

## Assessment of Level of Human Disturbance in Village-adjacent Natural Forest Plots in the Kerala Part of Nilgiri Biosphere Reserve

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### ABSTRACT

The structure and composition of tree community was analysed in ten forest plots, adjacent to villages, in the Kerala part of Nilgiri Biosphere Reserve (NBR), and the level of disturbance in each plot was determined. These plots represent secondary forest, generally dominated by evergreen light demanding, late and early successional species and deciduous species such as *Xylia xylocarpa*, *Terminalia paniculata*, *Macaranga peltata*, *Aglaiia malabarica*, *Alseodaphne semecarpifolia*, *Bischofia javanica*, *Wrightia tinctoria* etc. In all the plots, a distorted girth class distribution, with a drastic decline in the number of individuals of girth ranging from 20 cm to 60 cm, was noticed. The litter removal from the forest floor depicted a three-fold adverse effect on species richness; by way of physical removal of tree propagules along with other litter materials, run-off of tree propagules in the absence of litter layer and seedling mortality consequent to soil dryness and desiccation. However, in the forest plots adjacent to villages Kadasserri and Manikunmala, the species number increased due to invasion of exotic species from the adjoining landuse systems. In order to assess the level of disturbance in these plots, three forest quality indicators namely Ramakrishnan Index of Stand Quality (RISQ), Index of Ecological Quality (IEQ) and Index of Human disturbance (IHD) were measured. The high value for RISQ (more than 3) is an indicative of the fact that majority of the forest plots are under different stages of succession and need more time for their recovery from the anthropogenic disturbances. A positive correlation between any two forest quality indicators suggested that they are complementary to each other and helpful to accurately assess ecological and human factors responsible for the status of the forest stand and identify site-specific suitable conservation and management strategies.

Key Words: Chronic Disturbance; Disturbance Variables; Biomass Harvest; Tree Community; Tree Girth Class Distribution; Successional Status; Forest Quality Indicators.

### INTRODUCTION

The recognition of India as one of the four mega-diversity countries of Asia is derived largely from two of its most important biodiversity 'hot spots' viz., the Himalaya including the north-eastern hills along the northern border and the Western Ghats in the peninsular India. During the last few decades, India has accelerated its efforts to preserve biodiversity by taking positive steps like designation of more than 4 per cent of the total land area of the country as Protected Areas (PAs) (IUCN 1990). Some such areas were also brought under Biosphere Reserves (BRs). The Biosphere Reserve programme, initiated in early 1970s as an outgrowth of the

UNESCO's Man and Biosphere Programme (MAB), aimed at generating alternative models of sustainable development wherever the current models are destructive of ecological processes and natural diversity. Thus, in India eighteen BRs have been established and among them the Nilgiri Biosphere Reserve (NBR), located in the Western Ghats, is the First BR established in the Country. In NBR, like many other BRs some of the PAs also formed the part of the landscape. Like in many other types of forest areas, many of those located in PAs of NBRs are also facing different degrees of population pressure both by forest dwelling tribal societies and by the inhabitants adjacent to forests (CES 1990). The problem of human population is accentuated by the

livestock population. In addition, changing pattern of adjacent land use system are also very often exerting pressure on forest and associated biodiversity. The entire concept of BR is to remove potential threats of deforestation and manage areas so as to minimize human impacts and develop sustainable management system for both village/tribal landscape and forest landscape units. However, at a landscape level, the type, frequency and magnitude of human disturbance may vary among forest patches. In this context, attempts need to be made to quantify the extent of human stressors and disturbance in an area by following appropriate methods. This is possible only when detailed information on characteristic features of human habitat-adjacent forests patches and the ability of the forest patches to recover and maintain system process and biodiversity are available. Therefore, the specific objectives of the present study conducted in the village-adjacent forest patches in the Kerala part of Nilgiri Biosphere Reserve were to a) analyze the structure and composition of tree community, and b) assess the level of human disturbance and ecological quality of forest patches.

## METHODOLOGY

### Study Area

The area under Kerala part of Nilgiri Biosphere Reserve (latitude between 10°50' and 12°16'N and longitudes between 76° and 77°15'E), was divided into five parts at an interval of 12' latitude. In each latitude range, two forest patches were marked. In each of these ten forest patches, one plot which has a clear forest demarcation boundary and located adjacent to a village and/ or a tribal settlement was demarcated. Thus, a total ten plots namely Adackakundu (AK), Appencappu (AC), Kadasseri (KS), Manikunnumala (MK), Manaliampadam (MP), Munnadi (MU), Parackal (PC), Pattakarimba (PK), Punchavayal (PU) and Vellimuttam (VM) were selected (Figure 1) for the study.

### Vegetation Analysis

In each forest plot, five transects, each of 1000 m x 500 m were laid from the boundary between the forest and village/ settlement to the interior of the forest. While laying transects, a minimum of 200m distance was maintained between two adjacent transects in order to avoid auto-correlation. In each transect, six quadrats,

each of 20 m x 20 m size were established. Here also 200 m distance between two quadrats was maintained. The size of the quadrat was determined based on species-area curve. All trees (individuals with gbh more than 10.1 cm; gbh: girth at 1.37m above ground) in each quadrat were marked and their taxonomic identification ascertained with the help of Gamble (1928). Number of individuals and girth of each individual of a species were recorded. In the case of trees with large buttresses, the girth was measured from above the buttressed part. In each quadrat, one 5m x 5m sub-quadrat was laid to study the tree seedling (individuals with 1.0 to 10.0 cm, height  $\leq$  1 m) community.

