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Phyto-sociological changes in the Goima Forest, Gujarat due to human disturbances and their implications for conservation

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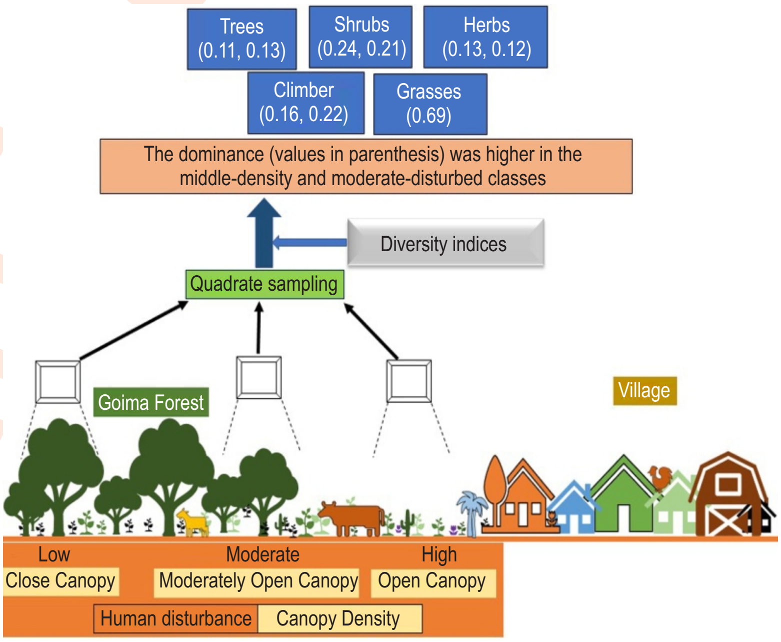
Abstract

Aim: The study aimed to understand the phytosociological changes by the impact of forest fringe human disturbance on the Goima forest of Valsad district in Gujarat.

Methodology: The study area was classified into different tree canopy density and disturbance classes, and ecological indices were calculated for each class following the quadrate survey method.

Results: A total of 772 individual plants of 141 species from 53 families were recorded during quadrate sampling, with variations in aspects being especially important predictors of biotic diversity. The study found that the maximum taxa of trees (30), herbs (24), and grasses (7) were reported in the high-disturbance class, while for shrubs (16) and climbers (10), it was in the middle-disturbance class. Dominance (D)was higher in the moderately dense forest as well as in the moderate disturbance class for trees (0.11, 0.13), shrubs (0.24, 0.21), herbs (0.13, 0.12), but for climbers, D was higher in dense forest (0.40) and in moderate disturbance class (0.22), and for grasses, it was higher in the moderately dense forest (0.69) and less disturbed class (0.58). Shannon's index (H) for trees (2.93), herbs (2.85), and grasses (1.68) was maximum in the higher disturbance class, while for shrubs (2.23) and climbers (2.10), it was highest in the low disturbance class.



Interpretation: The study highlights that the phytosociology of the Goima forest changes due to human disturbances. The importance of understanding and conserving biodiversity in the Goima forest, especially given its unique flora and its critical role in supporting local communities. The research provides valuable scientific information that can aid in the better management and protection of the forest area.

Key words: Canopy class, Goima forest, Human disturbance, Phytodiversity, Species distribution

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Introduction

The biodiversity of the world depends on self-sustaining ecosystems that include all the living beings on earth. However, increase in the human population on earth has accelerated exploitation of bio resources. The accelerated pace of global biodiversity loss has now received national and international attention. Knowledge of biodiversity and its co-existence with local communities is the key to the understanding of the ecological processes along with the natural and artificial changes they may undergo (Andrew *et al*., 2015). The multitudes of pressures that forests are subjected to in the current era need thoughtful management practices, based on systematic and scientific information.

India is one of the twelve mega-biodiversity countries and it faces enormous challenges in conserving biodiversity while guaranteeing livelihood and ecological security because the majority of its population directly depends on natural resources. Forest composition, structure, and species diversity are greatly affected by different disturbances and human activities like grazing, urban development (Mckinney, 2002), recreation, agricultural practices (Kelemen *et al.,* 2019), lack of knowledge, over-exploitation of natural resources (Hunter, 2007) and introduction of exotics are among the main causes (Mcbride *et al*., 1996; Zambrano *et al.,* 2019, Zaimes, 2020and Hise *et al.,* 2021). Phytosociological studies of forests are the pre-requisite of scientific management to understand and quantify the phyto-diversity of an area and to maintain overall health (Panda *et al.,* 2023; Arya *et al.,* 2017; Kumar and Saikia, 2020; Ekta *et al.,* 2020).

Goima is a unique ecosystem havinga river traversing the forest into two different forest areas which are surrounded by a few forest fringe settlements. The studied area falls in the northern most part of the Western Ghats which is home to many endangered and endemic life forms (Pujar, 2022). Comprehensive ecological and socio-economic studies can help in characterizing and quantifying the phytodiversity data which are vital to protect the unique floral diversity of the area. Goima forest is a fragmented forest and the fragmentation of natural landscapes through urbanization has been well-linked to biodiversity loss and changes in the ecological and ecosystem function (Zambrano *et al.,* 2019). In view of the above, present study the aimed to study phytodiversity changes due to human disturbance would thatcertainly helps in better management. It will provide important baseline data on how human settlements around a fragmented forest patchcan affect species and plant form composition.

