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Effect of disturbance on plant species abundance and density distribution in tropical forest of Sunsari district, Eastern Nepal

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Abstract

The disappearance of global tropical forests due to deforestation and forest degradation has reduced the biodiversity and carbon sequestration capacity. In these contexts, present study was carried out to understand the species composition and density in the undisturbed and disturbed stands of moist tropical forest located in Sunsari district of eastern Nepal. Study revealed that the forest disturbance has reduced the number of tree species by 33% and tree density by 50%. In contrary, both number and density of herb and shrub species have increased with forest disturbance.

Key words: Vegetation analysis, quadrat method, Charkoshe jungle

Introduction

Tropical forests harbor the greatest wealth of biological and genetic diversity. Covering only 7% of the earth's land surface, these forests have more than half of the worlds' species (May & Stumpf, 2000). Tropical forests comprise 52% of total global forests. Tropical forests are mainly found in the developing countries located in neotropics (about 50%) and South-East Asia (about 30%).

In Nepal, 3.63 million hectares land is under natural forests which accounts for about 25% of the total land area of the country. Tropical forests in Nepal are confined to the Terai and Siwaliks, which together comprise 1878000 ha of natural forest (FRSC, 1994). The carbon stock in living forest biomass in 2010 in Nepal was 133 t ha^{-1} (FAO, 2011). About 59% of the natural forests are broadleaved stands, 17% are conifers and 24% are mixed stands (Giri, 1996). Forest resources play an important role in the economy of Nepal and contribute 4.3% to the GDP. According to Shrestha *et al.* (2002), the tropical forest of Nepal includes about 487 plant species.

The forests have been sources of livelihood of many people from time immemorial. The non-timber plant resources which in most cases are much more valuable than timber resources are ignored. They increase the range of income generating options of forest-dependent villagers while avoiding some of the ecological costs of timber cutting. The valuable non-timber resources of forest are edible and medicinal fruits, seeds, leafy vegetables, twigs, nuts and bark, rattan, gum, latex, tannin and dyes.

The understory vegetation is an integral part of forest ecosystems supporting a wide range of floristic diversity and providing habitats and foods for many kinds of animals. It also influence community dynamics and succession patterns and contribute to nutrient cycling.

Disturbances lead to changes in structure and functioning of forest ecosystem. Regarding the structural changes, canopy thinning, creation of distinct canopy gaps, destruction of much of the top strata directly affect the hydrological cycle within the forest ecosystem. Disturbance also damages the functional aspects of the forest ecosystems by creating very rigorous conditions for both plant and microbial growth due to decreased organic matter content of soil, unfavorable pH and low nutrient supply. Disturbed forests show changes in species composition and density, stand biomass and productivity and in the patterns of nutrient cycling. Another major effect of disturbance is on species richness and diversity. The intermediate disturbance hypothesis (IDH) originally proposed by Connell (1978), predicts that diversity will be maximum at intermediate levels of disturbance.

Natural communities are inherently dynamic systems with respect to their species composition, structure and functional characteristics. The age-structure and densities of different populations constituting the communities change with time. The disappearance of tropical forests at an estimated rate of 1-2% per year comes at a time when our knowledge of their structure, composition, dynamics, diversity and taxonomy has been not fully unraveled (Hubbell & Foster, 1983). In order to fill this lacuna, the present work was undertaken with the view to understand species abundance, and structure in terms of density in the tropical forest of eastern Nepal.

Materials and Methods

Study area

The study was conducted in a Sal (*Shorea robusta* Gaertn.) dominated moist tropical forest of Sunsari district, eastern Nepal (latitude N 26°41' to 26°50' and longitude E 87°09' to 87°21'), within the altitude range of 220 to 370 m, msl (Fig. 1).

