International Journal of Ecology and Environmental Sciences 51: 687-698, 2025
ISSN: 2320-5199 (Online); https://doi.org/10.55863/ijees.2025.0877

Anthropogenic Impacts of Van Gujjars on Forest Structure and Regeneration in the Tarai Region of Uttarakhand

MOHD. ARIF ANSARI*, ASHISH TEWARI, IKRAMJEET MAAN, SHAHBAZ ALI AND YOGESH CHANDRA TRIPATHI

Department of Forestry, D.S.B Campus, Kumaun University Nainital, Uttarakhand, India

E-mail: mdansarif07@gmail.com, atewari69@gmail.com, ikrammaan@gmail.com, ali701480@gmail.com, yogiforestry24@gmail.com

ORCID: 0000-0001-5025-500X (MAA), 0000-0002-6466-6624 (AT), 0000-0001-5776-9935 (IM), 0009-0000-4451-2663 (SA), 0009-0004-3386-5067 (YCT)

***Corresponding author**

ABSTRACT

Tropical forests are critical ecosystems that support global biodiversity, regulate the climate, and sustain millions of livelihoods. However, escalating anthropogenic pressure poses significant threats to their structure, composition, and regenerative capacity. This study evaluated the impacts of human-induced disturbances by the Van Gujjar pastoral community on forest composition and regeneration in the Tanda Forest of the Tarai region, Uttarakhand, India. Three sites, each representing a distinct disturbance regime - Highly Disturbed (HD), Moderately Disturbed (MD), and Least Disturbed (LD) - were examined to assess variations in vegetation structure and regeneration patterns. A total of 39 plant species from 19 families and 37 genera were documented, with Fabaceae, Malvaceae, and Euphorbiaceae identified as the most dominant families. Species richness and tree density decreased along the disturbance gradient, with the highest values observed at the LD site (29 species, 920 ind/ha) and the lowest at the HD site (23 species, 420 individuals/ha). *Tectona grandis* was dominant across all regimes, whereas several native species, including *Acacia catechu, Dalbergia sissoo*, and *Butea monosperma,* were absent at the HD site. The regeneration potential also varied significantly, with seedling density being highest at the LD site (1060 ind/ha) and lowest at the HD site (320 ind/ha), indicating the adverse effects of fuelwood extraction, grazing, and lopping near settlements. Furthermore, invasive species, such as *Lantana camara* and *Parthenium hysterophorus*, proliferated in highly disturbed areas, further inhibiting native regeneration. These findings underscore the urgent need for integrated conservation strategies that encompass habitat restoration, sustainable resource management, and community-based livelihood alternatives to preserve forest biodiversity and ecological resilience in Tarai.

Key words: Anthropogenic disturbance, forest regeneration, Van Gujjars, Tarai region

INTRODUCTION

Tropical forests comprise a significant portion of global biodiversity, with 7% of the earth's surface housing nearly half of the world's species (Gallery 2014). They are massive carbon sinks with high biomass and productivity playing essential roles in the global carbon cycle (Sullivan et al. 2017, Wright 2010). Tropical forests provide crucial ecosystem services, including wildlife conservation, erosion protection, and habitat preservation (Sharma et al. 2023). However, the growing human population has removed more than 11 million km^2 (between 35 and 50%) of tropical forest canopies worldwide (Wright and Muller 2006). Forests support human sustenance and economic development by providing timber, fuelwood, fodder, and non-timber forest products (Srivathsa et al. 2023). In developing countries, approximately 20% of rural households (820 million rural people in tropical regions) rely on forest resources for income and livelihood, thereby contributing to food security and nutrition (Vedeld et al. 2007, Dlamini 2020, Anonymous 2020, Chhetri et al. 2022). Forests contribute to economic growth and employment, particularly in regions with well-managed forestry sectors (Wunder et al. 2014). In traditional pastoral communities, forests serve as a critical source of fodder for livestock (Öllerer et al. 2019). Fuelwood remains a primary energy source for forest-dependent communities where alternatives are limited (Eshetu 2024). However, this dependence on forest resources often leads to degradation, which threatens biodiversity and ecosystem stability (Bajpai et al. 2018).

In India, the Terai lowland landscape, spanning northern India and southern Nepal, is rich in biodiversity and fertile soil, serving as a transition between the mountain ecosystems and the plains (Palni and Rawat 2010, Sharma et al. 2023). Known for its high water table, streams, and wetlands, the terai region supports a diverse flora and fauna, including *Shorea robusta*, *Tectona grandis*, *Mallotus philippensis*, and *Trewia nudiflora* (Shukla 2009, Thorn et al. 2020). Agricultural expansion, urbanization, and infrastructure development have degraded forest structures, species richness, and regeneration (Osuri et al. 2017, Bajpai et al. 2018). Overharvesting, lopping for fodder, and grazing have led to forest fragmentation, the spread of invasive species, and biodiversity loss (Banerjee et al. 2023, Tenzin and Hasenauer 2016, Raghubanshi and Tripathi 2009). Protected areas face encroachment, disruption of regeneration, and reduced seedling establishment due to soil compaction from grazing (Neelakantan et al. 2019, Barlow et al. 2016). Resource exploitation alters species composition, favouring the invasion of native species (Negi et al. 2013). Addressing these threats requires restoration and conservation strategies that emphasize species diversity, community composition, and regeneration under varying disturbance regimes (Wright 2010, Seidl et al. 2014). Terai forests are ecologically significant and crucial for the livelihoods of local communities (Bhatta et al. 2013). Van Gujjars are a nomadic pastoral community known for rearing buffaloes in forests. They practice transhumance, migrating between Shivalik forests and Himalayan pastures while relying on customary grazing rights (Amir and Meulder 2023). Forest legislation, including the Indian Forest Acts 1927 and the Wildlife Protection Act of 1972, restricted their access to forest resources and challenged traditional practices (Sharma et al. 2012). They rely on forest resources such as fuelwood, fodder, and timber for their livelihood (Sharma et al. 2012). They inhabit traditional huts called Deras and Khatta in forests (Amir and Meulder 2023).

The present study sought to evaluate the anthropogenic impact of Van Gujjars on tree regeneration under varying disturbance regimes in the Tanda forest of the Terai region. This evaluation was conducted by analyzing the changes in forest structure, species composition, and distribution of regenerating individuals in response to human pressure.

