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RESEARCH ARTICLE

Phytosociological study and NDVI analysis of plant community along the Chessa River Bank on the Assam-Arunachal Pradesh Border

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Abstract

Phytosociology is the study of the composition, structure, and relationships within plant communities. This study represents a phytosociological assessment of herbaceous and shrub communities in the foothills of river bank Chessa river, on the borderline between Assam and Arunachal Pradesh. A total of five sites had been selected to survey along the bank of Chessa River, covering approximately 3 sq.km. Phytosociological data were collected during the period 2023 - 2024 using standard quadrat sampling methods. A total of 41 plant species were identified, and various ecological parameters including density, frequency, dominance, and diversity indices were calculated to assess the population structure and plant diversity of the herbaceous and shrub communities. The results reveal significant variations in species composition, abundance, and diversity among the study sites. Site 3 emerged as the most diverse, hosting the highest number of species and individuals, while Site 4 exhibited the lowest levels of plant diversity. The Importance Value Index (IVI) highlighted the ecological importance of certain species within each community. The findings underscore the importance of comprehensive plant diversity assessments and targeted conservation efforts to preserve plant diversity in the study area. The NDVI values obtained for the study area, ranging from 0.31 to 0.14, suggest a landscape characterized by sparse to moderate vegetation. Specifically, an NDVI value of 0.31 is indicative of areas with low to moderate vegetation cover, such as grasslands, crops.

Keywords: Phytosociology; Herbaceous Communities; Shrub Communities; Plant Diversity Assessment; Chessa River Bank; NDVI.

1. Introduction

Phytosociology refers to the study of plant communities and their ecological relationships (Rao, 2015). Phytosociological studies play a vital role in analyzing species diversity, and population dynamics, and evaluating the ecological condition of various species within a particular plant community (Rashid et al., 2023). In recent years, changes in species diversity along environmental gradients have emerged as a key area of focus in ecological research. These variations are often explained by factors such as productivity, climate, habitat diversity, and interactions between species. (Willig et al, 2003). Arunachal Pradesh and the Northeastern States of India exemplify mega hotspots, boasting a remarkable diversity of flora and fauna (Taro, 2021). Takhtajan considered the Northeastern part is as the primary center of origin of the Angiosperm and named it the 'Cradle of angiosperm'. The significance of these regions extends beyond their intrinsic biodiversity value, as they serve as living laboratories for understanding ecological processes and evolutionary dynamics. The northeastern part of India possesses a heterogenic geomorphology with a varied and conducive climate that provides a luxuriant growth of vegetation diversity with richness of endemic species and seasonal variation (Roy et al., 2015). In order to sustain ecosystem services like pollination, water purification, nutrient cycling, and other processes vital to human health and well-being, biodiversity is crucial. (Schulz et al., 2010).With the onset of climate change and the proliferation of invasive species, alongside significant alterations in land use patterns, ecosystems worldwide are grappling with unprecedented challenges (Sala, 2000). These challenges not only threaten the delicate balance of ecosystems but also jeopardize the intricate web of life that sustains biodiversity and ecosystem services essential for human health hazards (Pott, 2016). The role of the herbaceous plant canopy in shaping plant diversity and nutrient cycling within forest ecosystems represents a significant knowledge gap (Stefanowicz et al., 2021). Addressing these knowledge gaps and expanding our understanding of ecosystem dynamics is essential for devising effective conservation strategies and mitigating the adverse impacts of global environmental changes.

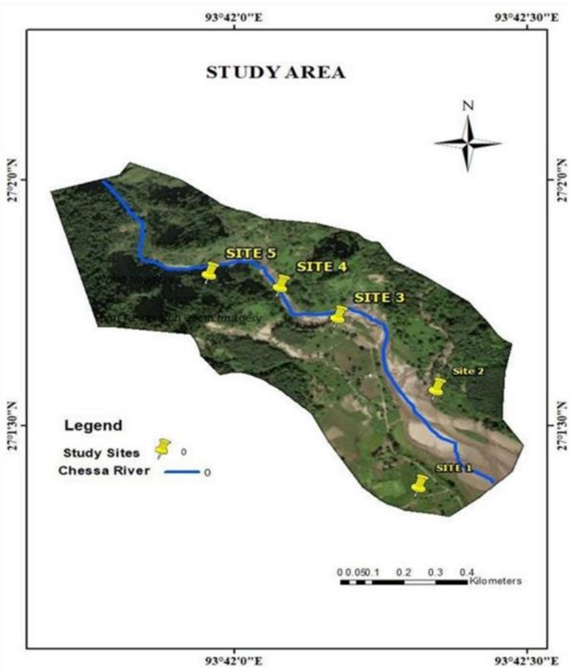

Figure 1. Map of study site – Chessa River Bank.