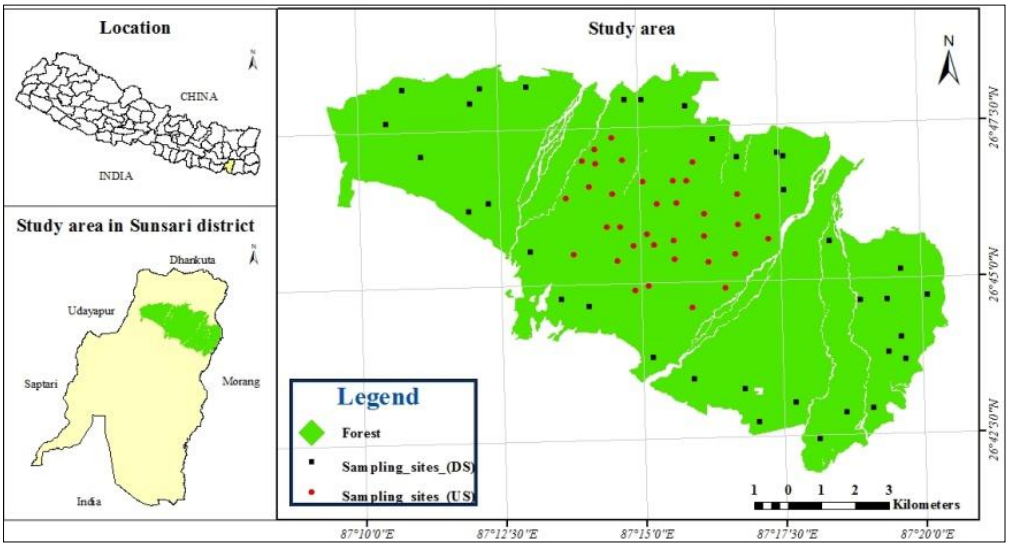

Figure 1. Map of the study area (tropical forest of Sunsari district, eastern Nepal).

The forest lies in the catchment area of Koshi River, one of the largest rivers in Nepal. The total area occupied by the forest is 11394 ha. The forest is bordered by the *Siwalik* hills in the north and Gangetic alluvial plain in the south. The soil mainly consists of deep alfisols.

The climate is tropical and monsoon type with three distinct seasons: dry and warm summer (March to May), wet and warm rainy (June to October), and dry and cool winter (November to February). The mean monthly minimum and maximum air temperature during 2005–2014 ranged from 10.9 to 25.3°C and 22.6 to 33.2°C, respectively. The average annual rainfall for the period was 1998.6 mm (Fig. 2). Pronounced rainfall occurred during the months of June to September. Relative humidity was higher in rainy season with highest value in August (92%).

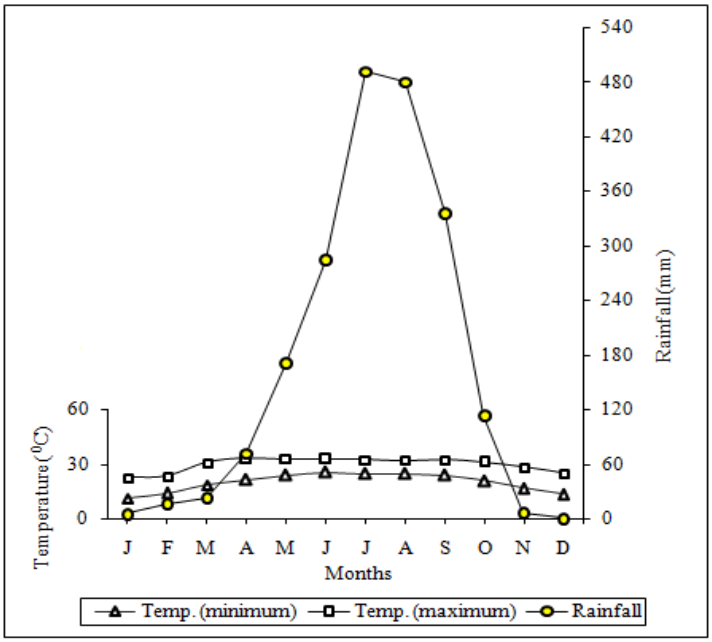

Figure 2. Ombrothermic representation of the climate of moist tropical forest region of Sunsari district, eastern Nepal. 2005–2014 (Source: Dept of Meteorology, Dharan, Nepal).

The central part (core area) of the forest is relatively undisturbed, while the peripheral part is affected by disturbance activities as removal for timber, livestock grazing, fuel-wood and litter collection, tree lopping, removal of poles for house-hold constructions and forest fires. The topstory of forest is dominated by the tropical species *Shorea robusta* (Dipterocarpaceae), associated with *Haldina cordifolia*, *Careya arborea*, *Dillenia pentagyna*, *Terminalia allata*, *T. bellirica*, *T. chebula*, *Lagerstroemia parviflora* etc. *Clerodendron infortunatum*, and *Murraya koenigii* are some of the main shrub species while *Chromolaena odorata* and *Achyranthes aspera* are dominant herbs.

