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Flowering Plant Diversity of Differentially Disturbed Region of Terai Sal (*Shorea robusta*) Forest in Eastern Nepal

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Abstract

Terai Sal (*Shorea robusta* C.F.Gaertn.) forest, characteristic forest of lowland of Nepal, faces direct and indirect impacts from various anthropogenic activities. The present work aimed to study and document the flowering plant diversity within differentially disturbed sites of Charali Sal forest. Additionally, we accessed the habitat condition, analyzed the invasion status and prioritize the threats faced by the plant communities and recommended ways to mitigate the prevalent threats. We employed purposive sampling technique to sample the forest areas and nested plot design for vegetation sampling. Thirty sample plots, each measuring 10 m × 10 m, were established on two differentially disturbed sites (disturbed and undisturbed) of Charali Sal forest. A total of 111 flowering plant species belonging to 39 families were documented in the sampling sites, with 90 total species (89 identified) in disturbed sites and 86 species (80 identified) in undisturbed sites. Although the disturbed sites contained higher number of flowering plants, the diversity indices (Simpson and Shannon-wiener's) indicated higher diversity on undisturbed site. Disturbed site exhibited higher human encroachment and higher invasion of alien species compared to undisturbed site. Specific habitat management plans should be devised for the control and eradication of invasive species from the Charali Sal forest. We highly recommend to delimit a buffer zone all around the forest perimeter to regulate local access inside the forest. Collecting and harvesting various forest products should be restricted to the buffer zone, while the inner forest areas should be under careful and strict management. Implementing these strict managemental strategies would be challenging, but it is crucial for preserving the natural integrity of the forest.

Keywords: Charali Sal forest, Flora, Jhapa district, Lowland, Tropical vegetation.

Introduction

Floristic exploration is an act of documenting plant species found in a certain geographic area (Simpson, 2006). It is important to study and document the floral wealth of an area as it aids in the process of preparing flora, updating the nomenclature, documenting the changes in the natural habitats, adding specimens to the herbaria, and assessing ecological status of plant species (Chalise et al., 2018; Sagar et al., 2003). Knowledge about the floral wealth of a forest can also provide the information on the overall natural resources, their usage, and conservation status, which are very important for preparing conservation and management strategies (Bhandari et al., 2018; Chaudhary et al., 2002). Thus, forest management requires comprehensive understanding of the plant species diversity (Dieler et al., 2017), community structure (Chai et al., 2016), and plant composition (Collins et al., 2017; Ssegwa & Nkuutu, 2006).

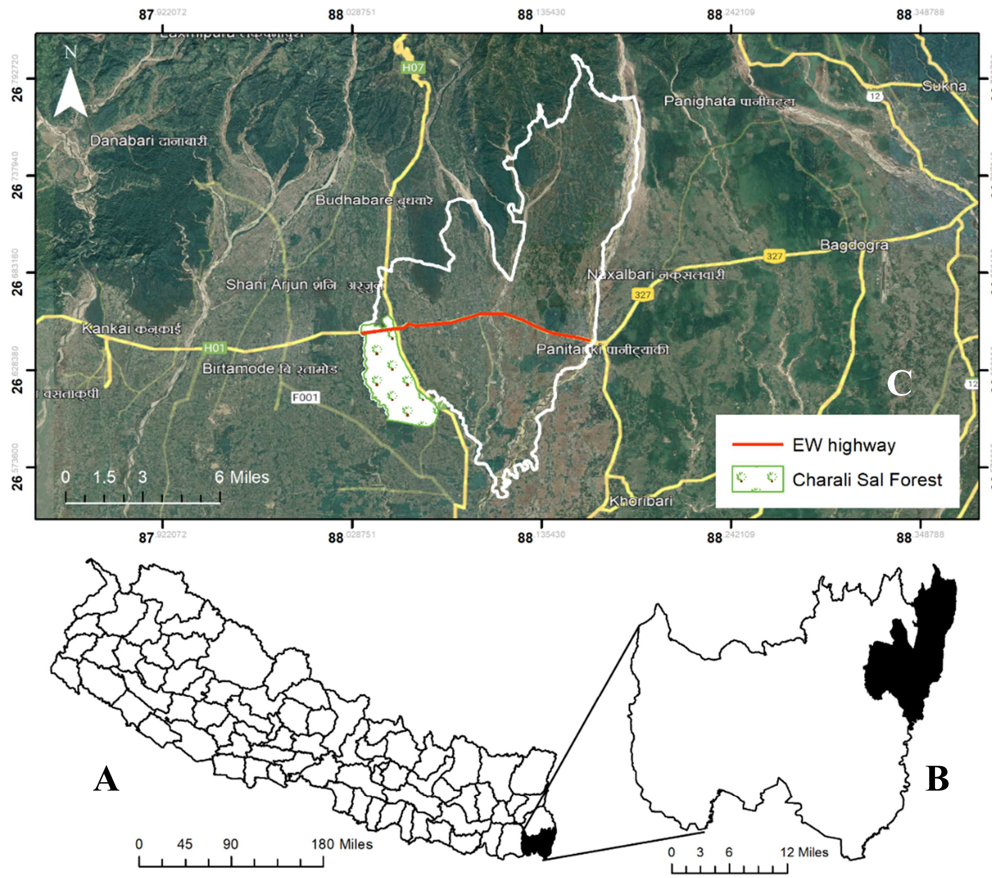
The tropical vegetation of Nepal is characterized by the dominance of Sal (*Shorea robusta* C.F.Gaertn.) forests (Gautam & Devoe, 2006; Rahman et al., 2009; Rautiainen & Suoheimo, 1997). These forests are considered to be one of the most threatened forest types because of their plummeting biodiversity (Posa et al., 2008; Sapkota et al., 2009; Tittensor et al., 2011). This is the result of the increasing demands of the fast-growing population (Squires, 2014), which are directly or indirectly dependent on forests and are causing overexploitation of natural resources (Naidu & Kumar, 2016). There have been numerous studies which explore vegetation, wildlife and other associated aspects of biodiversity in other parts of Nepal, however, only few tends to focus in eastern Nepal, particularly in Tropical belt. In recent years some researches have been focused in the tropical Sal forest of Jhapa district (Bhattarai, 2008, 2017; Bhattarai & Mandal, 2018; Sharma et al., 2021a, 2021b) and few new plant species have also been added to the flora of Nepal (Bhandari et al., 2021; Neupane et al., 2024; Sharma et al., 2021a). Despite of recent commendable approach to study the Tropical flora in eastern Nepal, the Charali Sal forest (also known as *Charali Nichajhoda* forest) was left unexplored. It is a fragmented part of once continuous and dense Terai Sal forest popularly known as *Char-Kose Ban*. Now, it is in-between dense residential areas and local people visit this forest daily to collect fuel wood, fodder, leaves, litter, fiddleheads, and yams. Anthropogenic activities, such as illegal harvesting of NTFPs, selective felling, invasion of alien plant species, encroachment, uncontrolled grazing, and forest fires, have been documented as the primary reason that have deteriorating the habitat condition and altering the species composition of Terai Sal Forest, and have suppressed the growth and regeneration of native species (Rahman et al., 2009; Srivastava et al., 2014; Xu et al., 2013). So, this study aimed to document the flowering plant diversity, habitat characteristics, status of invasion of alien plant species, and prioritize major threats in this fragment of Terai Sal forest. Additionally, it will help in assessing the outcome of current management practices and may provide information to formulate future management strategies.

