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Effects of anthropogenic disturbance on plant diversity and community structure of a sacred grove in Meghalaya, northeast India

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Abstract. This study analyses the effects of anthropogenic disturbance on plant diversity and community attributes of a sacred grove (montane subtropical forest) at Swer in the East Khasi Hills district of Meghalaya in northeast India. The undisturbed, moderately disturbed and highly disturbed stands were identified within the sacred grove on the basis of canopy cover, light interception and tree (cbh $\geq$ 15 cm) density. The undisturbed forest stand had >40% canopy cover, >50% light interception and a density of 2103 trees per hectare, whereas the highly disturbed stand had <10% canopy cover, <10% light interception and 852 trees per hectare. The moderately disturbed stand occupied the intermediate position with respect to these parameters. The study revealed that the mild disturbance favoured species richness, but with increased degree of disturbance, as was the case in the highly disturbed stand, the species richness markedly decreased. The number of families of angiosperms was highest (63) in the undisturbed stand, followed by the moderately (60) and highly disturbed (46) stands. The families Rubiaceae, Asteraceae and Poaceae were the dominant families in the sacred forest. Rubiaceae was represented by 11, 14 and 10 species in the undisturbed, moderately disturbed and highly disturbed stands, respectively, whilst the family Asteraceae had 16 species in the moderately disturbed stand and 14 species in the highly disturbed stand. The number of families represented by a single species was reduced significantly from 33 in the undisturbed stand to 23 in the moderately and 21 in the highly disturbed stand. The similarity index was maximum (71%) between the undisturbed and moderately disturbed stand and minimum (33%) between the undisturbed and highly disturbed stands. The Margalef index, Shannon diversity index and evenness index exhibited a similar trend, with highest values in the moderately disturbed stand. In contrast, the Simpson dominance index was highest in the highly disturbed stand. There was a sharp decline in tree density and basal area from the undisturbed (2103 trees ha^{-1} and 26.9 m^2 ha^{-1}) to the moderately disturbed (1268 trees ha^{-1} and 18.6 m^2 ha^{-1}) and finally to the highly disturbed (852 trees ha^{-1} and 7.1 m^2 ha^{-1}) stand. Density–girth curves depicted a successive reduction in number of trees in higher girth classes from the undisturbed to the moderately and highly disturbed stands. The log-normal dominance–distribution curve in the undisturbed and moderately disturbed stands indicated the complex and stable nature of the community. However, the short-hooked curve obtained for the highly disturbed stand denoted its simple and unstable nature.

Introduction

The degradation of tropical forests and destruction of habitat due to anthropogenic activities are the major causes of decline in global biodiversity. Therefore, in many areas reconstruction of disturbed ecosystems is being taken up on a priority basis, both for biodiversity conservation and for maintaining landscape productivity (Solbrig 1991). One of the challenging tasks before the ecologists is to understand the relationship between the biodiversity and functioning of ecosystems (Younes 1992; Davis and Richardson 1995). The anthropogenic disturbances greatly affect the biodiversity and structural characteristics of a community. Floristic composition is considered as one of the major distinguishing characters of a community (Dansereau 1960), and therefore, any depletion of biodiversity is bound to alter the community attributes. In view of growing threat to biodiversity, it is important to see how natural communities and their structural attributes are affected by progressive erosion of biodiversity caused by anthropogenic disturbances.

Meghalaya, with its varied physiography, soil and climatic conditions, supports different types of forests such as deciduous and evergreen tropical forests, subtropical semi-evergreen forest and subtropical pine forest. The forest flora of Meghalaya is remarkable in two ways. Firstly, it shows high endemism, and secondly, it consists of a number of taxa of the neighbouring states/countries (Balakrishnan 1981–1983). Shifting cultivation and unregulated tree felling have led to the destruction of virgin forests and development of secondary communities on disturbed sites in the state. However, despite these anthropogenic stresses, an estimated area of about 1000 km^2 in the state is covered by the sacred forests or sacred groves (Anonymous 1978) which are being managed and protected by the tribal communities on the grounds of religious beliefs. Some of these forests are still undisturbed, although their majority is in different stages of degradation. The sacred groves are rich in plant diversity and harbour a large number of valuable and endangered plant species (Haridasan and Rao 1985–1987). Since most of the sacred groves are located near human settlements, illicit cutting of trees and other human disturbances in these forests are progressively increasing. A survey of 56 sacred groves in the state by Tiwari et al. (1998) indicates that only about 12.5% is in the undisturbed state with almost complete canopy cover, while the rest are exposed to varying degrees of disturbance. Even in the same sacred grove it is not uncommon to find undisturbed forest stands as well as moderately to highly degraded forest patches, and these forest stands differ a great deal from each other. This paper focuses on the effects of disturbance on plant diversity and other structural attributes of a large sacred grove located at an altitude of 1990–2035 m a.s.l. near the village Swer in the southeastern part of the state of Meghalaya in northeast India. Because of the proximity to Swer, it is locally called 'Law Rynkiew Swer' (or Swer sacred grove).

Materials and methods

Study site

The Swer sacred grove, where the present study was carried out, is about 28 km south of Shillong (25°25′ N and 91°47′ E) on the way to Cherrapunji in the East Khasi Hills district of Meghalaya. It covers an area of ca. 40 ha on the hill 'Lum

Table 1. Canopy cover, light interception and tree density (± standard error) in the undisturbed, moderately disturbed and highly disturbed forest stands in the Swer sacred grove.