Sampling and vegetation analysis

Central part of the forest was treated as undisturbed forest (UF), and peripheral part as disturbed forest (DF). Study was conducted in UF and DF stands. Altogether, seventy permanent experimental plots, thirty five each in UF and DF were randomly established. In the present study stem of tree-species having ≥ 10 cm girth at breast height (GBH) were considered as trees (Lalfakawma *et al.*, 2009). For the analysis of trees, sampling plot of 20 m × 20 m was used while for shrubs nested quadrat of 5 m × 5 m and for herbs nested quadrat of 1 m × 1 m was established in the forest. Plant species recorded in all plots were

identified with the help standard literatures and herbarium specimens deposited at Tribhuvan University Regional Herbarium, Post Graduate Campus, Biratnagar, Nepal. Densities of plant species present within the plots were determined.

Results

Herb layer

The number of herb species increased with forest disturbance. Among the total 47 species, 26 species were present in both undisturbed and disturbed forests, while 30 species were enumerated from UF and 43 species from DF (Table 1). It showed 71% similarity in the vegetation of two stands (Table 5). So, 29% dissimilarity in the vegetation occurred due to the effect of disturbance. The four species present only in UF were *Piper*, *Hygrophilla*, *Curculigo* and *Lygodium*. Density of herbs increased with the forest disturbance (Table 1). The density values ranged between 20 and 38 individual m^{-2} in UF and DF, respectively.

Table 1. Density (D; individual m^{-2}) of herb species in undisturbed forest stand (UF) and disturbed forest stand (DF) of moist tropical forest in Sunsari district, eastern Nepal

Scientific names	Density (Individual m^{-2})	
	UF	DF
Chromolaena odorata (L.) R.M. King & H. Rob.	2.26	1.60
Oplismenus compositus (L.) P. Beauv.	3.89	3.20
Piper longum L.	2.26	–
Commelina benghalensis L.	1.54	0.77
Hedychium ellipticum Buch.-Ham. ex Sm.	0.43	0.09
Chrysopogon aciculatus (Retz.) Trin.	1.46	1.66
Sonchus asper (L.) Hill	0.06	0.69
Sida rhombifolia L.	0.8	2.06
Senna tora (L.) Roxb.	0.26	0.06
Eclipta prostrata (L.) L.	1.03	0.03
Desmodium triflorum (L.) DC.	0.49	1.31
Kyllinga brevifolia Rottb.	0.83	0.86
Blumea lacera (Burm. f.) DC.	0.51	0.74
Paspalum scrobiculatum L.	0.63	3.46
Bidens bipinnata L.	0.09	0.43
Achyranthes aspera L.	0.40	0.26
Abutilon indicum (L.) Sweet	0.26	1.06
Hygrophila auriculata (Schumach.) Heine	0.37	–
Veronica javanica Bl.	0.34	0.63
Evolvulus nummularius (L.) L.	0.37	1.69
Cyperus rotundus L.	0.43	2.49
Oxalis corniculata L.	0.37	1.14
Hemigraphis hirta (Vahl) T. Anderson	0.17	0.14
Cynodon dactylon (L.) Pers.	0.43	3.20
Curculigo orchioides Gaertn.	0.09	–
Ageratum conyzoides L.	0.14	1.69
Youngia japonica (L.) DC.	0.11	0.17
Tridax procumbens L.	0.09	0.11
Centella asiatica (L.) Urb.	0.09	0.31
Lygodium flexuosum (L.) Sm.	0.03	–

Imperata cylindrica (L.) Raeusch.	–	3.83
Mikania micrantha Kunth	–	0.60
Mimosa pudica L.	–	0.49
Eragrostis tenella (L.) P. Beauv. ex Roem. & Schult.	–	0.94
Digitaria ciliaris (Retz.) Koeler	–	0.94
Paederia scandens (Lour.) Merr.	–	0.09
Scoparia dulcis L.	–	0.20
Boerhavia diffusa L.	–	0.23
Hedyotis corymbosa (L.) Lam.	–	0.20
Chamaesyce hirta (L.) Millsp.	–	0.20
Caesulia axillaris Roxb.	–	0.29
Alysicarpus vaginalis (L.) DC.	–	0.11
Solanum americanum Mill	–	0.11
Hemarthria compressa (L. f.) R. Br.	–	0.14
Helminthostachis zeylanica L. (Hook.)	–	0.06
Ophioglossum sp.	–	0.06
Laphangium luteoalbum (L.) Tzvelev	–	0.03
Total	20.2	38.4

Shrub layer

Altogether, 16 species were recorded in the forest. Among them, 12 species were found in UF and 15 in DF and 11 species were common to both forests (Table 2). It showed 81% similarity between UF and DF (Table 5). So, 19% dissimilarity between two forests occurred due to effect of disturbance. A single species recorded only in UF was *Jasminum* sp., while 4 species like *Calotropis*, *Jatropha*, *Solanum* and *Callicarpa* were present only in DF. Density of shrubs increased with forest disturbance from 6377 to 7040 individual ha^{-1} (Table 2).