MATERIAL AND METHODS

Study area

The present study was conducted in the Tanda forest, located in the Terai region of Uttarakhand, India (Fig. 1). The Tanda range lies between 27°09' N and 28°59' N latitude and 79°21' E and 79°34' E longitude, at an elevation of 309 m asl. The Tanda forest is a mixed deciduous forest featuring *Tectona grandis* L.f., *Shorea robusta* C.F. Gaertn, *Mallotus philippensis* (Lam.) Müll.Arg., and *Trewia nudiflora* L., with understory of *Lantana camara* L., *Murraya koenigii* (L.) Spreng., and *Parthenium hysterophorus* (Bargali 2024). The climate is monsoonal, characterized by distinct seasons: summer, monsoon, and winter. Maximum temperatures varies from 16.7 ± 2.26°C in January to 37.9 ± 1.04°C in May, and the minimum temperatures between 8.2 ± 1.20°C in January and 23.4 ± 0.98°C in July. Annual rainfall averages 1407.9 ± 185.24 mm, mostly during monsoon months (Goel and Singh 2025). The soils range from brownish-grey to grayish-brown, with a silty clay loam to sandy loam texture, on flat to gently undulating terrain with fertile alluvial plains (Bajpai et al. 2018).

Site selection

Three sites were selected in proximity to Van Gujjar settlements within the Tanda forest range, based on criteria such as population density and permanence of settlements. Each site were classified into three disturbance regimes: (i) Highly Disturbed (1.76 ha), characterized by significant human activity (e.g., lopping, grazing, litter removal, intentional fire) and an open canopy (mean tree canopy cove >40%); (ii) Moderately Disturbed (1.8 ha), with moderate human activity and canopy cover (mean tree canopy cover 40-60%); and (iii) Least Disturbed (1.91 ha), with minimal human intervention and a closed canopy (mean tree canopy cover <60%), as per the methods of Kumar and Ram (2005) and Gogoi and Sahoo (2018). Cut pole density was estimated by counting all visibly cut young and mature tree stems (≤10 cm DBH) within each quadrat. Field indicators such as

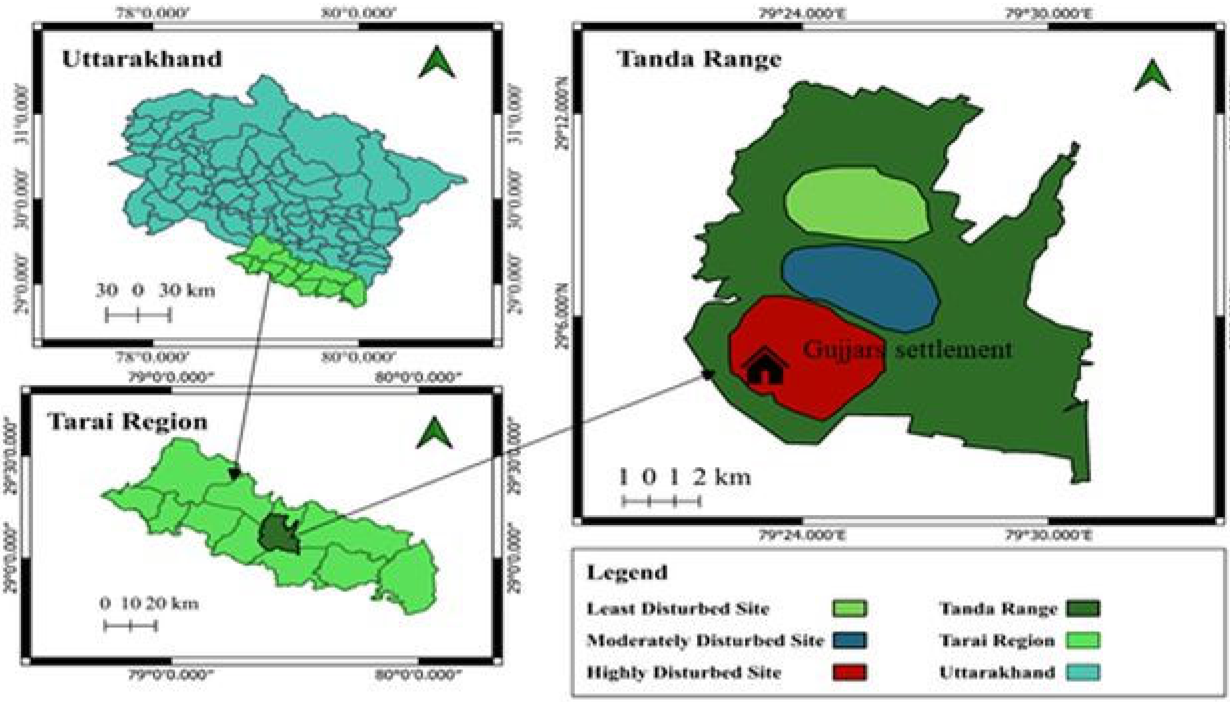

Figure 1. Location of the study area in Tanda Forest Range with the selected disturbance sites

uneven cut marks, scattered distribution, and proximity to settlements were used to identify poles removed through irregular harvesting.

Vegetation sampling

Three sample plots were established for each disturbance regime, and vegetation analysis was conducted using the quadrat method. Within each plot, five subplots measuring 10 × 10 m were randomly laid out for trees and saplings, 10 subplots of 5 × 5 m for shrubs, and 10 subplots of 1 × 1 m for herbs and seedlings, following the methods of Cottam and Curtis (1956) and Phillips (1959). Tree diameter was recorded at breast height (1.37 m), and individuals with a diameter at breast height (DBH) of less than 10 cm were classified as regenerative individuals. Based on diameter measurements, tree species were categorized into three groups: (a) seedlings (DBH < 10 cm), (b) saplings (DBH 11-30 cm), and (c) trees (DBH >30 cm) following Saxena and Singh (1982). Regeneration status and population structure of the tree species were determined following Saxena and Singh (1984). Vegetation parameters such as frequency, density, and importance value index for trees were calculated following Singh et al. (2014). For shrubs and herbs, the Provenance value (PV) index was calculated by summing up the value of relative density (RD) and relative frequency (RF) following Karki et al. (2017) and Fartyal et al. (2022).

$$\text{Provenance value (PV)} = \text{RD} + \text{RF}$$

RESULTS

Disturbance indicator and categorization

The analysis of disturbance indicators across highly disturbed (HD), moderately disturbed (MD), and least disturbed (LD) sites revealed significant variations in canopy cover, stem density, and human-induced pressures (Table 1). Canopy cover decreased from 68.15% in LD to 33.73% in HD, and stem density (>30 cm CBH) declined from 920 ind/ha in LD to 420 ind/ha in HD. The highest density of cut poles (73.33 stems/ha) and lopped trees (106.67 stems/ha) was in HD. Grazing pressure, indicated by dung pile density, was highest in HD (166.45 piles/ha), while fire scars were 20 patches/ha in HD, 6.67 patches/ha in MD, and absent in LD.