The present study encompasses the ecological composition, structure, and distribution of plant species. Hence, phytosociological studies provide valuable insights into the mechanisms driving ecosystem resilience and adaptation to environmental change. The primary aim of the study is to develop a phytosociological impact of herbaceous composition and dynamics to better understand its role in maintaining ecosystem stability. The study area encompassed the diverse ecosystems flanking both sides of the Chessa River of Arunachal Pradesh towards Assam. To achieve this objective, the study employed a multifaceted approach, encompassing the assessment of species richness, stand population structure, density, frequency, abundance, and the relationship between species. So this study mainly achieved two objectives. Firstly, it investigates herbaceous and shrub plants' phytosociology and diversity along the Chessa River. Secondly, it explores the analysis NDVI (Normalised Difference Vegetation Index) using the Landsat 9 Satellite imagery of the study area.

Table 1. Geographical locations of the selected study sites along the Chessa River bank.

Study site	Latitude	Longitude
S1	27° 1'20.17"N	93°42'24.07"E
S2	27° 1'29.62"N	93°42'16.20"E
S3	27° 1'40.65"N	93°42'13.99"E
S4	27° 1'43.84"N	93°42'7.15"E
S5	27° 1'47.94"N	93°42'4.18"E

2. Material and method

2.1. Study site

Chessa (Sessa) is a significant place situated in between Assam and foothills of Arunachal Pradesh that possess a holistic natural scenario in aspect to tourist activities. The Chessa River is a small stream flowing from the hilly regions of Arunachal Pradesh to downstream areas of Assam. The climate of the study area is subtropical, characterized by hot and humid summers and mild winters. Monsoon rains typically occur from June to September, bringing heavy rainfall and contributing to the region's lush vegetation. The climate in this region is distinguished by warm summers and frigid winters. The mean annual precipitation varies from 1960 to 3450 mm. A total 5 sites are selected on both sides of the Chessa River for phytosociological data collection (Figure 1). Table 1 shows the geographical locations of the selected study sites.

2.2. Phytosociological and plant diversity study

Analysis of phytosociological studies of herbs and shrubs community were carried out during the period of February 2023-March-2024 to cover all spectrum of vegetation in both side of the Chessa River. The entire study area is about 3 sq.km and a total of 5 sites are selected for convenience of the study area. In each plot 10 quadrats of 1m x 1m were selected. Thus total 50 quadrats were studied for population analysis to assess species richness, population structure, density, frequency, abundance, and the relationship between species and girth class. The current study stratifies the herbaceous vegetation and their role in maintaining ecosystems sustainability. The phytosociological analysis is carried out to understand vegetation features and to evaluate the species richness and variety that exist in the study region; standard methods have been implemented to analyze the density, frequency, abundance, IVI (Importance Value Index). The plants were identified using prior knowledge and reference materials (Kanjilal Herbarium, Shilong; Madhabdev University Herbarium, Narayanpur, Assam, along with referring Flora of Assam).

2.2.1. Phytosociological analysis

Density, Frequency, Abundance, and Basal area, were calculated as per Haruna et al., (2018) protocol.

$$\text{Density}=\frac{Total\ number\ of\ Individuals\ in\ all\ sampling\ units}{Total\ number\ of\ sampling\ units\ studied}$$

$$\text{Frequency} =\frac{Number\ of\ sampling\ units\ in\ which\ species\ occur}{Total\ number\ of\ sampling\ units\ studied}$$

$$\text{Abundance}=\frac{Total\ No.of\ individuals\ of\ species\ in\ all\ quadrats}{Total\ No.of\ quadrats\ in\ which\ the\ species\ occurred}$$

IVI is calculated by following method (Murthy et al., 2016).