Table 2. Density (D; individual ha^{-1}) of shrub species in undisturbed forest stand (UF) and disturbed forest stand (DF) of moist tropical forest in Sunsari district, eastern Nepal

Scientific names	**Density (Individual ha^{-1})**	
	UF	**DF**
Murraya koenigii (L.) Spreng.	1668.57	251.43
Phyllanthus reticulatus Poir.	1291.43	251.43
Osbeckia chinensis L.	1200	342.86
Lantana camara L.	1028.57	960
Clerodendrum infortunatum L.	445.71	1302.86
Pogostemon benghalensis (Burm f.) Kuntze	297.14	1245.71
Leea aequata L.	45.71	1108.57
Colebrookea oppositifolia Sm.	34.29	308.57
Vitex negundo L.	11.43	114.29
Jasminum sp.	182.86	–
Rauvolfia serpentina (L.) Benth. ex Kurz	91.43	22.86
Desmodium confertum DC.	80.00	800.00
Calotropis procera (Aiton) Dryand.	–	251.43
Jatropha curcas L.	–	11.43
Solanum torvum Sw.	–	34.29
Callicarpa macrophylla Vahl	–	34.29
Total	6377	7040

Tree layer

In the present study, 981 individuals of trees were recorded which belonged to 60 species, 51 genera, and 32 families (Table 3). Out of these, 57 species were present in UF, 38 in DF and 35 were common to both forest stands. The number of species found only in UF was 22, whereas that in DF was 3. It showed 74% similarity between UF and DF as per the Sorenson's similarity index (Table 5). So, 26% dissimilarity between two stands reflected the consequence of disturbance.

Table 3. Enumeration of tree species found in undisturbed forest stand (UF) and disturbed forest stand (DF) in moist tropical forest of Sunsari district, eastern Nepal

Scientific names	Local name/s	Families	Occurrence
Acacia catechu (L.f.) Willd.	Khayer	Mimosaceae	Both
Acacia ferruginea DC.	Khaur	Mimosaceae	UF
Acer oblongum Wall. ex DC.	Phirphire	Aceraceae	UF
Aegle marmelos (L.) Correa	Bel	Rutaceae	Both
Alangium salviifolium (L.f.) Wangerin	Asare	Alangiaceae	Both
Albizia julibrissin Durazz.	Rato Siris	Mimosaceae	Both
Albizia lebbeck (L.) Benth.	Padke Siris	Mimosaceae	Both
Albizia procera (Roxb.) Benth.	Thakar	Mimosaceae	Both
Alstonia scholaris (L.) R. Br.	Chhatiwan	Apocynaceae	Both
Anogeissus latifolius (Roxb. ex DC.) Bedd.	Paani Sahaj, Banjhi	Combrataceae	UF
Baliospermum solanifolium (Burm.) Suresh	Aaulea	Euphorbiaceae	Both
Bauhinia malabarica Roxb.	Amiltanki	Caesalpiniaceae	UF
Bombax ceiba L.	Simal	Bombacaceae	Both
Bridelia retusa (L.) A. Juss.	Gayo	Euphorbiaceae	Both
Careya arborea Roxb.	Kumbhi	Myrtaceae	Both
Cassia fistula L.	Raajbriksha	Caesalpiniaceae	Both
Cassia sp.		Caesalpiniaceae	UF
Cordia dichotoma G. Forst.	Bohori	Cordiaceae	UF
Cornus oblonga Wall.	Lati kath	Cornaceae	UF
Dalbergia latifolia Roxb.	Satisal	Papilionaceae	UF
Desmodium oojeinense (Roxb.) H. Ohashi	Sandan	Fabaceae	UF
Dillenia pentagyna Roxb.	Tantary	Dillaniaceae	Both
Diospyros chloroxylon Roxb.	Kalikath	Ebenaceae	UF
Diploknema butyracea (Roxb.) H.J. Lam.	Chiuri	Sapotaceae	Both
Ehretia laevis Roxb.	Datrungo	Cordiaceae	Both
Elaeagnus latifolia L.	Guyelo	Elaeagnaceae	UF
Falconeria insignis Royle	Khirro	Euphorbiaceae	Both
Ficus lacor Buch.-Ham.	Kavro	Moraceae	Both
Ficus racemosa L.	Dumri	Moraceae	Both
Ficus rumphii Blume	Sami	Moraceae	UF
Ficus semicordata Buch.-Ham ex Sm.	Khaniu	Moraceae	UF
Garuga pinnata Roxb.	Dabdabe	Burseraceae	Both
Gmelina arborea Roxb.	Khamari	Verbanaceae	UF
Grewia optiva J.R. Drumm. ex Burret	Syalphusro	Tiliaceae	Both
Haldina cordifolia (Roxb.) Ridsdale	Karma	Rubiaceae	Both
Heynea trijuga Roxb. ex Sims	Aankha taruwa	Meliaceae	UF
Holarrhena pubescens Wall. ex G. Don	Musabar	Apocynaceae	Both
Holoptelia integrifolia Planch.	Pipari	Ulmaceae	Both
Lagerstroemia parviflora Roxb.	Botdhayero	Lythraceae	Both