Material and Methods

Study Area

Charali Sal forest is located at 26.653º and 26.605º N; 88.035º and 88.064º E in Mechinagar municipality of the Jhapa district, Koshi Province in Nepal. Its boundary touches the areas of Bhadrapur, Birtamod and Arjundhara municipality. This forest falls in the Kanchenjunga Landscape (ICIMOD, WCD, GBPNIHSD, RECAST, 2017) and covers an area of 1718.47 hectares (HCF, 2015). The forest is regulated under the Community Forest Management System and has been divided into five Community Forests (CF) (Sundar Nichajhoda, Pragati, Hariyali, Chandragadi, and Hatemalo). The dominant tree species is *Shorea robusta* C.F. Gaertn., and other major associated tree species of this forest are *Lagerstroemia parviflora* Roxb., *Terminalia elliptica* Willd., *Schima wallichii* (DC.) Korth., *Bombax ceiba* L., *Dalbergia sissoo* Roxb. ex DC., *Mallotus nudiflorus* (L.) Kulju & Welzen *and Albizia lebbeck* (L.) Benth. Important Non-timber Forest Product (NTFPs) documented are *Asparagus racemosus* Willd., *Rauvolfia serpentina* (L.) Benth. ex Kurz and *Smilax aspera* L (HCF, 2015).

Figure 1:
Map of study area; ***A****: Nepal,* ***B****: Jhapa district and* ***C****: Mechinagar municipality.*



Sampling design

Sampling was conducted in Hatemalo CF employing purposive sampling technique. Two sampling sites were chosen based on a preliminary field visit, done in May 2023. The criteria for site selection were the distance from the nearest human settlement and the intensity of anthropogenic disturbances. The first site was close (ca 300 m) to the human settlement and it was regarded as disturbed site as it received frequent visits from locals, who regularly visit those areas of forest for various forest product (Non-Timber Forest Product, NTFPs). The second sampling site was deep (ca. 1030 m) into the forest and it was regarded as undisturbed as it experienced lesser human encroachments. Nested plot design was used for vegetation sampling. A transect (ca. 1000 m) was determined in each site. Following the transect, 15 sample plots, measuring 10 m × 10 m were sampled randomly in each sampling site, with distance of at least 50 m between plots. In each of these plots, a 5 m × 5 m plot was established. Subsequently, in each of 5 m × 5 m, a 1 m × 1 m plot was determined (Banag-Moran et al., 2022). All trees species were counted and documented which were within 10 m × 10 m plot. The diameter at breast height (137 cm) of trees (DBH>7cm) were also documented. Shrubs were documented from 5 m × 5 m plots whereas, herbs from 1 m × 1 m plots (Kent, 2011). Biophysical and disturbances (trampling, harvesting and fire) parameters as well as percentage tree canopy were estimated by visual estimation method and was noted for each sampling plots. In addition, 38 stakeholders, which included forest officials and local peoples, were interviewed to know their preference on site selection for harvesting forest products and harvesting intensity. Plant species occurring in the sampling plots were recorded, collected and identified by standard taxonomic process (Polunin & Stainton, 1984; Shrestha et al., 2022). Collection and preparation of herbarium specimens were followed according to the standard technique of Bridson and Forman (2010). Herbarium specimens are prepared and stored in the Mechi Multiple Campus Herbarium.