Floristic composition

A total of 39 species (18 trees, 9 shrubs, and 12 herbs) belonging to 19 families and 37 genera were identified across the three sites. Fabaceae,

Table 1. Details of disturbances indicators across three disturbance regimes

Disturbance indicators	Highly Disturbed	Moderately Disturbed	Least Disturbed
Canopy cover (%)	30-40	41-60	>61
Total stem density (ha^{-1})	420	780	920
Cut poles density (ha^{-1})	73.33	46.67	13.33
Lopped trees (ha^{-1})	106.67	80	26.67
Dung piles (ha^{-1})	166.45	80	33.33
Fire patches (ha^{-1})	20	6.67	-

Malvaceae, and Euphorbiaceae were the dominant families in these forests. Individuals belonging to Fabaceae were prominent among the trees, with *species such as Acacia catechu*, *Butea monosperma*, and *Dalbergia sissoo*. The Malvaceae family had four species: *Bombax ceiba*, a tree species, and *Sida cordata*, *Sida acuta*, and *Malvastrum coromandelianum*, all of which are herbaceous species. Moraceae and Apocynaceae were co-dominant families in all sites.

Vegetation attributes along the disturbance regimes

At all three sites, the highest number of species was represented by trees (*18*), followed by herbs (*12*), and shrubs (*9*). Of the 39 species, 29 species were found in the LD site, whereas 25 and 23 species were

Tree layer

A total of 18 tree species were distributed across all disturbance regimes, highest in LD (*11*), followed by MD (*9*) and HD (*7*) sites (Table 2). *Tectona grandis* was the dominant at the HD site (IVI 116.91), with *Trewia nudiflora* (IVI 35.86) and *Broussonetia papyrifera* (IVI 51.84) as co-dominants. *T. grandis* had the IVI values of 109.29 and 140.12 in MD and LD sites, respectively. *Eucalyptus globulus* and *Populus deltoides* were co-dominant at the MD site (IVI 43.39, 37.81, respectively), while *P. deltoides* was co-dominant at the LD site (IVI 34.99). *T. grandis*, *E. globulus*, and *P. deltoides* contributed significantly to MD and LD sites. *Acacia catechu*, *Alstonia scholaris*, *Butea monosperma*, *Cordia dichotoma*, *Dalbergia sissoo*, *Ficus racemosa*, and *Ficus religiosa* were absent in highly disturbed sites.

Shrub layer

A total of 12 species were observed in the shrub layer in all three sites, highest in HD (9) sites, followed by MD (7) and LD (6) sites. In the HD site, *L. camara* holds the maximum provenance value of 53.47, followed by *P. hysterophorus* (29.29) and *M. koenigii* (25.13). Across all sites, the provenance value of *L. camara* decreased with the disturbance intensity from high to low. However, *L. camara* and *Cannabis sativa* hold the highest PV values (57.47 and 48.21, respectively) at the MD site. The highest PV value was observed for *M. koenigii* (88.73), indicating dominance in the least disturbed site. *Calotropis procera* was the only species with a PV value of 7.64 recorded in the highly disturbed site (Table 3).

Herb layer

A total of 12 species were identified in the herb layer across the forest disturbance sites (Table 4), highest in LD site (12), followed by the MD (8) and the HD sites (7). *M. coromandelianum* had the maximum PV (45.83), followed by *Solanum nigrum* (36.22) and *S. acuta* (39.74). On the MD site, *M. coromandelianum* and *Oxalis corniculata* have the highest PV of 47.32 and 43.75, respectively. *Mentha arvensis, Phyllanthus niruri, Acalypha indica and Amaranthus spinosus* herb species were completely absent in the HD and MD sites (Table 4).

Population structure

The seedling density was highest at the LD site (1,060 ind/ha), followed by the MD site (480 ind/ha) and the HD site (320 ind/ha). Tree density was highest in the 61-90 cm girth class for the LD site (280 ind/ha). Similarly, for the 31-60 cm girth class, maximum tree density was 200 ind/ha for the LD site and lowest for the HD site (80 ind/ha). While trees were completely absent in the higher girth class (>121 cm) for the HD site. Tree density was predominantly observed in the intermediate girth class, with only a

Table 2. Distribution of tree species based on IVI across various disturbance regimes

Species name	Family	HD	MD	LD
Acacia catechu	Fabaceae	-	-	25.28
Alstonia scholaris	Apocynaceae	-	13.76	-
Bombax ceiba	Malvaceae	25.15	-	10.83
Broussonetia papyrifera	Moraceae	51.84	-	8.58
Butea monosperma	Fabaceae	-	14.30	-
Cordia dichotoma	Boraginaceae	-	15.73	-
Dalbergia sissoo	Fabaceae	-	-	12.11
Eucalyptus globulus	Myrtaceae	-	43.39	31.00
Ficus racemose	Moraceae	-	11.42	-
Ficus religiosa	Moraceae	-	-	9.42
Holoptelea integrifolia	Ulmaceae	23.07	-	-
Mallotus philippensis	Euphorbiaceae	-	-	18.60
Phyllanthus emblica	Phyllanthaceae	24.30	-	-
Populus deltoides	Salicaceae	22.86	37.81	34.99
Salvadora persica	Salvadoraceae	-	10.87	-
Syzygium cumini	Myrtaceae	-	12.62	20.40
Tectona grandis	Verbenaceae	116.91	140.12	109.29
Trewia nudiflora	Euphorbiaceae	35.86	-	19.51
Total		**299.99**	**299.72**	**299.91**

Note: HD- Highly disturbed, MD- Moderately disturbed, LD-Least disturbed

Table 3. Species compositions and provenance value of shrubs species along the disturbance regimes

Species name	Family	HD	MD	LD
Lantana camara	Verbenaceae	53.95	57.47	38.24
Carissa spinarum	Apocynaceae	21.75	13.70	-
Nerium indicum	Apocynaceae	7.64	-	12.25
Murraya koenigii	Rutaceae	25.13	29.96	88.73
Calotropis procera	Apocynaceae	7.64	-	-
Solanum xanthocarpum	Solanaceae	15.27	13.70	20.34
Parthenium hysterophorus	Asteraceae	29.29	9.56	14.22
Cannabis sativa	Cannabaceae	17.49	48.21	26.23
Ricinus communis	Euphorbiaceae	21.84	27.40	-
Total		**199.98**	**200**	**200**

Note: HD- Highly disturbed, MD- Moderately disturbed, LD-Least disturbed

few individuals in the >151 cm girth class across the entire disturbance gradient (Fig. 2).

