian rainforest is an important focal point for conservation efforts in Africa.

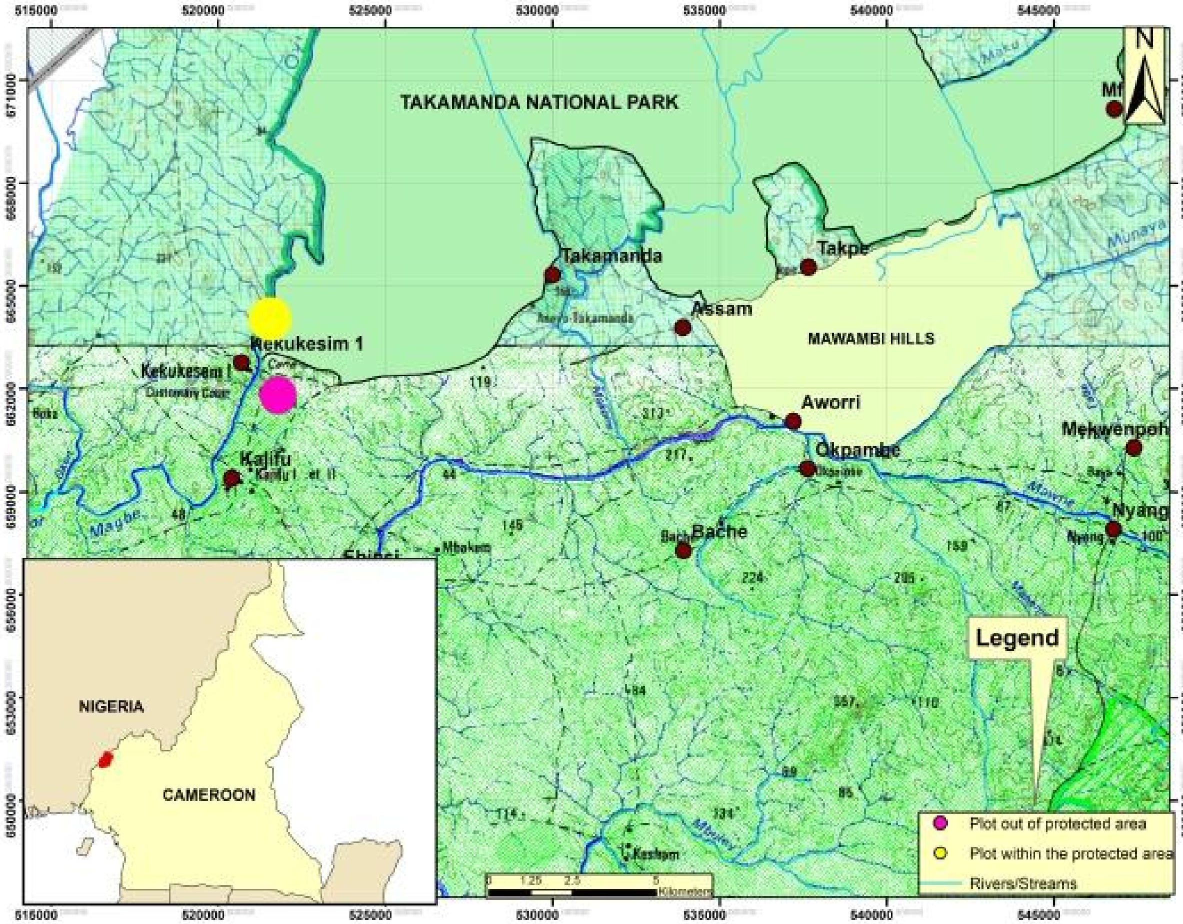

Figure 1. Map of the Takamanda rainforest showing the undisturbed and disturbed sites.