Data analysis

Important community parameters such as density, relative density, frequency, and relative frequency, cover and relative cover of flowering species were determined using following basic formulae.

$$\text{Density} = \frac{\text{Total number of individuals of a species in all plots}}{\text{Total number of quadrats studied}}$$

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which the species occurred}}{\text{Total number of quadrats studied}} X\ 100$$

$$\text{Cover} = \frac{\text{Total cover of individual species}}{\text{Total number of quadrats studied}}$$

$$\text{Relative density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of individuals of all species}} X\ 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Sum of frequency of all species}} X\ 100$$

$$\text{Relative cover} = \frac{\text{Cover of a species}}{\text{Sum of cover of all species}} X\ 100$$

To provide quantitative estimates of plant diversity, Simpson's Index and Shannon's diversity index as well as evenness indices were calculated by using following formula:

Simpson diversity index (D) = $1 - \sum(Pi)^2$

Simpson evenness index ($E_{1/D}$) = $\frac{1/D}{S}$ (Kent, 2011; Simpson, 1949)

Shannon-Wiener diversity (H') = $-\sum_{i=1}^{s} Pi \ln Pi$ (Shannon & Weaver, 1963)

Shannon-Wiener evenness Index (E)= $\frac{H'}{\ln S}$ (Pielou, 1975)

Where, *Pi* = Proportion of the number of individuals or the abundance of the *i*th species,

S = Number of species

ln = logbase_n.

Non-parametric statistical tests were performed to analyze the data. Various parameters of two differentially disturbed sampling sites were compared by applying Mann-Whitney U tests. Microsoft Excel and SPSS were used to cure and analyze data.

Results and Discussion

Habitat Characteristics and Human disturbances

Charali Sal (*Shorea robusta*) forest is one of the characteristic forests in the Terai and lower foothills of Nepal, which have been exploited since history as the timber source (Gautam & Devoe, 2006; Rahman et al., 2009; Rautiainen & Suoheimo, 1997). These forests have been affected from various anthropogenic activities such as, selective felling, invasion of alien species, uncontrolled grazing, annual forest fires, and over-exploitation of resources (Bhattarai, 2017; Rahman et al., 2009; Rautiainen & Suoheimo, 1997).

Table 1:

Biophysical variables (mean ± SE) recorded in two different sites with varying amount of anthropological disturbance in Charali Terai Sal Forest.

Biophysical variables	Disturbed Site	Undisturbed site	Overall
Elevation (m)	137.33 ± 1.18[a]	130.00 ± 1.38[b]	133.67 ± 1.12
Tree canopy cover (%)	52.00 ± 2.96[a]	65.00 ± 2.01[b]	58.50 ± 2.13
Shrub canopy cover (%)	29.25 ± 1.12[a]	29.06 ± 1.64[a]	29.16 ± 0.98
Herb canopy cover (%)	22.88 ± 1.33[a]	25.60 ± 1.67[a]	24.23 ± 1.08
Tree density (DBH > 7 cm)	5.87 ± 0.56[a]	6.80 ± 1.01 [a]	6.33 ± 0.57
Average tree DBH (cm)	12.78 ± 2.01[a]	11.66 ± 1.84[a]	12.22 ± 1.34
Species richness	24.33 ± 0.97[a]	21.13 ± 0.91[b]	22.73 ± 0.72
Spermococe alata cover (%)	42.00 ± 8.76[a]	48.33 ± 9.86 [a]	45.17 ± 6.50
Mimosa diplotricha cover (%)	1.33 ± 1.00[a]	0.00[a]	0.67 ± 0.51
Chromolaena odorata cover (%)	30.67 ± 6.19[a]	18.00 ± 4.50[a]	24.33 ± 3.94
Mikania micrantha cover (%)	18.83 ± 5.93[a]	7.50 ± 2.83[a]	13.17 ± 3.40

Values associated with same superscript letter are not statistically significant (comparisons based on Mann-Whitney U test).

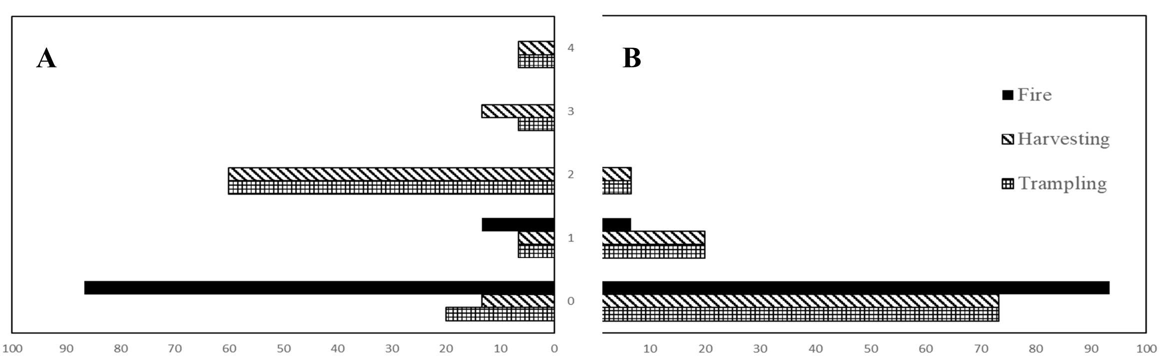


Figure 2:

Percentage plots experiencing certain type of disturbance. A: Disturbed site; B: Undisturbed site. (0= undisturbed; 1= less disturbed; 2= moderately disturbed; 3: highly disturbed; 4: severely disturbed)

The two sampling sites were disturbed differently as they encountered varying levels of disturbance from locals. Sample plots from disturbed site experienced a higher level of disturbance compared to the undisturbed site (Figure 2). Trampling and harvesting showed a strong positive relationship with disturbed site (Appendix II). The disturbed site was the first preference for most of the respondents (69%) as it was close to their residence, whereas, other

(18%) preferred both disturbed and undisturbed sites. They argued that many people would collect various forest product from the disturbed site, leaving nothing behind over time. So, they will move towards undisturbed site after disturbed site. The remaining 13% chose the undisturbed site as their preferred site, anticipating an abundance of forest product compared to disturbed site.

