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# REGENERATION POTENTIALS OF THE TREE SPECIES AT BC 32/4 IN SAKPONBA FOREST RESERVE, EDO STATE, NIGERIA

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Abstract

A good knowledge of the quantity, quality and regeneration potentials of the available resource provide a guide for rotation, decision making and good management planning, which are essential for sustainable forest management. Consequently, a study of the tree regeneration potential was carried out in the forest reserve The main objective of this study was to assess regeneration potential of BC 32/4 in Sakponba Forest Reserve Edo State Nigeria. Four blocks were sampled using systematic sampling technique. Each block consist of 16 samples from which 6 samples were randomly selected for the study and 6 sub plots laid for both adult and juvenile trees. In the 24 sample plots laid, 613 adult trees and 985 juvenile trees were encountered. *Gossweilerodendron balsamiferum*, *Funtumia elastica*, *Hylodendron gabunense, Pentaclethra macrophylla*, *Cordia millenii* sp. *Drypetes chevalieri*, *Strombosia postulata* and *Alfizia idiantifolia* families had the highest number representatives in the sample while *Funtumia elastica, Strombosia postulata* and *Gossweilerodendron balsamiferum* had the highest regeneration average basal area and volume per hectare of 2.9 $m^2$ and 1522 $m^3$ respectively. Regeneration potential indices were calculated for all species encountered. The species with regeneration potential indices greater than one (> 1) were considered not threatened in the community while species which had regeneration potential less than (< 1) were considered threatened in the community. It was recommended that sustainable harvesting of the tree species should be practised in order to sustain the regeneration potential of the reserve.

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## Introduction

Tropical rain forest has an outstanding natural vegetation type being the chief source of tropical hardwood for sawn timber, veneer, nuts, gums, resins, drugs and other useful plant products and animal protein (NWOBOSHI 1982). It constitutes the largest single forest biome of the world (GOWER et al. 2003). According to AKACHUKWU (1997), the tropical rain forest in Nigeria harbours over 560 trees species which attain a height of at least 12 m and a girth of 60 cm. In Nigeria, natural forest particularly rainforest are major reserves of wood resources for meeting the growing demand for wood. Apart from the growing knowledge of tropical rain forests in the Western scientific tradition, it must not be forgotten that within the tropics man has lived closed to nature and the intimate contact with tropical forests for millennia. The forests yielded all the products needed for his life, and he learned how to grow crops on inherently infertile rain forest soils, by shifting agriculture, moving the fields every 2 or 3 years and allowing forest regrowth to restore fertility. This practice which is referred to as shifting cultivation is still in existence today though minimal (WHITMORE 1998).

Tropical forests like all other forest formations are renewable, that is, they can be regenerated. This is however, only true when the forests are well managed. The problem of the tropical foresters is therefore not only how to make best use of existing natural forest resources but also how to perpetuate the productivity of the forests currently being exploited. The solution is made more difficult by the very structure, reproduction pattern and differential growing habits of the component trees and their responses to various degrees of disturbance. Consequently, one of the main considerations is the silvicultural systems to use in their management. HIGMAN et al. (2000), stated that the adoption of an appropriate regeneration method for any particular tree species depends very much on the manager's knowledge of the regeneration potentials of the species in the area. Regeneration is the process of renewal, restoration and growth that makes ecosystems resilient to natural fluctuation or events that cause damage or extinction. Ecosystems can be regenerative and every species is capable of regeneration.

Following a disturbance such as fire or pest outbreak in a forest, species will occupy, compete for space and establish themselves in the newly opened habitat and the new growth seedlings is known as regeneration. The regeneration potential of species is therefore the capability of the species to regenerate. A regeneration potential index less than one ($R_p < 1$) indicates a threatened status. This study therefore involves the assessment of Sakponba Forest Reserve in the rainforest ecological zone of Edo State Nigeria to ascertain its regeneration potential with a view to providing information that would enhance its sustainable management.