Materials and Methods

The study was conducted during January 2022 to September 2022 in the Goima forest which sprawls between 20° 24' 17" N and 20° 24' 43" N latitudes and 73° 02'45" E to 73° 01' 37" E longitudes in Valsad district of Gujarat state situated 55 m above mean sea level. It is a type 3B tropical moist deciduous reserve forest with a total area of 137.44 ha of forest falling under the Western Ghats (Champion and Seth, 1968). Kolak a perennial river often receives water from river Damanganga through a well-constructed canal system that traverses through Goima forests which divides it into two parts (Fig. 1). The study area was classified into two different categories based on the canopy density of that area *i.e.* density class and disturbance class. Density class is further classified as per the classification given by ISFR (2019): Dense Forest (canopy density of 70 % and above), Moderately dense forest (canopy density between 40 to 70 %), and Open forest (canopy density less than 40 %).

The anthropogenic disturbance was recorded based on the visual scale (Bisht *et al.,* 2022) with modification. The disturbance level was estimated and categorized into three main groups, *i.e.* High disturbance class (>60% lopping and cutting or >60% grazing), Moderate disturbance class (>20-60% lopping and cutting or >20-60% grazing) and Low disturbance class (<20% lopping and cutting or <20% grazing) areas (Fig. 1). Without taking into account differences as an unclassified forest, generic data was analyzed for comparison with classified data. A total of 135 quadrate were laid down to enumerate tree (10 x 10 m^2), shrubs (5 x 5 m^2), herbs, grasses and climbers (1 x 1 m^2) species. Quadrates were laid maintaining 400-500 m of distance between the subsequent quadrates. The plant species, habit, and total number of plants per quadrate were recorded. The plants were identified and recorded using the field guides (Krishen, 2013; Kehimkar, 2016). The unidentified plants were photographed systematically by Canon 3000 D and Nikon D5600 cameras and later identified using identification keys (Anon, 2008; Bor and Raizada, 1982; Shah, 1978; Singh *et al.,* 2000) at the Department of Basic Sciences, College of Forestry, Navsari Agricultural University, Navsari, Gujarat.

The density, density ha^{-1}, abundance, abundance ha^{-1}, frequency (%), composition (%), relative density (RD), relative frequency(RF) and relative abundance (RA) (Uddin *et al.,* 2020) were computed using standard formulas. The Importance Value Index (IVI) was computed by using the formula, (Uddin *et al.,* 2020) Importance Value Index (IVI) = Relative density (RD) + Relative frequency (RF) + Relative Abundance (RA). To compare diversity pattern of different disturbance classes other species diversity indexes, i.e. Species Richness (SR) or Menhinick Index (Menhinick, 1964), Species Evenness or Pielou Evenness Index (E) (Pielou, 1966), Simpson Dominance Index (D) (Simpson, 1949), Simpson's Index of Diversity (D-1), Shannon Weiner Index (H) (Shannon and Weaver, 1949), Margalef Species Richness Index (Marg.) (Margalef, 1958), The Brillouin Index (HB) (Brillouin, 1956), and The Berger-Parker Index (B_P) (Berger and Parker, 1970) were also computed using the software PAST (ver. 4.3.2) (Hammer *et al.,* 2013; Magurran, 2004).

Results and Discussion

In the Goima forest, a total of 772 individual plants of 141 species from 53 families were recorded during quadrat sampling (Table 2, Fig. 2). The plants were recorded in study is presented in

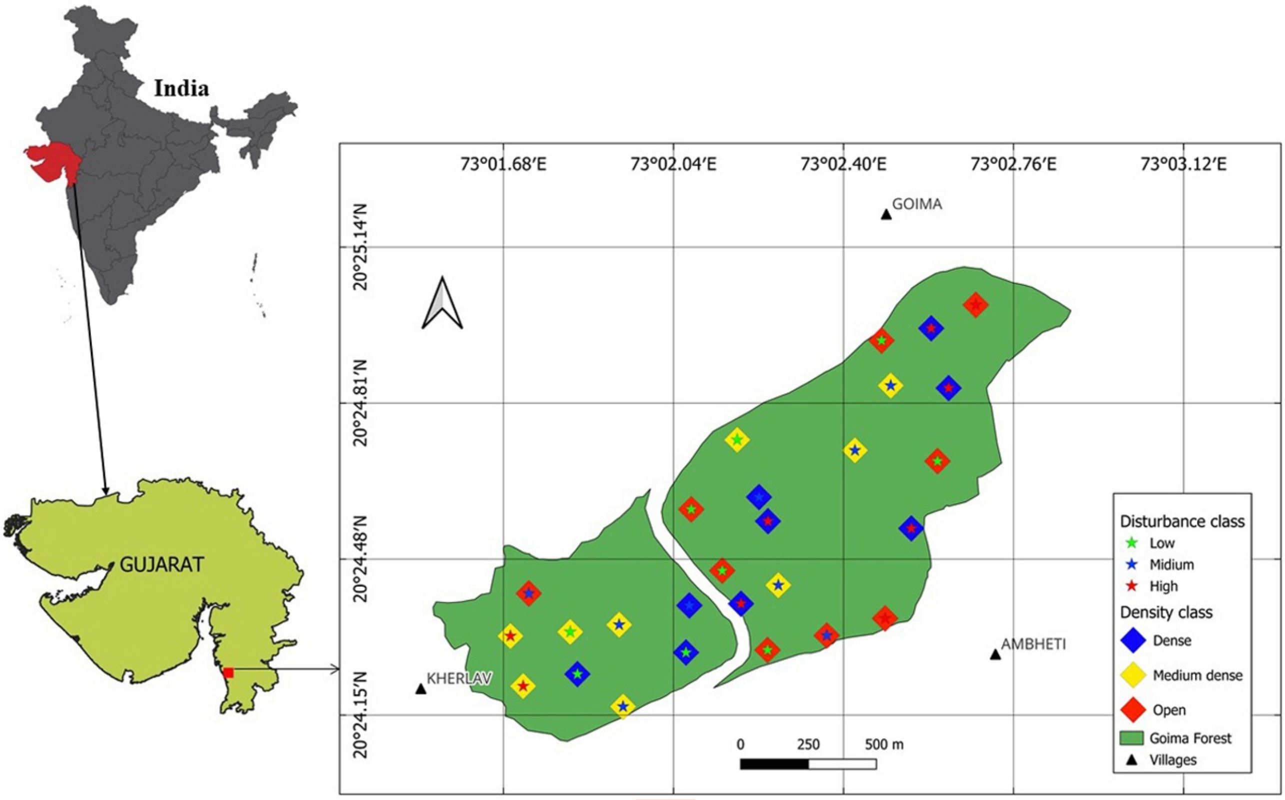

Fig. 1: Distance and Canopy density class-wise quadrates at Goima Forest area, Gujarat, India