Parameter	Stands		
	Undisturbed	Moderately disturbed	Highly disturbed
Canopy cover (%)	>40	10–40	<10
Light interception (%)	>50	10–50	<10
Tree density ha^{-1}	2103 ± 25	1268 ± 19	852 ± 13

Swer'. Extraction of mature trees, collection of fuel-wood by the villagers and grazing by domesticated animals are the major causes of disturbance in the sacred grove. As a result, the sacred grove has been fragmented into patches, which are in different stages of degradation. For the present study three patches representing undisturbed (15 ha), moderately disturbed (15 ha) and highly disturbed (10 ha) forest stands were demarcated within the sacred grove on the basis of canopy cover, light interception, and tree (cbh ≥ 15 cm) density (Table 1). The undisturbed forest stand had >40% canopy cover, >50% light interception and a density of 2103 trees per hectare, whereas the highly disturbed stand had <10% canopy cover, <10% light interception and a density of 852 trees per hectare. The moderately disturbed stand occupied the intermediate position with respect to these parameters. The undisturbed stand was mainly composed of tall trees (15–20 m height) with shrubs in the understorey. However, the moderately and highly disturbed stands had greater numbers of shrubs and herbs, respectively. The presence of bushy plants characterised the highly disturbed stand. Only few tall trees were present in the disturbed stands. The ground flora in the undisturbed and moderately disturbed stands was predominantly composed of tree seedlings, and herbs in the highly disturbed stand.

The climate of the area is monsoonic with distinct warm-wet and cool-dry seasons. The average annual rainfall is about 2500 mm, more than 85% of which is received during May–September. The mean annual temperature ranges from 3 to 22 °C. The soil is highly leached, poor in nutrients and acidic (pH 5–5.7) in nature (Barik et al. 1996). The vegetation of the sacred grove falls under semi-evergreen subtropical wet hill forest (Champion and Seth 1968). The forest canopy comprises evergreen tree species such as *Aporusa dioica*, *Beilschmiedia assamica*, *Daphniphyllum himalayense*, *Psychotria symplocifolia* and *Rhododendron arboreum* and deciduous trees like *Casearia vareca*, *Engelhardtia spicata* and *Glochidion khasicum*.

Methods

Vegetation analysis was carried out following the methods outlined by Misra (1968) and Mueller-Dombois and Ellenberg (1974) during October–December and March–May in 1999–2000. Quadrats of 10 m^2 were used for the analysis of the tree layer, 5 m^2 for the shrubs and 1 m^2 for the herbs and tree seedlings. About 1% of the area of each stand (0.15 ha each of the undisturbed and moderately disturbed, and 0.1 ha of the highly disturbed stand) was sampled by laying the quadrats randomly. The plant species present in the three stands were listed and frequency, density and basal cover of tree (cbh ≥ 15 cm) species were determined. Species richness, dominance and diversity were determined by computing the index of species richness (Margalef 1958), similarity index (Sørensen 1948), Shannon diversity index (Shannon and Weaver 1949), the importance value index (IVI) (Phillips 1959), Simpson dominance index (Simpson 1949) and evenness index (Pielou 1966).

Species identification was done following the regional floras and was counter-checked with the help of the herbarium of the Botanical Survey of India, Eastern Circle, Shillong.

Results

Species richness, diversity and distribution

A total of 168 species belonging to 120 genera, 192 species belonging to 130 genera and 132 species belonging to 96 genera were identified in the undisturbed, moderately disturbed and highly disturbed stands, respectively. Species richness (number of species per 100 m^2) was maximum (49) in the moderately disturbed stand, followed by the highly disturbed (42) and undisturbed (27) stands. The number of families decreased from 63 in the undisturbed stand to 46 in the highly disturbed stand. The species richness was maximum in the moderately disturbed stand, followed by the undisturbed and highly disturbed stands. The Shannon diversity index and evenness index exhibited a similar trend. In contrast, the Simpson index of dominance followed a reverse trend (Table 2). The families represented by a single species in the grove decreased from 33 in the undisturbed to 23 in the moderately disturbed and 21 in the highly disturbed stand. Rubiaceae and Asteraceae were dominant and co-dominant families, respectively, in the undisturbed stand. However, in the moderately disturbed stand Asteraceae was the dominant family and Rubiaceae ranked second. Asteraceae was also dominant in the highly disturbed stand, and Poaceae occupied the second position (Table 3).

The Sørensen index of similarity indicated a high degree of dissimilarity (67%) between the undisturbed and highly disturbed stand. The moderately disturbed stand was similar to the undisturbed stand (similarity index: 71%). There was a marked change in the growth form of the dominant species from the undisturbed to the disturbed stand. The undisturbed stand was dominated by trees, the moderately disturbed stand by shrubs and herbs, and the highly disturbed stand by herbs. *Heptapleurum khasianum* was the sole tree species present in the highly disturbed stand (Appendix 1).

The distribution of species among Raunkiaer's frequency classes showed that the frequency classes A and B gradually declined from the undisturbed to the highly disturbed stand. In contrast, the C, D and E classes showed a progressive increase in number of species from the undisturbed to the highly disturbed stand (Figure 1).

Table 2. Plant diversity and other community characteristics of the undisturbed, moderately disturbed and highly disturbed forest stands in the Swer sacred grove.

Parameter	Undisturbed stand	Moderately disturbed stand	Highly disturbed stand
Number of families	63	60	46
Number of genera	120	130	96
Number of species	168	192	132
Species richness (species per 100 m^2)	27 ± 2.9	49 ± 3.4	42 ± 2.8
Tree basal area (m^2 ha^{-1})	26.9 ± 1.7	18.6 ± 2.4	7.1 ± 0.7
Margalef index (species richness)	20.1	21.8	12.2
Shannon diversity index	2.2	2.3	2.0
Simpson dominance index	0.1	0.2	0.2
Evenness index	0.4	0.4	0.4

(± Standard error).