## Materials and Methods

Sakponba Forest Reserve is situated in the humid tropical rainforest zone of Nigeria. It lies on latitude 60°4'N and longitude 5°32'E. The forest reserve is located in Orhionmwon Local Government Area of Edo State. Sakponba Forest Reserve is divided into two main areas by River Jamieson, Area BC 29 and BC 32/4. It is gridded into 175 compartments. Out of these,101 are located in BC 29 and 75 in BC 32/4 (ISIKHUEMEN 1998). The geologic timescale is of tertiary age of the post middle colian period called the Benin Sands (OGUNTALA 1980). The topsoil is fine sandy loamy, reddish in color and less than 30 cm in depth. Down the profile at depths greater than 30 cm, the soil becomes coarser and darker reddish Chroma and becomes brick red as the depth increases (OGUNTALA 1980). The mean annual rainfall is 2162 mm. The wettest period is between July and September while the driest is between December and January.

Systematic sampling techniques was adopted for data collections and it involved four (4) blocks in the forest reserve. Each block consisted of 200 m × 200 m along the base line. Every block consists of sixteen (16) sample plots of 50 m × 50 m. Six (6) sample plots were randomly selected in each block. Each block therefore comprised six (6) sample plots. Implying that an area of 60,000 $m^2$ (6 ha) was assessed for the adult trees while 2,400 $m^2$ (0.24 ha) was assessed for tree regeneration in the reserve. However, only trees whose diameter at the breast height are less than 20 cm was regarded as juvenile trees (regeneration) – Figure 1. **Diameter girth tape** was used to measure diameter at breast height and diameter at the base while the **Spiegel relaskop** was used to measure the diameter at the middle, top and total height of the adult trees in each sample plot.


Fig. 1. Pictures of the study area

## Data Analysis

All tree species recorded in the field enumerated were scored in their respective families according to the documentation of KEAY (1989).

Equation 1 was used to obtain the number of each tree species represented in the respective size-classes.

$$N = n_1 + n_2 + \ldots\ldots\ldots\ldots + n_{24} \ldots\ldots\ldots\ldots \quad (1)$$

where:
$N$ – total number of individuals of each species in the representative size-classes
$n_{1\_}n_{24}$ – number of individual of each species in sample plot 1-24

The numbers of juvenile trees of each species from all the sample plots were added together, using equation 1, to obtain the total regeneration of each species in the sample.

### Basal Area Estimation

The basal area of each tree was calculated using eq. (2):

$$\mathrm{BA} = \frac{\pi D^2}{4} \quad (2)$$

where:
BA – basal area [m$^2$]
$\pi$ – constant (3.142)
$D$ – diameter at breast height

### Volume Estimation

The volume of each tree was estimated using the Newton's equation.

$$V = h\left(\frac{\mathrm{Ab} + 4\mathrm{Am} + \mathrm{At}}{6}\right) \quad (3)$$

where:
$V$ – volume
$h$ – height
Ab – diameter at the base
Am – diameter at the middle
At – diameter at the top

The basal area and volumes of the individual trees in all the sampling plots were properly sorted into their respective diameter classes. The basal area and volumes of tree in each size class were summed together using equation 4 and 5 respectively, to obtain the total basal area and volumes for each size class in all the sample plots.

$$B = \Sigma B \tag{4}$$

where:
$B$ – the basal area of all the trees in each size class at the sample plot level
$\Sigma B$ – summation of basal area of individual trees in each size class.

$$V = \Sigma V \tag{5}$$

where:
$V$ – the volume of the trees in each size class at the sample plot level.
$\Sigma V$ – summation of volume of individual tree in each class.

The total basal area and volumes of trees in each size class from all the sample plots were further summed together and divided by 4 (the number of hectares enumerated), using equation 6 and 7 respectively, to obtain the average basal area and the volumes of trees per hectares for each size class. These data showed the distribution of basal area and volumes among the various size classes.

$$\mathrm{AB} = \frac{\Sigma B}{4} \tag{6}$$

where:
AB – average basal area of the trees per hectare in each size class
$\Sigma B$ – summation of the basal areas of trees in each size class in the respective sample plot.

$$\mathrm{AV} = \frac{\Sigma \mathrm{V}}{4} \tag{7}$$

where:
AV – average volume of trees per hectare in each size class
$\Sigma V$ – summation of the volume of trees in each size class in the respective sample plot.