Regeneration of tree species

The regeneration of tree species varied across the disturbance regimes (Table 5). The total number of species in all life forms (Tree, Sapling, Seedling) was 12 in both LD and MD sites, whereas it decreased to 7 in the HD site. At the LD site, seedling density was highest (1060 ind/ha), followed by the MD site (740 ind/ha), and the HD site (320 ind/ha). Similarly, sapling density was also highest in the LD site (240 ind/ha) and lowest in the HD site (160 ind/ha). At the LD site, *T. nudiflora* has the highest seedling

Table 4. Species compositions and provenance value of herb species along the disturbance regimes

Species name	Family	HD	MD	LD
Amaranthus polygamus	Amaranthaceae	16.03	22.38	8.54
Cassia tora	Fabaceae	16.03	10.18	28.41
Sida cordata	Malvaceae	32.05	15.77	13.86
Solanum nigrum	Solanaceae	36.22	18.34	8.54
Malvastrum coromandelianum	Malvaceae	45.83	47.32	31.42
Sida acuta	Malvaceae	39.74	16.32	26.79
Xanthium strumarium	Asteraceae	14.10	25.95	8.54
Oxalis corniculata	Oxalidaceae	-	43.75	19.86
Mentha arvensis	Lamiaceae	-	-	15.47
Phyllanthus niruri	Phyllanthaceae	-	-	6.00
Acalypha indica	Euphorbiaceae	-	-	20.55
Amaranthus spinosus	Amaranthaceae	-	-	12.01
Total		**200**	**200**	**200**

Note: HD- Highly disturbed, MD- Moderately disturbed, LD-Least disturbed

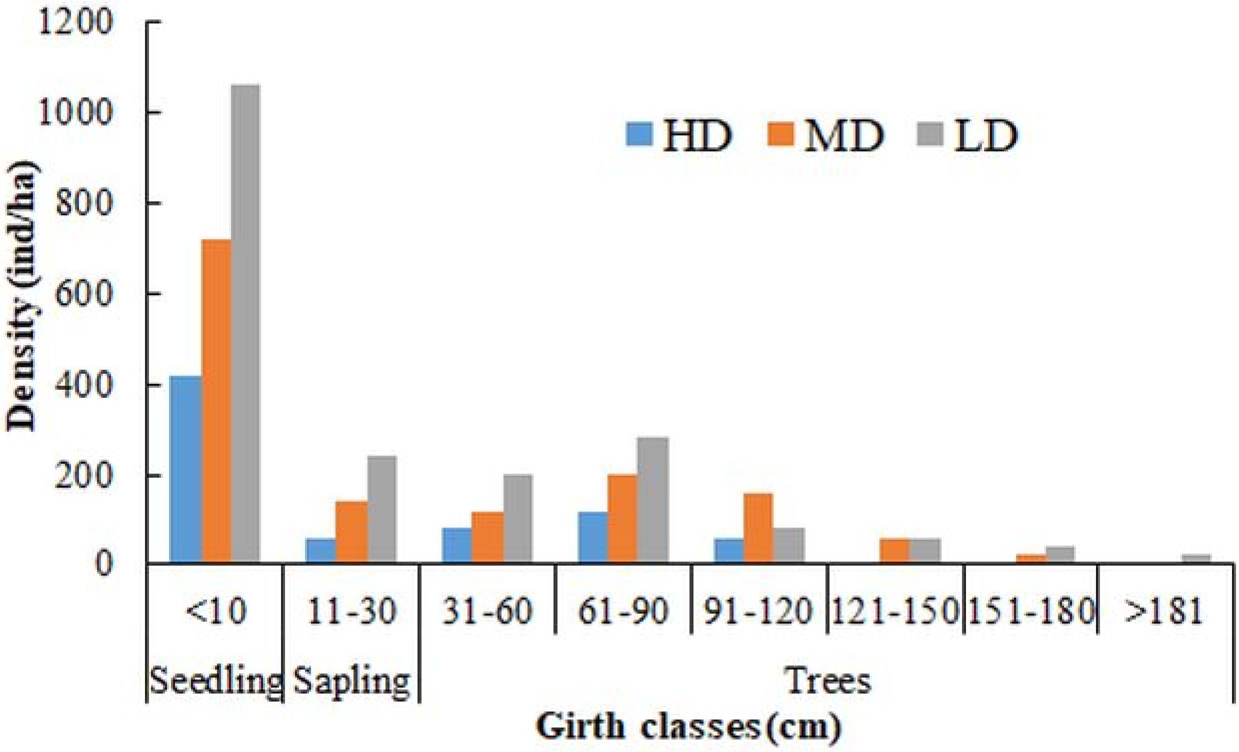

Figure 2. Population structure of trees across different girth classes

density (280 ind/ha), followed by *T. grandis* (180 ind/ha) and *S. cumini (*160 ind/ha), which showed good to fair regeneration. *B. ceiba*, *F. racemosa*, *and D. sissoo* had no seedlings in the LD site, indicating no regeneration in this area. At the MD site, *S. cumini* and *T. nudiflora* had relatively high seedling densities (180 ind/ha and 160 ind/ha, respectively), indicating good regeneration. However, no adults were present for *B. papyrifera*, *B. ceiba*, and *H. integrifolia*, as they exhibited new regeneration, indicating the initiation of seedling recruitment in response to canopy gaps created by disturbance. *B. monosperma* and *A. scholaris* seedlings were completely absent in the MD site, with few saplings and trees in the

Table 5. Regeneration status (density/ha) of tree species in the disturbance regimes

	LD				MD				HD			
Species name	**SD**	**SP**	**TR**	**RS**	**SD**	**SP**	**TR**	**RS**	**SD**	**SP**	**TR**	**RS**
Acacia catechu	-	-	40	No	-	-	-	-	-	-	-	-
Alstonia scholaris	-	20	-	New	-	20	20	Poor	-	-	-	-
Bombax ceiba	-	-	20	No	40	-	-	New	80	-	20	Fair
Broussonetia papyrifera	120	-	40	Fair	80	20	-	Fair	160	20	40	Fair
Butea monosperma	-	-	-	-	-	20	20	Poor	-	-	-	-
Cordia dichotoma	-	-	-	-	-	-	40	No	-	-	-	-
Dalbergia sissoo	-	-	20	No	-	-	-	-	-	-	-	-
Eucalyptus globulus	120	20	60	Fair	100	20	80	Fair	-	-	-	-
Ficus racemosa	-	-	40	No	-	-	-	-	-	-	-	-
Holoptelea integrifolia	-	-	-	-	40	-	-	New	-	20	20	Poor
Mallotus philippensis	140	60	60	Good	-	-	-	-	-	-	-	-
Phyllanthus emblica	-	-	-	-	-	-	-	-	-	40	20	Poor
Populus deltoides	60	20	80	Fair	60	20	60	Fair	-	-	20	No
Salvadora persica	-	-	-	-	-	-	20	No	-	-	-	-
Syzygium cumini	160	-	40	Fair	180	40	20	Good	-	-	-	-
Tectona grandis	180	60	240	Fair	80	60	280	Fair	80	60	100	Fair
Trewia nudiflora	280	60	40	Good	160	20	20	Good	-	20	40	Poor
Total	**1060**	**240**	**680**		**740**	**220**	**560**		**320**	**160**	**260**	