The intensity of harvesting forest products also varies quite significantly. Respondent preferring disturbed site visited more frequently, at least once or twice a week, compared to the undisturbed site, which receives one or two visits per month. Additionally, respondent mentioned to visit the disturbed site daily in the rainy season, when forest products such as, mushrooms and fiddlehead are available and are sold in the local market (as per the questionnaire survey with forest goers in May & June, 2023). Thus, the intensity of disturbance increased as the distance between sampling sites and nearest human settlements decreases. This correlation aligns with the frequent visits of locals as reported by Ghimire et al. (2005), and Ghubhaju and Ghimire (2009). The disturbed sites that are closer to the human settlements were the immediate target for fuel wood collection, and harvesting fodder, vegetables, medicinal plants and wild fruits (Ghimire et al., 2005). Locals primarily harvest wild vegetables such as, fiddleheads, yam, wild mushrooms, and *Lasia* leaves from the Charali Sal forest. Apart from vegetables, locals also harvest leaves of *Shorea robusta* for making plates, which are used in various rituals. Unfortunately, these frequent visits from local people have deteriorated the forest condition and reduced habitat quality in disturbed site.

Undisturbed site showed significantly higher tree canopy coverage (average percentage tree canopy cover per 100 m^2 ± standard error; 65.00 ± 2.01) compared to disturbed site (52.00 ± 2.96). However, the density of trees (DBH > 7 cm) and average tree DBH were not significantly different between the sites (Table 1). Moreover, a few tree stumps (5) were observed in the disturbed sites, which indicate towards illegal felling in the forest, which is mentioned by various earlier studies done in Nepal's as well as in Indian Sal Forest (Rahman et al., 2009; Rautiainen & Suoheimo, 1997). There was insignificant difference in herb and shrub percentage canopy cover between the two sampling sites. The higher shrub coverage in the disturbed sites was may be due to the presence of shrub species such as *Casearia graveolens, Murraya koenigii*, and also the invasive alien species like *Chromolaena odorata* which have the maximum canopy coverage (Table 1). The shrubs species in most of the disturbed plots were covered by *Mikania micrantha*. The significantly lower tree canopy cover may have favored the higher cover of these invasive species like *Chromolaena odorata*, as described by Sharma et al. (2022). Invasion of a new invasive species *Mimosa diplotricha* was also documented in disturbed sites. Due to the prevalence of these invasive species, the herb percentage canopy cover was less in disturbed sites as the growth and development of herbs species are documented to be suppressed by invasive species (Shicai et al., 2015; Xu et al., 2013).

Floristic Composition

A total of 111 flowering plant species belonging to 39 families were documented in the sampling plots. Overall, 108 (97.30 %) taxa were identified up to family, 105 (94.59) to genus and 100 (90.09) to species level (Appendix III). Fabaceae was the richest family (12 species), followed by Poaceae (11), Vitaceae (6), Lamiaceae (6), Phyllanthaceae (6) and Rubiaceae (5) (Appendix II). A higher number of flowering plant species were recorded in disturbed sites (90 total species; 89, identified species) compared to undisturbed sites (86 total; 80 identified) (Table 2). A floristic survey carried out by Bhattarai (2017) in similar Sal forest located in Jalthal, Jhapa documented 150 flowering plant species belonging to 128 genera under 75 families. In the similar kind of study in a Sal forest in Gorakhpur, India, Pandey and Shukla (2003) recorded a total of 208 plant species representing 165 genera and 72 familes. Similarly, Timsina et al. (2007) reported altogether 131 plant species in Sal forest of the western Terai. Shankar (2001), in a report for Sal-dominated forest in the Eastern Himalayan lowlands of the Mahananda Sanctuary, Darjeeling, India documented 156 plant species. Although present study mainly focused only on two differentially disturbed sites of Charali Sal forest, we were able to document such wealth of plant diversity. This forest encompasses a myriad of habitat inside it and may harbor unique floras, hence a comprehensive floristic analysis of this forest may provide some interesting and useful information on the diversity of this forest.

The composition of flowering plant species in undisturbed and disturbed showed dissimilarities. Plant species such as *Phlogacanthus thyrsiformis* (Roxb. ex Hardw.) Mabb., *Semecarpus anacardium* L.f., *Lasia spinosa* (L.) Thwaites, *Elephantopus scaber* L., *Commelina benghalensis* L., *Dillenia pentagyna* Roxb. *Pleurolobus gangeticus* (L.) J. St.-Hil. ex H. Ohashi & K. Ohashi, *Flemingia strobilifera* (L.) W.T.Aiton, *Vitex peduncularis* Wall. ex Schauer, *Pogostemon auricularius* (L.) Hassk., *Clerodendrum japonicum* (Thunb.) Sweet, *Perilla frutescens* (L.) Britton, *Azanza lampas* (Cav.) Alef., *Grewia asiatica* L., *Toona ciliata* M. Roem. and *Myrsine capitellata* Wall. were only documented in the Undisturbed site, whereas, *Artocarpus lacucha* Roxb. Ex Buch. -Ham., *Codariocalyx motorius* (Houtt.) H. Ohashi, *Colocasia esculenta* (L.) Schott, *Cornus oblonga* Wall., *Crassocephalum crepidioides* (Benth.) S. Moore, *Crotalaria albida* B. Heyne ex Roth., *Cyanotis cristata* (L.) D. Don, *Cyperus cyperoides* (L.) Kuntze, *Dactyloctenium aegyptium* (L.) Willd., *Digitaria bicornis* (Lam.) Roem. & Schult., *Duabanga grandiflora* (Roxb. ex DC.) Walp., *Imperata cylindrica* (L.) Raeusch., *Maesa* sp., *Mallotus nudiflorus* (L.) Kulju & Welzen, *Mimosa diplotricha* C. Wright, *Mussaenda roxburghii* Hook. f., *Pogonatherum crinitum* (Thunb.) Kunth, *Setaria* sp., *Sida rhombifolia* L., *Smilax* sp., *Sohmaea laxiflora (*DC.) H. Ohashi & K. Ohashi, *Spatholobus parviflorus* (Roxb. ex G.Don) Kuntze, *Spermacoce exilis* (L.O. Williams) C.D. Adams, *Uncaria sessilifructus* Roxb., *Urena lobata* L., and *Urochloa panicoides* P. Beauv. from the Disturbed site.