Measure of population density and productivity of the study area were obtained by adding together the average numbers of trees, basal area and volumes per hectare from all the size classes to obtain the number of trees, basal areas and volume per hectare respectively (equation 8 and 9).

$$\mathrm{TAB} = \mathrm{AB}_1 + \mathrm{AB}_2 + \qquad + \mathrm{AB}_9 \tag{8}$$

where:
TAB – total average basal area of trees per hectare
$\mathrm{AB}_1$–$\mathrm{AB}_9$ – the average basal area of trees per hectare, for size classes 1–10

$$TAV = AV_1 + AV_2 + \qquad\qquad + AV_9 \tag{9}$$

where:
TAV – total average volume of trees per hectare
$AV_1$–$AV_9$ – the average volume of trees per hectare, for size classes 1–9.

The total number of juvenile trees (regeneration) of each species in the sample were extrapolated using equation 10 to obtain the regeneration of each species per hectare

where:
*R* – the regeneration of each species per hectare
*H* – one hectare (10,000 $m^2$) of the forest
N – number of juvenile trees of each species in the sample
*A* – the total area sampled for the juvenile trees (2,400 $m^2$).

The regeneration potential of each species were estimated with the formula:

$$R_p = \frac{ni \cdot ri}{N} \tag{10}$$

where:
$R_p$ – natural regeneration potential index
ni – number of individual adult species per hectare
ri – number of regeneration or juveniles of species per hectare
*N* – total numbers of adult trees.

## Results

A total of 44 species of both adult and juvenile trees belonging to 40 families were considered. *Caesalpiniodeae* and *Olacaceeae* families had the highest numbers of juvenile trees each represented by 75 juvenile individual in the sampled area. They were followed by *Samyolaceae* family which was represented by 54 juvenile individuals. These were followed by *Mimosoideae* and *Rubaceae* families which were represented by 50 juvenile individuals while others such as *Annonaceae, Meliaceae Caesalpinioideae, Tiliaceae*, *Rubiaceae* and *Simaroubaceae* families had no juvenile individual. All other families had between 4 and 75 juvenile representatives in the sample. In the regeneration category (Table 1) 40 out of 44 species encountered in the study were represented by their juveniles. A total of 985 juvenile trees (trees with < 20 cm in dbh) were identified and counted in all the 24 sub plots. *Funtumia elastca* (75) and *Strombosia* *pustulates* (75) and *Homalum letestuii* (54) *Pentaclethra macrophylla* (50) *Rothmannia hispida* (50) were the five top most species represented in the regeneration category. On the other hand, *Anemidium mannii, Synsepalum stipulatum, Pycnanthus angolensis and Anonidium mannii* had the least number of juvenile representatives of four each in the sample.

Table 1

Juvenile trees regeneration

| Species | Number of sample plot | Number per hectare |
|---|---|---|
| *Tabernaemontana pachysiphon* | 8 | 33 |
| *Anthonotha macrophylla* | 8 | 33 |
| *Pycnanthus angolensis* | 4 | 17 |
| *Anonidium mannii* | 4 | 17 |
| *Brenania brieyi* | 12 | 50 |
| *Hannoa klaineana* | 8 | 33 |
| *Synsepalum stipulatum* | 4 | 17 |
| *Omphalocarpum procerum* | 8 | 33 |
| *Sphenocentrum jollyanium* | 8 | 33 |
| *Zanthoxylium zanthoxyloides* | 8 | 33 |
| *Ficus exasperate* | 12 | 50 |
| *Millettia aboensis* | 12 | 50 |
| *Nauclea diderrichii* | 8 | 33 |
| *Harungana madagascariensis* | 20 | 83 |
| *Cordia millenii* | 8 | 33 |
| *Milicia excelsia* | 8 | 33 |
| *Pycnanthus angolensis* | 12 | 50 |
| *Allanblackia floribunda* | 16 | 67 |
| *Musanga cecropioides* | 16 | 67 |
| *Cylicodiscus gabunensis* | 20 | 83 |
| *Piptadeniastrum africanum* | 16 | 67 |
| *Sterculiaa tragacantha* | 25 | 104 |
| *Maesopsis eminii* | 29 | 121 |
| *Trilepisium madagascariense* | 37 | 154 |

| | | |
|---|---|---|
| *Celtis zenkeri* | 29 | 121 |
| *Ricinodenchron heudelotii* | 29 | 121 |
| *Trichilia heudelotii* | 29 | 121 |
| *Pansinsytalia macroceras* | 45 | 188 |
| *Anonidium mannii* | 37 | 154 |
| *Hylodendron gabunense* | 29 | 121 |
| *Guarea cedrata* | 49 | 205 |
| *Pentaclethra macrophylla* | 50 | 208 |
| *Rothmannia hispida* | 50 | 208 |
| *Homalum letestuii* | 54 | 225 |
| *Albizia idiantifolia* | 45 | 188 |
| *Drypetes chevalieri* | 37 | 154 |
| *Gossweilerodendron balsamiferum* | 41 | 171 |
| *Funtumia elastic* | 75 | 313 |
| *Strombosia postulate* | 75 | 313 |