Note- HD- Highly disturbed, MD- Moderately disturbed, LD-Least disturbed, SD- Seedlings, SP- Saplings, TR- Trees, RS- Regeneration Status

HD site, indicating poor regeneration. At the HD site, the highest seedling density was observed for *B. papyrifera* (160 ind/ha) and *B. ceiba* (80 ind/ha), which exhibited reasonable and fair regeneration, respectively. In contrast, the seedlings of *H. integrifolia, P. emblica,* and T. *nudiflora* species were absent in the HD site, with very few saplings and trees indicating poor regeneration in the HD site. Species such as *P. deltoides* exhibited no regeneration at the HD site, highlighting the significant impact of high disturbance levels on recruitment and forest structure. In terms of percentage, At the LD site, 63.7% of species showed good to fair regeneration, indicating favorable recruitment conditions. The MD site had 50% of species with good to fair regeneration, reflecting moderate disturbance impacts. In contrast, the HD site showed 75% of species with poor to fair regeneration and no new recruitment, highlighting severe disturbance effects on forest regeneration.

DISCUSSION

Forest canopy cover supports biodiversity by providing habitats and enhancing ecosystem stability (Ishii et al. 2004). It serves as a disturbance indicator, with studies assessing forest disturbance levels based on canopy cover (Kumar and Ram 2005). In the present study, due to intensive lopping of branches and felling of trees for household purposes and construction by the Van Gujjars, the canopy cover has declined to less than 40% in the HD site. An earlier study by Prabhakar et al. (2006) also reported similar canopy cover loss (<40%) due to various development activities in 78% of the forest area in Uttarakhand, which includes degraded scrublands.
The effect of disturbances is also reflected in the species family distribution pattern of the selected three forest sites. The familial dominance of trees, shrubs, and herbs declined across the site along the disturbance gradient. In this study, a total of 12 families were recorded in the tree layer across all

three sites. Malvaceae, Moraceae and Fabaceae were the most species-rich families in the tree layer in the LD site. Similar dominance of these families has been reported in previous studies by Panda et al. (2013), Sahoo et al. (2017), and Sosef et al. (2017). In contrast, the absence of the Fabaceae family in the HD site highlights its significant utilization by the Van Gujjar community, reflecting its high socio-economic or ecological importance in these areas.

Vegetation parameters, including species richness and density, are significantly impacted by disturbances, which alter community composition and disrupt ecological processes across disturbance regimes (Fraterrigo and Rusak 2008). In the present study, the tree richness (18) of the forest was compared to other studies in the broader Tarai region. According to Poudyal et al. (2019), in the Tarai landscape, the tree species richness of 24 is documented, indicating more robust forest ecosystems, which is comparatively higher than the tree species richness observed in our study (18), which could be possible due to habitat disturbance, deforestation, and various anthropogenic pressures. Tree species richness in the present study decreased with increasing disturbance intensity (Table 2). The higher tree species richness in the LD site (12) was possible due to the inaccessibility of the forest and protection by the forest department from fuelwood collection, as well as the restriction of grazing animals by the Van Gujjars, which ultimately resulted in less human interference in the LD site. Conversely, the HD site, situated near Van Gujjar settlements, experienced significant grazing of livestock and extraction of fuelwood and fodder, leading to poor tree richness (7). Based on the intermediate disturbance hypothesis with no or little disturbance, only the competitive dominants can survive, while at sufficient high level of disturbance only fugitive species can survive, therefore the diversity is maximum at the intermediate level of disturbance (Petraitis et al. 1989), which is applicable in the present study having higher tree richness in LD (12) and MD (9) sites in comparison to the HD sites (7). The mild or least disturbance provides greater opportunity for species turnover, colonisation and persistence of high species richness (Petraitis et al. 1989).

The ratio of various age groups in the population determines the reproductive status of the population and indicates its future course (Odum 1971). The results of population structure in all sites suggest that the impact of human disturbance was significantly high on seedlings, saplings, and the density of trees in higher girth classes (Fig. 4). Singh and Singh (1992) suggested that a decline in individuals in higher size classes indicates poor regeneration and an increased risk of extinction. Similarly, this study found that tree density decreased with increasing girth, highlighting the species' vulnerability to environmental changes. These anthropogenic disturbances also altered the species composition in this area, favouring invasive species such as *L. camara, P. hysterophorus,* and *C. sativa* at the HD site.

The gradual decrease in density and basal area of trees along the disturbance gradient is attributed to the differences in the intensity of anthropogenic activities at the study sites. A similar trend of lower tree densities with increasing disturbance was also observed by Gogoi et al. (2017) and Rawal et al. (2012). Forest regeneration is a natural mechanism for restoring vegetative health and retaining lost biodiversity (Sagar and Singh 2004, Saxena and Singh 1984). In the present study, the number of trees, saplings and seedlings per unit area was used to assess the regeneration status and potential of forest species. A study conducted in the Kumaun Himalaya, Uttarakhand, by Chauhan et al. (2018) observed that regeneration status varied significantly across different sites, with lower disturbance levels having higher seedling densities, which was similar to our findings. This decline in seedling density at the HD site could be attributed to the intensive grazing of livestock by the Van-Gujjars near their settlements. Tree species such as *P. deltoides, T. nudiflora*, *H. integrifolia, and P. emblica* showed no to poor regeneration, while only *B. papyrifera* exhibited good regeneration in the HD site. Earlier studies have also observed that this species can thrive in areas affected by disturbances, such as fire and clear-cutting. The recruitment of *B. papyrifera* is positively related to its pre-disturbance (Ilisson and Chen 2009), which also adversely affected the regeneration of the native species (Kannan et al.

2014). *T. nudiflora* species was predominantly used as fodder and exhibited poor regeneration in the highly disturbed (HD) site, which could be possible due to over-exploitation of this species through the Van-Gujjars for their livestock.