Density and dominance

The tree density and basal area significantly decreased from the undisturbed to the moderately disturbed stand. In the highly disturbed stand the density was very low (Table 2). The density–girth distribution pattern showed a gradual decrease in density, with an increase in girth in all three stands (Figure 2). Also there was a progressive decrease in tree density in different girth classes from the undisturbed to the highly disturbed stand. The moderately and highly disturbed stands had a low density of mature trees and there was no tree of >70 cm girth in the highly disturbed stand. Distribution of basal area in different girth classes indicates that trees of intermediate girth classes covered a larger area than the young and mature trees in almost all stands. With increasing disturbance stress the total basal area of trees in different girth classes declined.

The dominance–distribution curve followed a log-normal distribution pattern in the undisturbed and moderately disturbed stands. However, the curve was short and hooked in the highly disturbed stand. *Rhododendron arboreum*, *Eurya japonica* and *Camellia cauduca* were dominant in the undisturbed stand. The first two were also present in the disturbed stands, but *Camellia cauduca* was replaced by *Psychotria symplocifolia* in the moderately disturbed stand and by *Eurya acuminata* in the highly disturbed stand. The IVI of the dominant species varied markedly from the undisturbed to the highly disturbed stand (Figure 3). The importance values of *Actinidia callosa*, *Aporusa roxburghii*, *Ardisia floribunda*, *Casearia vareca*, *Dischidia nummularia*, *Elsholtzia blanda*, *Erythroxylum kunthianum*, *Eurya acuminata*, *E. japonica*, *Exbucklandia populnea*, *Ficus nervosa*, *F. silhetensis*, *Glochidion assamicum*, *Ixora parviflora*, *Ligustrum myrsinites*, *Litsea citrata*, *L. salicifolia*, *Neolitsea zeylanica*, *Phyllanthus parvifolius*, *Rhododendron arboreum*, *Symplocos crataegoides*, *S. racemosa*, *Viburnum foetidum*, *V. simonsii* and *Vitex vestita* increased from the undisturbed to the highly disturbed stand, but those of *Aporusa dioica*, *Camellia cauduca* and *Symplocos spicata* decreased with the increase in the degree of disturbance.

Table 3. Distribution of plant families in the undisturbed, moderately disturbed and highly disturbed forest stands in the Swer sacred grove.

Undisturbed stand	No. of species	Moderately disturbed stand	No. of species	Highly disturbed stand	No. of species
Rubiaceae	11	Asteraceae	16	Asteraceae	14
Asteraceae	10	Rubiaceae	14	Poaceae	12
Poaceae	10	Poaceae	13	Rosaceae	10
Rosaceae	10	Rosaceae	11	Rubiaceae	10
Lauraceae	9	Lamiaceae	8	Euphorbiaceae	7
Euphorbiaceae	8	Ericaceae	7	Ericaceae	5
Lamiaceae	6	Euphorbiaceae	7	Lamiaceae	4
Smilacaceae	6	Orchidaceae	7	Lauraceae	4
Ericaceae	5	Lauraceae	6	Moraceae	4
Orchidaceae	5	Smilacaceae	6	Orchidaceae	4
Theaceae	5	Moraceae	4	Caprifoliaceae	3
Elaeocarpaceae	4	Oleaceae	4	Melastomataceae	3
Oleaceae	4	Piperaceae	4	Symplocaceae	3
Piperaceae	4	Scrophulariaceae	4	Theaceae	3
Celastraceae	3	Theaceae	4	Thymeliaceae	3
Gesneriaceae	3	Araliaceae	3	Violaceae	3
Melastomataceae	3	Caprifoliaceae	3	Zingiberaceae	3
Symplocaceae	3	Elaeocarpaceae	3	Apocynaceae	2
Thymeliaceae	3	Gesneriaceae	3	Araliaceae	2
Violaceae	3	Melastomataceae	3	Celastraceae	2
Anacardiaceae	2	Myrsinaceae	3	Cyperaceae	2
Apiaceae	2	Symplocaceae	3	Hypericaceae	2
Aquifoliaceae	2	Thymeliaceae	3	Myrsinaceae	2
Asclepiadaceae	2	Violaceae	3	Scrophulariaceae	2
Berberidaceae	2	Zingiberaceae	3	Smilacaceae	2
Caprifoliaceae	2	Acanthaceae	2	Acanthaceae	1
Cyperaceae	2	Apiaceae	2	Actinidiaceae	1
Hypericaceae	2	Apocynaceae	2	Amaranthaceae	1
Moraceae	2	Aquifoliaceae	2	Vitaceae	1
Myricaceae	2	Asclepiadaceae	2	Anacardiaceae	1
Acanthaceae	1	Berberidaceae	2	Apiaceae	1
Actinidiaceae	1	Celastraceae	2	Asclepiadaceae	1
Vitaceae	1	Cyperaceae	2	Dipsacaceae	1
Apocynaceae	1	Hypericaceae	2	Erythroxylaceae	1
Araceae	1	Myricaceae	2	Fabaceae	1
Araliaceae	1	Proteaceae	2	Flacourtiaceae	1
Balanophoraceae	1	Salicaceae	2	Hamamelidaceae	1
Chloranthaceae	1	Actinidiaceae	1	Liliaceae	1
Clusiaceae	1	Amaranthaceae	1	Menispermaceae	1
Convolvulaceae	1	Vitaceae	1	Piperaceae	1
Corylaceae	1	Anacardiaceae	1	Plantaginaceae	1
Daphniphyllaceae	1	Araceae	1	Proteaceae	1
Ebenaceae	1	Balanophoraceae	1	Rananculaceae	1
Erythroxylaceae	1	Chloranthaceae	1	Simaroubaceae	1
Fabaceae	1	Clusiaceae	1	Sterculiaceae	1
Flacourtiaceae	1	Convolvulaceae	1	Verbenaceae	1

Table 3. (*continued*)