Estimates of the regeneration per hectare revealed that *Funtumia elastica* had the highest regeneration of 313 juvenile trees per hectare followed by *Strombosia postulata* with 313 juvenile trees per hectare. Others were *Hylodendron gabunense* (121/ha), *Anonidium manni* (171/ha), *Guarea cedrata* (205/ha and *Rothmannia hispida* (208/ha).

Other tree species in the forest reserve had less than 100 juvenile trees per hectare. The forest therefore had an estimated population of 1736 adult and juvenile trees with 1634 juvenile trees and 102 adult trees that constituted about 94% of the population of juvenile per hectare while 6% of the population belonged to adult trees category.

The regeneration potential indices of all the species are presented in Table 2. The table showed that the regeneration potential indices of 11 (27%) species were greater than one (> 1), with *Strombosia postulate* and *Funtumia elastica* topping the list with 3.99 each. *Gossweilerodendron balsomiferum* (2.18). The remaining 30 (73%) species each had a regeneration potential index of less than one (< 1), while each of the 15 (37%) out of the 30 species, had a regeneration potential index of zero (0.00).

Table 2

Regeneration potentials of the species

| Species | $R_p$ |
|---|---|
| *Enanta chlorantha* | 0.00 |
| *Entandrophragma angolense* | 0.00 |
| *Tabameamontana Pachysipton* | 0.00 |
| *Anthonotha macrophylla* | 0.00 |
| *Khaya ivorensis* | 0.00 |
| *Pentaclethra macrophylla* | 0.00 |
| *Duboscia viridiflora* | 0.00 |
| *Pycnanthus angolensis* | 0.00 |
| *Brenania brieyi* | 0.00 |
| *Anonidium mannii* | 0.00 |
| *Hannoa klaineana* | 0.00 |
| *Brenania brieyi* | 0.00 |
| *Hannoa klaineana* | 0.00 |
| *Synsepalum stipulatum* | 0.04 |
| *Omphalocarpum procerum* | 0.09 |
| *Sphenocentrum jollyanium* | 0.09 |
| *Zanthoxylium zanthoxyloides* | 0.09 |
| *Ficus exasperate* | 0.13 |
| *Millettia aboensis* | 0.13 |
| *Nauclea chiderrichii* | 0.17 |
| *Harungana madagascariensis* | 0.21 |
| *Cordia millenii* | 0.26 |
| *Milicia excelsia* | 0.26 |
| *Pycnanthus angolensis* | 0.26 |
| *Allanlackia floribunda* | 0.34 |
| *Musanga cecropioides* | 0.34 |
| *Cylicodiscus gabunensis* | 0.43 |
| *Piptadeniastrum africanum* | 0.51 |
| *Sterculiaa tragacantha* | 0.53 |
| *Maesopsis eminii* | 0.62 |
| *Trilepisium madagascariense* | 0.79 |

| | |
|---|---|
| *Celtis zenkeri* | 0.93 |
| *Ricinodenchron heudelotii* | 0.93 |
| *Trichilia heudelotii* | 0.93 |
| *Pansinsytalia macroceras* | 0.96 |
| *Anonidium mannii* | 1.18 |
| *Hylodendron gabunense* | 1.23 |
| *Guarea cedrata* | 1.44 |
| *Pentaclethra macrophylla* | 1.60 |
| *Rothmannia hispida* | 1.60 |
| *Homalum letestuii* | 1.72 |
| *Albizia idiantifolia* | 1.91 |
| *Drypetes chevalieri* | 1.97 |
| *Gossweilerodendron balsamiferum* | 2.18 |
| *Funtumia elastic* | 3.19 |
| *Strombosia postulate* | 3.99 |
| $R_p$ < 1.0 implies threatened status | |

The 44 trees enumerated, had 1634 (94%) represented by their young ones (juvenile). However, 33 (73.3%) of the species were represented by both the adult and juvenile trees (Table 3, Table 4).