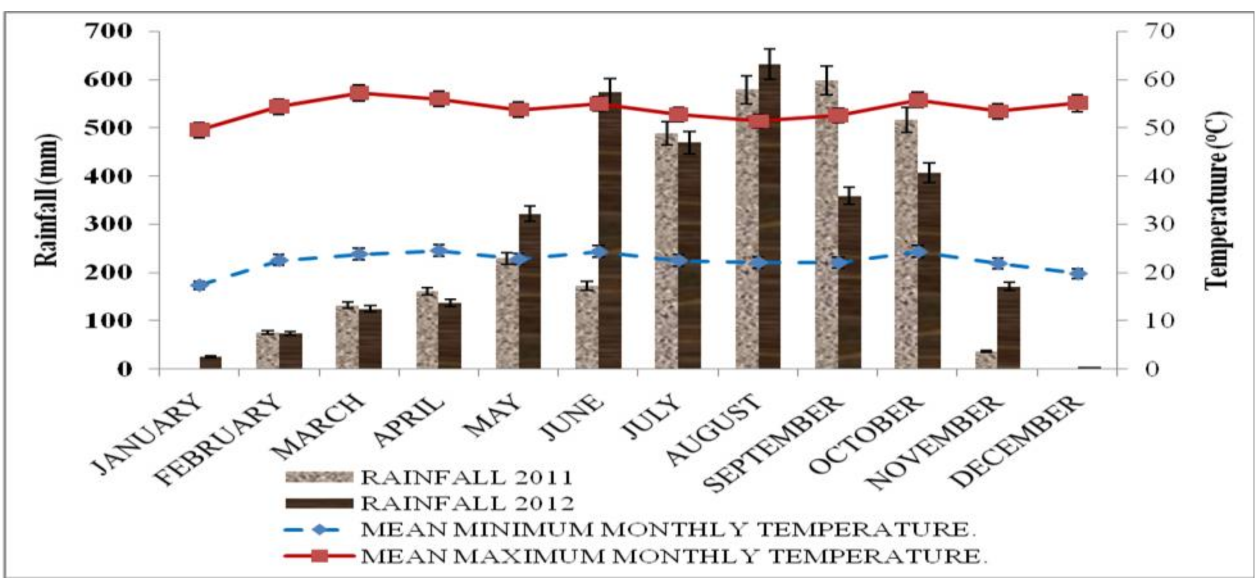

Figure 2. Monthly rainfall and temperature pattern of the Takamanda rainforest

Vegetation Assessments

A stratified systematic design was applied based on conservation status as undisturbed and disturbed sites of the Takamanda rainforest. A reconnaissance survey was undertaken along sides and a vegetative map of the area was used to select and lay out the sample plots. The undisturbed site is about 3.5 km from the disturbed site. The undisturbed site had a closed canopy (75-100%) while the disturbed site had an open canopy (25-50%) by visual observation. Eight linear transects (500m) and (400m) for undisturbed and disturbed sites running north, northeast, east, southeast, south, southwest, west and northwest. These were established in the field radiating from a point approximating the centre of each site. Radiating transects traversed swamps, plains, ridges, slopes and valleys. A total of 35 and 16 quadrats of 20X20 m were established in the 50ha undisturbed and 16ha disturbed plots respectively of the Takamanda rainforest. Four subquadrats of 2X2 m were systematically laid in all the 35 and 16 quadrats in both undisturbed and disturbed plots given a total of 140 and 64 subquadrats established respectively to avoid bias in subplot laying. All seedlings with a collar diameter of < 2.5cm and a height of < 150cm were recorded following Saenz and Finegan (2000) and Teketay (1997) with slight modifications and collar diameter was measured using a vernier calliper.

Statistical Analysis

One way ANOVA was performed to examine whether conservational status and human influences affected species richness and/ or density.

Linear curves were fitted to find the best function for describing the relationship between seedling and adult tree densities. The best function was selected based on the amount of variation explained (adjusted coefficient of determination) and statistical significance. The statistical analyses were performed using Genstat version 14.

The similarity in species composition of seedlings in the undisturbed and disturbed forest sites were compared using Sorensen's similarity index (Krebs 1999) calculated by using the following formula: $Ss = 2a / (2a + b + c)$ where, Ss= Sorensen's similarity coefficient, a = number of species with seedlings present in both conserved and human influenced forests, b = number of species with seedlings exclusively present in the conserved forest, and c = number of species with seedlings exclusively present in the human influenced forest. Sorensen's coefficient has a range between zero (no species in common) and 1 (complete similarity).

The spatial distributional patterns of the seedling populations within the different sites and forest conservation types were analyzed using the standardized Morisita's index (Ip), since it is relatively independent of population density (Krebs 1999). First the Morisita's index was computed as:

$Id = n (\sum x2 - \sum x) / [(\sum x)^2 - \sum x]$ where, n is the sample size, $\sum x$ and $\sum x2$ are the sum of the quadrat counts, and the sum of the quadrat counts square, respectively. Then two critical values for the Morisita's index were calculated using the following formulae:

Uniform index; $Mu = (\chi 2\ 0.975 - n + \sum xi) / (\sum xi - 1)$

Clumped index; $Mc = (\chi 2\ 0.025 - n + \sum xi) / (\sum xi - 1)$

where, $\chi 2$ 0.975 and $\chi 2$ 0.025 are values of chi-squared with (n-1) degrees of freedom that has 97.5% and 2.5% of the area to the right, respectively; xi = given a set of counts of organisms in a set of quadrats and n = number of quadrats. Finally, the standardized Morisita's index was calculated using the relevant formula out of the following four:

(1) $Ip = 0.5 + 0.5 (Id - Mc) / (n - Mc)$; when $Id \geq Mc > 1.0$
(2) $Ip = 0.5 (Id - 1) / (Mu - 1)$; when $Mc \geq Id > 1.0$
(3) $Ip = -0.5 (Id - 1) / (Mu - 1)$; when $1.0 > Id > Mu$
(4) $Ip = -0.5 + 0.5 (Id - Mu) / Mu$; when $1.0 > Mu > Id$

The standardized Morisita index of dispersion (Ip) has a range between -1 and +1, with 95% confidence limit at ± 0.5, where values of 0.0 indicate random dispersion, above 0.0 clumped dispersion and below 0.0 uniform dispersion.

Results

Seedlings Species Composition

A total of 106 species, representing 38 families and 89 genera were recorded as seedlings. 87 species representing 83 genera were recorded in the undisturbed site, and 48 species representing 40 genera were recorded in the disturbed site (Table 1).

Table 1: Species composition, frequency (number of plot in which a species occurred and density (seedlings ha^{-1}) of tree seedlings in undisturbed and disturbed forest sites