Lannea coromandelica (Houtt.) Merr.	Hallude	Anacardiaceae	Both
Mallotus pallidus (Airy Shaw) Airy Shaw	Sindure	Euphorbiaceae	UF
Mallotus repandus (Willd.) Mull. Arg.	Pithari	Euphorbiaceae	Both
Neolamarckia cadamba (Roxb.) Bosser	Kadam	Rubiaceae	DF
Oroxylum indicum L. Kurz	Totalo	Bignoniaceae	DF
Phyllanthus emblica L.	Amala	Euphorbiaceae	UF
Premna mollissima Roth	Gineri	Verbenaceae	UF
Schleichera oleosa (Lour.) Merr.	Kusum	Sapindaceae	Both
Semecarpus anacardium L.f.	Bhalayo	Anacardiaceae	Both
Shorea robusta Gaertn.	Sal	Dipterocarpaceae	Both
Spondias pinnata (L.f.) Kurz	Amaro	Anacardiaceae	UF
Sterculia villosa Roxb.	Odal	Sterculiaceae	UF
Stereospermum tetragonum DC.	Padari	Bignoniaceae	UF
Syzygium cumini (L.) Skeels	Jamun	Myrtaceae	Both
Syzygium nervosum A.Cunn. ex DC.	Kyamuna	Myrtaceae	Both
Tamarindus indica L.	Titri	Caesalpiniaceae	DF
Terminalia bellirica (Gaertn.) Roxb.	Barro	Combretaceae	Both
Terminalia chebula Retz.	Harro	Combretaceae	Both
Terminalia tomentosa Wight. & Arn.	Saj, Asna	Combretaceae	Both
Trema orientalis (L.) Blume.	Kunyel	Ulmaceae	Both
Ziziphus mauritiana Lam.	Bayer	Rhamnaceae	UF

Table 4. Density (D; individual ha^{-1}) of tree species (> 10 cm GBH) in undisturbed and disturbed forest stands of moist tropical forest in Sunsari district, eastern Nepal

	Density (Individual ha^{-1})	
	Undisturbed forest	**Disturbed forest**
Shorea robusta	100.00	64.29
Haldina cordifolia	39.29	21.43
Lagerstroemia parviflora	52.14	3.57
Baliospermum solanifolium	39.29	6.43
Terminalia tomentosa	16.43	15.00
Alangium salviifolium	25.71	19.29
Schleichera oleosa	12.14	12.14
Dillenia pentagyna	13.57	7.14
Terminalia bellirica	12.86	10.71
Syzygium cuminii	9.29	2.86
Mallotus pallidus	16.43	–
Diospyros chloroxylon	13.57	–
Lannea coromandelica	7.86	1.43
Holarrhena pubescens	10.71	0.71
Bombax ceiba	3.57	3.57
Dalbergia latifolia	7.86	–
Alstonia scholaris	5.00	2.14
Mallotus repandus	5.00	15.00
Falconeria insignis	4.29	7.14
Semecarpus anacardium	3.57	1.43
Cassia fistula	5.00	4.29
Careya arborea	4.29	4.29
Albizia lebbeck	7.14	5.71