Table 3

List of species represented with either juvenile or adult trees

| Species | Estimated regeneration/ha | Number of adult trees/ha |
|---|---|---|
| *Enanta chlorantha* | - | 1 |
| *Entandrophragma angolense* | - | 1 |
| *Tabamagmontana Pachysipton* | 33 | < 1 |
| *Anthonotha macrophylla* | - | 1 |
| *Khaya ivoriensis* | - | 1 |
| *Pentaclethra macrophylla* | - | 1 |
| *Duboscia viridiflora* | - | 1 |
| *Pycnanthus angolensis* | 17 | < 1 |
| *Brenania brieyi* | 50- | < 1 |
| *Anonidium mannii* | 17 | < 1 |
| *Hannoa klaineana* | 33 | < 1 |

| | | |
|---|---|---|
| *Synsepalum stipulatum* | 17 | 1 |
| *Omphalocarpum procerum* | 33 | 1 |
| *Sphenocentrum jollyanium* | 33 | 1 |
| *Zanthoxylium zanthoxyloides* | 33 | 1 |
| *Ficus exasperata* | 50 | 1 |
| *Millettia aboensis* | 50 | 1 |
| *Nauclea diderrichii* | 33 | 2 |
| *Harungana madagascariensis* | 83 | 1 |
| *Cordia Millenii* | 33 | 3 |
| *Milicia excelsia* | 33 | 3 |
| *Pycnanthus angolensis* | 50 | 2 |
| *Allanblackia floribunda* | 67 | 2 |
| *Musanga cecropioides* | 67 | 2 |
| *Cylicodiscus gabunensis* | 83 | 2 |
| *Piptadeniastrum africanum* | 67 | 3 |
| *Sterculiaa tragacantha* | 104 | 2 |
| *Maesopsis eminii* | 121 | 2 |
| *Trilepisium madagascariense* | 154 | 2 |
| *Celtis zenkeri* | 121 | 3 |
| *Ricinodenchron heudelotii* | 121 | 3 |
| *Trichilia heudelotii* | 121 | 3 |
| *Pansinsytalia macroceras* | 188 | 2 |
| *Anonidium mannii* | 154 | 3 |
| *Hylodendron gabunense* | 121 | 4 |
| *Guarea cedrata* | 205 | 4 |
| *Pentaclethra macrophylla* | 208 | 3 |
| *Rothmannia hispida* | 208 | 3 |
| *Homalum letestuii* | 225 | 3 |
| *Albizia idiantifolia* | 188 | 4 |
| *Drypetes chevalieri* | 154 | 5 |
| *Gossweilerodendron balsamiferum* | 171 | 5 |
| *Funtumia elastica* | 313 | 4 |
| *Strombosia pustulate* | 313 | 5 |

Table 4

List of species represented by both juvenile and adult trees

| Species | Estimated regeneration/ha | Number of adult trees/ha |
|---|---|---|
| *Synsepalum stipulatum* | 17 | 1 |
| *Omphalocarpum procerum* | 33 | 1 |
| *Sphenocentrum jollyanium* | 33 | 1 |
| *Zanthoxylium zanthoxyloides* | 33 | 1 |
| *Ficus exasperata* | 50 | 1 |
| *Millettia aboensis* | 50 | 1 |
| *Nauclea diderrichii* | 33 | 2 |
| *Harungana madagascariensis* | 83 | 1 |
| *Cordia millenii* | 33 | 3 |
| *Milicia excelsia* | 33 | 3 |
| *Pycnanthus angolensis* | 50 | 2 |
| *Allanblackia floribunda* | 67 | 2 |
| *Musanga cecropioides* | 67 | 2 |
| *Cylicodiscus gabunensis* | 83 | 2 |
| *Piptadeniastrum africanum* | 67 | 3 |
| *Sterculiaa tragacantha* | 104 | 2 |
| *Maesopsis eminii* | 121 | 2 |
| *Trilepisium madagascariense* | 154 | 2 |
| *Celtis zenkeri* | 121 | 3 |
| *Ricinodenchron heudelotii* | 121 | 3 |
| *Trichilia heudelotii* | 121 | 3 |
| *Pansinsytalia macroceras* | 188 | 2 |
| *Anonidium mannii* | 154 | 3 |
| *Hylodendron gabunense* | 121 | 4 |
| *Guarea cedrata* | 205 | 4 |
| *Pentaclethra macrophylla* | 208 | 3 |
| *Rothmannia hispida* | 208 | 3 |
| *Homalum letestuii* | 225 | 3 |
| *Albizia idiantifolia* | 188 | 4 |
| *Drypetes chevalieri* | 154 | 5 |
| *Gossweilerodendron balsamiferum* | 171 | 5 |
| *Funtumia elastica* | 313 | 4 |
| *Strombosia pustulata* | 313 | 5 |