Family	Species	code	Undisturbed site		Disturbed site	
			Freq.	Density ha^{-1}	Freq.	Density ha^{-1}
Anacardiaceae	*Pseudospondias microcarpa*	Psmi	2	36.76	-	-
	Sorindeia acuminate	Soac	23	772.05	-	-
Anisophylleaceae	*Anisphyllea polyneura*	Anpo	4	220.58	-	-
Annonaceae	*Annickia chlorantha*	Anch	7	165.44	4	156.25
	Polyathia sauveolens	Posa	17	661.76	-	-
	Xylopia aethiopica	Xyae	1	18.38	-	-
	Xylopia sp	Xysp	-	-	1	39.06
Apocynaceae	*Funtumia elastic*	Fuel	6	257.35	-	-
	Funtumia Africana	Fuaf	-	-	2	78.12
	Tabernaemontana crassa	Tacr	3	55.14	-	-
	Voacanga africana	Voaf	-	-	1	39.06
Bignoniaceae	*Newbouldia laevis*	Nela	1	18.38	-	-
Burseraceae	*Dacryodes igaganga*	Daig	2	36.76	-	-
	Dacryodes edulis	Daed	-	-	1	39.06
	Santiria trimera	Satr	2	36.76	-	-
Cecropiaceae	*Myrianthus arboreus*	Myar	-	-	3	195.31
	Myrianthus preussii	Mypr	8	183.82	-	-
Chrysobalanaceae	*Parinari excels*	Paex	1	18.38	-	-
Dichapetalaceae	*Dichapetalum sp*	Dich	2	36.76	-	-
	Tapura Africana	Taaf	6	349.26	-	-
Dracaenaceae	*Dracaena camerooniana*	Drca	-	-	1	39.06
Ebenaceae	*Diospyros preussii*	Diopr	14	441.17	-	-

*- indicate absence of species

Table 1: continues

Family	species	code	Undisturbed site		Disturbed site	
			Freq.	Density/ha	Freq.	Density/ha
Euphorbiaceae	*Crotonogyne preussii*	Crpr	1	18.38	-	-
	Drypetes preussii	Drpr	3	55.14	3	117.18
	Drypetes sp	Drsp	3	73.52	-	-
	Erythroccocca anomala	Eran	1	18.38	-	-
	Macaranga monandra	Mamo	1	18.38	-	-
	Maesobotrya staudtii	Mast	1	18.38	-	-
	Mallotus oppositifolius	Maop	3	128.67	11	1289.06
	Mareya micrantha	Mami	1	18.382	-	-
	Mareyopsis longifolia	Malo	2	36.76	-	-
	Plagiostyles africana	Plaf	17	330.88	1	195.31
	Ricinodendron heudelottii	Rihe	-	-	1	39.06
	Spondianthus preussii	Sppr	1	18.38	-	-
Flacourtiaceae	*Homalium longistylum*	Holo	3	55.14	-	-
	Scottellia coriacea	Scco	1	18.38	-	-
Guttiferea	*Allanblackia floribunda*	Alfl	1	18.38	-	-
	Garcinia kola	Gako	1	18.38	-	-
	Garcinia staudtii	Gast	-	-	1	39.06
Icacinaceae	*Lasianthera africana*	Laaf	21	937.50	7	625.00
Irvingiaceae	*Irvingia gabonensis*	Irga	2	55.14	2	78.12
Lauraceae	*Beilschmiedia obscura*	Beob	6	147.05	-	-
	Hypodaphnis zenkeri	Hyze	6	202.20	-	-

*- indicate absence of species

Table 1: continues

Family	species	code	Undisturbed site		Disturbed site	
			Freq.	Density/ha	Freq.	Density/ha
Lecythidaceae	*Petersianthus macrocarpus*	Pema	1	18.38	-	-
Leeaceae	*Leea guineensis*	Legu	1	36.76	-	-
Fabaceae	*Albizia adianthifolia*	Alad	-	-	1	78.12
	Albizia zygia	Alzy	-	-	3	195.31
	Afzelia bipendensis	Afbi	2	36.76	-	-
	Anthonotha macrophylla	Anma	8	220.58	4	234.375
	Calpocalyx dinklagei	Cadi	-	-	5	390.625
	Calpocalyx sp	Casp	-	-	1	78.12
	Distemonanthus benthamianus	Dibe	1	18.38	1	39.06
	Erythophleum ivorense	Eriv	1	18.38	-	-
	Hylodendron gabunense	Hyga	1	55.14	2	195.31
	Pentaclethera microphylla	Pemi	7	183.82	1	39.06
	Piptadeniastrum africanum	Piaf	1	18.38	-	-
	Pterocarpus soyauxii	Ptso	2	55.14	5	234.37
Melastomataceae	*Memecylon engleranus*	Meen	9	220.58	-	-
Meliaceae	*Carapa procera*	Capr	1	18.38	1	39.06
	Trichilia rubescens	Trru	19	698.52	2	117.18
	Trichilia welwitschii	Trwe	-	-	1	39.06

*- indicate absence of species

Table 1: continues

Family	species	code	Undisturbed site		Disturbed site	
			Freq.	Density/ha	Freq.	Density/ha
Menispermaceae	*Penianthus camerounensis*	Peca	9	330.88	1	39.06
Moraceae	*Antiaris africana*	Anaf	4	73.52	2	78.12
	Treculia obovoidea	Trob	21	882.35	1	39.06
Myristicaceae	*Pycnanthus angolensis*	Pyan	1	18.38	1	468.75
	Staudtia stipitata	Stst	7	183.82	-	-
Ochnaceae	*Campylospermum elongatum*	Cael	19	551.47	-	-
Olacaceae	*Octoknema affinis*	Ocaf	1	18.38	-	-
	Olax latifolia	Olla	1	36.76	-	-
	Olax mannii	Olma	1	18.38	-	-
	Strombosia grandifolia	Stgr	7	275.73	-	-
Pandaceae	*Microdesmis puberula*	Mipu	32	2279.41	6	703.12
Papilionaceae	*Angylocalyx oligophyllus*	Anol	2	1893.38	2	195.31
	Hypodophnis zenkerii	Hyze	-	-	1	39.06
	Angylocalyx pyneartii	Anpy	-	-	15	2695.31
	Baphia nitida	Bani	13	404.41	8	859.37
	Millettia sanagana	Misa	4	110.29	1	39.06
Polygalaceae	*Carpolobia alba*	Caal	15	459.55	2	78.12
	Carpolobia lutea	calu	-	-	-	234.37
Rubiaceae	*Bertiera laxa*	BeIa	1	18.38	-	-
	Coffea sp	Cosp	2	36.76	-	-
	Heinsia crinita	Hecr	5	91.91	-	-
	Ixora nematopoda	Ixne	5	183.82	-	-
	Massularia acuminata	Maac	5	147.05	-	-
	Pavetta staudtii	Past	1	55.14	5	234.37