Undisturbed stand	No. of species	Moderately disturbed stand	No. of species	Highly disturbed stand	No. of species
Gentiaceae	1	Dipsacaceae	1		
Hamamelidaceae	1	Erythroxylaceae	1		
Juglandaceae	1	Fabaceae	1		
Lardizabalaceae	1	Flacourtiaceae	1		
Lobeliaceae	1	Gentianaceae	1		
Malvaceae	1	Hamamelidaceae	1		
Meliaceae	1	Lardizabalaceae	1		
Menispermaceae	1	Liliaceae	1		
Olacaceae	1	Loranthaceae	1		
Plantaginaceae	1	Menispermaceae	1		
Proteaceae	1	Plantaginaceae	1		
Rutaceae	1	Simaroubaceae	1		
Scrophulariaceae	1	Sterculiaceae	1		
Sterculiaceae	1	Verbenaceae	1		
Urticaceae	1				
Verbenaceae	1				
Zingiberaceae	1				

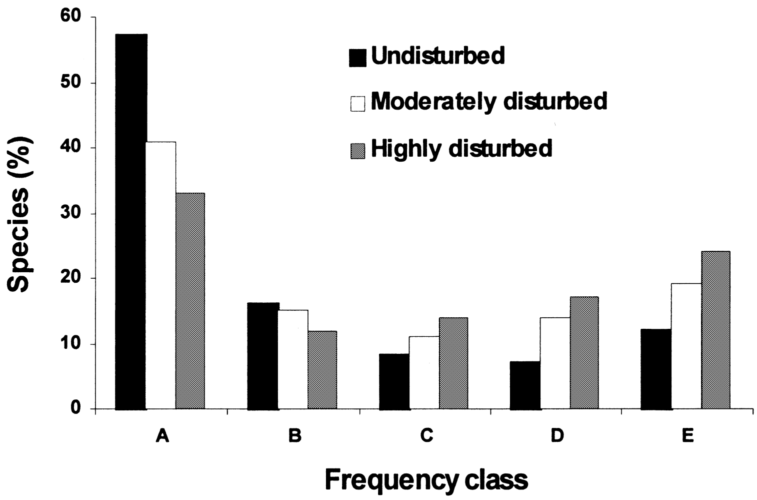

Figure 1. Raunkiaer's frequency class distribution in the undisturbed, moderately disturbed and highly disturbed forest stands in the Swer sacred grove.

Discussion

The cutting of mature trees for timber, collection of fuel-wood and cattle grazing were mainly responsible for the community organisation and altering the botanical composition of the sacred grove. Terborgh (1992) has emphasised that the activities

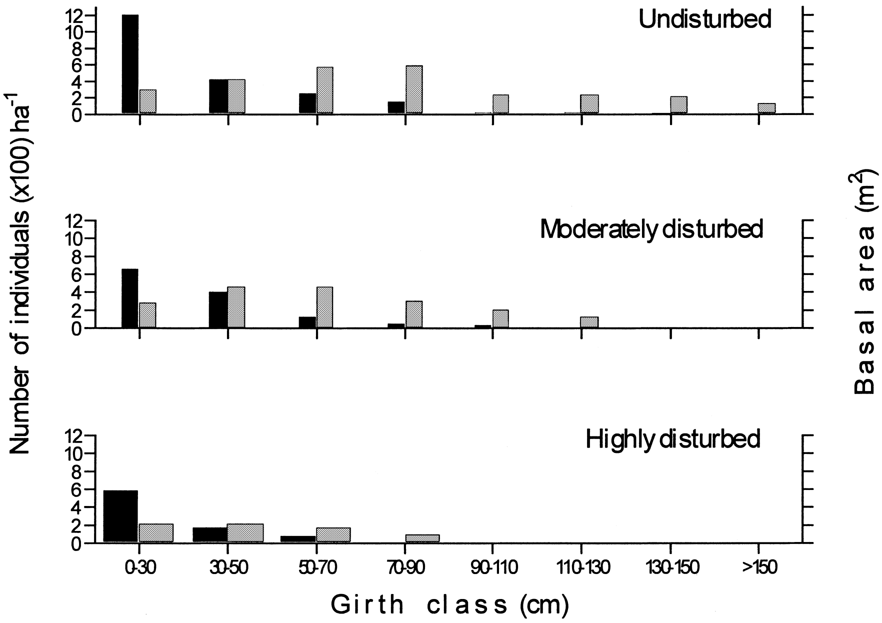

Figure 2. Density (black bars) and basal area (gray bars) of tree species of different girth classes in the undisturbed, moderately disturbed and highly disturbed forest stands in the Swer sacred grove.

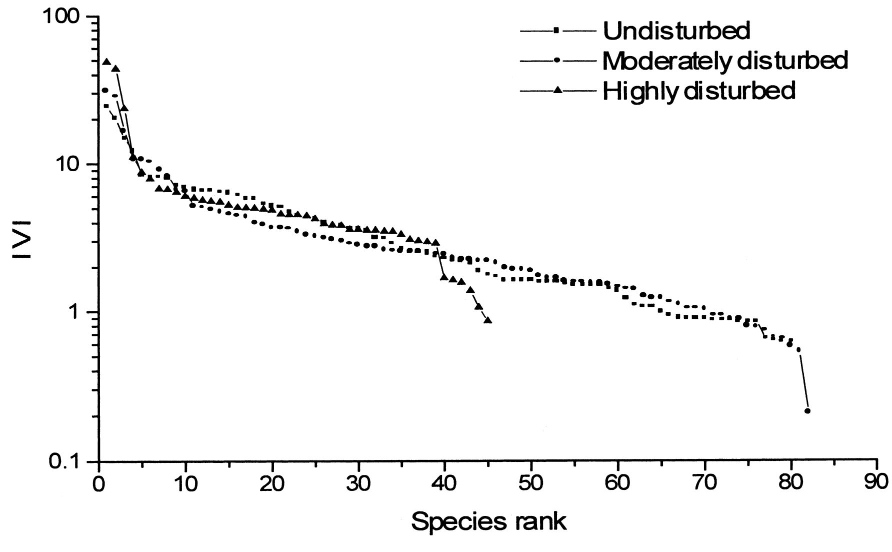

Figure 3. Dominance–distribution pattern in the undisturbed, moderately disturbed and highly disturbed forest stands in the Swer sacred grove.