The vegetation data were analyzed for relative density, relative frequency, relative dominance (Phillips 1959), and the sum of values for these parameters represented by Importance Value Index (IVI) for different species (Curtis 1959). Species diversity was calculated using a formula given by Shannon and Wiener (1963).

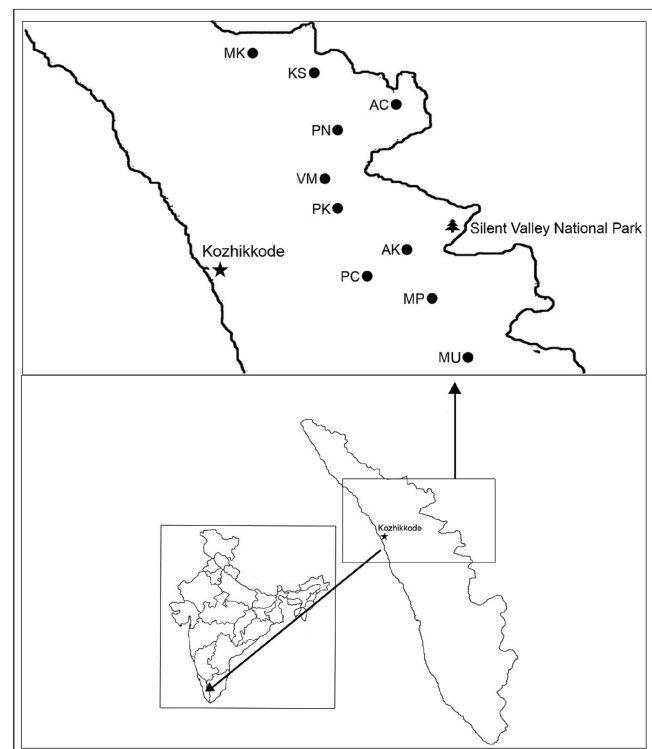


Figure 1. Location of plots established in the Kerala part of Nilgiri Biosphere Reserve.

### Determination of Disturbance Level and Stand Quality of Forest Plots

The village-adjacent natural forest may be primary or secondary and may be experiencing different levels of disturbance. Thus, indices namely Ramakrishnan Index of Stand Quality (RISQ), Index of human disturbance (IHD) and Index of ecological quality (IEQ) were calculated to compare the intensity of disturbances in the plots. The RISQ was calculated by following the method given by Chandrashekara and Sankar (1998). Considering the life history patterns, tree species can be categorised into primary species (shade tolerant evergreen species), late secondary species (evergreen species which regenerate under medium sized canopy gaps), early secondary species (evergreen heliophytic species which regenerate in large canopy gaps or open area) and deciduous species. The pioneer index value assigned to primary species, late secondary species, early secondary species and deciduous species (and also introduced species) was 1, 2, 3 and 4 respectively. Contribution of each category of species to the total IVI was multiplied by its pioneer index value. Sum of the values obtained for four categories of species was the RISQ.

$$\text{RISQ} = \sum \{(n_i/N)\} \times \text{species pioneer index}$$

where  $n_i$  = IVI of a given category of species;  $N$  = Total IVI of species of all categories and species pioneer index 1, 2, 3, and 4 for primary species, late secondary species, early secondary species and deciduous species respectively. RISQ value of a given plot can vary from 1.0 (undisturbed stand) to 4.0 (highly disturbed stand).

For calculating the IHD, in each forest plot, all visible indicators of human disturbance in all five transects (each of 1000 m x 500 m) were counted, and recorded on field data sheets. The indicators (variables) of human disturbance in the present study included a) number of larger stumps of harvested trees (>20 cm gbh), b) number of pollarded stumps (<20 cm gbh), c) number of coppiced stumps, d) number of branch cuttings, e) number of stem debarked, f) number of vehicle tracks, and g) number of foot paths. The formulae given by Mutangah (1996) were used to calculate the IHD.

$$\text{Individual Variable Index, } Y = C/C_{\text{max}} \quad (1)$$

where,  $C$  is variable value in a given plot,  $C_{\text{max}}$  is the maximum valuable value recorded.

$$\text{Index of Human Disturbance (IHD)} = \frac{\text{SY}}{N} \times 100 \quad (2)$$

where,  $N$  = number of variables studied.

The variables selected for calculating the IEQ were: a) percentage of canopy opening, b) canopy area covered by lianas (in percentage of total canopy area), and c) ground area (in percentage of total area of the plot) covered by i) the grasses, ii) native weeds, iii) exotic weeds. Above mentioned equations were also used for determining the Index of Ecological Quality (IEQ).