Table 1: continues

Family	species	code	Undisturbed site		Disturbed site	
			Freq.	Density/ha	Freq.	Density/ha
Rubiaceae	*Pavetta staudtii*	Past	1	55.14	5	234.37
	Psychotria bifae	Psbi	4	147.05	-	-
	Psychotria gabonica	Psga	29	2316.17	-	-
	Rothmannia hispida	Rohi	14	349.26	1	156.25
	Tarenn thomasii	That	1	18.38	-	-
Rutaceae	*Fagara heitzii*	Fahe	1	18.38	-	-
	Zanthoxylum gillettii	Zagi	1	18.38	-	-
Sapindaceae	*Chytranthus macrobotrys*	Chma	1	18.38	-	-
	Chytranthus tabotii	Chta	-	-	1	39.06
	Laccodiscus ferrugineus	Lafe	6	128.67	-	-
Sterculiaceae	*Cola ficifolia*	Cofi	4	91.91	-	-
	Cola millenii	Comi	-	-	2	156.25
	Sterculia tragacantha	Sttr	1	36.76	8	429.68
Thymelaeaceae	*Dicranolepis disticha*	Didi	3	55.14	-	-
Tiliaceae	*Grewia coriacea*	Grco	6	110.29	1	39.06
Ulmaceae	*Celtis mildbraedii*	Cemi	10	220.58	-	-
Violaceae	*Rinorea dentata*	Ride	3	147.05	14	2734.37
	Rinorea oblongifolia	Riob	-	-	3	273.43

*- indicate absence of species

The families with the highest number of species were Euphorbiaceae and Rubiaceae (11 species each) (Table 1) and were closely followed by Fabaceae and Olaceae (8 species and 4 species) respectively in undisturbed site. On the other hand the families with the highest number of species were Fabaceae and Papilionaceae (9 species and 5 species) (Table 1) respectively in the disturbed site. These were closely followed by Eupborbiaceae and Meliaceae (5 species and 4 species) respectively in the disturbed site (Table 1).

Microdemis puburula (32 quadrats), *Lasianthera africana* (21 quadrats) and *Treculia obovoidea* (21 quadrats) were the most frequently occurring individuals in the undisturbed site; they were closely followed by *Trichilia rubescens* (19 quadrats), *Plagiostyles africana* (17 quadrats) and *Polyathia sauveolens* (Table 1) In the disturbed site *Anglocalyx pynearttii* (15 quadrats) and *Rinorea dentata* were the most occurring species. These were closely followed by *Mallotus oppositifolius* (11 quadrats) (Table 1). Both forest sites were generally characterized by A low proportion (43% and 45%) of abundant species (> 90 tree's ha^{-1}) and corresponding low frequencies of occurrence in undisturbed and disturbed sites respectively (Table 1).

Density of Seedling Populations

The total seedling density of seedling population in the undisturbed site was recorded at 20073.53 seedlings ha^{-1} while 15039.06 seedlings ha^{-1} was recorded at the disturbed site (Table 2). The seedling densities of the undisturbed site were slightly higher than the disturbed site (Table 2). The species with the highest density were observed in the disturbed site (2734.37 seedling's ha^{-1}) while the lowest (18.38 seedling's ha^{-1}) were recorded in the undisturbed site (Table 1). The species with the highest densities were *Rinorea dentate* and *Angylocalyx pynaertii* in the disturbed site while *Microdesmis puberula* and *Lasianthera africana* were recorded in the undisturbed site (Table 1). A number of species (*Xylopia aethiopica, Newbouldia laevis, Crotonogyne preussii, Voacanga africana, Dracaena camerooniana Trichilia welwitschii* etc) recorded low species densities in both forest sites (Table 1). Species similarity index in both site was 0.41 (Table 2).

Table 2: Species richness, density (seedlings ha^{-1}), total number of family and similarities of seedlings in undisturbed and disturbed sites

Attributes	Form	Conservation status	
		Undisturbed site	Disturbed
Richness plot ha^{-1}	seedling	87	48
Total Density ha^{-1}	seedling	20073.53	15039.06
Total no. family	seedling	38	24
Genera	seedling	83	40
similarity Index	seedling	0.41	

Seedling-Adult Relationship Patterns

The pattern of juvenile – adult density relationship varied in undisturbed to disturbed sites (Figure 3 and 4). The relationship of seedling and mature tree densities were significantly ($P< 0.05$) different for both undisturbed and disturbed sites but the magnitude were generally low ($R^2 < 50\%$) in both forest sites. However the magnitudes were better in disturbed ($R^2 = 52.1\%$) and ($R^2 = 24.6\%$) undisturbed sites.