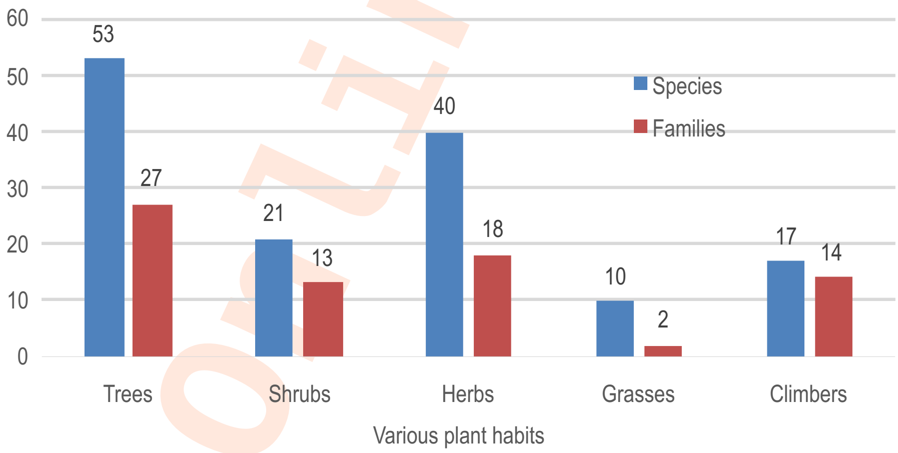

Fig. 2: Habit wise plant family distribution in the Goima Forest.

Table 1 and categorized as per their habit such asTrees (53 species, 27 families), shrubs (21 species, 13 families), herbs (40 species, 18 families), grasses (10 species, 2 families) and climbers (17 species, 14 families), respectively (Fig. 2). Soni and Namdeo (2022) reported 94 species from 36 families from various disturbed areas of of Ratanpur forest Chattisgarh. Relative density (RD=7.51), relative frequency (RF=4.59), abundance (per hectare) (Aha-1=0.82), relative abundance (RA=1.5), importance value index (IVI=13.554) and percent composition (C (%)=7.51) of *Tectona grandis* L. f.tree was maximum, followed by

Dendrocalamus strictus (Roxb.) Nees., and *Butea monosperma* (L.) Taub. (Table 1). In shrubs, *Carissa congesta* L. was recorded to have higher RD (8.55), RF (4.59), Aha-1 (0.23), RA (1.7), IVI (14.79) and C (%) (8.54), followed by *Flemingia strobilifera* (L.) W. T. Aiton., and *Sida acuta* L. (Table 1). Beek *et al.* (2018) reported that an increase in richness values on the landscape corresponds with the growing impact of human activities. *Alternanthera sessilis* (L.) R.Br. ex DC. herb had higher RD (3.76), RF (2.17), Aha^{-1} (0.009), RA (1.5), IVI (7.46), and C (%) (3.75), followed by *Haplanthus verticillatus* (Roxb.) Nees., and *Eranthemum roseum* (Vahl) R. Br. (Table 1). In grasses, RD (2.85), RF (2.17), Aha^{-1} (0.007), RA (1.2), IVI (6.186) and C (%) (2.85) of *Dichanthium annulatum* (Forssk.) Stapf. was higher, followed by *Cynodon dactylon* (L.) Pers. and *Apluda mutica* L. (Table 1).For climbers, RD (1.85), RF (1.69), Aha^{-1} (0.005), RA (1), IVI (4.45) and C (%) (1.81) of *Cocculus hirsutus* (L.) Diels. was highest, followed by *Asparagus racemosus* Willd., and *Mucuna pruriens* (L.) DC.(Table 1). Malav *et al*. (2023) also reported that the shrub and herbs have the highest IVI in protected sites as compared to unprotected sites.

Ecological indices are a practical and effective tool for monitoring biodiversity impairment linked to human disturbance in ecosystems. Dominance_D of unclassified forest was 0.027 (irrespective of plant habit for unclassified forest), however, in the middle density (0.045) and moderate disturbance (0.044) class, the dominance_D index was highest (Table 2). Inversely, Simpson_1-D index was highest for unclassified forests (0.973) and lowest for both middle-density and moderate disturbance classes (0.955 and 0.956, respectively). Shanon_H index showed higher diversity in the area. Open density forest class (4.185) and high disturbance areas (3.994) were recorded to have maximum Shanon_H index which represents higher diversity. Evenness_e^H/S was low (0.463) in unclassified forest areas, however, it was highest (0.699 and 0.654) in open forest and high disturbance classes, respectively. Brillouin diversity index of unclassified forest was 3.917, which was higher as compared to other classes. The open forest area (3.969) and high disturbance area (3.547) had the highest Brillouin diversity index value. Similar trends were observed in Margalef's (16.980, 15.030), Menhinick's (6.080, 5.426), and Fisher_alpha index (57.12, 45.91) for open and high disturbance areas, respecyively, which describes that the higher the index, the greater the species richness. The Berger-Parker index expresses the proportional importance of the most abundant type (Table 2). The Berger–Parker index reached its highest value (0.120) in areas having moderate physical disturbances.