of humans often do more to accelerate species loss than the operations of internal biological processes. Whittaker (1975) and Connell (1978) have pointed out that mild disturbance provides greater opportunity for species turnover, colonisation and persistence of high species richness. The findings of the present study, depicting maximum species richness and diversity in the moderately disturbed stand, are in conformity with the results of these workers. The overall dominance increased with the increase in disturbance stress. The family dominance changed from the undisturbed to the disturbed stands, the change being more conspicuous in the highly disturbed stand. A similar result has also been reported by Thorington et al. (1982), Parthasarathy and Karthikeyan (1997) and Parthasarathy and Sethi (1997). Rubiaceae, which was the dominant family in the undisturbed stand, no longer maintained its dominant position in the moderately disturbed and highly disturbed stands, in which Asteraceae was the dominant family. The co-dominant families in the undisturbed stand were Rubiaceae, Poaceae and Asteraceae, each being represented by 10 species. The Rubiaceae was also a co-dominant family in the moderately disturbed stand, while the highly disturbed stand had Poaceae as the co-dominant family. The shift in the position of the families in trees of their dominance seems to be linked with the level of anthropogenic disturbance.

The dominant growth form in the community also varied with the degree of disturbance. The trees were dominant in the undisturbed stand, shrubs in the moderately disturbed stand and herbs in the highly disturbed stand. Bhuyan et al. (2001) have also reported shrub species richness to be maximum in the mildly disturbed forests. Annuals and/or short-lived perennials were favoured by disturbance, which is in agreement with the findings of Raizada et al. (1998). Trees such as *Aporusa dioica*, *A. oblonga*, *Exbucklandia populnea*, *Glochidion assamicum*, *G. khasicum*, *Litsea citrata*, *L. salicifolia*, *Neolitsea zeylanica*, *Rhododendron arboreum*, *Rhus succedanea*, *Symplocos crataegoides*, *S. racemosa*, *S. spicata* and *Vitex vestita*, and a majority of shrubs which were present in the undisturbed as well as disturbed stands, appear to have greater ecological amplitude with respect to degree of disturbance. Tree species such as *Beilschmiedia brandisii*, *Carpinus viminea*, *Cleidion javanicum*, *Cleyera grandiflora*, *Cryptocarya andersonii*, *Cyclostemon assamicus*, *Daphniphyllum himalayense*, *Diospyros pilosula*, *Dysoxylum binectariferum*, *Elaeocarpus sikkimensis*, *Engelhardtia spicata*, *Eriobotrya dubia*, *Euonymus lawsonii*, *Kydia calycina*, *Machilus bombycina*, *M. duthiei*, *Olax acuminata*, *Olea salicifolia*, *Sorbus microphylla*, *Spondias pinnata* and *Zanthoxylum khasianum*, which were absent from the disturbed stands, appear to be more vulnerable to anthropogenic disturbance. *Heptapleurum khasianum* was restricted only to the highly disturbed stand, which indicates that it is either a shade-intolerant species or it cannot compete with the primary tree species growing in the undisturbed and moderately disturbed stands. However, the disturbance appears to favour the growth of *Ardisia floribunda*, *A. paniculata*, *Eranthemum pulchellum*, *Ficus clavata*, *F. eracta*, *Lonicera japonica* and *Lyonia ovalifolia*, which were confined only to the disturbed stands. Mild disturbance favoured the growth of shrubs.

A progressive reduction in tree density and tree basal area from the undisturbed to the highly disturbed stand observed in the present study, agrees with the findings of Bhuyan et al. (2001) in a tropical wet evergreen forest in Arunachal Pradesh, northeast India. This could be due to cutting of mature trees from the moderately disturbed stand, and extraction of trees of lower girth classes from the highly disturbed stand. Log-normal dominance–distribution curves in the undisturbed and moderately disturbed stands depict the stability of the community, while shorter hooked curves, as seen in the highly disturbed stand, indicated an increased loss of species from the community. The IVIs of the dominant species increased from the undisturbed to the highly disturbed stand, which is in conformity with the findings of Kadavul and Parthasarathy (1999), Visalakshi (1995) and others who studied the forests of peninsular India.

Conclusions

The present study suggests that the mild disturbance caused to the sacred grove vegetation due to collection of fuel-wood, extraction of trees for timber, and cattle grazing does not adversely affect the plant diversity of the sacred grove. However, the increased degree of disturbance caused loss in plant diversity and brought about changes in community characteristics. The community structure is drastically changed in terms of floristic composition, species density, and tree population structure. The disturbance led to thinning of the woody layer and change in the forest microclimate which, in turn, might have impaired regeneration processes of the tree species on the one hand, and helped colonisation and establishment of shade-intolerant shrubs and annuals on the other hand.

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Appendix 1

Plant diversity in the undisturbed (UD), moderately disturbed (MD) and highly disturbed (HD) forest stands in the Swer sacred grove. Values given represent the IVI of trees (cbh ≥ 15 cm).