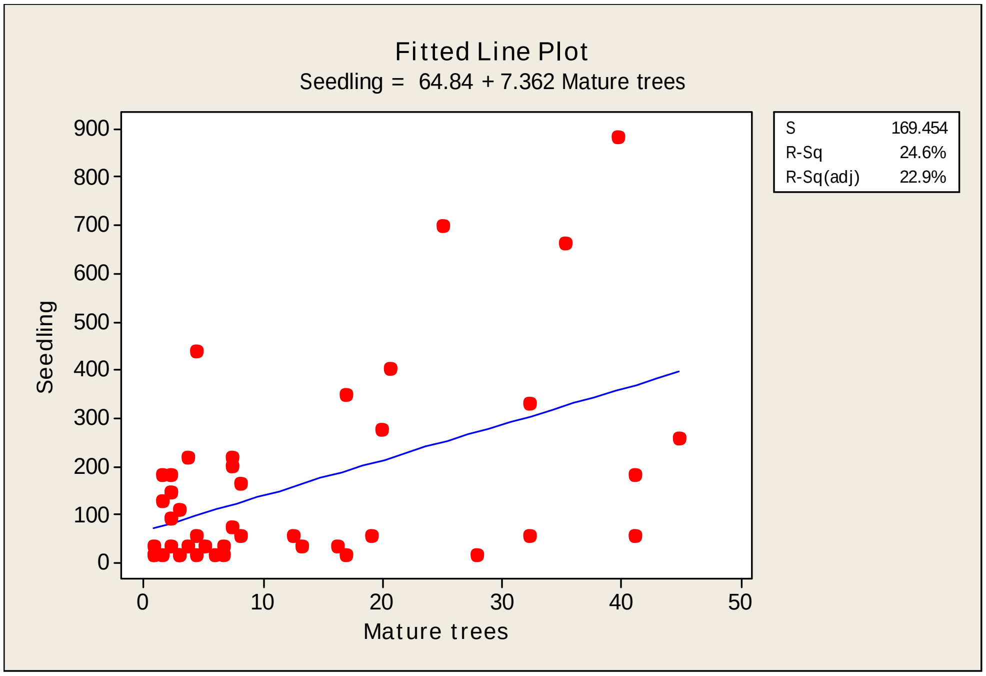

Figure 3. Relationship between seedling densities (seedlings ha^{-1}) and mature trees (trees ha^{-1}) in an undisturbed site of the Takamanda rainforest

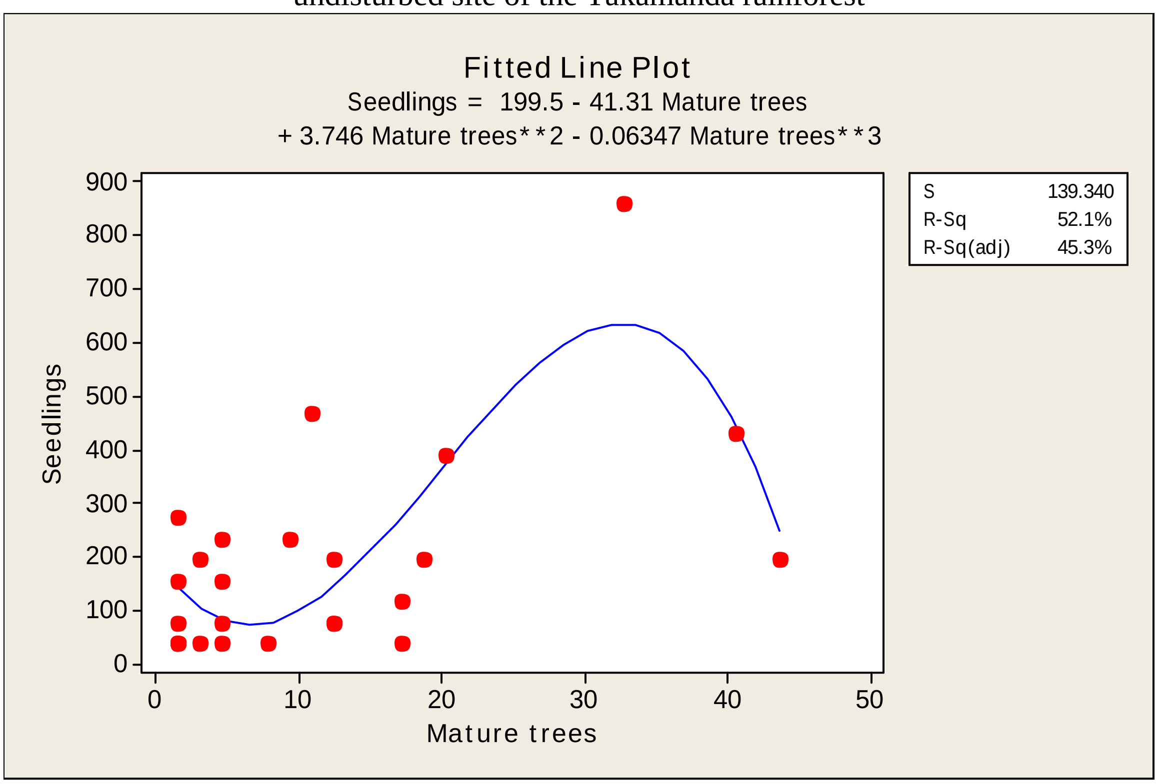

Figure 4: Relationship between seedlings densities (seedlings ha^{-1}) and mature trees (trees ha^{-1}) in the disturbed site of the Takamanda rainforest

Spatial Distribution of Seedling Population

The standardised Morisita's index values varied across species in both undisturbed and disturbed sites (Table 3). The different seedling population recorded clumped, uniform and random dispersion pattern in both forest sites (Table 3). Generally, most of the species showed clumped distribution (Table 3) and (Figure 4).