Pandey and Shukla (2003) reported that moderate to low disturbance with dense entangled vegetation usually contained less common and rare species; similar observations were made in this study as these thickets help to conserve the special habitat conditions and provide protection for the natural regeneration of several infrequent and rare plant species. Alpha diversity indices of different classified forests revealed significant diversity in the Goima forest. Maximum species of trees (32), shrubs (16), herbs (29), and climbers (6) were recorded in open-density classes however, maximum individuals of trees (94), shrubs (76), and grasses (17) were recorded from the middle-density class, herb (88) in dense class and climbers (16) from open class forest (Table 3). Higher Dominance_D of trees (0.11), shrubs (0.24), herbs (0.13), and grasses (0.69) was higher in middle-density areas and for climbers (0.40), it was highest in dense areas. Simpson_1-D also followed the same trend as dominance_D in an inverse manner. Shannon_H index was recorded maximum in open forest areas for all the plant forms evaluated. Evenness_e^H/S index value of trees was higher in dense areas as compared to other plant forms that are higher in open forest areas. Dudipala *et al.* (2023) report that the Pench forest has a Shannon–Weiner index of 2.92 and a Simpson index of 0.103, suggesting moderate biodiversity with low dominance among trees, saplings, and the herb layer in the region. Brillouin index of diversity for trees, herbs, climbers, and grasses was higher in the open forest area however, for shrubs, it was higher in moderately dense forest areas (Table 3). Mestre *et al.* (2017) also reported similar results that the herb-layer structure and diversity is highly influenced by canopy-layer composition. Shirima *et al.* (2015) record similar observations that anthropogenic disturbance can modify canopy structure and denser forest canopies have a negative impact on herbaceous biomass. Variations in aspect and soil drainage of Goima forest were important predictors of biotic diversity as richness and diversity of trees and shrubs were significantly higher in sites with high geomorphologic heterogeneity than in sites that exhibited little change in terrain or soil conditions (Burnett *et al.,* 1998). The values for Menhinick, Margalef, and Fisher_alpha index of all the plant forms was higher in open density classes areas, except for Fisher_alpha of grasses which were higher in dense forests (Table 3). In tree (0.28), herbs (0.23), shrubs (0.43) and grasses (0.82), the Berger-Parker index was reported higher in moderately dense areas which reflects proportional abundance of the most abundant type in the area.

The maximum taxa of trees, herbs, and grass species were reported in the high disturbance class, whereas for shrubs and climbers it was in the middle-distance class (Table 3). Dominance_D and Simpson_1-D index of trees (0.13 and 0.88), shrubs (0.20 and 0.80), herbs (0.12 and 0.88), and climbers (0.22 and 0.77) were higher in moderate disturbance class however, for grasses (0.58 and 0.42) it was higher in less disturbed class (Table 3). Shannon_H index for trees (2.93), herbs (2.85) and grasses (1.68) was maximum in the higher disturbance class whereas in shrubs (2.23) and climbers (2.10), it was highest in the low disturbance class. Linderman and Lepczyk (2013) also reported that modification of ecological composition is a variable response relative to exurban expansion and points to high potential modification of sensitive ecosystems and vegetation. Fyfe (2023) suggests that humans can impact vegetation in mainly two ways either by reducing the extent of tree cover or humans altering the compositional makeup of vegetation by deliberate selection of species. The values for species Evenness_e^H/S index of trees (0.70) and shrubs (0.62) were reported maximum in the low disturbance class, for herb (0.73) and climber (0.90) it was higher

Table 1: List of species of trees, shrubs, herbs, grasses, and climbers found in Goima Forest.