Shorea robusta was the dominant tree species in both sampling sites, however, its dominance over other associated tree species was more pronounced in disturbed site. Frequent disturbances in the natural Sal forest have documented to favor the single species dominance of *S. roubsta* (Sapkota et al., 2010). Additionally, *S. robusta* shows resistant to forest fires and other external disturbance factors and have proved to be more aggressive than other associated species through die-back mechanism (Champion & Seth, 1968), which may be the reason of high, relative density of *S. robusta* in disturbed site. Other associated tree species were *Syzygium kurzii* (Duthie) N.P. Balakr., *Heynea trijuga* Roxb. ex Sims, *Lagerstroemia parviflora* Roxb., *Dillenia pentagyna* Roxb., *Cornus oblonga* Wall., *Careya arborea* Roxb., and *Syzygium nervosum* A. Cunn. ex DC.

Trees species are known to show different response towards anthropogenic disturbance (Sapkota et al., 2009). *Dillenia pentagyna* Roxb. and *Schima wallichii* (DC.) Korth. were only recorded in disturbed site and can be regarded as ‘disturbance tolerant’, whereas, *Myrsine capitellata* Wall., *Mallotus nudiflorus* (L.) Kulju & Welzen, *Semecarpus anacardium* L.f., *Toona ciliata* M. Roem., *Holarrhena pubescens* Wall. ex G. Don, *Brassaiopsis hainla* (Buch. -Ham.) Seem. were documented only in undisturbed sites and can be regarded as ‘disturbance sensitive’ (Figure 3). The tree density (Table 1) and the number of tree species was higher in undisturbed region (13) compared to the disturbed sites (9).

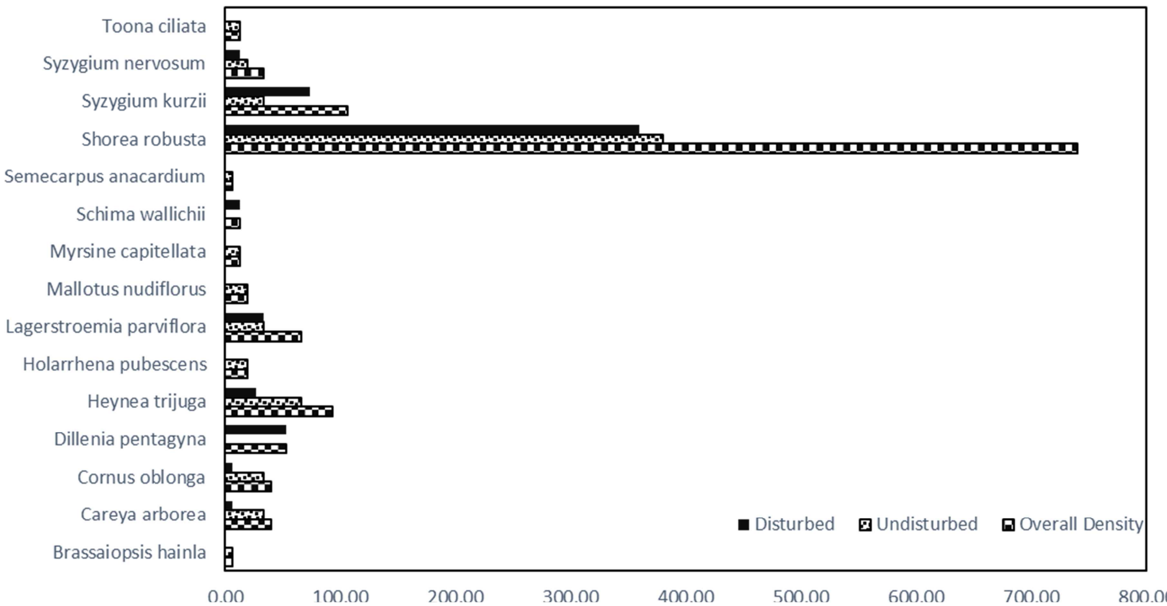


Figure 3:
Density of tree species in the sampling sites of Charali Sal Forest.

In terms of the diversity index, both the Simpson (D) as well as Shannon-Wiener (H') indices showed higher diversity in undisturbed sites compared to disturbed sites, because as per the Simpson's index, if the D value increases the diversity decreases and as per the Shannon-wiener index, higher the H' value more diverse is the site; that findings are also supported by the values of evenness indexes (Kent, 2011; Pielou, 1975; Shannon & Weaver, 1963; Simpson, 1949;) (Table 2). So, although the number of species are higher in the disturbed sites the undisturbed sites are more diverse and the species are evenly distributed throughout the site.