Table 3. Morisita's index and pattern of distribution of seedlings in undisturbed and human disturbed sites

species	Undisturbed site		Disturbed site	
	Ip	Distribution Patterns	Ip	Distribution Patterns
Albizia zygia	-	-	1.0	C
Afzelia bipendensis	0.0	Ra	-	-
Angylocalyx oligophyllus	0.7	C	1.0	C
Angylocalyx pynatii	-	-	1.0	C
Anisphyllea polyneura	1.0	C	-	-
Annickia chlorantha	0.5	C	-0.1	U
Anthonotha macrophylla	0.6	C	0.9	C
Antiaris africana	0.1	C	0.0	Ra
Baphia nitida	0.6	C	1.0	C
Beilschmiedia obscura	0.6	C	-	-
Campylospermum elongatum	0.0	Ra	-	-
Carpolobia alba	0.6	C	0.0	Ra
Carpolobia lutea	-	-	-0.2	U
Celtis mildbraedii	0.3	C	-	-
Coffea sp	0.0	U	-	-
Cola ficifolia	0.5	C	-	-
Cola millenii	-	-	1.0	C
Dacryodes igaganga	0.0	Ra	-	-
Dichapetalum sp	0.0	Ra	-	-
Dicranolepis disticha	-0.1	U	-	-
Diospyros preussii	0.6	C	-	-
Drypetes preussii	-0.1	U	-0.1	U
Drypetes sp	0.6	C	-	-
Funtumia africana	-	-	0.0	Ra
Funtumia elastica	1.4	C	-	-
Grewia coriacea	-0.2	U	-	-
Hylodendron gabunense	-	-	1.0	C
Heinsia crinita	-0.1	U	-	-
Hylodendron gabunense	-	-	1.0	C
Homalium longistylum	-0.1	U	-	-
Hypodaphnis zenkeri	0.9	C	-	-
Irvingia gabonensis	1.0	C	0.0	Ra
Ixora nematopoda	1.0	C	-	-
Laccodiscus ferrugineus	0.3	C	-	-
Lasianthera africana	0.7	C	1.0	C
Mallotus oppositifolius	1.0	C	1.0	C

species	Undisturbed site		Disturbed site	
	Ip	Distribution Patterns	Ip	Distribution Patterns
Mareyopsis longifolia	0.0	Ra	-	-
Massularia acuminata	0.7	C	-	-
Memecylon engleranus	0.5	C	-	-
Microdesmis puberula	0.8	C	1.0	C
Microdesmis zenkeri	-	-	1.0	C
Millettia sanagana	0.7	C	-	-
Myrianthus preussii	0.5	C	-	-
Myrianthus arboreus	-	-	1.0	C
Pausinystalia macroceras	1.0	C	-	-
Pavetta staudtii	-	-	0.3	C
Penianthus camerounensis	0.7	C	-	-
Pentaclethera microphylla	0.6	C	-	-
Plagiostyles africana	-0.4	U	-	-
Polyathia sauveolens	0.6	C	-	-
Pseudospondias microcarpa	0.0	Ra	-	-
Psychotria bifae	1.0	C	-	-
Psychotria gabonica	0.9	C	-	-
Pterocarpus soyauxii	1.0	C	0.3	C
Rinorea digitata		C	1.0	-
Rinorea dentata	1.0	C	-	-
Rinorea oblongifolia	-	-	1.0	C
Rothmannia hispida	0.5	C	-	-
Santiria trimera	0.0	U	-	-
Sorindeia acuminata	0.5	C	-	-
Staudtia stipitata	0.6	C	-	-
Sterculia tragacantha	-	-	0.5	C
Strombosia grandifolia	1.0	C	-	-
Tabernaemontana crassa	-0.1	U	-	-
Tapura africana	1.0	C	-	-
Treculia obovoidea	0.7	C	-	-
Trichilia rubescens	0.6	-	1.0	C

*where Ra = random, C = clumped, U = uniform (are dispersion patterns).

Seventy percent of the seedling species recorded clumped distribution in both undisturbed and disturbed sites (Table 3). 16.2% of seedlings were observed to show uniformed distribution in the undisturbed site while 12% were observed to show uniformed distribution in the disturbed site (Table 3). 11.1% and 16% in undisturbed and disturbed sites respectively showed random seedling distribution (Table 3).

The standardised Morisita's index varied in types and level of distribution of similar seedling species in both forest sites (Figure 5). *Trichilia rubescens*, *Pterocarpus soyauxii*, *Microdesmis puberula*, *Baphia nitida*, *Anthonotha macrophylla* and *Angylocalyx oligophyllus* in both forest sites showed clumped pattern of distribution but had different levels of morisita's index (Figure 3.5). *Irvingia gabunensis* and *Carpolobia alba* in both sites showed clumped and random distribution (Figure 5). The clumped distribution of *Irvingia gabunensis* was recorded in the undisturbed site while the random pattern was recorded in the disturbed site (Figure 5). *Annickia chlorantha* showed both clumped and uniform pattern of distribution in both forest stand (Figure 5). The clumped pattern in *Annickia chlorantha* was observed in the undisturbed site while the uniform pattern of distribution was observed in the disturbed site (Figure 3.5). *Drypetes preussii* and *Antiaris africana* showed uniform and random dispersion. The uniform pattern was observed in the undisturbed site while the random in the disturbed site (Figure 5).