The 613 adult trees enumerated in the sample plots gave a total basal area of about 377.6 $m^2$ and a total volume of about 9,132 $m^3$. The basal area and volume per hectare of the forest reserve were estimated as 62.9 $m^2$ and 1,522 $m^3$ respectively (Table 5). The distribution of the basal area per hectare among the diameter size classes (Table 5) showed that diameter class 9 had the highest basal area of about 17.6 $m^2$ per hectare followed by diameter classes 7, 8 and 6, with standing volumes of about 385.8 $m^3$, 286.8 $m^3$ and 337.2 $m^3$ per hectares respectively.

Table 5

Basal area and volume per hectare of the species

| Class size [cm] | Basal area/4 ha | Volume/4 ha |
|---|---|---|
| 20–29 | 2.5 | 65.0 |
| 30–39 | 3.0 | 73.9 |
| 40–49 | 3.3 | 87.1 |
| 50–59 | 14.5 | 372.7 |
| 60–69 | 39.5 | 1,014.2 |
| 70–79 | 58.7 | 1,459.6 |
| 80–89 | 81.4 | 2,023.1 |
| 90–99 | 69.6 | 1,721.2 |
| 100 cm above | 105.1 | 2,315.3 |
| Total | 377.6 | 9,132.0 |

## Discussion

The regeneration potential indices calculated for the species encountered in the study showed the various species' regeneration capabilities and conservation status in the study area. The results in table 1 and 2 showed that the regeneration potentials of the tree species in the study area was generally poor, with only 45% (18 species) of the tree species encountered having more than 100 juvenile trees per hectare and their regeneration potential indices greater than one (>1). This was not even up to half of the 40 species in table 3 that were represented by both the juvenile and adult individuals. This has a serious implication on the regeneration and conservation of the various species encountered and the renewal of the forest in general. Since regeneration is one means of forest renewal (Nwaboshi 1982). This is similar to the result obtained by Nur et al. (2016) where 36% of the tree species (17 out of 47) are regenerating in the study area, while majority of the tree species (64%) are not getting favourable conditions to regenerate. ADDO-FORDJOUR et al. (2009) also reported only 29 regenerating tree species from 12 families for the Tinte Bepo Forest Reserve in Ghana. CECCON et al. (2004) and WALE et al. (2012) also noted that lack of adequate regeneration is an issue recognized by foresters and ecologist. MALIK and BHATT (2016) also observed limited regeneration and subsequently declining populations of some dominant native species. Furthermore, JAYAKUMAR and NAIR (2013) observed in their study that only 10 lspecies regenerated well with one of the dominant species having no seedlings which is an indicative of poor regeneration potential. Species such as *Gossweilerodendron balsamiferum, Funtumia elastica, Hylodendron gabunense* and others in Table 2 had high regeneration potential indices (>1), exhibited high potentialities to perpetuate their populations in the community and renew the entire forest. This implies that they have high ability to replace their population effectively and can also replace other tree species which have threatened status in the community. These species were able to regenerate successfully in the area probably because of their ability to produce large quantities of viable seeds, withstand shading, suppression and compete favourably for growth resources in the micro climate under the closed canopy.

In terms of sustainable forest management, the natural regeneration of *Funtumia elastica, Strombosia postulata, Gossweilerodendron balsamiferum, Hylodendron gabunense* and others with high regeneration potential indices, offer enough potential to support sustained yield harvest without any need for artificial intervention. Artificial regeneration is useful where natural seeding of the desired species is absent and difficult to obtain or where their performance is poor and unreliable, and there is need to correct any imbalance between regeneration and exploitation (NWOBOSHI 1982). On the other hand, *Omphalocarpum procerum, Harungana madagascariensis, Pycnathus angolensis* and other species in Table 2 with low regeneration potential indices (< 1) have threatened status. A tree species with less than 1.0 regeneration potential index is considered as a rare species (PATHASARANTHY and KARTHIKEYAN 1997, FORMECU 1999). They have very low potentialities to perpetuate their own populations in that community. Their continued existence in that community is therefore threatened because of their low natural abilities to replace their adult populations in that community. These species could not regenerate successfully in the area probably because they could not do well in the micro climate under the closed canopy.

The species that were considered most threatened in the study area were those with regeneration potential index of zero (0.00). They were represented by either very few adult or juvenile trees as shown in Table 2.

Those species with less than one (>1) adult tree per hectare without regeneration included *Pycnathus angolensis, Brenania, brieyi, Ananidium mommi, and Tabamagmontiana pachysipton*. Species with few regenerations per hectare, but no adult individuals were *Entandrophragma angolense, Khaya ivorensis, Anthenotha macrophylla* etc. The scanty representation of some trees species in this study is typical of the tropical rain forest ecosystem NWOBOSHI (1982) and ETUKUDO (2000) reported that a forest may be rich in tree species with hundreds of them sometimes found in a single hectare, but some species may be represented by only one to three individuals per hectare. According to PARTHASARATHY and KARTHIKEYAN (1997), a species with less than ten individuals per hectare is considered as rare and endangered species.

Generally, the absence of either their adults or regeneration from all the sample plots indicated their scarcity in the area, which is a sign of endangered or threatened status. The scarcity representation or low regeneration potentials and threatened status of some of the species in the area may be due to their low seed production and viability and/or high mortality rate in the area. This is because the success of the natural regeneration of any species depends on its seed availability, viability and seeding establishment as well as shade tolerance. Unfortunately, some economically desirable species in the tropics, example *Triplochiton scleroxylon* do not fruit yearly. Those that do, hardly have good seed years at regular intervals. Sometimes, the seeds may be eaten by insects, birds and rodents before or after falling from the trees (NWOBOSHI 1982). Although there was no sign of any recent exploitation of timber in the area, the scanty representation and low regeneration of some tree species especially those with non-timber values could be attributed to their over exploitation for non-timber uses. For example, the fruits and trees of *Irvingia gabonensis*, *Afzelia* spp., *Brachystegia* spp., *Allanblackia floribunda*, *Baillonella toxisperma* and *Garcinia cola* are collected for use by humans. This would render their seeds unavailable for their successful natural regeneration and thus be responsible for their scarcity in the area. The stem and branches of *Garcinia mannie* are used as chewing sticks for hygiene. Over exploitation of this species could make its regeneration scarce in the area, since the adult individuals that should produce more seeds for successful natural regeneration would be lacking. Most of the well-known and highly demanded economic species encountered in the study area, such as *Brachystegia* spp., *Afzelia, Bipindensis, Pterocarpus seyauxii, Piptadeniastrum africanum, Ballonella toxisperma, Lovoa trichilioides, Nauclea diderrichii, khaya ivorensis, Entandrophragma utile*, and *Termimalia superba* had threatened status. The management and conservation implications or species with threatened status in the area include impossibility of sustained yield harvest of such species from the forest without artificial intervention. This means that the application of appropriate silvicultural techniques would be necessary to enhance the seeding production, growth and survival of such species in the area.

With the very large number of smaller trees, the population structure in the study area would favour sustained yield harvest through regular recruitment from lower diameter-size classes into higher diameter-size classes. OGBONAYA (2002) opined that a juvenile size class population of about 35% is ideal for sustained yield harvest. An estimated juvenile tree population of about 4,105 per hectare (Table 2) which was about 99% of the total tree population per hectare, was therefore more than enough to support sustained yield harvest per hectare.

## Conclusion

The regeneration potential indices of the species encountered showed that only 45% of the species had their regeneration potential indices greater than one (>1). The regeneration potentials for the various species in the reserve indicated that sustained yield production of wood is very possible. This will be achieved with the adoption of appropriate silvicultural measures that can enhance the regeneration, survival and growth of the species with threatened status. It also requires the adoption of natural forest management to ensure the conservation and sustainable utilization of all tree species in the reserve and the genetic resources. It is therefore recommended that seed trees should be left standing during harvesting to produce seeds for the next generation of tree crops.

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