## RESULTS AND DISCUSSION

### Vegetation Structure and Composition

Vegetation structure, species composition and ecosystem processes have been identified as essential components for long term persistence of an ecosystem (Dorren et al. 2004). Measures of vegetation structure provide information on habitat conditions and ecosystem productivity and help to predict successional pathways. In fact, a comparative account of vegetation structure and composition also provides information on differences in types, severity and impacts of disturbance in any two forest patches. In this context, studies conducted on vegetation structure and composition in the forest patches located adjacent to the human habitation in the Kerala part of NBR has special relevance. In terms of dominant species composition, forest patches bordering the human habitation are generally dominated by evergreen light demanding, late and early successional species and deciduous species such as *Xylia xylocarpa*, *Terminalia paniculata*, *Macaranga peltata*, *Aglaia malabarica*, *Alseodaphne semecarpifolia*, *Bischofia javanica*, *Wrightia tinctoria* etc (Table 1). It is also reported that in these plots, contribution by the species characteristic to the relatively undisturbed evergreen forests to the total Importance Value Index was also considerably less (Chandrashekara 2011). Inability of primary tree species of evergreen forests to establish in the plots bordering the human habitation indicates severity of biotic pressure in these plots. Similar observation has been made in a logged temperate forest of Sikkim, where due to logging, the light demanding species dominated the shade tolerant evergreen species (Sundriyal and Sharma 1996). However, not all forest plots near human habitation seem to be experiencing

similar levels of disturbance. For instance, in the forest plot at KS better regeneration of shade tolerant evergreen species was observed. The reason for low disturbances in the plot KS is its occurrence in a comparatively difficult terrain. It is a general notion that the tree-covered village landscapes lessen the anthropogenic pressure on forest plots (Duelli and Obrist 2003). However, the present study did not support this view. Here, even plots adjacent to the tree-covered village landscape showed poor regeneration of species characteristic to evergreen forests.

Unrestricted and open accessibility may cause enhanced utilization of forest resource and eventually lead to a species-poor state (Vetaas 1993). For instance, in plots at MU, PK and PU, the number of tree species in the seedling phase was lesser than that in other plots (Table 2). This could be due to frequent collection of litter from the forest floor and other anthropogenic disturbances. It may be pointed out here that, the litter removal from forest floor has tri-fold effect on species-richness namely, physical removal of tree propagules while collecting litter, runoff of tree propagules due to the absence of the litter layer and seedling mortality due to soil dryness and desiccation.

Table 1. Importance Value Index (IVI) of dominant tree species in seedling (gbh <10 cm; height <1.0 m) and tree (gbh >10.1 cm) phases in forest plots located adjacent to the human habitation in the Kerala part of NBR. Plot names and their codes are in bold face.

Seedlings		Trees	
Species	IVI	Species	IVI
<b>Adackakundu (AK)</b>			
<i>Aglaia malabarica</i> Sasidh. (Meliaceae)	54.6	<i>Aglaia malabarica</i> Sasidh. (Meliaceae)	47.3
<i>Alseodaphne semicarpifolia</i> Nees (Lauraceae)	36.0	<i>Bischofia javanica</i> Bl. (Euphorbiaceae)	32.6
<i>Acronychia pedunculata</i> (L.) Miq. (Rutaceae)	33.9	<i>Myristica malabarica</i> Lamk. (Myristicaceae)	19.1
<i>Cinnamomum malabratrum</i> (Burm.f.) Ber. et Presl. (Lauraceae)	10.5	<i>Syzygium cumini</i> (L.) Skeels (Myrtaceae)	17.4
<i>Ardisia solanacea</i> Roxb. (Myrsinaceae)	8.8	<i>Antiaris toxicaria</i> (Pers.) Lesch. Moraceae	16.8
<b>Appencappu (AC)</b>			
<i>Xylocarpus xylocarpa</i> (Roxb.) Taub. (Mimosaceae)	56.5	<i>Xylocarpus xylocarpa</i> (Roxb.) Taub. (Mimosaceae)	44.6
<i>Terminalia paniculata</i> Roth (Combretaceae)	46.5	<i>Terminalia paniculata</i> Roth (Combretaceae)	31.6
<i>Macaranga peltata</i> (Roxb.) Muell.-Arg. (Euphorbiaceae)	43.8	<i>Trewia polycarpa</i> Benth. (Euphorbiaceae)	24.7
<i>Aporosa lindleyana</i> (Wt.) Ball. (Euphorbiaceae)	21.7	<i>Wrightia tinctoria</i> R.Br. (Apocynaceae)	19.8
<i>Strychnos nux-vomica</i> L. (Loganiaceae)	19.0	<i>Lagerstroemia microcarpa</i> Wt. (Lythraceae)	18.7
<b>Kadasseri (KS)</b>			
<i>Aglaia malabarica</i> Sasidh. (Meliaceae)	76.2	<i>Myristica malabarica</i> Lamk. (Myristicaceae)	48.1
<i>Myristica malabarica</i> Lamk. (Myristicaceae)	30.1	<i>Aglaia malabarica</i> Sasidh. (Meliaceae)	35.4
<i>Alseodaphne semicarpifolia</i> Nees (Lauraceae)	26.5	<i>Dimocarpus longan</i> Lour. (Sapindaceae)	16.3
<i>Palaquium ellipticum</i> (Dalz.) Engl. (Sapotaceae)	17.3	<i>Knema attenuata</i> (Wall. ex Hk.f & Thoms.) Warb. (Myristicaceae)	14.6
<i>Diospyros bourdillonii</i> Brand. (Ebenaceae)	13.6	<i>Syzygium laetum</i> (Ham.) Gandhi (Myrtaceae)	13.4
<b>Manikunnumala (MK)</b>			
<i>Wrightia tinctoria</i> R.Br. (Apocynaceae)	46.8	<i>Dalbergia latifolia</i> Roxb. (Fabaceae)	16.0
<i>Dalbergia latifolia</i> Roxb. (Fabaceae)	38.2	<i>Artocarpus hirsutus</i> Lamk. (Moraceae)	13.0
<i>Ervatamia heyneana</i> (Wall.) Cooke (Apocynaceae)	23.2	<i>Albizia odoritissima</i> (L.f.) Benth. (Mimosaceae)	12.2
<i>Garcinia Morella</i> (Gaertn.) Desr. (Clusiaceae)	20.7	<i>Ficus exasperate</i> Vahl (Moraceae)	11.6
<i>Aporosa lindleyana</i> (Wt.) Ball. (Euphorbiaceae)	19.5	<i>Mallotus tetracoccus</i> (Lamk.) M.-A. (Euphorbiaceae)	11.4

**Manaliampadam (MP)**

<i>Xylocarpus xylocarpa</i> (Roxb.) Taub. (Mimosaceae)	73.4	<i>Xylocarpus xylocarpa</i> (Roxb.) Taub. (Mimosaceae)	60.9
<i>Terminalia paniculata</i> Roth (Combretaceae)	24.3	<i>Macaranga peltata</i> (Roxb.) Muell.Arg. (Euphorbiaceae)	34.1
<i>Macaranga peltata</i> (Roxb.) Muell.-Arg. (Euphorbiaceae)	14.2	<i>Terminalia paniculata</i> Roth (Combretaceae)	25.9
<i>Wrightia tinctoria</i> R.Br. (Apocynaceae)	11.6	<i>Albizia odoritissima</i> (L.f.) Benth. (Mimosaceae)	19.3
<i>Terminalia crenulata</i> Roth (Combretaceae)	10.7	<i>Terminalia crenulata</i> Roth (Combretaceae)	17.3

**Munnadi (MU)**

<i>Xylocarpus xylocarpa</i> (Roxb.) Taub. (Mimosaceae)	73.1	<i>Xylocarpus xylocarpa</i> (Roxb.) Taub. (Mimosaceae)	54.4
<i>Terminalia paniculata</i> Roth (Combretaceae)	38.7	<i>Terminalia paniculata</i> Roth (Combretaceae)	26.2
<i>Albizia odoritissima</i> (L.f.) Benth. (Mimosaceae)	26.4	<i>Macaranga peltata</i> (Roxb.) Muell.-Arg.	24.0
<i>Terminalia crenulata</i> Roth (Combretaceae)	24.5	<i>Anacardium occidentale</i> L. (Anacardiaceae)	19.2
<i>Mallotus philippensis</i> (Lamk.) M.-A. (Euphorbiaceae)	21.7	<i>Albizia odoritissima</i> (L.f.) Benth. (Mimosaceae)	13.9

**Parackalel (PC)**

<i>Xylocarpus xylocarpa</i> (Roxb.) Taub. (Mimosaceae)	77.9	<i>Terminalia paniculata</i> Roth (Combretaceae)	64.8
<i>Strychnos nux-vomica</i> L. (Loganiaceae)	23.1	<i>Xylocarpus xylocarpa</i> (Roxb.) Taub. (Mimosaceae)	52.4
<i>Aporosa lindleyana</i> (Wt.) Baill. (Euphorbiaceae)	21.6	<i>Wrightia tinctoria</i> R.Br. (Apocynaceae)	20.4
<i>Schleichera oleosa</i> (Lour.) Oken (Sapindaceae)	15.3	<i>Grewia tiliifolia</i> Vahl (Teliaceae)	13.6
<i>Mallotus philippensis</i> (Lamk.) M.-A. (Euphorbiaceae)	13.7	<i>Sterospermum colais</i> (Buch.-Ham. ex Dillw.) Mabb. (Bignoniaceae)	13.5

**Pattakarimba (PK)**

<i>Terminalia paniculata</i> Roth (Combretaceae)	87.0	<i>Lagerstroemia microcarpa</i> Wt. (Lythraceae)	39.1
<i>Persea macrantha</i> (Nees) Kosterm. (Lauraceae)	32.3	<i>Hydnocarpus pentandra</i> (Ham.) Oken	35.9
<i>Schleichera oleosa</i> (Lour.) Oken (Sapindaceae)	31.9	<i>Schleichera oleosa</i> (Lour.) Oken (Sapindaceae)	29.1
<i>Ardisia solanacea</i> Roxb. (Myrsinaceae)	28.9	<i>Terminalia paniculata</i> Roth (Combretaceae)	24.4
<i>Mallotus philippensis</i> (Lamk.) M.-A. (Euphorbiaceae)	26.2	<i>Ardisia solanacea</i> Roxb. (Myrsinaceae)	19.6

**Punchavayal (PU)**

<i>Xylocarpus xylocarpa</i> (Roxb.) Taub. (Mimosaceae)	61.0	<i>Xylocarpus xylocarpa</i> (Roxb.) Taub. (Mimosaceae)	69.9
<i>Terminalia paniculata</i> Roth (Combretaceae)	38.0	<i>Terminalia paniculata</i> Roth (Combretaceae)	67.3
<i>Sterculia villosa</i> Roxb. (Sterculiaceae)	30.9	<i>Tectona grandis</i> L.f. (Lamiaceae)	27.1
<i>Holarrhena pubescens</i> (Buch.-Ham.) Wall. ex Don (Apocynaceae)	29.8	<i>Dalbergia latifolia</i> Roxb. (Fabaceae)	22.9
<i>Dalbergia latifolia</i> Roxb. (Fabaceae)	28.6	<i>Terminalia crenulata</i> Roth (Combretaceae)	10.9

**Vellimuttam (VM)**

<i>Aglaia malabarica</i> Sasidh. (Meliaceae)	54.6	<i>Aglaia malabarica</i> Sasidh. (Meliaceae)	33.1
<i>Alseodaphne semicarpifolia</i> Nees (Lauraceae)	36.0	<i>Bischofia javanica</i> Bl. (Euphorbiaceae)	29.7
<i>Acronychia pedunculata</i> (L.) Miq. (Rutaceae)	33.9	<i>Dimocarpus longan</i> Lour. (Sapindaceae)	22.7
<i>Xylocarpus xylocarpa</i> (Roxb.) Taub. (Mimosaceae)	13.9	<i>Syzygium cumini</i> (L.) Skeels (Myrtaceae)	19.5
<i>Cinnamomum malabratrum</i> (Burm.f.) Ber. et Presl. (Lauraceae)	10.5	<i>Myristica malabarica</i> Lamk. (Myristicaceae)	18.4

There are evidences to indicate that even disturbance can enhance the species number in forest plots (Ohsawa et al. 1986). Occurrence of comparatively more number of species in plots at KS and MK than in other plots could be due to better regeneration of evergreen and deciduous species. On the other hand, number of species in the plot at MK was not much different from

that recorded in plots like KS and MK due to the fact that certain non-forest species such as *Grevillea robusta* and *Coffea arabica* were also noticed here. Thus, measurement of species richness of a forest is not enough for forest quality analysis.

In plots at PC and PK, tree density was considerably lower than in other plots (Table 3). Collection of

Table 2. Basic information on vegetation with respect to tree seedling community (gbh <10.1cm) in forest plots located adjacent to the human habitation in the Kerala part of NBR

Plot name	Number of species	Density (no. ha <sup>-1</sup> )	Basal area (cm <sup>2</sup> ha <sup>-1</sup> )	Shannon's Diversity Index
Adackakundu (AK)	43	4687	7038.93	3.195
Appencappu (AC)	21	3680	7301.2	2.598
Kadasseri (KS)	25	3099	6474.51	2.781
Manikunnumala (MK)	23	1896	3763.97	2.853
Manaliampadam (MP)	30	2794	3108.28	3.018
Munnadi (MU)	16	2153	2483.81	2.473
Parackalel (PC)	26	2294	4573.27	2.858
Pattakarimba (PK)	19	2063	3452.4	2.420
Punchavayal (PU)	13	2560	1855.06	2.360
Vellimuttam (VM)	36	2973	5344.6	3.081

Table 3. Basic information on vegetation with respect to mature tree community (gbh <10.1cm) in forest plots located adjacent to the human habitation in the Kerala part of NBR

Plot name	Number of species	Density (no. ha <sup>-1</sup> )	Basal area (cm <sup>2</sup> ha <sup>-1</sup> )	Shannon's Diversity Index
Adackakundu (H3)	36	893	49.84	3.126
Appencappu (H8)	47	809.5	49.09	3.282
Kadasseri (H9)	84	1408	70.81	3.605
Manikunnumala (H10)	86	1870	89.69	4.082
Manaliampadam (H1)	31	758	18.76	2.957
Munnadi (H2)	47	1427	22.32	3.268
Parackalel (H4)	28	467	25.62	2.788
Pattakarimba (H5)	35	699	82.74	3.022
Punchavayal (H7)	39	1109	11.92	2.686
Vellimuttam (H6)	34	772	49.26	3.313

poles and fuel wood by the local people was identified as the major reason for such a decline in tree density. Grazing, browsing and trampling of seedlings were also the reasons for low seedling density and poor recruitment of seedlings to higher girth classes. Such negative

impacts of biomass harvest and cattle grazing on regeneration of tree communities have been reported for subtropical pine forest of Northern India (Maikhuri et al. 2000) and wet evergreen forests of northeast India (Bhuyan et al. 2003). However, the present study has enabled to identify another factor responsible for low tree density. In the forest plot at PK, litter collection from the forest floor was found to be responsible for poor regeneration of tree seedlings and loss or mortality of un-established seedlings. Contrary to this, in the plot at MU, tree density was more due to the fact that the dominant species (*Xylia xylocarpa* and *Terminalia paniculata*) have the high reproductive ability like regeneration through root suckers, coppices and seeds.

Decline in tree density due to disturbance need not affect the total basal area in a forest patch. For instance, compared to other plots, the plot at PK had high basal area and low density of tree community (Table 3). This may be attributed to the fact that here a large number of coppiced shoots and also trees belonging to larger girth classes were present. In the plot at MU, despite comparatively high tree density, the basal area was less due to selective logging in the past and pole collection in recent days. However, this plot maintained higher tree density due to coppiced shoots of some of the dominant tree species. In the plot at PU, as compared to all other plots, basal area was significantly low due to absence or poor representation of tree species having coppicing ability. Similar observation was reported from a montane forest of Java (Smiet 1992).

Measures of species diversity provide information on trophic structure necessary for ecosystem resilience (Nicols and Nicols 2003). It has been widely believed that disturbances can alter species diversity in an ecosystem (Mackey and Currie 2001). However, magnitude of change in species diversity is determined by disturbances, their intensity and frequency. In the present study, species diversity index values in the seedling phase in plots like MU, PK and PU were considerably lower than in other plots (Table 2). Similar observation was made in plots like MP, AK, PC, PK and PU for the species diversity index values of the tree phase (Table 3). Two reasons have been identified for the low diversity value in these plots. In some of these plots, microclimate was harsh and conducive for the over-dominance of certain species that could withstand such situations and restrict the establishment of evergreen species. According to Pascal (1988), continuous disturbance in the low and midland forests of the Western Ghats could lead to the impoverishment of soil. Such forests are known for

poor species diversity and over dominance of *Xylia xylocarpa*, a deciduous species. In some plots, over-harvest of selected species for fuel wood and poles can be attributed for comparatively low species diversity. Among the village-adjacent forest plots, those at KS and MK showed a relatively high species diversity values both for mature tree and seedling phases. In these plots, occurrence of micro-sites suitable for the establishment of evergreen and deciduous species and absence of over dominance of any single species were responsible for high species diversity. Thus, it is clear that when the disturbance is intense or more frequent only a few species can thrive well and suppress the diversity. On the other hand at intermediate level of disturbance, as observed in KS and MK, there is a balance between competitive exclusion and loss of competitive dominants; conditions favour the coexistence of competitive species and disturbance tolerant species (Mackey and Currie 2001). Thus, comparatively high species diversity was recorded in these two plots.

Tree girth class distribution pattern in forest stands has been used as the indicator of forest stand quality. For instance, according to Richards (1952) a healthy forest stand will have an exponential girth class distribution of trees with clear preponderance to lower girth classes. In the present study, all the forest plots have shown distorted exponential girth class distribution (Figure 2). Careful analysis of girth class distribution patterns in these plots may provide some indication of disturbance history. For instance, in plots at PC and PK, trees belonging to the girth class 150.1 cm to 180.0 cm and >180.1 cm respectively were represented well (Figure 2) as compared to the trees belonging to lower girth classes. This may be due to the fact that prior to land acquisition by the Government in 1950s, selection felling was conducted. During selective logging operations larger individuals of *Trewia polycarpa*, species of *Ficus* and also defective trees of *Terminalia paniculata* were not been harvested since their harvesting was not economical. Such trees are now contributing to the highest girth class in the forest patch. The past selective logging operations also led to the creation of more number of canopy open space of large sizes. Such canopy openings may lead to increase in number of individuals in the lower girth classes, as observed mainly in VM and PU, by providing favourable microclimate for light-demanding evergreen, deciduous and invasive species. On the other hand, in some of the plots like AK, PC, PK trees of lower girth classes are lesser than those of higher girth classes. There are also studies to indicate a drastic

decline in the number of individuals, particularly in the girth class 20 cm - 60 cm, in different forests due to either legal or illegal harvest of poles by the local people (Dixit and Rajvanshi 1998, Chandrashekara and Jayaraman 2002). Since harvesting is easy and the products can be used as poles, beams and agricultural implements, trees of 20 cm to 60 cm in girth are preferred.

### Level of Disturbance in Forest Plots

It is clear that the villagers' dependence on forest resources is a major causative for the degradation of forest plots adjacent to villages. Despite prohibition, the resource collection at different forms, magnitude and frequency is continuing in these forest plots. The resultant ecological changes have profound effects on the forest species composition and structure. For sustainable conservation of management of forest plots, the current challenge is to quantify the rates and effects of biodiversity decline and habitat change to enable the stakeholders and managers of forest to plan rationally on appropriate measures of conservation and management. Recent trends towards this goal have been on the development of habitat environmental indicators that would measure the natural resource volume and rate of resource depletion. Information from such findings could be used as basis of setting up policy guidelines. Therefore, in the present study, three forest indicators that will provide important information of ecological and social significance have been used. The parameters used for estimating the indicator value are those that can be measured locally and that may influence change in forest structure and composition. In the present study two vegetation indices (Ramakrishnan Index of Stand Quality - RISQ and Index of Ecological Quality-IEQ) and one human disturbance indicator (Human Disturbance Index-IHD) were applied for interpretation of results.

Among ten forest plots studied, the one at KS showed significantly low values for the IHD (Table 4) and IEQ (Table 5). The estimated value for RISQ in this plot was 1.29 and 1.89 respectively for the seedling and tree community (Figure 3). The low RISQ value also means high percentage contribution by the primary species to the density and basal cover of tree seedlings and tree communities. Thus, it is possible to conclude that the forest is under progressive succession and moderate level of protection can help it to recover from the disturbance. Contrary to this, forest plots at PU and MU showed high value for the RISQ, suggesting that the contribution by evergreen species of different successi-