Table 2:
Summary of floristic analysis of two differentially disturbed sites of Charali Sal Forest.

Floristic Parameters	Disturbed	Undisturbed
Number of families	35	37
Number of genus	76	68
Number of species	90	86
Simpson index (D)	0.9739	0.9684
Shannon index(H')	3.8532	3.9369
Simpson's evenness ($E_{1/D}$)	0.0118	0.0132
Shannon's evenness (E)	0.8810	0.8844

Invasion status

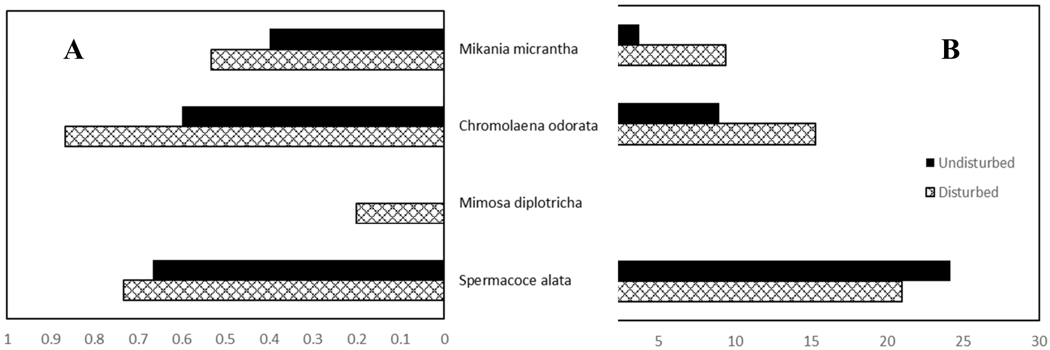


Figure 4:
Status of invasive species in Charali Sal Forest. ***A****: Frequency;* ***B****: Cover of four different invasive species.*

Four invasive species, namely, *Chromolaena odorata* (L.) R.M. King & H. Rob., *Mikania micrantha* Kunth, *Mimosa diplotricha* C. Wright, and *Spermacoce alata* Aubl. were documented in the sampling sites of Charali Sal forest. *Spermococe alata* showed the highest coverage (percentage coverage per 100 m^2 ± standard error; 45.17 ± 6.50) in the overall sampling sites followed by *Chromolaena odorata* (24.33 ± 3.94), *Mikania micrantha* (13.17 ± 3.40) and *Mimosa diplotricha* (0.67 ± 0.51) (Table 1). Invasive species were more frequent with comparatively higher cover on disturbed site. Invasion of alien plant species is primarily favored by anthropogenic causes which create canopy gaps as in disturbed site (Baret et al., 2008; Burnham & Lee, 2010). Forest canopy gaps and abundance of invasive plant species are negatively correlated with each other (Khaniya & Shrestha, 2020; Sharma et al., 2022). Among four invasive species, *Mimosa diplotricha* was recorded only from disturbed sites and showed comparatively less frequency and percentage coverage (Figure 4), which suggest its recent invasion in the disturbed site.

Invasion of alien plant species is considered as a form of biological pollution related to anthropogenic disturbance leading to the extinction of native species (Srivastava et al., 2014). Invasive alien plant species are known to alter the ecosystem functioning, decrease abundance, and richness of native species through competition, predation, and allelopathic effects, and altering community composition (Shicai et al., 2015). For instance, several studies have documented similar impacts of *Mikania micrantha* (Saikia & Khan, 2013; Xu et al., 2013) and *Mimosa diplotricha* (Basu & Gosh, 2003; Jaysree, 2005; Vasu, 2003; Witt et al., 2020) on native shrubs and herbs species. Therefore, higher frequencies and coverage of alien species in the disturbed sites is mainly due to higher anthropogenic disturbances and this can negatively impact the population of native species in the Charali Sal forest. Hence, due to this coupling effect of anthropogenic disturbances and invasion of alien species the native species of disturbed sites are under immediate threat.

Anthropogenic disturbance and plant diversity

Anthropogenic disturbances are known to greatly influence a variety of ecological attributes, including species interactions, population dynamics, community composition, and ecosystem function (Wei et al., 2013). Terai Sal forests are highly affected by various activities of local people who rely upon the forest for their subsistence (Gautam & Devoe, 2006;

Rahman et al., 2009; Riberio et al., 2015). The dependency of local people on forests is unavoidable worldwide (Sharma, 2015). People living around Charali Sal forest heavily rely upon the forest for various forest products (as discussed in Gautam & Devoe, 2006; Poudyal, 2013). Understanding the need and use of ecosystem goods and services by the local people is crucial to propose conservation and management efforts. Therefore, forest management programs which are able to incorporate sustainable use of forest products should be implemented urgently (Riberio *et al.* 2015; Sharma, 2015).

Conclusion and Recommendation

Due to the combined effects of higher human encroachment and invasion of alien species, the disturbed sites were comparatively less diverse than undisturbed sites. There is an urgent need to propose habitat management plans for the control and eradication of invasive species from the Charali Sal forest. We highly recommend to delimit a buffer zone all around the forest perimeter to regulate local access inside the forest. Collecting and harvesting various forest products should be restricted to the buffer zone, while the inner forest areas should be under careful and strict management. Implementing these strict managemental strategies would be challenging, but it is crucial for preserving the natural integrity of the forest.

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Appendix I

Pearson correlation coefficients among biophysical and disturbance parameters. (*. Correlation is significant at the 0.05 level (2-tailed); **.Correlation is significant at the 0.01 level (2-tailed).)

	Plot	Plot type	Elevation	Tree canopy	Trampling	Harvesting	Fire	Species richness	S. alata	M. diplotricha	C. odorata	M. micrantha	Tree density	Average Tree DBH	Shrub Cover
Plot type	-.173														
Elevation	**.366***	**-.618****													
Tree canopy	-.161	**.584****	-.305												
Trampling	-.203	**-.665****	.320	**-.430***											
Harvesting	-.144	**-.730****	**.412***	**-.506****	**.936****										
Fire	-.315	-.111	-.036	-.163	.134	.083									
Species richness	.222	-.426*	**.625****	-.146	.251	.215	-.103								
S. alata	-.137	.091	.013	.075	.239	.162	.126	.000							
M. diplotricha	**-.508****	-.333	.152	-.031	.360	.290	**.641****	.091	-.029						
C. odorata	.334	-.277	**.465****	-.031	.060	.028	-.201	**.488****	-.181	.096					
M. micrantha	.238	-.229	.176	.059	-.047	-.150	-.127	**.427***	-.349	.031	.272				
Tree density	.151	.047	.047	-.160	-.021	-.004	**.363***	-.228	.026	.157	-.061	-.197			
Average Tree DBH	-.205	-.058	.063	.165	.109	.075	-.289	**.418***	.163	-.067	.252	.252	**-.676****		
Shrub Cover	-.051	-.058	.345	.020	.073	.069	.128	.048	**.503****	.188	**.482****	-.269	.082	.197	
Herb cover	**.575****	-.328	.287	-.168	.063	.088	-.122	.003	-.034	-.205	.118	.206	.071	-.228	-.014

Appendix II

List of families with the number of species.

Family	Number of Species
Acanthaceae	1
Amaranthaceae	1
Anacardiaceae	1
Apocynaceae	2
Araceae	3
Araliaceae	1
Asparagaceae	2
Asteraceae	4
Bignoniaceae	1
Combretaceae	1
Commelinaceae	4
Cornaceae	1

Costaceae	1
Cyperaceae	4
Dilleniaceae	1
Dioscoreaceae	2
Dipterocarpaceae	1
Euphorbiaceae	2
Fabaceae	12
Hypoxidaceae	1
Lamiaceae	6
Lauraceae	3
Lecythidaceae	1
Lythraceae	2
Malvaceae	4
Melastomataceae	1
Meliaceae	2
Moraceae	2
Myrtaceae	3
Phyllanthaceae	6
Poaceae	11
Primulaceae	3
Rubiaceae	5
Rutaceae	1
Salicaceae	1
Smilacaceae	2
Theaceae	1
Vitaceae	6
Zingiberaceae	2
Total (Identified)	108

Appendix III

List of flowering plant species present in the sampling plots along with their respective family, habit and IUCN conservation status.

Scientific names	Family	abit	IUCN conservation status
Achyranthes aspera L.	Amaranthaceae	H	NE
Ampelocissus latifolia (Roxb.) Planch.	Vitaceae	L	NE
Amphicarpaea edgeworthii Benth.	Fabaceae	C	NE
Antidesma acidum Retz.	Phyllanthaceae	Sh	LC
Ardisia solanacea Roxb.	Primulaceae	Sh	NE
Artocarpus lacucha Roxb. Ex Buch.-Ham.	Moraceae	T	NE

Asparagus racemosus Willd.	Asparagaceae	C	NE
Azanza lampas (Cav.) Alef.	Malvaceae	Sh	NE
Boesenbergia longiflora (Wall.) Kuntze	Zingiberaceae	H	NE
Brassaiopsis hainla (Buch.-Ham.) Seem.	Araliaceae	T	*
Bridelia stipularis (L.) Blume	Phyllanthaceae	Sh	LC
Bridelia tomentosa Blume	Phyllanthaceae	Sh	LC
Callicarpa macrophylla Vahl	Lamiaceae	Sh	LC
Carex sp.	Cyperaceae	H	*
Careya arborea Roxb.	Lecythidaceae	T	*
Casearia graveolens Dalzell	Salicaceae	Sh	NE
Chlorophytum arundinaceum Baker	Asparagaceae	H	NE
Chromolaena odorata (L.) R.M.King & H. Rob.	Asteraceae	Sh	NE
Cissus repens Lam.	Vitaceae	C	NE
Clerodendrum infortunatum L.	Lamiaceae	Sh	LC
Clerodendrum japonicum (Thunb.) Sweet	Lamiaceae	Sh	LC
Codariocalyx motorius (Houtt.) H.Ohashi	Fabaceae	Sh	NE
Colocasia esculenta (L.) Schott	Araceae	H	LC
Combretum roxburghii Spreng.	Combretaceae	L	NE
Commelina benghalensis L.	Commelinaceae	H	LC
Commelina caroliniana Walter	Commelinaceae	H	LC
Cornus oblonga Wall.	Cornaceae	T	LC
Crassocephalum crepidioides (Benth.) S.Moore	Asteraceae	H	NE
Crotalaria albida B.Heyne ex Roth	Fabaceae	H	LC
Curculigo orchioides Gaertn.	Hypoxidaceae	H	NE
Cyanotis cristata (L.) D.Don	Commelinaceae	H	LC
Cyperus cyperoides (L.) Kuntze	Cyperaceae	H	LC
Cyperus diffusus Vahl	Cyperaceae	H	LC
Dactyloctenium aegyptium (L.) Willd.	Poaceae	H	NE
Dalbergia stipulacea Roxb.	Fabaceae	L	LC
Digitaria bicornis (Lam.) Roem. & Schult.	Poaceae	H	NE
Dillenia pentagyna Roxb.	Dilleniaceae	T	NE
Dioscorea deltoidea Wall. ex Griseb.	Dioscoreaceae	C	NE
Dioscorea pentaphylla L.	Dioscoreaceae	C	NE
Duabanga grandiflora (Roxb. ex DC.) Walp.	Lythraceae	T	LC
Elephantopus scaber L.	Asteraceae	H	NE
Ficus hispida L.f.	Moraceae	T	LC
Flemingia strobilifera (L.) W.T.Aiton	Fabaceae	Sh	NE
Glochidion lanceolarium (Roxb.) Voigt	Phyllanthaceae	Sh	NE
Grewia asiatica L.	Malvaceae	Sh	LC

Grona heterocarpos (L.) H.Ohashi & K.Ohashi	Fabaceae	Sh	NE
Hedychium thyrsiforme Sm.	Zingiberaceae	H	NE
Hellenia speciosa (J.Koenig) S.R.Dutta	Costaceae	H	LC
Heynea trijuga Roxb. ex Sims	Meliaceae	T	LC
Holarrhena pubescens Wall. ex G.Don	Apocynaceae	T	LC
Ichnocarpus frutescens (L.) W.T.Aiton	Apocynaceae	C	NE
Imperata cylindrica (L.) Raeusch.	Poaceae	H	LC
Knoxia sumatrensis (Retz.) DC.	Rubiaceae	Sh	NE
Lagerstroemia parviflora Roxb.	Lythraceae	T	LC
Lasia spinosa (L.) Thwaites	Araceae	H	LC
Leea aequata L.	Vitaceae	Sh	NE
Leea asiatica (L.) Ridsdale	Vitaceae	Sh	NE
Leea indica (Burm.f.) Merr.	Vitaceae	Sh	LC
Litsea monopetala (Roxb.) Pers.	Lauraceae	T	LC
Machilus gamblei King ex Hook.f.	Lauraceae	T	LC
Maesa sp.	Primulaceae	Sh	*
Mallotus nudiflorus (L.) Kulju & Welzen	Euphorbiaceae	T	LC
Mallotus philippensis (Lam.) Müll.Arg.	Euphorbiaceae	Sh	LC
Melastoma malabathricum L.	Melastomataceae	Sh	NE
Microstegium vimineum (Trin.) A.Camus	Poaceae	H	NE
Mikania micrantha Kunth	Asteraceae	C	NE
Mimosa diplotricha C.Wright	Fabaceae	Ssh	NE
Murdannia japonica (Thunb.) Faden	Commelinaceae	H	NE
Murraya koenigii (L.) Spreng.	Rutaceae	Sh	LC
Mussaenda roxburghii Hook.f.	Rubiaceae	Sh	NE
Myrsine capitellata Wall.	Primulaceae	Sh	NE
Oplismenus burmanni (Retz.) P.Beauv.	Poaceae	H	NE
Oplismenus compositus (L.) P.Beauv.	Poaceae	H	LC
Paspalum distichum L.	Poaceae	H	LC
Perilla frutescens (L.) Britton	Lamiaceae	H	LC
Phlogacanthus thyrsiformis (Roxb. ex Hardw.) Mabb.	Acanthaceae	Sh	NE
Phoebe lanceolata (Nees) Nees	Lauraceae	T	LC
Phyllanthus amarus Schumach. & Thonn.	Phyllanthaceae	H	NE
Pleurolobus gangeticus (L.) J.St.-Hil. ex H.Ohashi & K.Ohashi	Fabaceae	Sh	NE
Pogonatherum crinitum (Thunb.) Kunth	Poaceae	H	NE
Pogostemon auricularius (L.) Hassk.	Lamiaceae	H	NE
Schima wallichii (DC.) Korth.	Theaceae	T	LC
Scindapsus officinalis (Roxb.) Schott	Araceae	C	NE
Scleria levis Retz.	Cyperaceae	H	NE

Semecarpus anacardium L.f.	Anacardiaceae	T	LC
Setaria sp.	Poaceae	H	*
Shorea robusta C.F.Gaertn.	Dipterocarpaceae	T	LC
Sida rhombifolia L.	Malvaceae	Ssh	NE
Smilax ovalifolia Roxb. ex D.Don	Smilacaceae	C	NE
Smilax sp.	Smilacaceae	C	*
Sohmaea laxiflora (DC.) H.Ohashi & K.Ohashi	Fabaceae	Ssh	NE
Spatholobus parviflorus (Roxb. ex G.Don) Kuntze	Fabaceae	L	LC
Spermacoce alata Aubl.	Rubiaceae	Ssh	NE
Spermacoce exilis (L.O.Williams) C.D.Adams	Rubiaceae	H	NE
Stereospermum sp.	Bignoniaceae	T	*
Syzygium cumini (L.) Skeels	Myrtaceae	T	LC
Syzygium kurzii (Duthie) N.P.Balakr.	Myrtaceae	T	NE
Syzygium nervosum A.Cunn. ex DC.	Myrtaceae	T	LC
Tetrastigma leucostaphylum (Dennst.) Alston	Vitaceae	L	NE
Toona ciliata M.Roem.	Meliaceae	T	LC
Uncaria sessilifructus Roxb.	Rubiaceae	Sh	NE
Urena lobata L.	Malvaceae	Sh	LC
Urochloa panicoides P.Beauv.	Poaceae	H	LC
Urochloa ramosa (L.) T.Q.Nguyen	Poaceae	H	LC
Vitex peduncularis Wall. ex Schauer	Lamiaceae	T	LC