Plants	Family	RD	RF	A ha^{-1}	RA	IVI	C (%)
			Trees				
Acacia catechu (L.f.)Willd.	Mimosaceae	1.17	1.45	0.41	0.7	3.328	1.166
Acacia leucophloea (Roxb.)Willd.	Fabaceae	0.13	0.24	0.27	0.5	0.846	0.13
Acacia nilotica (L.) Del.ssp. indica (Benth.) Brenan	Mimosaceae	0.13	0.24	0.27	0.5	0.846	0.13
Aegle marmelos (L.) Correa	Rutaceae	0.13	0.24	0.27	0.5	0.846	0.13
Albizia lebbeck (L.)Benth.	Mimosaceae	0.26	0.24	0.54	1	1.451	0.259
Albizia procera (Roxb.) Benth.	Mimosaceae	0.13	0.24	0.27	0.5	0.846	0.13
Anacardium occidentalis L.	Anacardiaceae	0.13	0.24	0.27	0.5	0.846	0.13
Annona squamosa L.	Annonaceae	0.13	0.24	0.27	0.5	0.846	0.13
Anthocephalus cadamba (Roxb) Miq.	Rubiaceae	0.13	0.24	0.27	0.5	0.846	0.13
Azadirachta indica A. Juss.	Meliaceae	0.52	0.72	0.36	0.6	1.877	0.518
Bauhinia malabarica Roxb.	Fabaceae	0.13	0.24	0.27	0.5	0.846	0.13
Bauhinia purpurea L.	Fabaceae	0.65	0.72	0.45	0.8	2.165	0.648
Bridelia retusa (L.) A.Juss.	Euphorbiaceae	0.39	0.72	0.27	0.5	1.589	0.389
Butea monosperma (Lam.)Taub.	Fabaceae	2.72	1.69	0.81	1.4	5.837	2.72
Careya arborea Roxb.	Lecythidaceae	0.13	0.24	0.27	0.5	0.846	0.13
Caryota urens L.	Arecaceae	0.13	0.24	0.27	0.5	0.846	0.13
Cassia fistula L.	Caesalpinaceae	0.13	0.24	0.27	0.5	0.846	0.13
Cordia dichotoma G. Forster	Boraginaceae	0.39	0.48	0.41	0.7	1.585	0.389
Dalbergia sissoo sensu Miq.	Fabaceae	0.13	0.24	0.27	0.5	0.846	0.13
Dendrocalamus strictus	Poaceae	3.63	2.9	0.63	1.1	7.635	3.627
Diospyros melanoxylon Roxb.	Ebeneceae	0.91	0.72	0.63	1.1	2.74	0.907
Erythrina variegata L.	Fabaceae	0.13	0.24	0.27	0.5	0.846	0.13
Eucalyptus tereticornis Sm.	Myrtaceae	0.65	0.48	0.67	1.2	2.319	0.648
Ficus asperrima Roxb.	Moraceae	0.39	0.48	0.41	0.7	1.585	0.389
Ficus benghalensis L.	Moraceae	0.13	0.24	0.27	0.5	0.846	0.13
Ficus hispida L. f.	Moraceae	0.26	0.48	0.27	0.5	1.218	0.259
Ficus relegiosa L.	Moraceae	0.13	0.24	0.27	0.5	0.846	0.13
Garuga pinnata Roxb.	Burseraceae	0.13	0.24	0.27	0.5	0.846	0.13
Gmelina arborea Roxb. ex Sm.	Verbenaceae	0.13	0.24	0.27	0.5	0.846	0.13
Grewia tilifolia Vahl.	Tiliaceae	1.42	1.21	0.59	1	3.678	1.425
Haldina cordifolia (Roxb.) Ridsdale	Rubiaceae	0.13	0.24	0.27	0.5	0.846	0.13
Holarrhena antidysenterica Wall. Ex A. DC.	Apocynaceae	0.26	0.48	0.27	0.5	1.218	0.259
Holoptelea integrifolia (Roxb.) Planch.	Ulmaceae	0.65	0.48	0.67	1.2	2.319	0.648
Ixora arborea Roxb.	Rubiaceae	1.04	1.21	0.43	0.8	3.005	1.036
Leucaena leucocephala (Lam.) de Wit	Fabaceae	0.26	0.24	0.54	1	1.451	0.259
Madhuca indica J.F. Gmel.	Sapotaceae	0.52	0.97	0.27	0.5	1.96	0.518
Mangifera indica L.	Anacardiaceae	1.17	1.45	0.41	0.7	3.328	1.166
Mallotus philippensis (Lam.) Muell.-Arg.	Euphorbiaceae	0.39	0.24	0.81	1.4	2.056	0.389
Manilkara hexandra (Roxb.) Dubard, Ann.	Sapotaceae	0.13	0.24	0.27	0.5	0.846	0.13
Manilkara zapota (l.) p.royen	Sapotaceae	0.65	0.48	0.67	1.2	2.319	0.648
Meyna laxiflora Robyns	Rubiaceae	0.26	0.24	0.54	1	1.451	0.259
Millettia pinnata (L.) Panigrahi	Fabaceae	0.65	0.97	0.34	0.6	2.208	0.648
Mitragyna parvifolia (Roxb.) Korth	Rubiaceae	0.39	0.72	0.27	0.5	1.589	0.389
Morinda tomentosa Roxb.	Rubiaceae	1.17	1.69	0.35	0.6	3.468	1.166
Oroxylum indicum (L.) Kurz	Bignoniaceae	0.52	0.24	1.08	1.9	2.661	0.518
Phyllanthus Emblica L.	Phyllanthaceae	0.26	0.48	0.27	0.5	1.218	0.259
Pithecellobium dulce (Roxb.)Benth.	Mimosaceae	0.26	0.24	0.54	1	1.451	0.259
Polyalthia longifolia (Sonn.) Thwaites	Annonaceae	0.91	0.48	0.95	1.7	3.053	0.907
Prosopis juliflora (Sw.) DC.	Mimosaceae	0.39	0.24	0.81	1.4	2.056	0.389
Psidium guajava L.	Myrtaceae	0.13	0.24	0.27	0.5	0.846	0.13
Tectona grandis L.f.	Lamiaceae	7.51	4.59	0.83	1.5	13.554	7.513
Terminalia crenulata (Heyne) Roth	Combretaceae	1.17	1.21	0.49	0.9	3.229	1.166
Ziziphus mauritiana Lam.	Rhamnaceae	0.26	0.24	0.54	1	1.451	0.259