Syzygium nervosum	4.29	0.71
Terminalia chebula	2.86	1.43
Desmodium oojeinense	2.86	–
Garuga pinnata	2.86	0.71
Ehretia laevis	2.86	1.43
Sterculia villosa	2.14	–
Anogeissus latifolius	1.43	–
Bridelia retusa	2.14	0.71
Albizia procera	0.71	1.43
Grewia optiva	2.14	0.71
Cassia sp.	2.14	–
Ficus lacor	1.43	0.71
Bauhinia malabarica	1.43	–
Heynea trijuga	1.43	–
Acer oblongum	1.43	–
Acacia ferruginea	1.43	–
Ficus rumphii	1.43	–
Acacia catechu	2.14	0.71
Albizia julibrissin	0.71	0.71
Cordia dichotoma	1.43	–
Premna mollissima	1.43	–
Cornus oblonga	1.43	–
Trema orientalis	1.43	0.71
Spondias pinnata	0.71	–
Aegle marmelos	0.71	7.86
Diploknema butyracea	0.71	1.43
Elaeagnus latifolia	0.71	–
Ficus racemosa	0.71	1.43
Ficus semicordata	0.71	–
Stereospermum tetragonum	0.71	–
Ziziphus mauritiana	0.71	–
Gmelina arborea	0.71	–
Holoptelia integrifolia	0.71	0.71
Phyllanthus emblica	0.71	–
Neolamarckia cadamba	–	0.71
Oroxylum indicum	–	2.14
Tamarindus indica	–	1.43
Total	466.4	234.3

Table 5. Sorenson's similarity indices in different growth forms of vegetation between undisturbed and disturbed forest stands in moist tropical forest of Sunsari district, eastern Nepal

Growth forms	Similarity (%)	Dissimilarity (%)
Trees	74	26
Shrubs	81	19
Herbs	71	29

The proportions of family to species and genera to species were higher in UF whereas the proportion of family to genera was same in both forests (Table 6).

Table 6. Ratio of species, genus and family in undisturbed and disturbed forest stands of moist tropical forest in Sunsari district, eastern Nepal

Forest types	Family: Species	Genus: Species	Family: Genus
Undisturbed	1.78	1.19	1.50
Disturbed	1.73	1.15	1.50

Plant community structure in terms of density has been compared between undisturbed and disturbed forests. The UF had higher density of trees (466 trees ha^{-1}) as compared to DF (234 trees ha^{-1}) (Table 4, Figs. 3-4). The density of trees varied greatly in both forests ranging from 1–100 trees ha^{-1}. In UF, the density ranged from 1 trees ha^{-1}, each for thirteen species (22.8% species) to 100 trees ha^{-1} for *Shorea robusta* (1.8% species) (Fig. 3).

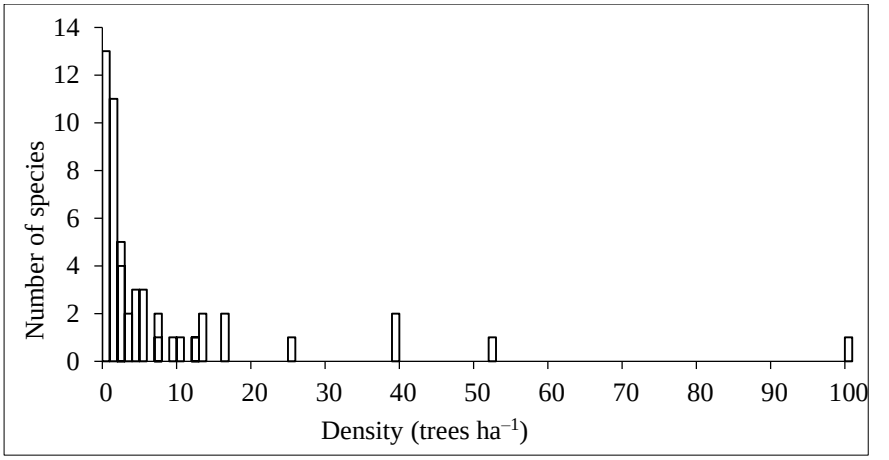

Figure 3. Species individual relationships of tree species in undisturbed forest stand of moist tropical forest in Sunsari district, eastern Nepal

The density value for disturbed forest was one tree ha^{-1}, each for eleven species (28.9%) and 64 for *Shorea robusta* (2.6% species) (Fig. 4). Based on density value, the second dominant species was *Haldina cordifolia* with 39 trees ha^{-1} in UF and 21 trees ha^{-1} in DF.