IVI=Relative Density+ Relative Frequency+ Relative Abundance

$$\text{Relative Density}=\frac{Density\ of\ the\ species\ \times 100}{Total\ density\ of\ all\ the\ species}$$

$$\text{Relative frequency}=\frac{Frequency\ of\ all\ the\ species\times 100}{Total\ frequency\ of\ all\ the\ species}$$

$$\text{Relative Abundance}=\frac{Abundance\ of\ a\ species\ x\ 100}{Total\ Abundance}$$

2.2.2. Diversity analysis

Biodiversity indices are used to measure different characteristics of biological community and ecosystem evenness. The Shannon Diversity Index (Shannon, 1948) takes into account both species abundance and evenness to reflect ecosystem complexity, whereas the Simpson Dominance Index (Simpson, 1949) evaluates the probability that two randomly chosen individuals belong to the same species, suggesting dominance levels. The Menhinick Index (Menhinick, 1964) links species richness to sample size, while evenness (Smith and Wilson, 1996) evaluates how uniformly species are distributed. The Margalef Index (Margalef, 1958) highlights biodiversity by evaluating species richness based on the number of species and individuals, while Equitability (Pielou, 1966) shows how equally species are distributed, providing information about community balance. These indices used together offer a thorough understanding of the diversity and health of ecosystems.

2.3. NDVI Analysis

NDVI is calculated using the following formula (Landsat 9):

$$\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}$$

$$\text{NDVI} = \frac{(\text{Band 5} - \text{Band 4})}{(\text{Band 5} + \text{Band 4})}$$

Table 2. Information of acquired Landsat satellite images

Date of data Acquired	Spacecraft ID/ Sensor	Data type	Path	Row	Projection	Datum	UTM Zone	Spatial Resolution
18.04.2023	Landsat 9	OLI	135	41	UTM	WGS84	46	30 m