CONCLUSIONS

The Tanda Forest, located within the Tarai region of Uttarakhand, is subject to considerable anthropogenic pressures, including agricultural expansion, grazing, and fuelwood collection. These activities have led to habitat degradation, biodiversity loss, and disruption of regeneration processes. This study examined the impact of such disturbances, particularly in proximity to Van Gujjar settlements, where forest resource utilization, such as lopping, tree felling, and grazing, has resulted in reduced canopy cover, decreased tree density, and diminished species richness. In areas experiencing high levels of disturbance, there is a proliferation of invasive species (*L. camara, P. hysterophorus, C. sativa*). In contrast, key native species (*A. catechu, B. monosperma, C. dichotoma, D. sissoo, M. phillippensis, S. cumini, F. racemosa*) are absent, indicating unsustainable utilization practices. Furthermore, the poor regeneration of palatable species (*T. nudiflora, H. integrifolia,* and *P. emblica*) suggests potential local extinctions, posing a threat to ecological balance. Addressing these challenges necessitates an integrated approach that balances conservation with sustainable livelihoods for Van Gujjars. Alternative income sources, such as agroforestry, ecotourism, and value-added dairy production, can enhance economic resilience while reducing dependence on forest resources. Afforestation initiatives, strategic tree planting near settlements, and sustainable resource management practices can further mitigate the ecological impacts. Capacity-building programs, vocational training, and participatory governance will empower the community to become an active environmental steward. A holistic strategy that integrates socioeconomic development with conservation efforts is essential for preserving both the well-being of Van Gujjars and the long-term sustainability of Tarai forests.

ACKNOWLEDGEMENTS

We sincerely thank the Uttarakhand Forest Department for granting us permission to conduct our research in the forests of the Tarai region. Their support and facilitation of fieldwork were instrumental in the successful completion of this study. We deeply appreciate their commitment to promoting scientific research for sustainable forest management and conservation.

Authors' contributions: The author, Ashish Tewari and Ikramjeet Maan has conceptualized and designed the study and significantly contributed to manuscript editing. Mohd. Arif Ansari has conducted all the field research, collected the data, interpreted it, and written the manuscript. Shahbaz Ali and Yogesh Chandra Tripathi worked on re-writing and proof reading of the manuscript.

Conflict of interest: The authors affirm that they have no competing interests.

REFERENCES

Amir, Z. and De Meulder, B. 2023. Contested forests: The Van Gujjars' struggle to settle. Journal of Landscape Architecture, 18(1), 30-39. https://doi.org/10.1080/18626033.2023.2258722

Anonymous. 2020. Global Forest Resources Assessment 2020. FAO, Rome. http://www.fao.org/forestry/fra/fra2020/en/

Bajpai, O., Dutta, V., Chaudhary, L.B. and Pandey, J. 2018. Key issues and management strategies for the conservation of the Himalayan Terai forests of India. International Journal of Conservation Science, 9(4), 749-760. https://ijcs.ro/public/IJCS-18-64_Bajpai.pdf

Banerjee, S., Das, D., Zhang, H. and John, R. 2023. Grassland–woodland transitions over decadal timescales in the Terai–Duar savanna and grasslands of the Indian subcontinent. Forest Ecology and Management, 530, 742-764. https://doi.org/10.1016/j.foreco.2022.120764

Bargali, S.S. 2024. Biological invasion, biodiversity, and people. Journal of Environmental Biology, 45(1), ecl-2. https://doi.org/10.22438/jeb/45/l/Ecl-2

Barlow, J., Lennox, G.D., Ferreira, J., Berenguer, E., Lees, A.C., Nally, R.M. and Gardner, T.A. 2016. Anthropogenic disturbance in tropical forests can double biodiversity loss from deforestation. Nature, 535(7610), 144-157. https://doi.org/10.1038/nature18326

Bhatta, B., Karna, A.L., Dev, O.P. and Springate-Baginski, O. 2013. Participatory forest management in the Nepalese Tarai: Policy, practice, and impacts. pp. 199-242. In: Forests, People and Power. Routledge, London. https://

doi.org/10.4324/9781849771399-9

Chauhan, J.S., Gautam, A.S. and Negi, R.S. 2018. Natural and anthropogenic impacts on forest structure: A case study of Uttarakhand state. Open Environmental Research Journal, 11(1), 11-38. https://doi.org/10.2174/1874213001811010038

Chhetri, B., Rayamajhi, S. and Baral, S. 2022. Importance of Forest and Non-forest Environmental Resources to Sustainable Rural Livelihoods: Insights from a Case Study in Nepal. Pp. 133-150. In: Melles, G.B. (Ed.), Designing Social Innovation for Sustainable Livelihoods, Springer, Singapore. https://doi.org/10.1007/978-981-16-8452-4_7

Cottam, G. and Curtis, J.T. 1956. The use of distance measures in phytosociological sampling. Ecology, 37(3), 451-460. https://doi.org/10.2307/1930167

Dlamini, C.S. 2020. Contribution of forest ecosystem services toward food security and nutrition. pp. 179-196. In: Leal Filho, W., Azul, A.M., Brandli, L., Özuyar, P.G. and Wall, T. (Eds.), Zero Hunger. Encyclopedia of the UN Sustainable Development Goals. Springer, Cham. https://doi.org/10.1007/978-3-319-95675-6_67

Goel, S. and Singh, R. 2025. Rainfall variability and probability analysis in Tarai and mid Himalayan regions of Uttarakhand. MAUSAM, 76(2), 6349. https://doi.org/10.54302/mausam.v76i2.6349

Eshetu, S. 2024. Fuelwood from natural forests' contribution to households' energy use and its effect on carbon dioxide emission in Delanta District, Northeastern Ethiopia. International Journal of Forestry Research, 2024, 7768742. https://doi.org/10.1155/ijfr/7768742

Fartyal, A., Khatri, K., Bargali, K. and Bargali, S.S. 2022. Altitudinal variation in plant community, population structure and carbon stock of *Quercus semecarpifolia* Sm. forest in Kumaun Himalaya. Journal of Environmental Biology, 43(1), 133-146. http://doi.org/10.22438/jeb/43/1/MRN-2003

Fraterrigo, J.M. and Rusak, J.A. 2008. Disturbance-driven changes in the variability of ecological patterns and processes. Ecology Letters, 11(7), 756-770. https://doi.org/10.1111/j.1461-0248.2008.01191.x

Gallery, R.E. 2014. Ecology of tropical rain forests. Pp. 247-272. In: Monson, R. (Ed.), Ecology and the Environment. Plant sciences (Vol. 8). Springer, New York. https://doi.org/10.1007/978-1-4614-7501-9_4

Gogoi, A. and Sahoo, U.K. 2018. Impact of anthropogenic disturbance on species diversity and vegetation structure of a lowland tropical rainforest of Eastern Himalaya, India. Journal of Mountain Science, 15(11), 2453-2465. https://doi.org/10.1007/s11629-017-4713-4

Gogoi, A., Sahoo, U.K. and Singh, S.L. 2017. Assessment of biomass and total carbon stock in a tropical wet evergreen rainforest of Eastern Himalaya along a disturbance gradient. Journal of Plant Biology and Soil Health, 4(1), 8-20.

Ilisson, T. and Chen, H.Y. 2009. Response of six boreal tree species to stand-replacing fire and clearcutting. Ecosystems, 12(5), 820-830. https://doi.org/10.1007/s10021-009-9259-z

Ishii, H.T., Tanabe, S.I. and Hiura, T. 2004. Exploring the relationships among canopy structure, stand productivity, and biodiversity of temperate forest ecosystems. Forest Science, 50(3), 342-355. https://doi.org/10.1093/forestscience/50.3.342

Kannan, R., Shackleton, C.M. and Shaanker, R.U. 2014. Invasive alien species as drivers in socio-ecological systems: Local adaptations towards use of Lantana in Southern India. Environment, Development and Sustainability, 16(3), 649-669. https://doi.org/10.1007/s10668-013-9500-y

Karki, H., Bargali, K., Bargali, S.S. and Rawat, Y.S. 2017. Plant diversity, regeneration status and standing biomass under varied degree of disturbances in temperate mixed oak-conifer forest, Kumaun Himalaya. International Journal of Ecology and Environmental Sciences, 43(4), 331-345.

Kumar, A. and Ram, J. 2005. Anthropogenic disturbances and plant biodiversity in forests of Uttaranchal, Central Himalaya. Biodiversity and Conservation, 14, 309-331. https://doi.org/10.1007/s10531-004-5047-4

Neelakantan, A., DeFries, R. and Krishnamurthy, R. 2019. Resettlement and landscape-level conservation: Corridors, human-wildlife conflict, and forest use in Central India. Biological Conservation, 232, 142-151. https://doi.org/10.1016/j.biocon.2019.01.033

Negi, V.S., Maikhuri, R.K. and Rawat, L.S. 2013. Ecological assessment and energy budget of fodder consumption in Govind Wildlife Sanctuary, India. International Journal of Sustainable Development & World Ecology, 20(1), 75-82. https://doi.org/10.1080/13504509.2012.747993

Odum, E.P. 1971. Fundamentals of Ecology. Saunders, Philadelphia 574 pp.

Öllerer, K., Varga, A., Kirby, K., Demeter, L., Biró, M., Bölöni, J. and Molnár, Z. 2019. Beyond the obvious impact of domestic livestock grazing on temperate forest vegetation: A global review. Biological Conservation, 237, 209-219. https://doi.org/10.1016/j.biocon.2019.07.007

Osuri, A.M., Chakravarthy, D., Mudappa, D., Raman, T.S., Ayyappan, N., Muthuramkumar, S. and Parthasarathy, N. 2017. Successional status, seed dispersal mode and overstorey species influence tree regeneration in tropical rainforest fragments in Western Ghats, India. Journal of Tropical Ecology, 33(4), 270-284. https://doi.org/10.1017/S0266467417000219

Palni, L.S. and Rawal, R.S. 2010. Conservation of Himalayan bioresources: An ecological, economical and evolutionary perspective. pp. 369-402. In: Sharma, V.P. (Ed.), Nature at Work: Ongoing Saga of Evolution. Springer, Cham. https://doi.org/10.1007/978-81-8489-992-4_23

Panda, P.C., Mahapatra, A.K., Acharya, P.K. and Debata, A.K. 2013. Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape level assessment. International Journal of Biodiversity and Conservation, 5(10), 625-639. https://doi.org/10.5897/IJBC2013.0581x

Petraitis, P.S., Latham, R.E. and Niesenbaum, R.A. 1989. The maintenance of species diversity by disturbance. The Quarterly Review of Biology, 64(4), 393-418. https://www.jstor.org/stable/2830102

Phillips, E.A. 1959. Methods of Vegetation Study. Henry Holt, New York, USA. 136 pages.

Poudyal, B.H., Maraseni, T. and Cockfield, G. 2019. Impacts of forest management on tree species richness and composition: assessment of forest management regimes in Tarai landscape, Nepal. *A*pplied Geography, 111, 102078. https://doi.org/10.1016/j.apgeog.2019.102078

Prabhakar, R., Somanathan, E. and Mehta, B.S. 2006. How degraded are Himalayan forests? Current Science, 91(1), 61-67. https://www.currentscience.ac.in/Volumes/91/01/0061.pdf

Raghubanshi, A.S. and Tripathi, A. 2009. Effect of disturbance, habitat fragmentation and alien invasive plants on floral diversity in dry tropical forests of Vindhyan Highland: A review. *Tropical Ecology,* **50**(1), 57-69.

Rawal, R.S., Gairola, S. and Dhar, U. 2012. Effects of disturbance intensities on vegetation patterns in oak forests of Kumaun, West Himalaya. Journal of Mountain Science, 9, 157-165. https://doi.org/10.1007/s11629-012-2029-y

Sagar, R. and Singh, J.S. 2004. Local plant species depletion in a tropical dry deciduous forest of northern India. Environmental Conservation, 31, 55-62. https://doi.org/10.1017/S0376892904001031

Sahoo, T., Panda, P.C. and Acharya, L. 2017. Structure, composition and diversity of tree species in tropical moist deciduous forests of Eastern India: A case study of Nayagarh Forest Division, Odisha. Journal of Forestry Research, 28, 1219-1235. https://doi.org/10.1007/s11676-017-0408-5

Saxena, A.K. and Singh, J.S. 1982. A phytosociological analysis of woody species in forest communities of a part of Kumaun Himalaya. Vegetatio, 50(1), 3-22. https://doi.org/10.1007/BF00120674

Saxena, A.K. and Singh, J.S. 1984. Tree population structure of certain Himalayan forest associations and implications concerning their future composition. Vegetatio, 58, 61-69. https://doi.org/10.1007/BF00044928

Seidl, R., Rammer, W. and Spies, T.A. 2014. Disturbance legacies increase the resilience of forest ecosystem structure, composition, and functioning. Ecological Applications, 24(8), 2063-2077. https://doi.org/10.1890/14-0255.1

Sharma, A., Patel, S.K. and Singh, G.S. 2023. Variation in species composition, structural diversity, and regeneration along disturbances in tropical dry forest of Northern India. Journal of Asia-Pacific Biodiversity, 16(1), 83-95. https://doi.org/10.1016/j.japb.2022.11.004

Sharma, J., Gairola, S., Gaur, R.D. and Painuli, R.M. 2012. Forest utilization patterns and socio-economic status of the Van Gujjar tribe in sub-Himalayan tracts of Uttarakhand, India. Forestry Studies in China, 14, 36-46. https://doi.org/10.1007/s11632-012-0102-9

Shukla, R.P. 2009. Patterns of plant species diversity across Terai landscape in north-eastern Uttar Pradesh, India. Tropical Ecology, 50(1), 111-122.