Plant species	Family	UD	MD	HD
Tree species				
Aporusa dioica (Roxb.) Muell.-Arg.	Euphorbiaceae	8.2	6.7	6.0
A. oblonga Muell.-Arg.	Euphorbiaceae	5.2	4.0	4.5
A. roxburghii Baill.	Euphorbiaceae	3.9	4.6	5.0
Beilschmiedia brandisii Hk.f.	Lauraceae	7.0	–	–
Carpinus viminea Wall. ex Lindl.	Corylaceae	0.6	–	–
Cinnamomum pauciflorum Nees	Lauraceae	3.2	5.2	–
C. tamala Fr. Nees	Lauraceae	0.9	1.4	–
Cleidion javanicum Bl.	Euphorbiaceae	1.8	2.6	–
Cleyera grandiflora Hk.f. and Th. ex Dyer	Theaceae	0.9	–	–
Cryptocarya andersonii King ex Hk.f.	Lauraceae	5.9	–	–
Cyclostemon assamicus Hk.f.	Euphorbiaceae	1.6	–	–
Daphniphyllum himalayense (Benth.) Muell.-Arg.	Daphniphyllaceae	8.2	–	–
Diospyros pilosula (DC.) Hiem.	Ebenaceae	3.7	–	–
Dysoxylum binectariferum Hk.f. and Bedd.	Meliaceae	4.7	–	–
Echinocarpus dasycarpus Benth.	Elaeocarpaceae	2.2	1.7	–
E. murex Benth.	Elaeocarpaceae	1.4	0.9	–
Elaeocarpus acuminatus Wall. ex Mast.	Elaeocarpaceae	0.0	1.9	–
E. sikkimensis Mast.	Elaeocarpaceae	2.3	–	–
Engelhardtia spicata Leschn ex Bl.	Juglandaceae	7.2	–	–
Eriobotrya dubia Decne.	Rosaceae	2.5	–	–
Euonymus lawsonii Cl. and Pr.	Celastraceae	1.7	–	–
Exbucklandia populnea (R. Br. ex Griff) R.W. Br.	Hamamelidaceae	0.9	1.2	8.7
Garcinia cowa Roxb ex DC	Clusiaceae	0.6	1.6	–
Glochidion assamicum Hk.f.	Euphorbiaceae	1.0	2.8	5.6
G. khasicum Hk.f.	Euphorbiaceae	6.7	3.9	5.0
G. lanceolarium (Roxb) Voight	Euphorbiaceae	–	1.6	3.8
Helicia excelsa Bl.	Proteaceae	–	1.7	0.9
H. nilagirica Bedd.	Proteaceae	1.4	2.6	–
Heptapleurum khasianum Cl.	Araliaceae	–	–	1.4
Ilex embelioides Hk.f.	Aquifoliaceae	1.6	0.5	–
I. khasiana Purk.	Aquifoliaceae	1.5	0.2	–
Kydia calycina Roxb.	Malvaceae	4.2	–	–
Leucosceptrum canum Sm.	Lamiaceae	0.0	0.7	–
L. coreanum Sm.Exot.	Lamiaceae	–	0.7	–
Litsea citrata Bl.	Lauraceae	1.5	3.3	5.8
L. khasyana Meissn.	Lauraceae	–	3.7	4.6
L. salicifolia (Roxb ex Nees) Hk.f.	Lauraceae	1.6	2.6	4.2
Machilus bombycina King ex Hk.f.	Lauraceae	1.6	–	–
M. duthiei King ex Hk.f.	Lauraceae	2.2	–	–
Macropanax undulatus (Wall ex G. Don.) Seem.	Araliaceae	–	1.2	–
Myrica esculenta Buch-Ham ex D. Don.	Myricaceae	4.4	3.2	–
M. nagi Hk.f.	Myricaceae	5.1	3.2	–
Neolitsea zeylanica Merr.	Lauraceae	0.9	2.5	5.7
Olax acuminata Benth.	Olacaceae	2.1	–	–
Olea salicifolia Wall. ex Cl.	Oleaceae	1.6	–	–
Photinia notoniana Wt. and Arn.	Rosaceae	3.6	1.2	–

Appendix 1. (*continued*)

Plant species	Family	UD	MD	HD
Picrasma javanica Bl.	Simaroubaceae	–	0.9	0.0
Pyrus pashia D.Don.	Rosaceae	–	1.0	3.5
Rhododendron arboreum Sm.	Ericaceae	24.1	31.6	43.8
Rhus succedanea (non L.) Gamble.	Anacardiaceae	0.0	1.3	4.9
Schima wallichii (DC.) Korth.	Theaceae	3.6	4.5	–
Sorbus microphylla Decaisne.	Rosaceae	2.3	–	–
Spondias pinnata (Linn f.) Kurz.	Anacardiaceae	2.9	–	–
Strobilanthes adanatus Clarke.	Acanthaceae	1.21	0.8	–
Symplocos crataegoides D. Don.	Symplocaceae	1.1	2.6	2.9
S. racemosa Roxb.	Symplocaceae	2.5	3.0	4.4
S. spicata Roxb.	Symplocaceae	6.4	4.9	3.3
Vitex vestita Roxb.	Verbenaceae	0.9	1.1	1.7
Wendlandia paniculata DC.	Rubiaceae	4.0	2.3	–
Zanthoxylum khasianum Hk.f.	Rutaceae	5.4	2.8	–
Shrub species				
Acanthopanax aculeatum Seem.	Araliaceae	–	1.9	–
Actinidia callosa Lindl.	Actinidiaceae	3.8	4.8	6.7
Ardisia floribunda Wall.	Myrsinaceae	0.9	1.6	3.9
A. paniculata Roxb.	Myrsinaceae	–	1.5	3.0
Berberis wallichiana DC.	Berberidaceae	4.5	6.6	–
Camellia cauduca Brandis.	Theaceae	14.9	10.7	5.2
Casearia vareca Roxb.	Flacourtiaceae	8.5	10.7	11.1
Coffea khasiana Hk. f.	Rubiaceae	2.7	3.0	1.6
Colquhounia coccinea Wall.	Lamiaceae	–	0.8	–
Daphne cannabina Wall.	Thymeliaceae	0.0	0.0	0.0
D. hamiltonii Wall.	Thymeliaceae	0.0	0.0	0.0
D. involucrata Wall.	Thymeliaceae	0.0	0.0	0.0
Dendrocalamus hookerii Munro.	Poaceae	8.0	9.1	6.4
Dischidia nummularia R.Br.	Asclepiadaceae	1.1	2.1	3.5
Elsholtzia blanda Benth.	Lamiaceae	0.9	2.5	3.0
Eranthemum pulchellum Andrews.	Acanthaceae	–	0.7	1.6
Erythroxylum kunthianum Wall. ex Kurz.	Erythroxylaceae	6.6	4.5	1.1
Eupatorium adenophorum Spreng.	Asteraceae	0.0	0.0	0.0
E. odoratum Linn.	Asteraceae	0.0	0.0	0.0
Eurya acuminata DC.	Theaceae	6.1	10.3	23.5
E. japonica Thunb.	Theaceae	20.1	28.5	48.4
Ficus clavata Wall. ex Miq	Moraceae	–	0.0	0.0
F. eracta Thunb.	Moraceae	–	0.0	0.0
F. nervosa Heyne ex Roth.	Moraceae	1.6	2.4	3.5
F. silhetensis Miq.	Moraceae	1.9	2.9	3.8
Gaultheria fragrantissima Wall.	Ericaceae	1.6	3.5	–
G. griffithiana Wight.	Ericaceae	6.7	5.1	–
Ixora parviflora Vahl.	Rubiaceae	1.5	1.9	3.6
Leptodermis griffithi Hk.f.	Rubiaceae	0.7	1.0	–
Ligustrum myrsinites Decne.	Oleaceae	1.5	2.0	4.5
L. nepalensis Wall.	Oleaceae	3.1	2.5	3.5
L. robustum (Roxb.) Bl.	Oleaceae	–	2.2	6.8
Lonicera japonica Thunb.	Caprifoliaceae	–	2.2	3.6
Loranthus scurrula Linn.	Loranthaceae	–	1.6	–
Lyonia ovalifolia (Wall) Druce.	Ericaceae	–	2.8	5.1
Mohonia nepalensis DC.	Berberidaceae	0.0	1.6	–