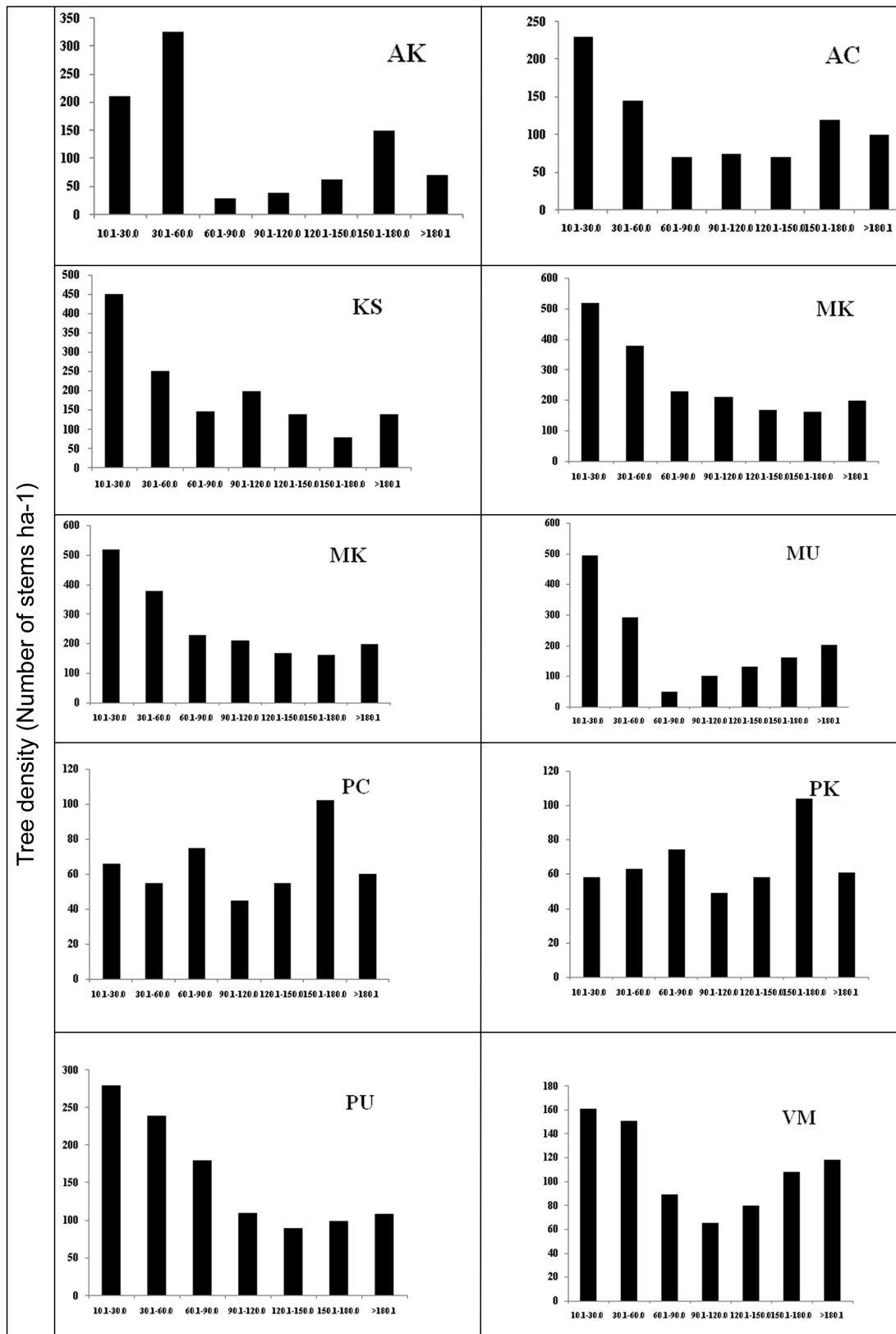


Figure 2. Girth class distribution of tree community in forest plots located adjacent to the human habitation in the Kerala part of NBR.

Table 4. Index of Human Disturbance (IHD) values for forest plots located adjacent to the human habitation in the Kerala part of NBR.

Variables	Mean Cmax (0.5 km <sup>-1</sup> )	C/C <sub>Max</sub> in Forest Plots									
		AK	AC	KS	MK	MP	MU	PC	PK	PU	VM
Number of larger stumps (> 20 cm gbh) of harvested trees	76.3	0.78	0.33	0.21	0.7	0.88	0.72	0.93	0.67	1.00	0.53
Number of pollarded trees (< 20 cm gbh)	321.3	0.76	0.19	0.11	0.99	0.82	0.96	0.82	1.00	1.00	0.22
Number of coppiced stems	138.75	0.57	0.16	0.11	0.88	0.61	1.00	0.56	0.33	0.52	0.14
Number of stems with branch cuttings	66.3	0.62	0.57	0.53	0.94	0.81	0.98	0.78	0.87	1.00	0.51
Number of debarked stems	122.5	0.54	0.04	0	0.53	0.56	0.93	0.43	0	1.00	0
Number of vehicle tracks	13.8	0.77	0.45	0.27	0.09	0.87	0.72	0.71	0.82	1.00	0.75
Number of foot paths	60	0.89	0.23	0.19	0.71	0.81	0.77	0.88	1.00	0.79	0.83
<b>Y= Sum C/Cmax of all variables</b>		4.93	1.97	1.42	4.84	5.36	6.08	5.11	4.69	6.31	2.98
<b>Sum/Y</b>		0.70	0.28	0.20	0.69	0.77	0.87	0.73	0.67	0.90	0.43
<b>Sum/Y (in %)</b>		70.4	28.1	20.3	69.1	76.6	86.9	73.0	67.0	90.1	42.6

Table 5. Index of Ecological Quality (IEQ) values for forest plots located adjacent to the human habitation in the Kerala part of NBR.

Variables	Mean C max (0.5 km <sup>-1</sup> )	C/C <sub>Max</sub> in Forest Plots									
		AK	AC	KS	MK	MP	MU	PC	PK	PU	VM
Open canopy area (% of total canopy area)	87.5	0.68	0.56	0.38	0.97	0.78	0.98	0.81	0.65	1.00	0.92
Ground cover by grasses (% of total forest floor area )	50.8	0.62	0.25	0.06	1.00	0.68	0.77	0.76	0.33	0.49	0.89
Ground cover by exotic weeds (% of total forest floor area )	28.1	0.58	0.52	0	0.82	0.63	0.73	0.69	0.26	1.00	0.94
Ground cover by exotic weeds (% of total forest floor area )	11.2	0.91	0.84	0.68	1.00	0.89	0.84	0.79	0.65	0.96	0.78
Canopy coverage by lianas	62.8	0.83	0.75	0.49	1.00	0.92	0.82	0.89	0.11	0.69	0.12
<b>Y= Sum C/Cmax of all variables</b>		3.62	2.92	1.61	4.79	3.90	4.14	3.94	2.00	4.14	3.65
<b>Sum/Y</b>		0.72	0.58	0.32	0.96	0.78	0.83	0.79	0.40	0.83	0.73
<b>Sum/Y (%)</b>		72.4	58.4	32.2	95.8	78.0	82.8	78.8	40.0	82.8	73.0

onal categories such as primary, late secondary and early secondary to the total importance values of tree seedling and tree communities was significantly low. High values obtained for IHD and IEQ for these two plots also indicate the constant and high magnitude disturbance regimes in these plots. It is interesting to note that for the forest plot at MK, the RISQ values were lower than those for PU and MU; while the opposite trend was recorded for the IEQ values. This is probably because in the plot at MK the native understorey species are not

affecting the regeneration and establishment of evergreen species of different successional status. In addition, high percentage of canopy coverage by lianas recorded in this plot (Table 5) could also reduce the quantum of light falling on the forest floor. The reduced light availability might be reducing the establishment of light demanding species and supporting the recruitment and establishment of primary and late secondary species of evergreen forests.

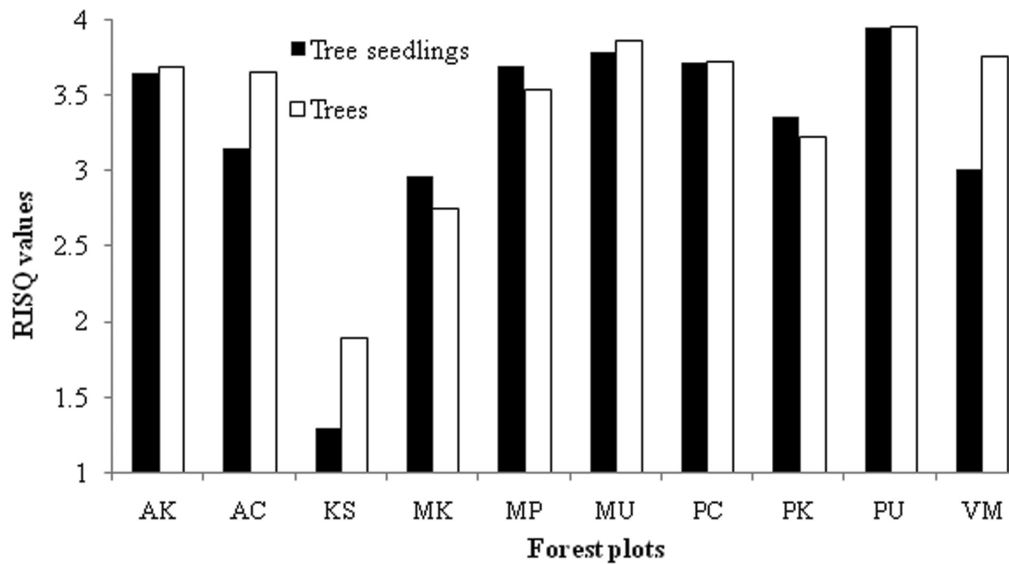


Figure 3. Ramakrishnan Index of Stand Quality (RISQ) value for tree seedling and tree communities in forest plots located adjacent to the human habitation in the Kerala part of NBR.

In the present study, in general, a positive correlation between HDI and IEQ, HDI and RISQ, and IEQ and RISQ was recorded. Therefore, it is clear that these forest indicators do not provide contradictory information for rapid assessment of forest quality. Measuring the values for all the above three indicators can help us to assess accurately ecological and human factors responsible for the present condition of forest plots and identify suitable conservation and management strategies.

## CONCLUSIONS

A large chunk of forest area in the Nilgiri Biosphere Reserve (NBR) has long porous boundaries, often bordering human settlements. Though the commercial exploitation of forest resources has been brought to an end as early as 1980s, incidences of unauthorised collection of minor forest products are not uncommon. The lack of regulation, coupled with rampant, unauthorised exploitation has contributed to forest degradation and altering the species composition. In fact, the NBR harbors unique endemic flora and fauna which makes it an important area of biodiversity. In this context, appropriate strategies and actions to ensure biodiversity conservation and management in the village-adjacent forests need to be undertaken. The priority can be given for strengthening research to gather better information

and understanding of the village-adjacent forests for chalk out programmes to sustainable biodiversity conservation, minimizing forest dependency on forest biomass is an important strategy by making villages self-sufficient with required resources and promotion of natural regeneration of species characteristic of primary forests and enrichment planting to accelerate the rate of progressive succession.

Finally, it can be concluded that the NBR management needs to follow the concept of BR in its true sense, which strongly advocates the conservation of bio-resources in all its landscape units (Batisse 1982).

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