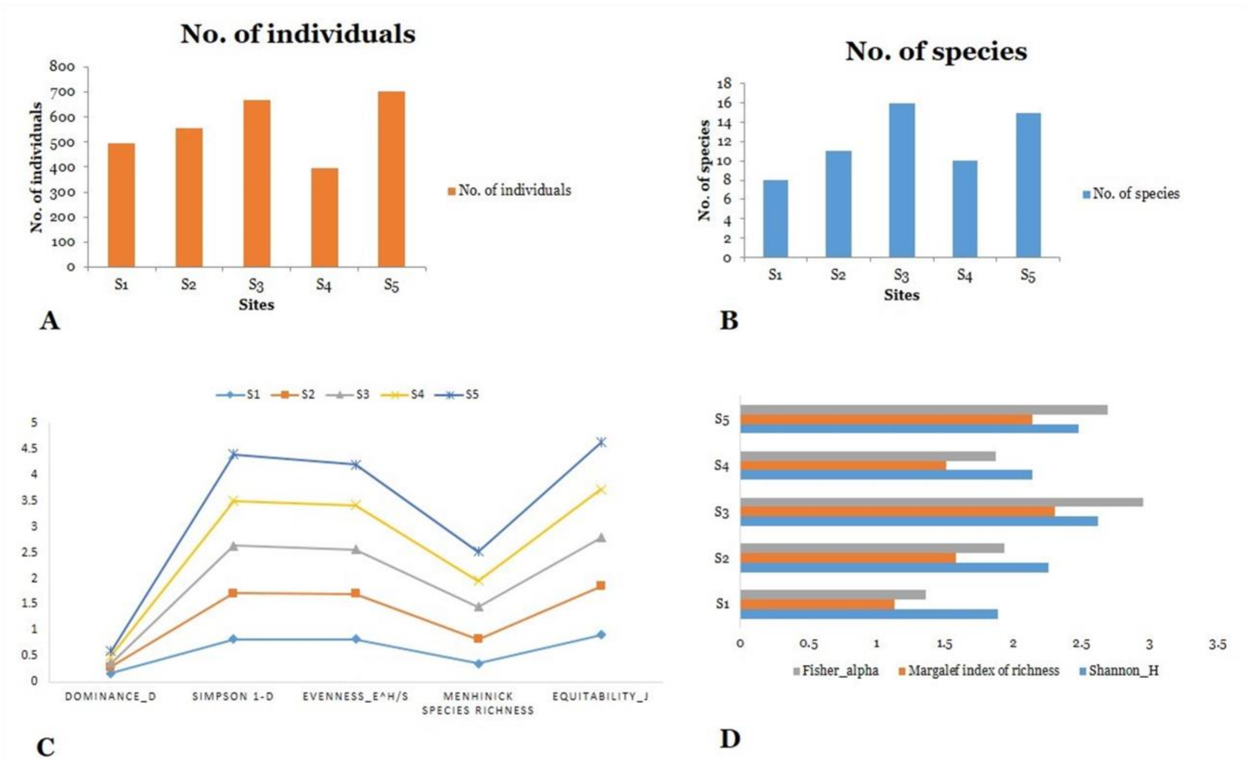

Figure 2. (A) Number of individual of herbaceous species in Chessa River Bank. (B) Number of herbaceous species in Chessa River Bank. (C) Biodiversity indices of herbaceous species in five different sites of Chessa River Bank. (D) Shannon H, Margalef index of richness and Fisher alpha of herbaceous species in five different sites of Chessa River Bank.

This specific index is the most widely used vegetation index for analyzing global greenery. The NDVI scale ranges from -1 to +1, with higher values indicating denser vegetation.

Landsat 9 satellite images were downloaded from USGS Earth Explorer to examine NDVI. The features of satellite pictures are mentioned in the Table 2.

2.4. Data and Statistical analysis

Preliminary statistical analysis was performed using MS Excel. Biodiversity Assessment for plant species was analysed in Past software (Version-0.3). NDVI Analysis was performed in ArcGIS 10.8.

3. Results

A total of 41 plant species were identified from the study sites, and for each site, Density, Frequency, Dominance, and IVI were calculated differently. The dataset encompasses a diverse range of plant species, each with its frequency of occurrence across the sites. Table 3 provides an overview of plant species distribution across five sites (S1 to S5), showing notable variation in species presence and abundance. Sites S1 and S3 have higher species counts and total individual counts, with plants like *Lantana camara*, *Axonopus compressus*, and *Oxalis acetosella* being particularly abundant across multiple sites. Site S3 has the highest number of individuals (1160), followed by S5 (1050) and S2 (940), indicating that these sites support a larger population of diverse plant species. Some species, such as *Cyperus rotundus* and *Mimosa pudica*, are abundant but more site-specific, showing limited presence across all sites (Table 3). This data highlights significant site-based variability in plant abundance and diversity across the assessed areas.

3.1. Biodiversity Assessment for herbaceous species

The biodiversity assessment in Figure 2(A-D) highlights variation in herbaceous species diversity across five sites, labeled S1 to S5. Site S3 consistently emerges as the most diverse, with the highest number of species (16) and individuals (667) (Figure 2(A) and Figure 2(B)). This site has the lowest dominance value (0.08), indicating a balanced distribution of species, and a high Simpson's Index value (0.92), reflecting a rich and varied community. The Shannon Diversity Index further supports this, showing S3 with the highest value (2.62), and thus the highest overall species diversity among the sites. Site S3 also scores highest on both the Menhinick and Margalef indices, which measure species richness, and has a notable Fisher's Alpha value of 2.95, (Figure 2(D)) reinforcing its richness and ecological stability.

In contrast, Site S1 exhibits the lowest diversity, with only 8 species and a dominance value of 0.17, suggesting a concentration of fewer species. Its Simpson's Index (0.83) and Shannon diversity index (1.89) are also the lowest among the sites, indicating limited diversity and species richness. The evenness values (e^H/S) across sites remain relatively high, from 0.79 to 0.87, suggesting a fairly even spread of species in each area. Equitability (J) values are similarly high across the sites, indicating that species in all sites are relatively equally abundant, though slight variations exist (Figure 2(C)).

Overall, Site S3 stands out for its biodiversity, high evenness, and low dominance, indicating a well-balanced ecosystem, while Site S1 reflects a lower diversity and higher dominance, pointing to a more concentrated and less varied community of species. This analysis underscores the ecological value of Site S3, making it the richest and most balanced site among those assessed.