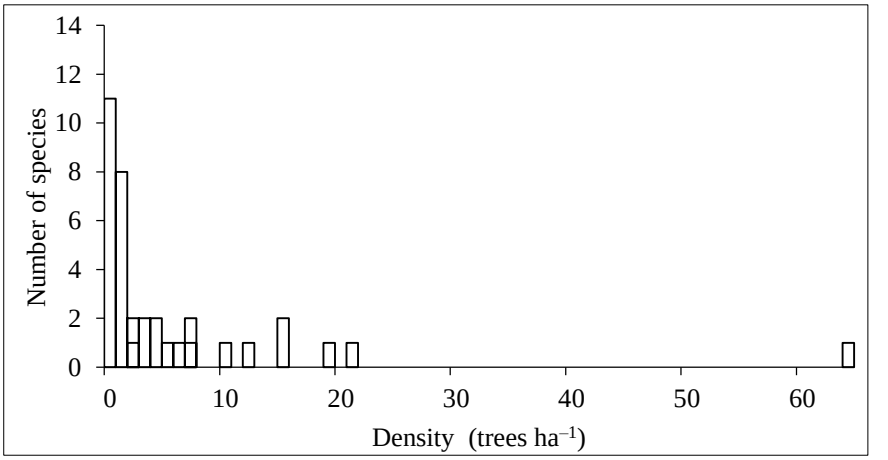

Figure 4. Species individual relationships of tree species in disturbed forest stand of moist tropical forest in Sunsari district, eastern Nepal

Discussion

Herb and Shrub layer

Forest disturbances resulted in the formation of fragmented, exposed, and nutrient poor sites, awaiting recolonization. Colonization on disturbed site by successional species generally occurs through stump, root and rhizome sprouts and through seeds. Both herb and shrub species were higher in number in DF which may be due to edge effect and open canopy favoring light loving plants. On the other hand, lower number of species in UF could be attributed to the dense canopy of trees which tended to suppress the undergrowth from obtaining sufficient sunlight required for germination, growth and development in light loving species.

So far Sorenson's similarity is concerned herbs and shrubs in DF showed 19–29% dissimilarity with the UF, which reflects the consequence of disturbance. Among the total species, 26 herb and 11 shrub species were present in both forest stands. High species overlap between UF and DF can be explained in part by their intactness, similarity in structure and their position on the landscape, and similar geography.

Oplismenus compositus, an annual herb of family Poaceae was dense in UF (4 individual m^{-2}) while *Imperata cylindrica* was dense in DF (4 individual m^{-2}). It may be due to their light weight seeds easily dispersed by wind. Among the shrubs, *Murraya koenigii* was dominant as per the density value in UF. It may be due to its shade and moisture loving nature. In DF, *Clerodendrum infortunatum* was dense. It may be associated with its high proliferation capacity in less fertile soil. Herb and shrub species content and their density increased in DF. It is in accordance with the "Intermediate Disturbance Hypothesis" which states that under intermediate levels of disturbance diversity is highest (van der Maarel, 1993).

Tree layer

Species content

Knowledge of tree species content is elementary to total forest biodiversity as it provides resources and habitats for almost all other forest species. In DF, 19 species (33%) were eliminated as compared to UF. The eliminated species were represented by few individuals in UF. Among them, 7 species were represented by 1 individual each, 9 species by 2 individuals each, 2 species by 3 individuals each and 1 species by 19 individuals. It means that they are more prone to local extinction as compared to the heavily exploited species with relatively high population. The reduction in the density of some important species like *Shorea robusta* (by 35.7%) and *Haldina cordifolia* (by 45.4%) suggests the selective felling by local people because of their high demand in construction works, timber and other purposes. However, the convincing (existing) population of locally high demanded species in DF suggests their high regeneration capacity.

The occurrence of 13 species (22.8%) with single individual in UF of present study is in range with the report of Sagar *et al.* (2003) for Indian dry forest species (18–30% species of > 30 cm GBH). Upadhaya *et al.* (2004) reported 42–53% of the total species represented by one or two individuals in sub-tropical humid forest of Meghalaya, India. The occurrence of many species with single individual in less disturbed forests might be due to unfavorable regeneration conditions, lack of appropriate habitat or both. In spite of this, species

composition in the undisturbed and disturbed stands of present forest is more or less similar, which may be attributed to the similar topography, soil and climatic conditions (Gautam & Mandal, 2013) and to the sufficient movement of propagules and pollens through the landscape.

Stand density

The variation in the composition of dominant tree species and forest stand density in tropical forests of world is mainly due to variation in biogeography and habitat disturbance (Mani & Parthasarathy, 2009). In the present study, the reduced density in DF was largely attributed to a low proportion of young trees belonging to smaller girth classes. The lower tree density could be a result of higher edge to area ratio and a subsequent increase in exposure to the physical environment. It may also be attributed to the selective cutting of straight boles of tree for use as poles by local people. The stand density of the present forest is lower, higher or comparable to some tropical forests of Nepal and India (Table 7).

Table 7. Stand density of tree species in tropical forests of Nepal and India

Forests and localities	Density (trees/ha)	References
Tropical Plateau Sal, eastern Nepal	580	Mandal (1999)
Sal, Bhabar-Terai, Nepal	152–264	Rautiainen (1999)
Tropical, Bardia, Nepal	348	Shrestha & Jha (1997)
Sal, western Terai, Nepal	220	Timilsina *et al.* (2007)
Tropical dry evergreen, India	771–1285	Anbarashan & Parthasarathy (2013)
Tropical moist, eastern Nepal	234–466	Present study

Conclusions

This study has revealed the abundance and density of ecologically as well as commercially valuable timber and non-timber forest plants in the study area. Sustainable management of forests requires holistic approach in which both timber and non-timber forest plants are managed in accordance with their ecological attributes. Moreover, the effect of forest disturbance is severe on both number of tree species (decreased by 33%) and tree density (decreased by 50%). To maintain the carbon sequestration capacity of the present forest, tree cutting should be banned and plantation should be done in open space. Sapling should be allowed to regenerate so that status of biodiversity would be restored.

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References

Anbarashan, M. & N. Parthasarathy 2013. Tree diversity of tropical dry evergreen forests dominated by single or mixed species on the Coromandel Coast of India. *Tropical ecology* 54(2): 179–190.

Connell, J.H. 1978. Diversity in tropical rain forests and coral reefs. *Science* 199: 1302–1310.

FAO 2011. *State of the world's forests*. Food and Agriculture Organization, Rome.

FRSC 1994. *Deforestation in the Terai Districts 1978/79–1990/91*, Forest Research and Survey Centre, Ministry of Forests and Soil Conservation, Publication Number 60, pp 9.

Gautam, T.P. & T.N. Mandal 2013. Soil characteristics in moist tropical forest of Sunsari District, Nepal. *Nepal Journal of Science and Technology* 14: 35–40.

Giri, M.K. 1996. Conservation and management of biological resources in Nepal Himalaya. In: *Conservation and Management of Biological Resources in Himalaya* (Eds. P.S. Ramakrishnan, A.N. Purohit, K.G. Saxena, K.S. Rao & R.K. Maikhuri). G.B. Pant Institute of Himalayan Environment and Development, Almora and Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi. pp 153–161.

Hubbell, S.P. & R.B. Foster 1983. Diversity of canopy trees in a neotropical forest and implications for conservation. In: *Tropical Rain forest: Ecology and Management* (Eds. S.L. Sutton, T.C. Whitmore & A.C. Chadwick). Blackwell Scientific Publications. Oxford. pp. 25-41.

Lalfakawma, U.K. Sahoo, S. Roy, K. Vanlalhriatpuia & P.C. Vanalalhluna 2009. Community composition and tree population structure in undisturbed and disturbed tropical semi-evergreen forest stands of north-east India. *Applied ecology and environmental research* 7(4): 303-318.

Mandal, T.N. 1999. *Ecological analysis of recovery of landslide damaged Sal forest ecosystem in Nepal Himalaya* (Ph.D. Thesis). Banaras Hindu University, Varanasi, India.

Mani, S. & N. Parthasarathy 2009. Tree population and above-ground biomass changes in two tropical dry evergreen forest sites of peninsular India. *Tropical Ecology* 50: 249–258.

May, R.M. & M.P.H. Stumpf 2000. Species-area relations in tropical forests. *Science* 290: 2084-2086.

Rautiainen, O. 1999. Spatial yield model for *Shorea robusta* in Nepal. *Forest Ecology and Management* 119: 151–162.

Sagar, R., A.S. Raghubanshi & J.S. Singh 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *Forest Ecology and Management* 186: 61–71.

Shrestha, K.K. & P.K. Jha 1997. *Plant diversity and evaluation of conservation measures in the Royal Bardia National Park (RBNP)*. A report submitted to World Wildlife Fund Nepal Program, Kathmandu, Nepal.

Shrestha, T.B., J.P.B. Lilleso, L.P. Dhakal & R. Shrestha 2002. Forest and vegetation types of Nepal. Ministry of Forests and Soil Conservation, HMG/Nepal, Natural Resource Management Sector Assistance Programme (NARMSAP), Tree Improvement and Silviculture Component, Kathmandu, Nepal.

Timilsina, N., M.S. Ross & J.T. Heinen 2007. A community analysis of sal (*Shorea robusta* Gaertn. f.) forests in the western Terai of Nepal. *Forest Ecology and Management* 241(1–3): 223–234.

Upadhaya, K., H.N. Pandey, P.S. Law & R.S. Tripathi 2004. Diversity and population characteristics of woody species in subtropical humid forest exposed to cultural disturbances in Meghalaya, Northeast India. *Tropical ecology* 45: 303–314.

van der Maarel, E. 1993. Some remarks on disturbance and its relations to diversity and stability. *Journal of Vegetation Science* 4: 733–736.