Table continued

Shrubs							
Abelmoschus moschatus Medic.	Malvaceae	1.3	1.45	0.11	0.8	3.537	1.295
Abutilon indicum (L.) Sweet	Malvaceae	1.3	1.21	0.14	1	3.454	1.295
Caesalpinia bonduc (L.) Roxb.	Caesalpinaceae	0.26	0.48	0.07	0.5	1.218	0.259
Calotropis procera (Ait.) Dryand	Apocynaceae	0.65	1.21	0.07	0.5	2.331	0.648
Carissa congesta L.	Apocynaceae	8.55	4.59	0.23	1.7	14.791	8.549
Colebrookea oppositifolia Sm.	Lamiaceae	0.13	0.24	0.07	0.5	0.846	0.13
Datura metel L.	Solanaceae	0.65	0.97	0.08	0.6	2.208	0.648
Desmodium gangeticum (L.) DC.	Fabaceae	2.2	1.45	0.19	1.3	4.998	2.202
Flemingia strobilifera (L.) W.T.Aiton	Fabaceae	3.11	1.93	0.20	1.4	6.467	3.109
Helicteres isora L.	Sterculiaceae	0.26	0.48	0.07	0.5	1.218	0.259
Jasminum multiflorum (Burm. f.) Andrews	Oleaceae	0.65	0.97	0.08	0.6	2.208	0.648
Jatropha curcus L.	Euphorbiaceae	0.26	0.48	0.07	0.5	1.218	0.259
Jatropha gossypiifolia L.	Euphorbiaceae	0.13	0.24	0.07	0.5	0.846	0.13
Lantana camara L.	Verbenaceae	1.3	1.69	0.10	0.7	3.665	1.295
Malachra capitata L.	Malvaceae	0.65	0.72	0.11	0.8	2.165	0.648
Ocimum gratissimum L.	Lamiaceae	0.13	0.24	0.07	0.5	0.846	0.13
Phyllanthus reticulatus Poir.	Phyllanthaceae	0.39	0.72	0.07	0.5	1.589	0.389
Sida acuta Burm. f.	Malvaceae	2.33	2.9	0.10	0.7	5.944	2.332
Sida cordata (Burm. f.) Borss. Waalk.	Malvaceae	0.26	0.48	0.07	0.5	1.218	0.259
Strobilanthes aspera Wight.	Acanthaceae	0.39	0.24	0.20	1.4	2.056	0.389
Woodfodia fruticosa (L.) Kurz	Lythreceae	0.13	0.24	0.07	0.5	0.846	0.13
Herbs							
Acalypha indica L.	Euphorbiaceae	0.26	0.48	0.003	0.5	1.218	0.259
Achyranthes aspera L.	Amaranthaceae	1.55	1.69	0.005	0.8	4.06	1.554
Adenostemma lavenia (L.) Kuntze	Asteraceae	0.13	0.24	0.003	0.5	0.846	0.13
Aeschynomene indica L.	Fabaceae	0.13	0.24	0.003	0.5	0.846	0.13
Agave americana L.	Asparagaceae	0.13	0.24	0.003	0.5	0.846	0.13
Ageratum conyzoides L.	Asteraceae	1.42	0.97	0.007	1.3	3.698	1.425
Alternanthera sessilis (L.) R.Br. ex DC.	Amaranthaceae	3.76	2.17	0.009	1.5	7.462	3.756
Argemone mexicana L.	Papaveraceae	0.26	0.48	0.003	0.5	1.218	0.259
Bidens pilosa L.	Asteraceae	0.13	0.24	0.003	0.5	0.846	0.13
Biophytum sensitivum L.	Oxalidaceae	0.13	0.24	0.003	0.5	0.846	0.13
Blumea lacera (Burm.f.) DC.	Asteraceae	0.52	0.97	0.003	0.5	1.96	0.518
Caesulia axillaris Roxb.	Asteraceae	0.13	0.24	0.003	0.5	0.846	0.13
Centella asiatica (L.) Urb.	Apiaceae	0.13	0.24	0.003	0.5	0.846	0.13
Chrozophora rottleri (Geis.) Juss.	Euphorbiaceae	0.91	0.97	0.005	0.8	2.705	0.907
Colocasia esculenta (L.) Schott	Araceae	0.13	0.24	0.003	0.5	0.846	0.13
Commelina benghalensis L.	Commelinaceae	3.24	2.66	0.006	1.1	6.976	3.238
Conyza bonariensis (L.) Cronquist	Asteraceae	0.13	0.24	0.003	0.5	0.846	0.13
Corchorus aestuans L.	Asteraceae	0.13	0.24	0.003	0.5	0.846	0.13
Crotalaria filipes Benth.	Fabaceae	1.68	1.21	0.007	1.2	4.128	1.684
Cyanthillium cinereum (L.) H.Rob	Asteraceae	0.13	0.24	0.003	0.5	0.846	0.13
Cyathocline purpurea (Buch.-Ham. ex D.Don)	Asteraceae	0.13	0.24	0.003	0.5	0.846	0.13
Eclipta alba (L.) L.	Asteraceae	0.39	0.72	0.003	0.5	1.589	0.389
Emila sonchifolia (L.) DC. ex Wight	Asteraceae	0.26	0.48	0.003	0.5	1.218	0.259
Eranthemum roseum (Vahl) R. Br.	Acanthaeceae	3.5	2.66	0.007	1.2	7.322	3.497
Euphorbia hirta L.	Euphorbiaceae	0.78	0.97	0.004	0.7	2.456	0.777
Garangea maderaspatana (L.) Poir.	Asteraceae	0.13	0.24	0.003	0.5	0.846	0.13
Glinus lotoides L.	Molluginaceae	0.13	0.24	0.003	0.5	0.846	0.13
Haplanthus verticillatus (Roxb.) Nees	Acanthaeceae	3.76	2.17	0.009	1.5	7.462	3.756
Hemigraphis latebrosa (Roth) Nees	Acanthaeceae	1.04	0.72	0.007	1.3	3.028	1.036
Justica procumbance Linn.	Acanthaeceae	0.13	0.24	0.003	0.5	0.846	0.13
Leucas aspera (Willd.) Link	Lamiaceae	0.13	0.24	0.003	0.5	0.846	0.13
Oxalis corniculata L.	Oxalidaceae	0.52	0.97	0.003	0.5	1.96	0.518
Parthenium hysterophorus L.	Asteraceae	0.26	0.48	0.003	0.5	1.218	0.259

Table continued

Phyllanthus niruri	Phyllanthaceae	0.26	0.24	0.005	1	1.451	0.259
Rungia pectinata (L.) Nees	Acanthaeceae	0.26	0.24	0.005	1	1.451	0.259
Spermacoce articularis L.f.	Rubiaceae	0.13	0.24	0.003	0.5	0.846	0.13
Sphaeranthus indicus L.	Asteraceae	0.13	0.24	0.003	0.5	0.846	0.13
Tridax procumbense L.	Asteraceae	2.2	2.17	0.005	0.9	5.274	2.202
Urena lobata L.	Malvaceae	0.13	0.24	0.003	0.5	0.846	0.13
Verbascum chinense	Scrophulariaceae	0.65	0.24	0.014	2.4	3.266	0.648
Grasses							
Apluda mutica L.	Poaceae	0.39	0.72	0.003	0.5	1.589	0.389
Bothriochloa pertusa (L.) A. Camus	Poaceae	0.13	0.24	0.003	0.5	0.846	0.13
Chloris barbata Sw.	Poaceae	0.39	0.72	0.003	0.5	1.589	0.389
Cynodon dactylon (L.) Pers.	Poaceae	0.52	0.97	0.003	0.5	1.96	0.518
Cyperus compressus L.	Cyperaceae	0.13	0.24	0.003	0.5	0.846	0.13
Cyperus pangorei Rottb.	Cyperaceae	0.13	0.24	0.003	0.5	0.846	0.13
Dactyloctenium aegyptium (L.) Willd.	Poaceae	0.13	0.24	0.003	0.5	0.846	0.13
Dichanthium annulatum (Forssk.) Stapf	Poaceae	2.85	2.17	0.007	1.2	6.186	2.85
Echinochloa colona (L.) Link	Poaceae	0.13	0.24	0.003	0.5	0.846	0.13
Imperata cylindrica (L.) Raeusch.	Poaceae	0.13	0.24	0.003	0.5	0.846	0.13
Climbers							
Abrus precatorius L.	Fabaceae	0.26	0.48	0.003	0.5	1.218	0.259
Ampelocissus latifoli	Vitaceae	0.13	0.24	0.003	0.5	0.846	0.13
Asparagus racemosus Willd.	Asparagaceae	0.39	0.72	0.003	0.5	1.589	0.389
Butea superba (Roxb.) (BS)	Fabaceae	0.26	0.48	0.003	0.5	1.218	0.259
Cardiospermum halicacabum L.	Sapindaceae	0.13	0.24	0.003	0.5	0.846	0.13
Celastrus paniculatus Willd.	Celastracea	0.13	0.24	0.003	0.5	0.846	0.13
Clitoria terntia L.	Fabaceae	0.26	0.48	0.003	0.5	1.218	0.259
Cocculus hirsutus (L.) Diels	Menispermaceae	1.81	1.69	0.005	1	4.455	1.813
Combretum ovalifolium Roxb.	Combretaceae	0.13	0.24	0.003	0.5	0.846	0.13
Dioscorea bulbifera L.	Dioscoreaceae	0.13	0.24	0.003	0.5	0.846	0.13
Gloriosa superba	Liliaceae	0.13	0.24	0.003	0.5	0.846	0.13
Ipomoea purpurea (L.) Roth	Convolvulaceae	0.13	0.24	0.003	0.5	0.846	0.13
Leptadenia reticulata (Retz.) Wight & Arn.	Apocynaceae	0.13	0.24	0.003	0.5	0.846	0.13
Mucuna pruriens (L.) DC.	Fabaceae	0.39	0.72	0.003	0.5	1.589	0.389
Mukia maderaspatana (L.) M. Roem.	Cucurbitaceae	0.26	0.48	0.003	0.5	1.218	0.259
Oxystelma esculentum (L. fil.) R. Br.	Asclepiadaceae	0.39	0.72	0.003	0.5	1.589	0.389
Ventilago denticulata Willd.	Rhamnaceae	0.26	0.48	0.003	0.5	1.218	0.259

Table 2: Diversity index of plant species against different forest classes of Goima Forest

	Density class			Disturbance class			
	D	**M**	**O**	**HDC**	**MDC**	**LDC**	
Taxa_S	70	68	94	83	75	76	141
Individuals	270	263	239	234	267	271	772
Dominance_D	0.036	0.045	0.023	0.028	0.044	0.030	0.027
Simpson_1-D	0.964	0.955	0.978	0.972	0.956	0.970	0.973
Shannon_H	3.728	3.616	4.185	3.994	3.659	3.861	4.179
Evenness_e^H/S	0.594	0.547	0.699	0.654	0.518	0.625	0.463
Brillouin	3.380	3.275	3.696	3.547	3.303	3.488	3.917
Menhinick	4.260	4.193	6.080	5.426	4.590	4.617	5.075
Margalef	12.320	12.020	16.980	15.030	13.240	13.390	21.06
Fisher_alpha	30.66	29.73	57.12	45.91	34.66	35.09	50.55
Berger-Parker	0.104	0.126	0.084	0.090	0.120	0.074	0.085

D=dense forest, M=moderately dense forest, O=open forest, HDC=Higher disturbance class, MDC=Moderate disturbance class and LDC=Low disturbance class

Table 3: Diversity indices of the plant species in the Goima Forest based on density classes and disturbance classes