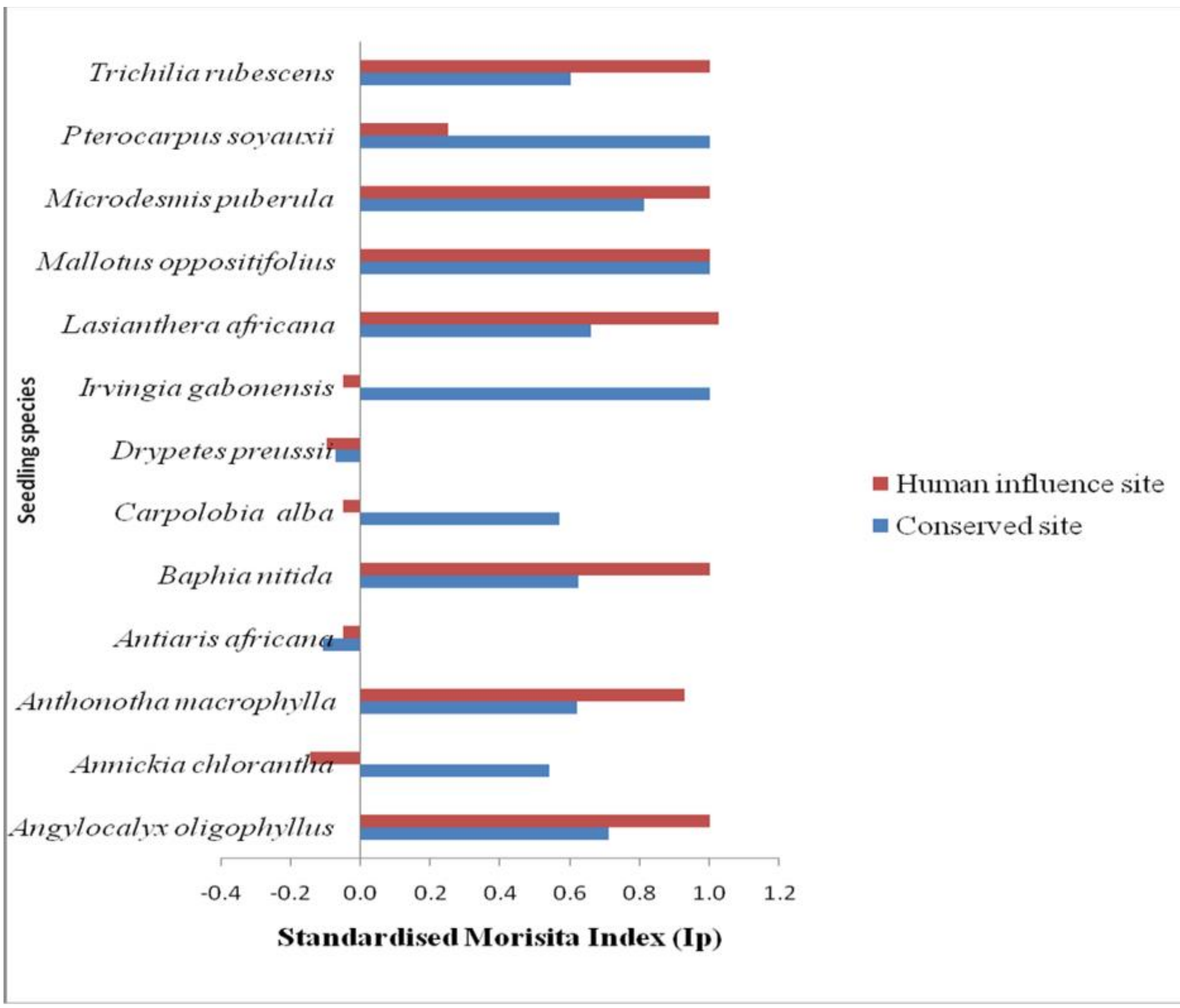

Figure 5: Comparison of distribution patterns of similar tree seedlings in undisturbed and disturbed sites

Discussion

Seedlings Species Composition

Generally, seedlings representing 106 species were recorded across the sites. The number of seedling tree species recorded in the undisturbed site (87) was higher than the number recorded in other protected forests, such as Gran Sabana (45) in southern Venezuela, Laba (59) and Tiogo (64) in Burkina Faso (Zida *et al*., 2007) while in the disturbed forest site (48) had the least number of tree seedling species when compared with Laba and Tiago forest in Burkina Faso (Zida *et al*., 2007). The results showed a conspicuous difference in species composition in both forest sites. The high species richness in undisturbed forest site could be attributed to little disturbance and a favourable biotic and abiotic factors which encourage seedling growth and establishment. Low species richness in the disturbed forest site could probably be due to disturbances such as over harvesting of NTFPs, indiscriminate logging of trees and inadequate seed dispersal agents to carry seeds to sites of eventual establishment (Ndah *et al*., 2013a; Sunderland *et al*., 2003). Furthermore, the low species richness in the disturbed forest site perhaps could stem from the encroachment of forest and its conversion into cocoa and palm plantations. This finding is in line with Nguh (2013) on land tenure and land use dynamics in the South West Region of Cameroon. Similar patterns of high seedlings tree species richness and correspondingly high seedling abundance have also been shown in tropical forest (Nicotra *et al*., 1999; Rettenmaier and Folster 1999).