Appendix 1. (*continued*)

Plant species	Family	UD	MD	HD
Mussaenda glabra Vahl.	Rubiaceae	1.1	1.7	−
M. roxburghii Hk.f.	Rubiaceae	0.6	1.4	−
Neillia thyrsiflora D.Don.	Rosaceae	0.0	0.6	−
Osbeckia capitata Benth.	Melastomataceae	0.0	0.0	0.0
O. crinita Naud.	Melastomataceae	0.0	0.0	0.0
O. rostrata D.Don.	Melastomataceae	0.0	0.0	0.0
Phyllanthus parvifolius Ham.	Euphorbiaceae	0.9	3.7	7.9
Pogostemon strigosus Benth.	Lamiaceae	5.8	8.4	−
Psychotria symplocifolia Kurz.	Rubiaceae	12.2	16.8	−
Salix psilostigma Anders.	Salicaceae	−	1.5	−
S. tetrasperma Roxb.	Salicaceae	0.9	0.9	−
Saprosma ternatum Hk.f.	Rubiaceae	6.4	2.2	2.9
Sarcandra glabra (Thunb) Nakai.	Chloranthaceae	1.5	0.9	−
Senecio densiflorus Wall.	Asteraceae	0.9	1.0	−
Viburnum foetidum Wall.	Caprifoliaceae	2.5	3.7	5.5
V. simonsii Hk.f and Th.	Caprifoliaceae	0.9	2.2	4.9
Climbers				
Buettneria grandiflora Colebr. ex Wall.	Sterculiaceae	+	+	+
Celastrus championii Benth.	Celastraceae	+	+	+
C. paniculatus Willd.	Celastraceae	+	+	+
Embelia floribunda Wall.	Myrsinaceae	−	+	−
Hedera helix Cl.	Araliaceae	+	+	+
Holboellia latifolia Wall.	Lardizabalaceae	+	+	−
Hoya longifolia Wall.	Asclepidaceae	+	+	−
Jasminum grandiflorum Linn.	Oleaceae	+	+	−
Mastersia eleistocarpa Backer.	Fabaceae	+	+	+
Melodinus khasianus Hk.f.	Apocynaceae	+	+	+
Paederia foetida Linn.	Rubiaceae	+	+	+
Parameria pedunculosa Benth.	Apocynaceae	−	+	+
Piper betel Linn.	Piperaceae	+	+	−
P. griffithii C.DC	Piperaceae	+	+	−
P. mullesua D. Don.	Piperaceae	+	+	−
P. thomsonii Hk.f.	Piperaceae	+	+	+
Rubia cordifolia Linn.	Rubiaceae	−	+	+
Rubia sp.	Rubiaceae	+	+	+
Rubus alceofolius Poir.	Rosaceae	−	+	+
R. ellipticus Sm.	Rosaceae	+	+	+
R. hexagynus Roxb.	Rosaceae	−	+	+
R. khasianus Cordot.	Rosaceae	+	+	+
R. lasiocarpus Sm.	Rosaceae	+	+	+
Smilax aspera Linn.	Smilacaceae	+	+	+
S. ferox Kunth.	Smilacaceae	+	+	+
S. lensiofolia Roxb.	Smilacaceae	+	+	−
S. myrtillus DC.	Smilacaceae	+	+	−
S. perfoliata Lour.	Smilacaceae	+	+	−
S. quadrata DC.	Smilacaceae	+	+	−
Stephania japonica (Thunb.) Miers.	Menispermaceae	+	+	+
Uncaria laevigata Wall.	Rubiaceae	−	+	+
Vitis lanata Roxb.	Vitaceae	+	+	+

Appendix 1. (*continued*)

Plant species	Family	UD	MD	HD
Herbaceous species				
Achyranthes aspera Linn.	Amaranthaceae	−	+	+
Ainsliaea latifolia (D. Don) Sch.	Asteraceae	−	+	+
A. pteropoda DC.	Asteraceae	−	+	+
Aphania allughas (Retz.) Rosc.	Zingiberaceae	−	+	+
Amomum subulatum Roxb.	Zingiberaceae	−	+	+
Anaphalis adnata Wall. ex DC.	Asteraceae	−	+	+
A. timmua D. Don.	Asteraceae	−	+	+
Anotis oxyphylla (G. Don) Hk.f.	Rubiaceae	−	+	+
A. waghtiana Hk.f.	Rubiaceae	−	+	+
Balanophora dioica Br.	Balanophoraceae	+	+	−
Brunella vulgaris Linn.	Lamiaceae	−	+	+
Centella asiatica Linn.	Apiaceae	+	+	+
Chrysopogon aciculatus Bl.	Poaceae	−	+	+
Cosmos bipinnatus Cav.	Asteraceae	−	+	+
Crassocephalum crepidioides (Benth) Moore	Asteraceae	−	−	+
Cymbopogon khasianus Stapf. ex Bor.	Poaceae	+	+	+
Cynodon dactylon Pers.	Poaceae	−	+	+
Cyperus esculentus Linn.	Cyperaceae	+	+	+
C. rotundus Linn.	Cyperaceae	+	+	+
Didymocarpus griffithii Wt.	Asteraceae	−	+	+
Digitaria corymbosa Roxb.	Poaceae	−	+	+
Dimeria fuscescens Trin.	Poaceae	−	+	+
Dipsacus asper DC.	Dipsacaceae	−	+	+
Echinochloa frumentacea Link.	Poaceae	+	+	−
Elatostemma rupestre (D. Don) Wedd.	Asteraceae	+	+	−
Eleusine coracana Gaertn.	Poaceae	+	+	+
Fragaria indica Andr.	Rosaceae	+	+	+
Galium rotundifolium auct. non Linn.	Rubiaceae	+	+	+
Gerbera macrophylla Benth and Hk.f.	Asteraceae	+	+	+
Gnaphalium luteoalbum Linn.	Asteraceae	−	+	+
Hedychium coronarium Koen.	Zingiberaceae	+	+	+
Hemiphragma heterophyllum Wall.	Scrophulariaceae	+	+	+
Hydrocotyle javanica Linn.	Apiaceae	+	+	−
Hypericum japonicum Thunb.	Hypericaceae	+	+	+
H. sampsonii Hance.	Hypericaceae	+	+	+
Hypochaeris radicata Linn.	Asteraceae	+	+	−
Ipomoea alba Linn.	Convolvulaceae	+	+	−
Leonurus sibiricus Linn.	Lamiaceae	+	−	−
Leucas ciliata Benth.	Lamiaceae	−	+	+
Leucea linifolia Spreng.	Lamiaceae	+	−	−
Lindenbergia urticaefolia Lehm.	Scrophulariaceae	−	+	+
Ophiopogon parviflorus Hk.f.	Liliaceae	−	+	+
Panicum khasianum Munro ex Hook.	Poaceae	+	+	+
P. montanum Roxb.	Poaceae	+	+	+
Paspallum dilatatum Poir	Poaceae	+	+	+
Phragmites carka (Retz.) Steud.	Poaceae	+	+	+
Procris wightiana Wall.	Urticaceae	+	−	−
Plantago major Linn.	Plantaginaceae	+	+	+
Potentilla kleiniana W&A.	Rosaceae	+	+	+
P. mooniana Wight.	Rosaceae	+	+	+

Appendix 1. (*continued*)

Plant species	Family	UD	MD	HD
Pratia begonifolia (Wall.) Lindl.	Lobeliaceae	+	−	−
Scutellaria discolor Coleb.	Lamiaceae	+	+	+
Setaria verticillata Beaur.	Poaceae	+	+	+
Sonchus arvensis Linn.	Asteraceae	+	+	+
S. oleraceus Linn.	Asteraceae	+	+	+
S. radigatum Linn.	Asteraceae	+	+	+
Swertia chirata Ham.	Gentiaceae	+	+	−
Thalictrum penduaum Wall.	Rananculaceae	−	−	+
Themeda triandra Forsk.	Poaceae	+	−	−
Triodex sp.	Asteraceae	+	−	−
Vandelia crustacea (L) Benth.	Scrophulariaceae	−	+	−
V. multiflora (Roxb.) D. Don.	Scrophulariaceae	−	+	−
Viola arcuata Bl.	Violaceae	+	+	+
V. diffusa Gmg.	Violaceae	+	+	+
V. patrinii DC.	Violaceae	+	+	+
Epiphyte				
Aeschynanthes parasiticus (Roxb.) Wall.	Gesneriaceae	+	+	−
A. sikkimensis (*Cl.*) Stapf	Gesneriaceae	+	+	−
A. superba Cl.	Gesneriaceae	+	+	−
Bulbophyllum griffithii (Lindl) Reichb.	Orchdaceae	+	+	+
Cymbidium eburneum Lindl.	Orchidaceae	−	+	+
Dendrobium formosum Roxb.	Orchidaceae	+	+	−
D. pauciflorum King & Pantl.	Orchidaceae	+	+	−
D. sulcatum Lindl.	Orchidaceae	+	+	−
Pholidota sp.	Orchidaceae	−	+	+
Rhaphidophora decursiva Schott.	Araceae	+	+	−
Sarcochilus manii Hk.f.	Orchidaceae	+	+	+
Vaccinium griffithianum Wt.	Ericaceae	+	+	+
V. sprengelii G. Don.	Ericaceae	+	+	+
V. vacciniaceum (Roxb.) Sleum.	Ericaceae	−	+	+

+: present; −: absent; 0.0: no individuals with cbh ≥ 15 cm.

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