Singh, J.S. and Singh, S.P. 1992. Forests of Himalaya: Structure, Functioning and Impact of Man. Gyanodaya Prakashan, Nainital, India. 294 pages.

Singh, N., Tamta, K., Tewari, A. and Ram, J. 2014. Vegetational analysis and regeneration status of *Pinus roxburghii* Roxb. and *Quercus leucotrichophora* forests of Nainital forest division. Global Journal of Science Frontier Research: C Biological Science, 14(3), 41-48.

Sosef, M.S., Dauby, G., Blach-Overgaard, A., van der Burgt, X., Catarino, L., Damen, T., Deblauwe, V., Dessein, S., Dransfield, J., Droissart, V., Duarte, M.C., Engledow, H., Fadeur, G., Figueira, R., Gereau, R.E., Hardy, O.J., Harris, D.J., de Heij, J., Janssens, S., Klomberg, Y., Ley, A.C., Mackinder, B.A., Meerts, P., van de Poel, J.L., Sonke, B., Stevart, T., Stoffelen, P., Svenning, J-C., Sepulchre, P., Zaiss, R., Wieringa, J.J. and Couvreur, T.L.P. 2017. Exploring the floristic diversity of tropical Africa. BMC Biology, 15, 1-23. https://doi.org/10.1186/s12915-017-0356-8

Srivathsa, A., Vasudev, D., Nair, T., Chakrabarti, S., Chanchani, P., DeFries, R. and Ramakrishnan, U. 2023. Prioritizing India's landscapes for biodiversity, ecosystem services, and human well-being. Nature Sustainability, 6(5), 568-577. https://doi.org/10.1038/s41893-023-01063-2

Sullivan, M.J., Talbot, J., Lewis, S.L., Phillips, O.L., Qie, L., Begne, S.K., Chave, J., Cuni-Sanchez, A., Hubau, W., Lopez-Gonzalez, G., Miles, L., Monteagudo-Mendoza, A., Sonke, B., Sunderland, T., ter Steege, H., White, L.J.T., Affum-Baffoe, K., Aiba, S-I., de Almeida, E.C., de Oliveira, E.A., Alvarez-Loayza, P., Davila, E.A., Andrade, A., Aragao, L.E.O.C., Ashton, P., Aymard C, G.A., Baker, T.R., Balinga, M., Banin, L.F., Baraloto, C., Bastin, J-F., Berry, N., Bogaert, J., Bonal, D., Bongers, F. Brienen, R., Camargo, J.L.C., Ceron, C., Moscoso, V.C., Chezeaux, E., Clark, C.J., Pacheco, A.C., Comiskey, J.A., Valverde, F.C., Coronado, E.N.H., Dargie, G., Davies, S.J., De Canniere, C., Djuikouo K, M.N., Doucet, J-L., Erwin, T.L., Espejo, J.S., Ewango, C.E.N., Fauset, S., Feldpausch, T.R., Herrera, R., Gilpin, M., Gloor, E., Hall, J.S., Harris, D.J., Hart, T.B., Kartawinata, K., Kho, L.K., Kitayama, K., Laurance, S.G.W., Laurance, W.F., Leal, M.E., Lovejoy, T., Lovett, J.C., Lukasu, F.M., Makana, J-R., Malhi, Y., Maracahipes, L., Marimon, B.S., Marimon Jr, B.H., Marshall, A.R., Morandi, P.S., Mukendi, J.T., Mukinzi, J., Nilus, R., Vargas, P.N., Camacho, N.C.P., Pardo, G., Pena-Claros, M., Petronelli, P., Pickavance, G.C., Poulsen, A.D., Poulsen, J.R., Primack, R.B., Priyadi, H., Quesada, C.A., Reitsma, J., Rejou-Mechain, M., Restrepo, Z., Rutishauser, E., Salim, K.A., Salomao, R.P., Samsoedin, I., Sheil, D., Sierra, R., Silveira, M., Slik, J.W.F., Steel, L., Taedoumg, H., Tan, S., Terborgh, J.W., Thomas, S.C., Toledo, M., Umunay, P.M., Gamarra, L.V., Vieira, I.C.G., Vos, V.A., Wang, O., Willcock, S. and Zemagho, L. 2017. Diversity and carbon storage across the tropical forest biome. Scientific Reports, 7(1), 39102. https://doi.org/10.1038/srep39102

Tenzin, J. and Hasenauer, H. 2016. Tree species composition and diversity in relation to anthropogenic disturbances in broad-leaved forests of Bhutan. International Journal of Biodiversity Science and Ecosystem Services Management, 12(4), 274-290. https://doi.org/10.1080/21513732.2016.1206038

Thorn, J.P., Thornton, T.F., Helfgott, A. and Willis, K.J. 2020. Indigenous uses of wild and tended plant biodiversity maintain ecosystem services in agricultural landscapes of the Terai Plains of Nepal. Journal of Ethnobiology and Ethnomedecine, 16, 1-25. https://doi.org/10.1186/s13002-020-00382

Vedeld, P., Angelsen, A., Bojö, J., Sjaastad, E. and Berg, G. 2007. Forest environmental incomes and the rural poor. Forest Policy and Economics, 9, 869-879. https://doi.org/10.1016/J.FORPOL.2006.05.008

Wright, S.J. 2010. The future of tropical forests. Annals of New York Academy of Sciences, 1195(1), 1-27. https://doi.org/10.1111/j.1749-6632.2010.05455.x

Wright, S.J. and Muller-Landau, H.C. 2006. The future of tropical forest species. Biotropica, 38(3), 287–301. https://doi.org/10.1111/j.1744-7429.2006.00154.x

Wunder, S., Angelsen, A. and Belcher, B. 2014. Forests, livelihoods, and conservation: Broadening the empirical base. World Development, 64, S1-S11. https://doi.org/10.1016/j.worlddev.2014.03.007

Received:21st August 2025
Accepted:12th December 2025