3.2. Biodiversity assessment for shrub species

The data in Figures 3 (A-C) provides a biodiversity assessment of shrub species across five sites (S1 to S5). Site S3 stands out as the most diverse, with 10 species and 493 individual plants, indicating high species richness and abundance (Figure 3(A) and Figure 3(B)). Its dominance value (0.13) is the lowest among all sites, suggesting an even distribution of species, and it has the highest Simpson's Index value (0.87), reflecting high biodiversity. The Shannon Index for Site S3 (2.13) further confirms its rich species diversity. Both the Menhinick (0.45) and Margalef (1.45) indices,

Table 3. Name of plants with number of individuals.

Sl. No	Name of the Plants	S1	S2	S3	S4	S5
1	*Acmella paniculata*	43	0	0	0	0
2	*Ambrosia cordifolia*	0	0	0	0	26
3	*Axonopus compressus*	72	0	79	0	143
4	*Bidens pilosa*	10	0	0	0	44
5	*Carex carnua*	0	0	34	0	68
6	*Cassia tora*	0	0	36	0	41
7	*Clerodendrum infortunatum*	0	0	38	0	5
8	*Colocasia esculenta*	0	0	27	0	29
9	*Cyperus brevifolius*	0	0	0	0	59
10	*Cyperus compressus*	0	0	0	0	13
11	*Cyperus corymbosus*	0	68	0	0	0
12	*Cyperus difformis*	0	75	55	86	0
13	*Cyperus rotundus*	81	80	60	0	0
14	*Cyrtococcum patens*	0	52	0	30	0
15	*Desmodium laburnifolium*	0	0	59	0	0
16	*Eleusine indica*	0	0	22	0	0
17	*Eupatorium odoratum*	60	0	12	0	0
18	*Heliotropium indicum*	0	0	54	0	0
19	*Imperata cylindrica*	0	0	77	0	0
20	*Lantana camara*	122	98	76	88	219
21	*Leersia hexandra*	0	0	8	11	0
22	*Leucas aspera*	0	0	0	0	14
23	*Melastoma malabathricum*	0	8	10	0	0
24	*Mimosa pudica*	0	134	104	74	97
25	*Murdannia nudiflora*	0	35	26	23	18
26	*Oldenlandia corymbosa*	0	32	0	0	0
27	*Oxalis acetosella*	149	39	79	54	73
28	*Pavetta indica*	0	14	65	0	0
29	*Peperomia pellucida*	0	27	24	59	23
30	*Phyllanthus niruri*	0	0	34	43	80
31	*Pleioblustus simonii*	0	0	19	0	0
32	*Persicaria macrantha*	57	0	16	0	0
33	*Pouzolzia zeylanica*	34	107	0	36	56
34	*Saccharum arundinaceum*	0	16	0	45	15
35	*Saccharum procerum*	0	25	28	8	27
36	*Scoparia dulcis*	48	0	65	0	0
37	*Sida acuta*	55	0	53	23	0
38	*Sida cordifolia*	0	25	0	14	0
39	*Solanum nigrum*	20	0	0	0	0
40	*Solanum torvum*	117	0	0	0	0
41	*Triumfetta rhomboidea*	0	105	0	20	0
Total		**868**	**940**	**1160**	**614**	**1050**

which measure species richness, are highest for Site S3, underscoring its ecological richness. Additionally, Site S3 has the highest Fisher's Alpha value (1.78), indicating greater diversity compared to other sites (Figure 3(C)).

On the other hand, Site S5 is the least diverse, with only four species and a high dominance value (0.48), implying that a few species dominate the site. Its Simpson's Index (0.52) and Shannon Index (0.90) are also the lowest, highlighting limited biodiversity. Evenness (e^H/S) and Equitability (J) values for Site S5 are also low (0.62 and 0.65, respectively), suggesting uneven species distribution.

Overall, Site S3 shows the highest biodiversity and most balanced species distribution among the study sites, while Site S5 has the lowest diversity and a less even spread of species. This pattern indicates that Site S3 supports a richer and more varied shrub community, whereas Site S5 has a limited variety of species with a few dominant ones.

3.3. Sorenson-Dice similarity index for herbaceous species

Sørensen-Dice similarity index values for herbaceous species between pairs of sites (S1 to S5), reflecting the degree of similarity in species composition between them (Table 4). Site S2 and S4 have the highest similarity (0.76), indicating that these sites share many species in common. Site S4 and S5 also show a relatively high similarity index of 0.56, suggesting moderate overlap in species composition. In contrast, S1 and S4 have the lowest similarity (0.22), highlighting significant differences in species diversity between these sites. Overall, the indices reveal varying levels of species overlap, with some sites sharing more common species, while others exhibit distinct plant communities.

Table 4. Sorenson-Dice similarity index for herbaceous species. *S1=Site-1, S2=Site-2, S3=Site-3, S4=Site-4 and S5=Site-5.

Site	S2	S3	S4	S5
S1	0.32	0.42	0.22	0.35
S2		0.44	0.76	0.46
S3			0.54	0.58
S4				0.56

3.4. Sorenson-Dice similarity index for shrub species

Table 5 presents the Sørensen-Dice similarity index for shrub species across five sites (S1 to S5), showing the degree of similarity in shrub species composition between site pairs. The highest similarity is observed between Sites S2 and S4, with an index of 0.73, indicating significant overlap in shrub species. Other site pairs, such as S3 and S4 (0.40) and S3 and S5 (0.43), exhibit moderate similarity, while pairs involving Site S1, such as S1 and S2 (0.18) and S1 and S5 (0.22), show low similarity, suggesting distinct species compositions. Overall, the data indicates that certain sites share more shrub species, while Site S1 is relatively unique in its shrub diversity compared to the other sites.

Table 5. Sorenson-Dice similarity index for shrub species. *S1=Site-1, S2=Site-2, S3=Site-3, S4=Site-4 and S5=Site-5.

	S 2	S3	S4	S5
S1	0.18	0.40	0.40	0.22
S2		0.50	0.73	0.40
S3			0.40	0.43
S4				0.44

Table 6. Ecological parameters of plant species of Chessa River Bank. *TNI=Total number of individuals, IVI=Importance Value Index and TBA=Total Basal Area

Name of the Plants	*TNI*	*Density*	*Relative density*	*Frequency*	*Relative frequency*	*Abundance*	*Relative abundance*	*TBA (m^2/ha)*	*IVI*
Acmella paniculata	43	0.86	0.928	8	0.978	10.75	0.928	0.0014	2.835
Ambrosia cordifolia	26	0.52	0.561	6	0.733	6.5	0.561	0.0004	1.856
Axonopus compressus	294	5.88	6.347	28	3.423	73.5	6.347	0.0023	16.117
Bidens pilosa	54	1.08	1.166	14	1.711	13.5	1.166	0.001	4.043
Carex carnua	102	2.04	2.202	18	2.2	25.5	2.202	0.0008	6.605
Cassia tora	77	1.54	1.662	16	1.956	19.25	1.662	0.0116	5.281
Clerodendrum infortunatum	43	0.86	0.928	10	1.222	10.75	0.928	0.0015	3.079
Colocasia esculenta	56	1.12	1.209	20	2.445	14	1.209	0.0116	4.863
Cyperus brevifolius	59	1.18	1.274	8	0.978	14.75	1.274	0.0008	3.525
Cyperus compressus	13	0.26	0.281	6	0.733	3.25	0.281	0.0002	1.295
Cyperus corymbosus	68	1.36	1.468	16	1.956	17	1.468	0.0004	4.892
Cyperus difformis	216	4.32	4.663	26	3.178	54	4.663	0.0008	12.505
Cyperus rotundus	221	4.42	4.771	26	3.178	55.25	4.771	0.0015	12.721
Cyrtococcum patens	82	1.64	1.77	18	2.2	20.5	1.77	0.0006	5.741
Desmodium laburnifolium	59	1.18	1.274	8	0.978	14.75	1.274	0.0008	3.525
Eleusine indica	22	0.44	0.475	8	0.978	5.5	0.475	0.0012	1.928
Eupatorium odoratum	72	1.44	1.554	18	2.2	18	1.554	0.0102	5.309
Heliotropium indicum	54	1.08	1.166	8	0.978	13.5	1.166	0.0027	3.31
Imperata cylindrical	77	1.54	1.662	12	1.467	19.25	1.662	0.0009	4.792
Lantana camara	603	12.06	13.018	86	10.513	150.75	13.018	0.0672	36.55
Leersia hexandra	19	0.38	0.41	12	1.467	4.75	0.41	0.0003	2.287
Leucas aspera	14	0.28	0.302	6	0.733	3.5	0.302	0.0011	1.338
Melastoma malabathricum	18	0.36	0.389	10	1.222	4.5	0.389	0.0015	2
Mimosa pudica	409	8.18	8.83	54	6.601	102.25	8.83	0.0205	24.261
Murdannia nudiflora	102	2.04	2.202	38	4.645	25.5	2.202	0.0028	9.05
Oldenlandia corymbosa	32	0.64	0.691	6	0.733	8	0.691	0.0001	2.115
Oxalis acetosella	394	7.88	8.506	48	5.868	98.5	8.506	0.0031	22.88
Pavetta indica	79	1.58	1.706	14	1.711	19.75	1.706	0.0011	5.123
Peperomia pellucida	133	2.66	2.871	18	2.2	33.25	2.871	0.0013	7.943
Phyllanthus niruri	157	3.14	3.389	30	3.667	39.25	3.389	0.0052	10.446
Pleioblastus simonii	19	0.38	0.41	6	0.733	4.75	0.41	0.0046	1.554
Persicaria macrantha	73	1.46	1.576	18	2.2	18.25	1.576	0.0046	5.352
Pouzolzia zeylanica	233	4.66	5.03	34	4.156	58.25	5.03	0.0086	14.217
Saccharum arundinaceum	76	1.52	1.641	24	2.934	19	1.641	0.0024	6.216
Saccharum procerum	88	1.76	1.9	28	3.423	22	1.9	0.0015	7.223
Scoparia dulcis	113	2.26	2.44	26	3.178	28.25	2.44	0.0022	8.058
Sida acuta	131	2.62	2.828	32	3.912	32.75	2.828	0.0041	9.568
Sida cordifolia	39	0.78	0.842	14	1.711	9.75	0.842	0.0007	3.395
Solanum nigrum	20	0.4	0.432	8	0.978	5	0.432	0.0006	1.842
Solanum torvum	117	2.34	2.526	10	1.222	29.25	2.526	0.0045	6.274
Triumfetta rhomboidea	125	2.5	2.699	22	2.689	31.25	2.699	0.0105	8.087

3.5. Ecological parameters of plant species of Chessa River Bank

Ecological parameters for plant species along the Chessa River bank, showing substantial variation in plant abundance and distribution (Table 6). *Lantana camara* emerges as the most dominant species with the highest total number of individuals (TNI = 603), density (12.06), and an Importance Value Index (IVI = 36.550), highlighting its significant presence and influence within the plant community. Other species with high density and IVI include *Mimosa pudica* (TNI = 409, IVI = 24.261) and *Oxalis acetosella* (TNI = 394, IVI = 22.880), indicating they are also highly abundant and ecologically important.

In contrast, species like *Leucas aspera* and *Cyperus compressus* have low values in terms of density, frequency, and abundance, suggesting limited presence along the river bank. These metrics reflect a community where a few species, such as *Lantana camara*

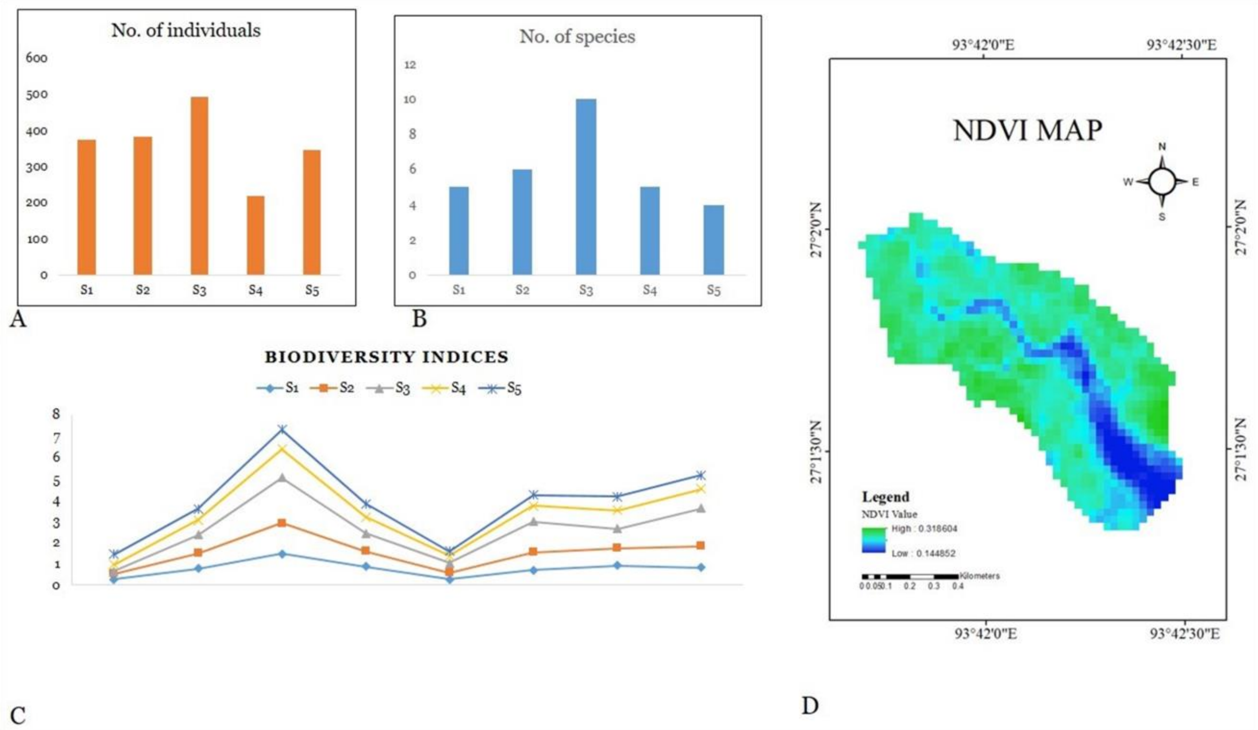

Figure 3. (A) Number of individuals of shrub species in Chessa River Bank. (B) Number of species of shrub species in Chessa River Bank. (C) Biodiversity indices of shrub species in five different sites of Chessa River Bank. (D) Normalized Difference Vegetation Index (NDVI), 2023

and *Mimosa pudica*, play dominant roles in structure and ecosystem function, while numerous other species have relatively minor impacts.

3.7. NDVI analysis

The NDVI results of the vegetation cover in the Chessa River area in 2023 is presented in Figure 3(D). NDVI values range from −1 to +1, with values closer to +1 indicating strong chlorophyll content and healthy vegetation, while values near −1 correspond to non-vegetative land covers. Areas with healthy vegetation are depicted in green, whereas non-vegetated areas are shown in blue [Figure 3(D)]. The green regions, representing vegetated areas, exhibit stronger near infrared spectral reflectance, signifying that most visible light is used for biomass production. This results in NDVI values between 0.31 and 0.14, representing areas with well-conditioned plants, high leaf biomass, canopy closure, and high chlorophyll content.

4. Discussion

Vegetation cover in ecosystems with low primary productivity is vital for offering services like climate regulation and water management (Millennium Ecosystem Assessment, 2005). Research has shown that shifts in species composition are causing notable changes in ecological processes (Joshi et al., 2024). Species interactions are fundamental to numerous ecosystem functions and processes, including nutrient cycling and food webs. These interactions can differ based on the evolutionary history and environmental conditions in which they take place (Lang and Benbow, 2013). In the study area, ecosystems are influenced by a wide range of factors, including climate, physiography, geology, and vegetation, which show significant variability.

Identifying and classifying distinct plant communities and variants correlated with soil type, the study enhances understanding of the ecological dynamics of a particular area. The provided table 01 indicates the abundance of various plant species across five different sites (S1 to S5). Site 3 stands out with the highest total abundance of plants, totalling 1,160 individuals, followed by Sites 5, 2, 1, and 4. Some species are exclusively found in specific sites, indicating habitat preferences or localized distribution patterns. For instance, *Acmella paniculata* is solely present in Site 1, while *Ambrosia cordifolia* is found only in Site 5. