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Impact of Tourism on Forest Habitat Surrounding in Unakoti: An Important Archaeological Site of Tripura, North-East India

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Abstract

In this paper, we described the effects of tourism on forest habitat diversity, structure and biomass potential. To assess the effects of tourism pressure on surrounding forest habitat, we recorded and scored all ongoing disturbances factor in all selected forest stand. Tree species richness, stem density, basal area and population structure were investigated in two categories of forest stand i.e., occasionally visited and frequently visited forest areas selected based on remoteness and closeness to the tourist spot. The study revealed that the tree species richness ($F = 86.174$, $p < 0.001$) and diversity ($F = 86.174$, $p < 0.001$) varied along the disturbance gradient in different stands. Total stem density ($F = 100.92$, $p < 0.001$) and basal area ($F = 43.06$, $p < 0.001$) of the forest stands were significantly affected by visitors impact factors. Resource extraction and encroachment by local communities has been cited as a major impediment to the efficient management of protected forests. Proper management of protected forests is crucial to avoid further loss of forest resources and biodiversity. Our results suggest that forest conservation measures need to be equally accompanied by archaeological sculpture protection to achieve a more sustainable tourism development in the site.

Keywords: *Forest structure, frequently visited areas, occasionally visited areas, tourism, Unakoti*

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INTRODUCTION

Tourism has become one of the most important economic activities for countries around the globe. Tourism is one of the world's largest and fastest-growing industries [1]. In terms of quality of the environment, both natural and man-made is essential to tourism. Jafari defines tourism as "a study of man away from his usual habitat, of the industry which response to his needs, and of the impacts that both he and the industry have on the host socio-cultural, economic and physical environments" [2]. It involves many activities that can have adverse environmental effects [3].

Most of the tropical forests, especially those in protected areas, sanctuaries and national parks are regularly influenced by local human activity [4, 5] or even by the tourist visitors. Harvesting of forest resources to meet the livelihoods of the local needs can impact forest regeneration, structure, and diversity [6, 7]. National parks and sanctuaries beyond doubt protect the forests, but uncaptioned and improper opening of these areas to the public for tourism is also damaging forests diversity and structure [8]. The pursuit of outdoor recreational activities as part of tourism especially surrounded by forests is increasing and getting popularity due to green and clean environment [9]. Such popularity attracting a huge amount of tourist visits in those landscapes and generating good tourism revenue, but can lead substantial effects on the surrounding ecosystem [10–12].

Due to the large number of tourism traffic and absence of suitable management plan may lead to potential environmental impacts on frequently visited tourist spots [13]. The main negative environmental impact taking place can be characterized by the consequences of tourists' behavior while navigating the site. Historic scenic landscape surrounded by forest is interesting natural ecosystems which may be losing its aesthetic value due to random climbing and movement by visitors and may lead to the permanent damage of the sculpture or associated area of interest [14]. Areas with high concentrations of tourist activities may generate a huge amount of solid waste, thus their improper disposal directly affects the surrounding environment, adjacent stream and water bodies [15]. Tourism also contributes to fragmentation loss of suitable habitats via overutilization of resource, pollution and waste generation [16]. Over-extraction of a variety of forest products can potentially degrade forest, especially due to the unsustainable harvesting methods of forest products collection [17–19]. Tourism may suddenly increase anthropogenic pressures due to the encroachment of forest land for commercial use, also leading deforestation, resource overutilization, and forest degradation [20, 21]. Surroundings of potential tourist spot directly occupy by high human density and lead surface water pollution by the result of tourism pressure [22]. A number of visitors per year or annual tourist traffic may directly or indirectly have a positive impact over the tourist sites [23]. These will increase over trampling which may impact on ground vegetation by using the same trail over and over again by trampling the vegetation and this may lead to loss of vegetation and degradation of plant communities [24]. Furthermore, over trampling due to high annual tourist traffic has a serious impact on soil [3]. Forest fires may be considered as a major and permanent threat to indigenous species of flora and fauna, which leads to the enormous damage to the entire forest ecosystems; tourist spots are more vulnerable to fire as the results of numerous picnic leaving fire traces [25].

Unakoti is the prime tourist spot of Unakoti Tripura District in the Kailashahar Sub-division in the North-eastern Indian state of Tripura. The famous bas relife sculptures of unakoti carved on the vertical rock cliffs display colossal sculptures of Shive's head (more than 6m high), Devi, group of rock- cut Ganesha figures along with two standing images of elephant-headed figures & an image of Vishnu. Some loose sculptures identified as an image of Vishnu, Hara – Gauri, Hari – Hara, Narasingha, Ganesha, Hanumana *etc*. are kept in a sculpture shed made at the top of the hill. While the marvelous rock carvings, murals with their primitive beauty form the chief attraction, natural beauty including mountain scenery and waterfalls are an added bonus. According to the regional people at Unakoti, there were a sculptor & potter named '*Kallu Kumar'*. The local tribals believe that it was Kallu Kumar who had carved all these images and sculptures [26]. An important festival of the State followed by a big fair popularly known as "*Ashokastami"* fair is held at Unakoti '*Tirtha*' at Kailashahar every year in the month of March/April. *Mela* and the rite of bathing appear to be the special characteristic of Unakoti. Shivaratri, Makar Sankranti, and Ashokastami Mela are the famous festivals of Unakoti. Thousands of religious people gather on that occasion to perform rituals and take a holy dip in the water of '*Astami kunda*'. The bathing rite is a special function at Unakoti which is actually the main object of a gathering of pilgrims at Shivaratri, Makar Sankranti, and Ashokastami Mela.

Besides an archaeologically important place of the State Tripura, Unakoti covers a large area of scenic landscape with dense forest ecosystem. It also contains a mosaic of surrounding natural vegetation and which is a part of the state's Reserve Forest (RF). This forest area has been facing serious anthropogenic disturbances due to high tourism traffic and other associated activities. Increase in tourism traffic and continuous shifting of human settlements within forested areas of Unakoti have severely increased the degradation of floral and faunal diversity. Since, tourism activities have significant impacts (both negative and positive) on the natural environment and its components – soil, vegetation, wildlife and water [27]. Thus, the present study was designed to evaluate the major impacts related to the tourism industry in Tripura and other anthropogenic disturbances on existing landscape and surrounding vegetation of Unakoti. Hence, it was felt necessary to assess the vegetation structure and tree species composition, forest biomass and carbon stock with the determination of soil physicochemical properties, soil organic carbon stock in this tourist site of Tripura.

MATERIALS AND METHODS

Study Site

The State Tripura has a tropical climate and receives adequate rainfall during the monsoons. The local flora and fauna bear a close affinity and resemblance with floral and faunal components of Indo-Malayan and Indo-Chinese sub-regions. The State is located in the bio-geographic zone of 9B-North-East hills [28] and possesses extremely rich biodiversity. The state lies between 22°56' to 24°32' N latitude and 90°09' to 92°20' E longitude. The state experiences three different climates of tropical savanna, tropical monsoon, and humid subtropical climatic condition. The temperature in the state ranges from 21°C to 38°C in summer, whereas it fluctuates from 13°C to 27°C in the winter season. The annual rainfall ranges from 1922 mm to 2855 mm. As per the report of the Forest Survey of India [29], total forest and tree cover in the state is 8,044 km^2 *i.e.*, 76.71 % of the total State's geographical area.

According to the classification of Champion and Seth [28], the forests of the state have been classified into six types: I) East Himalayan Lower Bhabar Sal, II) Cachar Tropical Evergreen forests, III) Moist Mixed Deciduous Forests, IV) Low Alluvial Savannah Woodland, V) Moist Mixed Deciduous Forests, Dry Bamboo Breaks, and VI) Secondary Moist Bamboo Breaks. The forests of Tripura are divided into two major forest type groups. These are - i) Semi-Evergreen Forests and ii) Moist Deciduous Forests. Moist Deciduous Forests are further divided into two distinct categories, namely, a) Moist Deciduous Sal Forests and b) Moist Deciduous Mixed Forests.

Field Survey and Data Collection

The study was conducted under two disturbance regimes (a) Occasionally visited forest sites (areas situated at remotely from the sites of frequent tourist visits) and b) frequently visited forest sites around Unakoti. Several methods have been developed to estimate disturbance intensity in forest ecosystems [30–34].

In the present study, the classification and selection of forest communities were based on remoteness and closeness to the tourist spot. Sites which are very close to the walking trail *i.e.*, the edge of the road was considered as frequently visited by tourist and areas not visited by tourists but occasionally forest dwellers visited that sites for NTFPs collection which is 20 m far away from tourist walking routes were considered as occasionally visited sites to avoid biasness in the sampling strategy.

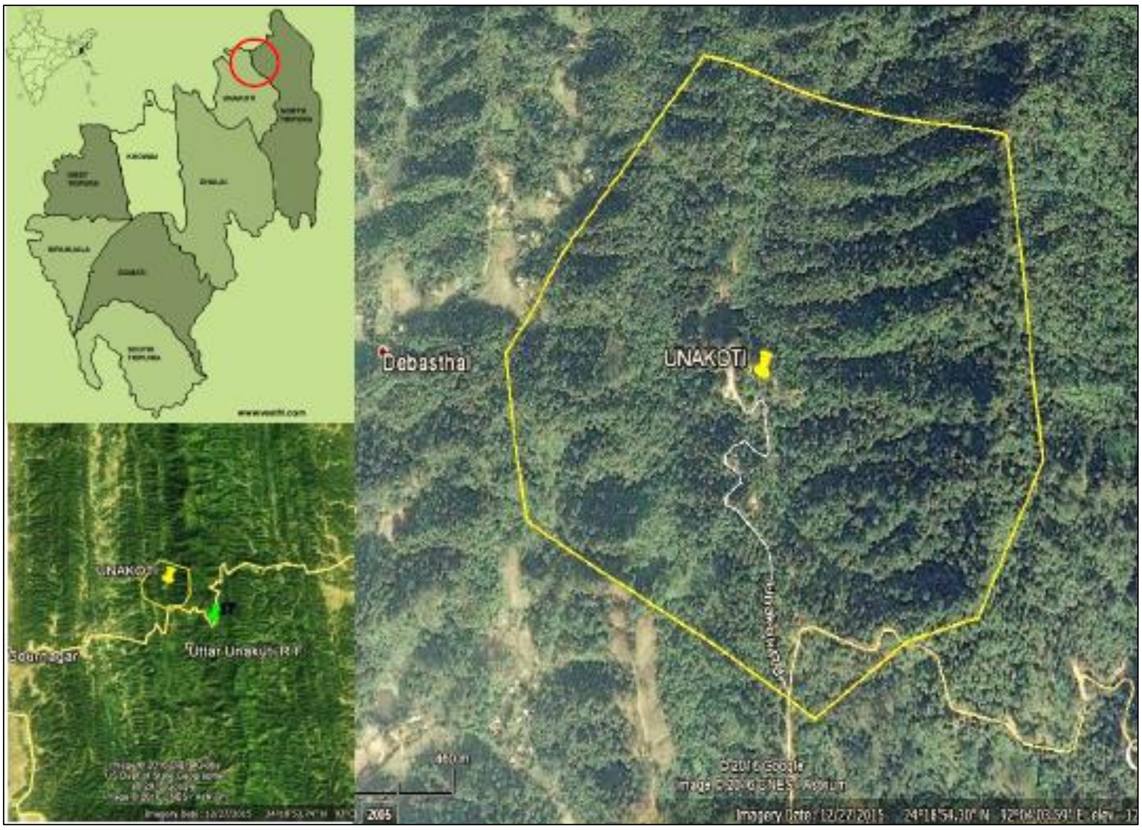

Fig. 1: *Showing study area selected for the present study.*

Table 1: *Location of the sample plots selected for assessing the impact of tourism on stand diversity, vegetation structure and biomass in the study area.*

Plot Id	Stand Category	Geo-coordinates
SP 1	Occasionally visited forest sites	24°19'12.6"N, 92°04'01.5"E
SP 2		24°19'02.8"N, 92°03'56.3"E
SP 3		24°18'56.3"N, 92°03'51.7"E
SP 4		24°19'4.26"N, 92°4'8.31"E
SP 5		24°18'59.43"N, 92°4'10.22"E
SP 6		24°18'56.37"N, 92°4'10.97"E
SP 1	Frequently visited forest sites	24°19'06.7"N, 92°04'06.3"E
SP 2		24°19'09.0"N, 92°03'56.5"E
SP 3		24°19'8.95"N, 92°4'3.74"E
SP 4		24°19'4.69"N, 92°4'1.72"E
SP 5		24°18'56.20"N, 92°3'59.85"E
SP 6		24°18'52.79"N, 92°4'3.58"E

The study used a modified scoring pattern [35] to estimate tourism impact (visitor impact factors) as well as an anthropogenic disturbance in surrounding forest habitat. These included No. of visitors per year, Water pollution, Trampling impact on Vegetation, Trampling impact on Soil, Land encroachment, Solid waste, Forest Resource Extraction, Traces of Fire, Introduction of exotic species, Aesthetic disturbances. Scoring was established as 1 = absence, 2 = low, 3 = moderate, and 4 = high for all 12 study plots and calculations determined the total intensity of disturbance (Table 1). The relationship between stand structural variables and disturbance factor along the selected plot were also established to show how visitor impact factors affect the surrounding forest ecosystem.

Vegetation Analysis

For the first attempt of conducting a study on analytical features by evaluating population structure and stand characteristics of the study sites was assessed based on the existing methodologies of earlier workers from the extensive research and demonstration and the following parameter was done for the preliminary assessment of the natural phyto-resources of Unakoti (study area). Basal area (m^2) is calculated using the following equation which is simply the area of a circle (area = πr^2) and it is measured at 1.37 m above ground. Species density is an expression of the numerical strength of a species where the total number of individuals of each species in all the quadrats is divided by the total number of quadrats studied. The density of the species within the selected area is simply the number of trees per unit area and expressed as the number of trees per hectare basis (1 ha = 10000 m^2). For the present report, only the species density was assessed to get a population strength over the selected plot of all species counted (0.1 ha).

Diversity Indices

Analytical features of the community plant were quantitatively analyzed from field data for abundance, density and frequency [36] with relative frequency, relative density, relative basal area and Importance Value Index (IVI) following Mueller–Dombois and Ellenberg [37]. Tree species diversity, dominance index of the stand and evenness of the stand of both the selected vegetation types was calculated followed by Shannon and Weiner [38]; Simpson [39] and Pielou [40] respectively. Some important factors which attribute as a key factor when calculating diversity are species richness and evenness. Richness is a measure of the number of different kinds of organisms present in a particular area and evenness compares the similarity of the population size of each of the species considered as the relative abundance of the different species that make up the richness of an area.

Estimation of Biomass and Carbon Density

There is a conventional method followed in several studies from the same eco-region of North-East India and also used in other states of the Indian territory [41, 42] insisted the suitability for biomass estimation followed by the Non-destructive method *i.e.*, growing stock estimation using volume equation and then volume was converted into biomass by using wood specific gravity of selected tree species developed by Forest Research Institute [43] In the case of non-availability of species-specific volume equation allometric biomass equation *i.e.*, Above Ground Biomass (AGB) = $\exp[-0.37+0.33*\ln(DBH)+0.933*\ln(DBH)^2-0.122*\ln(DBH)^3]$ developed by Chambers *et al.*

[44] is being considered for biomass estimation where AGB was calculated per trees in kg and diameter at breast height (DBH) in cm which has been successfully used by researchers of the North-eastern region [45, 46]. Above ground biomass, carbon was calculated followed by IPCC [47] suggested carbon fraction of 0.50 as used likewise other studies [48].

Status of Soil Physical and Chemical Properties

Soil samples were collected from four different corners from each of the quadrat maintaining 3 layers of the soil strata with the help of soil auger from 0–10, 10–20, 20–30 cm respectively. In total 24 samples were collected from each depth class from both the selected forest. The in-situ soil temperature was noted by using a digital soil thermometer. Collected soil samples were brought to the laboratory and air-dried. Samples were passed through a 2 mm sieve to remove stones, roots and large organic residues before conducting analyses of physical and chemical characteristics. Bulk density was determined by the core method of Blake and Hartge [49]. The moisture content was determined followed by dry mass basis [50]. Soil pH was measured in 1:1 *i.e*., soil: water suspensions with a glass electrode on a pH meter [51]. Soil organic carbon (SOC %) was determined by Walkley-Black Method [52] and carbon stock density of soil was estimated by following Pearson *et al*. [53]. Mass of carbon per unit volume is calculated by multiplying carbon concentration (reported as percent mass) times bulk density (g/cm^3). Bulk density equals the oven-dry weight of the soil core divided by the core volume.

RESULTS

Tree Species Richness and Diversity

A total of 47 tree species of 40 genus and 21 families were recorded at >10 cm girth at breast height (gbh). The observed number of species was recorded comparatively higher in relatively lower disturbed areas (39 species and 18 families) than frequently visited forest areas (18 species and 14 families). In terms of diversity measures, mean Shannon-Weiner Diversity index was recorded higher in occasionally visited areas (2.87) ranged 2.58–3.21 and lower in frequently visited forest areas (1.98) ranged 1.79–2.17. Mean Menhinick's richness index was 3.84 ranged 3.21–4.83 as higher and 2.20 ranged 2.02–2.5 as lower in occasionally visited and frequently visited forest areas respectively. Simpson's dominance index ranged 0.04–0.10 with a mean value of 0.07 in occasionally visited areas and ranged 0.13–0.19 with a mean value of 0.17 in frequently visited areas. The value of this index ranges between 0 and 1; where greater values indicate high stand dominance with few species, or 0 represents infinite diversity and 1 no diversity. Therefore, the bigger the value of Simpson's dominance index, the lower diversity. Pielou's evenness index for occasionally visited areas ranged 0.77–0.94 with a mean value of 0.87 comparatively higher than the value of 0.84 in frequently visited forest areas. An evenness index is an indication of numeric equality between the communities and the value should range from 0 to 1; values close to 0 indicate a community is very uneven; and thus, when there is less variation in communities between species the value of this index should be close to 1.Forest composition was dominated by *Cassia siamea, Bauhinia acuminate, Anogeissus acuminate, Ficus racemosa, Litsea glutinosa, Mitragyna rotundifolia, Sterculia villosa, Toona ciliate.* The Shannon's index (t=3.82, df=11; p<0.05) was significantly greater in occasionally visited areas than frequently visited forest areas and Simpson's index (t =5.93, df=11, p<0.001) was significantly greater in occasionally visited areas than frequently visited forest areas (Table 2).

Table 2: *Quantitative values of forest diversity and structure in occasionally visited and frequently visited surrounding forest areas of Unakoti Forest ecosystem (± SEM, n=12).*

Diversity Indices	Occasionally visited forest sites	Frequently visited forest sites	F-value	p-value
No. of Species	39±1.23	18±0.48	86.174	<0.001
No. of Genus	32±0.28	20±0.57	216.13	<0.001
No. of Family	18±0.47	14±0.40	24.14	<0.05
Dominance Index	0.07±0.01	0.17±0.008	70.20	<0.001
Diversity Index	2.87±0.15	1.98±0.06	22.52	<0.001
Evenness Index	0.87±0.023	0.85±0.012	0.33	>0.05
Menhinick Index	3.84±0.22	2.20±0.07	51.38	<0.001

Vegetation Structure

Across different designated areas tree density and basal cover varied considerably. A total of 290 stems ha^{-1} (>10cm gbh) with basal area of 22.37 m^2 ha^{-1} and stem density of 166.67 stem ha^{-1} with basal area of 9.90 m^2 ha^{-1} was recorded in occasionally visited areas and frequently visited forest areas respectively. In occasionally visited areas maximum no. of trees falls within the girth class of 30–60 and 60–90 whereas in frequently visited forest areas maximum no. of individuals falls within the girth class of 60–90 which follows a dissimilar trend in girth distribution (Figure 3). Similarly in case of height class distribution across height class interval <6, 6–9, 9–12, 12–15, 15–18, 18–21, 21–24, 24–27, 27–30 and >30 meter showed maximum no. of trees falls within the height class interval of >6 with stand density of 63.33 trees ha^{-1} followed by height class interval of 12–21 with stem density of 60.00 trees ha^{-1} of same height class; 9–12; 15–18, 24–2; 27–30. The result of ANOVA showed significant variation in stand characteristics. Stand density and basal cover of tree species was significantly different in all the selected stands (F=100.92, p<0.001 and F=43.06, p<0.001, respectively). Furthermore, results of the *t-test* also suggested that stem density (t=10.54, p<0.001) and basal area (t=8.79, p<0.001) was significantly higher in occasionally visited areas than frequently visited forest areas (Table 3).

Tree Aboveground Biomass and Carbon Stock

In terms of aboveground biomass pattern, present estimation recorded higher biomass density of 104.28 Mg ha^{-1} with carbon content of 52.14 Mg.ha^{-1} as 50% of total dry biomass and lower biomass of 47.99 Mg ha^{-1} with carbon content of 23.99 Mg ha^{-1} observed in occasionally visited and frequently visited forest areas respectively (Table 3) which follows a drastic reduction in their quantitative parameters. In terms of biomass productivity aboveground, biomass varies significantly from site to site (F=52.30, P<0.001) and among the classified forest stand (t=9.08, P<0.05). Total biomass density for frequently visited forest areas showed comparatively lower biomass content and considered as disturbed forest. Due to the unusual clear felling of trees and comparatively lesser number of mature trees, the formation of the secondary forest through natural regeneration was found is very high.

Disturbance Factors

Disturbance factors along with the scored value (Table 4) were found at high extent in frequently visited forest areas however forest resource extraction in terms of a collection of firewood and non-timber forest products was more prominent in occasionally visited areas. The trampling impact on soil, Aesthetic disturbances and weed species was also frequently noted, indicating a degree of high level of intervention by visitors to the site. Significant relationships were found between disturbance factors and most of the diversity and structural attributes associated with the surrounding habitat (Table 6).

Soil Physical and Chemical Properties

Determination of soil physicochemical properties with the following soil parameters viz., Soil moisture content (%), bulk density, pH, organic carbon percent (SOC %) and soil organic carbon stock (SOC stock. The result obtained for the study sites are illustrated in Table 5. The present study summarized the result based on the selected two different categories of land use. In terms of soil quality soil pH slightly varies from low disturb areas to frequently visited forest areas to with a range of 5.25–5.62 and 5.22–5.40 was recorded in low and frequently visited forest areas respectively at various soil depth which showed the acidic nature of the soil.

Table 3: *Vegetation structure across all plots in two different designated areas of Unakoti forest ecosystem (± SEM, n=12).*

Stand Category	Occasionally visited forest sites	Frequently visited forest sites	F-value	*p*-value
Total no. of trees	87.00±0.42	50.00±1.10	99.62	<0.001
Mean trees/plot	29.00±0.51	16.67±0.33	287.73	<0.001
Tree density ha^{-1}	290.00±4.48	166.67±10.85	100.92	<0.001
Basal area (m^2 ha^{-1})	22.37±1.78	9.90±0.69	43.06	<0.001
Mean height (m)	11.82±0.49	12.13±0.44	0.46	>0.05
Biomass (Mg ha^{-1})	104.28±7.36	47.99±3.34	52.30	<0.001
Carbon (Mg ha^{-1})	52.14±3.68	23.99±1.67	52.30	<0.001

Table 4: *Qualitative assessment of disturbances due to tourism traffic and disturbances made by forest fringe communities in Unakoti forest ecosystem of Tripura.*

Stand category	Plot Id	No. of visitors per year	Water pollution	Trampling impact on Vegetation	Trampling impact on Soil	Land encroachment	Solid waste	Forest Resource Extraction	Traces of Fire	Introduction of exotic species	Aesthetic disturbances
Occasionally visited forest sites	1	2	2	2	3	2	1	4	2	2	1
	2	1	2	2	2	1	1	4	2	1	2
	3	2	1	1	2	2	2	3	1	1	1
	4	2	1	2	2	2	1	3	1	1	2
	5	1	1	2	3	2	1	4	1	1	3
	6	2	1	3	2	1	1	2	1	1	2
	Mean	1.67	1.33	2.00	2.33	1.67	1.17	3.33	1.33	1.17	1.83
Frequently visited forest sites	1	4	3	4	4	4	3	2	2	3	4
	2	4	3	3	4	3	4	1	2	3	4
	3	3	2	4	3	4	3	1	2	2	4
	4	4	4	4	4	4	4	1	1	3	4
	5	4	4	4	4	2	3	2	1	3	3
	6	4	2	4	3	3	2	1	2	2	2
	Mean	3.83	3.00	3.83	3.67	3.33	3.17	1.33	1.67	2.33	3.50

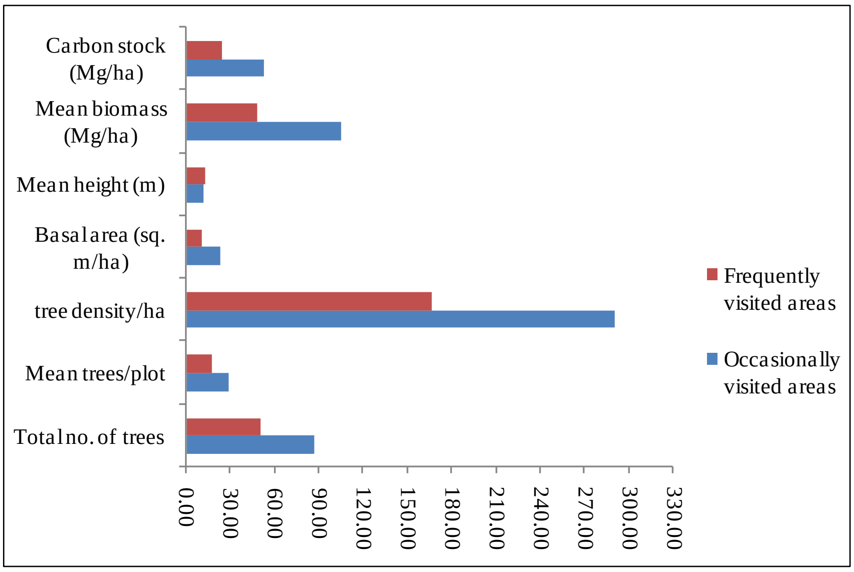

Fig. 2: *Graphical comparison of stand structural parameters of occasionally visited and frequently visited forest areas.*

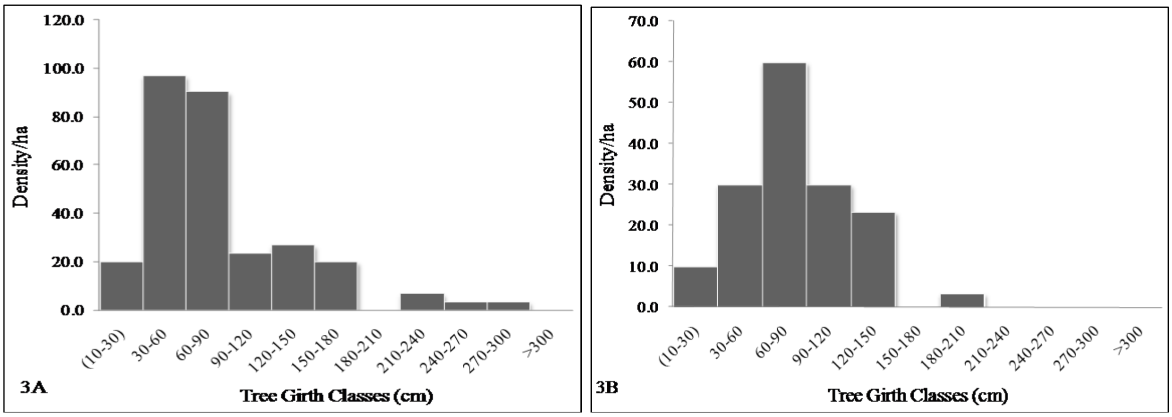

Fig. 3: *Girth class distribution of tree density in occasionally visited areas (3A) and frequently disturbed areas (3B) of Unakoti forest ecosystem.*

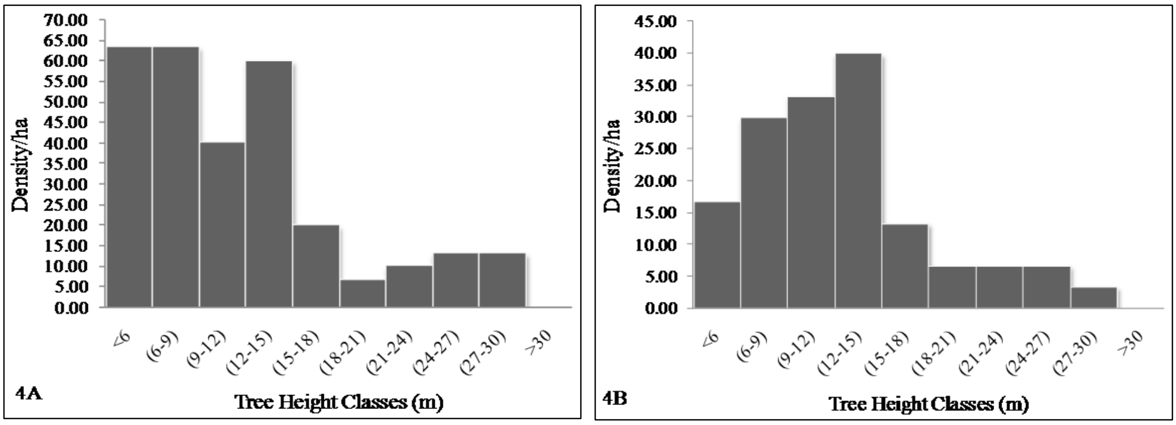

Fig. 4: *Height class distribution of tree density in occasionally visited areas (4A) and frequently disturbed areas (4B) of Unakoti forest ecosystem.*

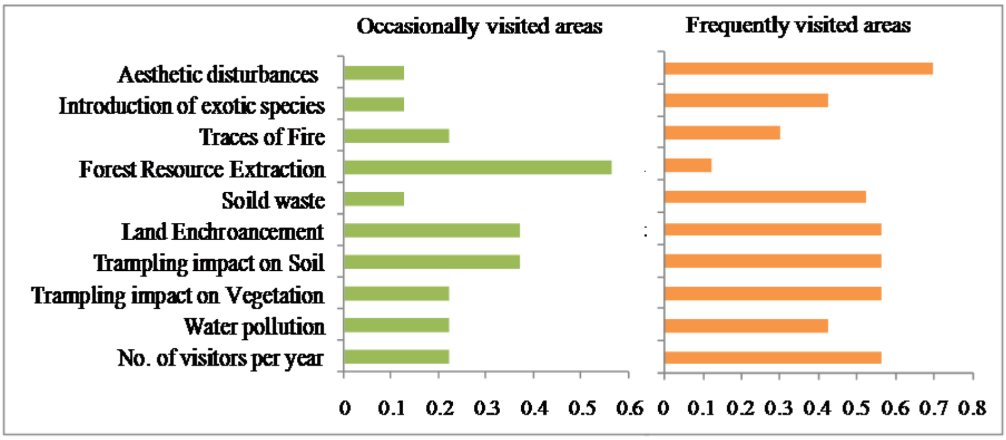

Fig. 5: *Log converted score value of tourism impacts in occasionally visited and frequently visited forest areas.*

Fig. 6: *(A) Mosaic of surrounding vegetation, (B) Archaeological features of the study site, (C) Scenic landscape of the study site, (D) a part of frequently visited forest areas, (E) illegal logging in the frequently visited areas, (F–G) water resources, (H) occasionally visited forest areas (moist deciduous and secondary mixed forest) of the surrounding forest ecosystem s of Unakoti, Tripura, North-East India.*

Table 5: *Soil edaphic properties, soil organic carbon (%) and SOC stock in Mg ha^{-1} (Mean±S.E) of different designated areas of Unakoti forest ecosystem of Tripura under present study.*

Site Id	Soil depth (cm)	pH	Moisture Content	BD (g/cm^3)	SOC %	SOC Stock (Mg ha^{-1})
Occasionally visited forest sites	0–10	5.62±0.28	15.49±0.56	1.30±0.11	1.41±0.19	117.78±2.42
	10–20	5.25±0.19	17.65±0.5	1.39±0.3	1.29±0.09	
	20–30	5.48±0.38	16.26±0.82	1.40±0.27	1.10±0.5	
Frequently visited forest sites	0–10	5.40±0.24	12.34±0.37	1.56±0.22	0.98±0.4	112.23±2.94
	10–20	5.22±0.05	13.75±0.83	1.48±0.34	0.74±0.6	
	20–30	5.23±0.17	15.49±0.39	1.55±0.02	0.62±0.04	

The moisture content of the soil was found to be higher in occasionally visited areas (15.49–17.09%) compared to frequently visited forest areas (12.34–15.49 %). SOC % and SOC stock showed a definite pattern of distribution at a specified depth as SOC % was higher in occasionally visited areas (1.10–1.41) compared to frequently visited forest areas (0.62–0.98). The soil carbon stock exhibits considerable special variability, both horizontally according to land use and vertically within the soil profile.

DISCUSSIONS

Tourism and Impact on Surrounding Ecosystem

Forest diversity declined with increasing disturbance [54]. Disturbed stands showed low equitability or high dominance and the undisturbed stand exhibited high equitability or low dominance [55**]**. Significant relationships were found between frequently and occasionally disturbed sites along tourist disturbance gradient. Disturbance typically affects the diversity and structural attributes [33, 34**].** The numbers of species, diversity index, stem density, above ground tree biomass declined significantly as the disturbances increased in frequently visited forest sites whereas positive correlation with no effects on diversity indices and stand structural were found in occasionally disturbed sites. The effect of disturbance on species dominance (F=70.20, $p<0.001$) and evenness (F=0.33, $p>0.05$) was found to be very minute as a reduction of species abundance is a common trend in much ecological disturbance analysis [55, 56**]**. In occasionally disturbed areas a close relationship was only found between stand density and disturbances (R^2 = 0.53, $p>0.05$) (Table 6). On the other hand, the significant relationship of disturbance with species richness (R^2 = 0.66, p=0.05) and biomass stock (R^2 = 0.71, $p<0.05$) was found with positive effects (Table **7**). Since disturbance parameters did not cause any significant effects on the tree stem density in frequently disturbed areas. A close association was found between tree biomass and tree density ha^{-1} and it can be presumed that homogeneity in species composition along with their diameter class distribution is the key determinant of enhanced productivity. The correlation analysis along regression coefficient showed that the species richness and above ground tree biomass were positively associated with visitor disturbance factors. Forest resource extraction and Forest degradation by forest fringe communities is quite an evident by leaving the low level of growing stock inside the forest. The livelihood of the people living close to forest extremely linked to the forest ecosystem and depends on the forest for a variety of forest products can potentially degrade forest if harvested unsustainably which is reported from many studies [18, 19**]**.

Decreasing total density and basal area with increasing disturbance intensity were also found by other workers [30, 32**]**. Forests adjacent to villages are frequently visited for firewood and timber collection and are considered as intensively logged forest rather RF or PF. The relationship between these variables is negative, which indicates that as hydrogen and porosity increase, strength decreases. In most cases, the relationship is obscured by the large variability in environmental conditions among the study plots and by the lack of standardized sampling techniques [57]. However, analyses concerning the relationship between species diversity and productivity in forest ecosystems produced ambiguous results [58]. In this study, the ongoing disturbance intensities were correlated with diversity indices and stand structural variable at the plot scale as also reported in some other studies [59]. Severe disturbances reduced total species diversity in the dry forest [60, 61]. However the present reserve forest part has been experiencing disturbance due to tourism traffic for many years, the level of disturbance was evidently not severe enough to result in a decline in diversity and situation needs more research and long-term monitoring [34].

This is under-mentioned that present study area is an archaeologically important site and a potential tourism is alarming at a considerable rate which further leaving a number of drastic effects which is leading to the gradual disappearance of natural beauty due to lacking management perspectives. Tourism developments based on carrying capacity and sustainable development may become relevant in this scenario for proper management of natural resources so that the present as well as future generations may enjoy nature's beauty, and thereby enhance tourist flows and revenues. Sustainable tourism development meets the needs of present tourists and host regions while protecting and enhancing the opportunity for the future. It is envisaged as leading to management of all resources in such a way that economic, social and aesthetic needs can be fulfilled while maintaining cultural integrity, essential ecological processes and biological diversity and life support systems' [62].

Our present synthesis revealed a positive relationship between tourism traffic and associated forest degradation. Aesthetic disturbances i.e., scenic landscape and interesting ecosystems were encountered by visitors due to random climbing and movement on site's rock-cut features is leaving drastic effects which may lead to the permanent damage of the sculpture or associated area of interest. Deposition of solid waste in the areas where a high concentration of tourist activities generates a high amount of solid. Solid waste disposal is a serious problem and improper disposal can be a major despoiler of the natural environment, adjacent stream, scenic areas, and roadsides. Solid waste and littering can degrade the physical appearance of the water [15]. Tourism also contributes to habitat loss and fragmentation via its ecological footprint in terms of resource requirements and pollution and waste [16]. Furthermore, anthropogenic pressures due to forest encroachment of land causing shrinkage of forest resources, deforestation, and forest degradation [21] and due to this deforestation and biodiversity loss became a common event [20]. A large no. of people including forest-dwelling communities is responsible for this. In many of the cases, encroachers are involved directly by occupying

***Table 6:** Regression coefficients of stand structural variables and visitors impact factors of occasionally disturbed areas.*

Parameters		Coefficient	Std.err.	t-value	p-value	R^2
Species richness	Constant	1.46	0.05	29.79	0.00	
	Visitors impact factors	0.35	0.23	1.54	0.19	0.37
Tree density ha^{-1}	Constant	**2.42**	**0.02**	**134.84**	**0.00**	
	Visitors impact factors	**0.18**	**0.08**	**2.11**	**0.10**	**0.53**
Above ground biomass (Mg ha^{-1})	Constant	2.03	0.02	91.06	0.00	
	Visitors impact factors	0.15	0.10	1.47	0.22	0.35

***Table 7:** Regression coefficients of stand structural variables and visitors impact factors of frequently disturbed areas.*

Parameters		Coefficient	Std.err.	t-value	p-value	R^2
Species richness	Constant	**0.83**	**0.14**	**6.00**	**0.00**	
	Visitors impact factors	**0.75**	**0.27**	**2.76**	**0.05**	**0.66**
Tree density ha^{-1}	Constant	2.50	0.67	3.75	0.02	
	Visitors impact factors	-0.70	1.31	-0.53	0.62	0.07
Above ground biomass (Mg ha^{-1})	Constant	**0.80**	**0.28**	**2.82**	**0.05**	
	Visitors impact factors	**1.76**	**0.56**	**3.14**	**0.03**	**0.71**

the land inside dense forest before the land is utilized for agricultural practices or clear felling activities. Fuel wood gathering is often concentrated in tropical dry forests and degraded forest areas [63]. We also encountered diversity and ecological corridors which are along streams are somewhere inaccessible for most of the species due to pollution which is the result of tourism pressure and water flown along the area.

Diversity along a Disturbance Gradient

In the present study, a general comparison of forest structural variable along disturbance gradient especially control by the regular visitors within an archaeological tourist site surrounded by natural vegetation. The study also compared forest biomass and carbon under two categories of selected forest habitat. The current level of disturbance intensities created by tourists was correlated with forest diversity and structural variable at the plot scale as also reported by Majumdar *et al*. **[**35]. In general, increasing disturbance intensity can eliminate many species and trees for timber, firewood, food, and other resources required by villagers residing in and around the forests. The study revealed that the number of tree species ($F = 86.174$, $p < 0.001$), genus ($F = 216.13$, $p < 0.001$) and families ($F = 24.14$, $p < 0.05$) was significantly reduced following a high level of disturbance. Removal of tree species due to infrastructure development and clear felling of trees may significantly have reduced the diversity of the major plant groups or families. The disturbances created by the tourist reduced plant diversity, which may be due to the differences in the disturbance force driven by the visitors between frequently visited and occasionally visited forest sites. Disturbance effects on the indices of overall species diversity ($F = 22.52$, $p < 0.001$) and dominance ($F = 70.20$, $p < 0.001$) further can be explained by the reduction or modification of suitable available habitats.

The comparison of present analysis with other similar studies may have been affected due to differences in sampling methodology, forest age, geographical, climatic, local biotic factors and anthropogenic disturbances into tourism development. Relatively low species diversity in frequently visited forest areas may be attributed to the forest management practice pattern where clear felling of tree species for infrastructure development and other associated activities was undertaken which further clearly reflects an ecological imbalance [46]. The present range of species richness was very less than the range (37–144) reported from Tripura state [64], 312 angiosperm plant species listed from tropical dry evergreen forests of peninsular India [**65**]; 449 angiosperm species from Nanmangalam Reserve Forest in Southern India [66]; 247 species from Kalakad-Mundanthurai Tiger Reserve of southern Western Ghats in India [67]; 241 tree species from five different forest types of North Andaman Islands [68]. The number of observed species, genus and families varied significantly between two stand categories and comparatively less habitat heterogeneity. The value of Shannon's diversity index is generally higher in tropical forests, reported as 5.06 and 5.40 for young and old stands respectively [69]. In Indian forests, it ranges from 0.83 to 4.1 [70]. Present mean value of Shannon's diversity index (3.23) was greater, whereas mean Shannon–Weiner Diversity index was recorded higher in relatively occasionally visited areas (2.87) ranged 2.58–3.21 and lower in frequently visited forest areas (1.98) ranged 1.79–2.17 which falls within an earlier reported range (0.04–0.30) in Tripura [64]. The range of dominance index reported for the tropical forest of India varies from 0.21 to 0.92. The present mean Simpson dominance index ranged 0.04–0.10 with a mean value of 0.07 in occasionally visited areas and ranged 0.13–0.19 with a mean value of 0.17 in frequently visited forest areas which were comparatively greater than the average value of dominance index in tropical forests of 0.06 [69]. It was also reported that the less disturbed has a high density of tree species due to restricted access to humans [32]. However, in the present study mean Pielou's evenness index for occasionally visited areas ranged 0.77–0.94 with a mean value of 0.87 comparatively higher than the value of 0.84 in frequently visited forest areas indicated less variation in species composition and number within the communities. Reduction of species abundance is a common trend in much ecological disturbance analysis [56]. Although the dominance of certain individual taxa can increase following disturbance, the total diversity of the community is typically reduced

[55]. It was also reported that disturbance may have enhanced the abundance of some small tree species in logging gaps or forest openings, whereby they regenerated aggressively by sucker growth [31, 71] which may ultimately increase the overall dominance index.

Differences in Forest Structure along Disturbance

It is an established that the biomass is a function of tree density, height and basal area at any given location. These parameters contribute to the above-ground biomass which differs with site, habitat, forest successional stage, the composition of the forest, species variability and varying tree density *etc*. [72]. Our results clearly suggested that at frequently visited forest areas, tree density was less than occasionally visited areas. Stand density decreased with increasing girth and height class intervals which is a typical characteristic of the tropical forest ecosystem [73]. Effect of disturbance on tree population structure was compared using girth class distribution. It was clearly found that in occasionally visited areas stand density along different girth class category, however, did not show typical reverse J-shaped distribution as observed in the natural forest [30, 35] and an indicator of changes in population structure and species composition [74]. This obviously leads to increased variability in tree species sizes and irregular tree diameter distribution. Disturbance also resulted in adverse effects on overall forest structure as stem density and basal area were reduced significantly under severe anthropogenic pressure and significantly less in frequently visited forest areas as compared to occasionally visited forest areas. Decreasing total density and basal area with increasing disturbance intensity were also reported by other workers [30, 32]. The low basal area in the disturbed forest may be explained by the removal of large trees of value as timber. On the other hand, tree numbers were very low in the larger girth class (>150 cm) in frequently visited forest areas which suggests the clear felling of the larger trees of high commercial value.

Biomass Allocation and Carbon Stock

Forest lands sequester CO_2 in larger quantities and for longer periods of time than many other land uses. Converting agricultural, developed, or degraded land to the forest can increase the amount of carbon sequestered. Re-establishing trees on the previous forestland is a specific type of management. The effect of disturbance on the capacity of the forest fragments to sink carbon varied significantly between different forest fragments. Natural disturbance and logging exert a stronger influence on forest carbon stocks. Moreover, it has been found that under low natural mortality, forest-wide total ecosystem carbon stocks increased between 0% and 40% when planned harvests were implemented; however, carbon stocks decreased with greater harvest levels (>40%) and elevated disturbance rates [75]. Areas close to the tourist spot has very low carbon stock compared to the forest situated in remote areas. This may due to the changes in forest composition and structure during the disturbance, occurred at very different rates; and biomass generally recovers more rapidly than species richness [76]. Aboveground biomass and carbon stock increased with the increase in tree girth.

Soil Analysis

In a natural ecosystem, soil plays a very important role in regulating the environment. Soil organic matter is a key attribute which influences soil's capacity to support ecosystem services. The differences in soil organic carbon (SOC) stock is mainly influenced by land use types, this suggests that differential use of forest land have a fundamental difference in net primary productivity and carbon cycling processes. In terms of SOC stock present study did not follow a definite pattern of soil organic carbon % and SOC stock distribution. It may be due to overexploitation of forest resources and forest land encroachment soil carbon reduces faster [77]. However present study is comparable with the findings of Singh *et al*. [78] in tropical moist deciduous forest of Mizoram who reported SOC stock of 82.1–134.1 Mg ha^{-1} and also comparable with the reported SOC stock range of 31.0 – 62.90 Mg ha^{-1} in the top 30 cm depth depending upon the tree density and age of the standing tree [79]. As the forest ages the organic matter deposition as a result of litterfall and along with the reduced soil disturbance the soil switches from losing carbon to beginning to sequester carbon [80] and the estimation of SOC stock in two different management categories is relatively small effort of understanding the carbon stock potential of the study area which was 52.14 Mg ha^{-1} and 23.99 Mg ha^{-1} in low and frequently visited forest areas respectively. Soil organic carbon sequestration potential of primary and secondary forests in Northeast India studied by Vashum *et al*. **[**81**]** revealed that the mean SOC was found to be much higher in both upper (0–15 cm) and lower (15–30 cm) layer of the primary forest (5.25% and 3.12%) than the secondary forest (2.97% and 1.88%) respectively.

CONCLUSION

Present study assigned several factors to assess the impacts resulted from tourism traffic on fragile forest ecosystem surrounding the Archaeological site Unakoti of the State Tripura and preliminary study indicated the intensity of impacts whether positive or negative which may lead to poststructural changes in diversity indices and forest structural attributes and biodiversity maintenance at a local level in some instances. It was also found that low and heavily disturbed sites had a high rate of species regeneration which if well protected could lead to the recovery of these sites and restore the ecological integrity of the forest fragments to effectively provide ecosystem services including carbon sequestration. The global picture is one in which tourism, like many other industries that have a large ecological footprint and lead to clearance of natural areas, is not necessarily a net contributor to biodiversity conservation [82]. Respecting and enhancing the historic heritage, authentic culture, traditions and distinctiveness of host communities, with maintaining and enhancing the quality of landscapes, both urban and rural, and avoiding the physical and visual degradation of the environment are also to be considered. Therefore further studies at a more micro scale are needed to assess the effect of disturbance on diversity and structure at the level of such forest ecosystem.

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