In this study, we generally noticed that most of the tree seedling species had a low frequency of seedlings distribution in both forest sites. This may be due to habitat modification either by biotic or abiotic factors, which cause poor seedling establishment. This finding is in agreement with Chang-Yang *et al*., (2013) on long-term seedling dynamics in rainforest and seedling survival and growth of ectomycorrhizal trees in the rainforest, respectively. However, some of the tree seedling species (*Microdesmis puberula*, *Psychotria gabonica*, *Sorindeia acuminate*, *Angylocalyx pynatii*, *Rinorea dentate* and *Mallotus oppositifolius*) frequently occurred in both undisturbed and undisturbed forest sites. This frequent occurrence of these seedling tree species can be attributed to the ability of the seeds or seedlings having high adaptability to a wide biotic and environmental condition for seed germination or seedlings establishment. This finding ties with works of Metz *et al*., (2008)

Seedling Population Densities

The results showed slight differences in the total tree seedling densities both undisturbed and disturbed forest sites. Nevertheless, most tree of the seedling species showed great variation in seedling densities within and between forests sites. The high variation in seedling densities within site could be attributed to the fact that some of the mature trees of these seedling species produce large amounts of viable seeds which are carried by dispersal agents to suitable sites for establishment. Another possible reasons may be due to little predation, herbivory and pathogen attack on both seeds and seedlings of the species, thus enabling growth and establishment. These findings are in line with Benitez-Malvido and Lemus-Albor (2004) on seedling community and interaction of herbivory and predation in rainforests. The high densities between sites could mainly be due to disturbances common in the disturbed site such as logging, establishment of farms and indiscriminate harvesting of forest products have resulted in the damaging of fragile niches (Ndah *et al*., 2013a). This difference in density in sites can also be ascribed to modification of microclimates in which these species grow. This result is in conformity with finding of Egbe *et al*., (2012) on forest disturbance and natural regeneration in an African rainforest in south west Cameroon. Also the high winds during some months of the year and the undulating nature of the disturbed forest site result in tree snapping, tree fall and landslide affected seedling establishment. However, *Rinorea dentate* and *Angylocalyx pynaertii* seedlings had the highest seedling densities in both forest sites. This may be attributed to gaps that allow sunlight, appropriate moisture and temperature for seed germination and eventually establishment. This finding is similar to results obtained by Bonger and Popma (1990) on leaf dynamics of seedlings in relation to canopy gaps. *Microdesmis puberula* and *Lasianthera africana* also recorded the highest densities in the undisturbed site. The high densities of these species in the undisturbed and disturbed forest sites could be linked to the fact that most of these species fruits yearly and much of their seeds are left on the forest floor for future germination and establishment. The two forest sites showed great disparity both in the kind and type of species. Probably, the high disturbances in the disturbed site have resulted in the destruction of seedling species. Uriarte *et al*., (2004) and Eilu and Obuea (2005) reported that disturbances in forest ecosystems can lead to fragmentation of habitats; species become endangered and other endemic species extinct in the ecosystem resulting to loss of seedling population. Egbe *et al*., (2012) also reported that logging and extraction of most mature trees in the forest ecosystem reduces the regeneration of the species.

Relationships between Seedlings-Adult Densities Patterns

The relationship between seedlings and adult tree densities was generally weak in both undisturbed and disturbed forest sites. Perhaps, the weak relationship may be due to the high disturbance in the disturbed site and the porous nature of the undisturbed site where hunting and collection of NTFPs is still common in communities around the park (Ndah *et al*., 2013b). The relation was better for the disturbed forest site than for the undisturbed forest site. This could be attributed to pioneer species which take advantage of created gaps for establishment in the site.

The clumped pattern of distribution was recorded in species of both forest sites. Ndah *et al*., (2013) and Odum (1996) reported that contagious or clumped distribution is common in nature. Uniformed distribution pattern reported at both sites could be explained by feeding habitats of animals as well as wind action dispersing propagules in the forest sites (Ndah *et al*., 2012).

Spatial Patterns of Seedling Population

Overall, the spatial analysis revealed that the natural regeneration of the species studied was clumped. The clumped or aggregated spatial pattern is very common among tropical tree species (Ndah *et al*., 2013b; Gonzalez-Rivas *et al*., 2009; Condit *et al*., 2000). Poor propagule dispersal and poor conditions (moisture levels, temperature, nutrients, light etc) may lead to such patterns (Gonzalez-Rivas *et al*., 2009; Condit *et al*., 2000). However, some of the seedling species in both forest sites recorded uniform and random patterns of distribution. Perhaps these seedling populations are not dispersal- limited and /or seed to seedling establishment is not limited by both biotic and abiotic factors. This finding is in line with Franklin and Rey (2007) who reported on spatial patterns of trees, sapling and seedling species in tropical forest. The clumped variation in similar species (*Trichilia rubescens*, *Pterocarpus soyauxii*, *microdemis puberula*, *Mallotus oppositifolius*, *Lasianthera africana*, *Baphia nitida* and *Angylocalyx olligophyllus* of both sites could be due to limited number of dispersers and competition of which species providing maximum energy benefit to be visited by dispersers and eventual dispersal of propagules. The clumped pattern of some of these species could be attributed to a resource base-niche differentiation resulting to habitat specialization, so that different species are best suited to different habitats, where they are competitively dominant and relatively more abundant. Furthermore, the topography, a major physical factor, plays a vital role in seedling composition, growth and distribution in tropical forest (Gonzalez-Rivas *et al*., 2009; Condit *et al*., 2000).

Conclusion

Generally, the population density and frequency of species is low, especially in disturbed site where species richness and abundance are lower. Species frequencies undisturbed were equally low with most species had just single individual. This suggests illegal exploitation of some of these resources. Spatial distribution is generally clumped indication of poor dispersal of seeds and or limited number of dispersal agents to carry propagules far of mother plant to avoid competition. However, uniformed and random distributions of some species were recorded in both forest sites. This suggests that seedling populations are changing in both conserved and human influence sites. Consequently, measures like natural regeneration inside and outside the National Park should be assisted through direct seeding, seedling planting, method of nursery establishment for restoration and manipulation to improve biotic and abiotic condition to improve seed dispersals, seedling establishment and growth.

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