	Canopy Density Classes														
	Trees			Shrubs			Herb			Climbers			Grasses		
	D	M	O	D	M	O	D	M	O	D	M	O	D	M	O
S	26	24	32	14	14	16	19	16	29	5	10	11	6	4	6
D	0.07	0.11	0.08	0.22	0.24	0.10	0.11	0.13	0.07	0.40	0.16	0.11	0.30	0.69	0.19
1-D	0.92	0.89	0.91	0.78	0.77	0.91	0.89	0.87	0.9	0.60	0.84	0.89	0.70	0.31	0.81
H	2.89	2.69	3.01	1.94	1.92	2.54	2.49	2.29	3.00	1.23	2.08	2.31	1.50	0.66	1.72
e^H/S	0.70	0.64	0.64	0.50	0.49	0.80	0.64	0.62	0.69	0.68	0.80	0.91	0.75	0.48	0.93
Bril.	2.53	2.36	2.55	1.69	1.69	2.13	2.21	1.98	2.58	0.85	1.50	1.68	1.03	0.49	1.24
Menh.	2.71	2.48	3.56	1.67	1.61	2.33	2.03	2.05	3.16	1.58	2.58	2.75	1.90	0.97	1.81
Marg.	5.53	5.06	7.05	3.06	3.00	3.90	4.02	3.65	6.32	1.74	3.32	3.61	2.17	1.06	2.09
F_A	12.07	10.41	19.53	5.26	5.04	8.55	7.45	7.06	15.68	3.98	13.11	15.54	6.33	1.64	5.40
B_P	0.14	0.28	0.25	0.40	0.43	0.15	0.17	0.23	0.13	0.60	0.33	0.19	0.50	0.82	0.27
	Disturbance Classes														
	HDC	MDC	LDC	HDC	MDC	LDC	HDC	MDC	LDC	HDC	MDC	LDC	HDC	MDC	LDC
S	30	25	25	14	16	15	24	21	22	8	10	9	7	3	5
D	0.09	0.13	0.08	0.17	0.21	0.15	0.08	0.12	0.09	0.16	0.22	0.14	0.24	0.33	0.58
1-D	0.91	0.88	0.93	0.83	0.80	0.85	0.93	0.88	0.91	0.84	0.78	0.86	0.77	0.67	0.42
H	2.93	2.64	2.86	2.15	2.03	2.23	2.85	2.47	2.66	1.97	1.90	2.10	1.68	1.10	0.90
e^H/S	0.62	0.56	0.70	0.61	0.48	0.62	0.73	0.56	0.65	0.90	0.67	0.90	0.77	1.00	0.490
Bril.	2.53	2.31	2.47	1.79	1.80	1.95	2.45	2.13	2.34	1.33	1.42	1.46	1.26	0.60	0.69
Menh.	3.11	2.61	2.76	2.14	1.77	1.82	2.81	2.49	2.33	2.53	2.29	2.60	1.81	1.73	1.12
Marg.	6.40	5.31	5.45	3.46	3.40	3.32	5.36	4.69	4.68	3.04	3.06	3.22	2.22	1.82	1.34
F_A	15.35	11.30	12.25	7.22	5.94	5.95	12.47	10.07	9.35	18.57	8.54	16.36	5.11	00	2.14
B_P	0.23	0.30	0.16	0.33	0.39	0.29	0.14	0.21	0.17	0.30	0.42	0.25	0.40	0.33	0.75

D=dense forest, M=moderately dense forest, O=open forest,HDC=Higher disturbance class, MDC=Moderate disturbance class and LDC=Low disturbance class, S=No of species, D=Dominance_D, 1-D=Simpson_1-D, H=Shannon_H, e^H/S=Evenness_e^H/S, Bril.=Brillouin, Menh.=Menhinick, Marg.=Margalef, F_A=Fisher_Alpha, B_P=Berger-Parker in lower disturbance class and for grasses in moderate disturbance class (1.00). The Brillouin index value of trees (2.53), herbs (4.45) and grasses (1.26) were reported maximum in the high disturbance class, whereas for shrubs (1.95) and climbers (1.46), it was higher in the lower disturbance class. The values for Menhinick, Margalef and Fisher_alpha index of trees, shrubs, herbs, and grasses were maximum in the high disturbance class, however, the values for Menhinick and Margalef index for grasses were highest in the low disturbance class and the Fisher_alpha index in high disturbance class (Table 3). Berger-Parker index for trees, shrubs, herbs, and climbers was maximum in the moderate disturbance class as compared to grasses, which was higher in the low disturbance class (Table 3). Hoang *et al.* (2011) noted that plant species composition between slightly and heavily disturbed forests showed significant differences. They also recorded that species having low conservation value were found commonly in heavily disturbed areas, while rare and endangered species were reported in least disturbed forests, similar observations were recorded in this study. Andrew *et al.* (2015) also reported that the total richness and Shannon-Wiener diversity and shrub richness decrease with distance from the River and increase in grazing intensity. Schlaepfer *et al.* (2018) also reported that diversity is negatively affected by anthropogenic habitat fragmentation. Lata *et al*. (2024) also noted that species diversity is a crucial attribute of a community, playing a key role in promoting ecosystem stability.

Plant species richness of an area is generally far more tightly correlated with topographic position, soil type, and precipitation than with edaphic factors (Clark *et al.,* 1999; Gentry, 1988), however, human settlements affect adjoining ecosystems through biotic processes, including exotic species introduction, wildlife subsidization, disease transfer, land cover conversion, fragmentation and habitat loss (Massada *et al.,* 2014) impact plant growth and litterfall patterns, which in turn affect the decomposition process and soil health (Banerjee *et al*., 2023). Describes heavy grazing can kill plants or lead to a marked reduction in competition from palatable plants or plants liable to trampling damage, and resistant to usually unpalatable species expanding their cover. Sebald *et al.* (2021) reported that beta diversity buffered the disturbance impacts on landscape-level biomass stocks more strongly as compared to alpha diversity. Goudie (2019).

The present study concludes that understanding biodiversity and how it coexists with local communities is essential for comprehending ecological processes and potential natural and man-made alterations to them. Forests now face a variety of stressors, which calls for intelligent management techniques based on methodical and scientific data. Ecological and socio-economic research that is in-depth can aid in characterizing and quantifying biodiversity data, which is essential to safeguard the region's distinctive floral diversity. This forest region has to be protected and conserved since it is essential to the local population's ability to support themselves. Efforts to safeguard the forest's biodiversity are essential in the face of increasing anthropogenic pressures and habitat degradation.

The phytosociological study of the Goima Forest in Gujarat highlights the significant impact of human disturbances on forest biodiversity and composition. The research recorded 772 individual plants across 141 species from 53 families, revealing variations in species richness, abundance, and diversity indices across different disturbance and canopy density classes. The highest species diversity and richness were observed in open and high disturbance areas, suggesting that moderate to high levels of human activity can alter forest composition and promote the proliferation of certain species. The study underscores the necessity for tailored management strategies to mitigate human impacts and preserve the unique biodiversity of the Goima Forest. Overall, comprehensive data on species diversity and the effects of anthropogenic activities are crucial for developing effective conservation practices that balance ecological health with the needs of local communities.

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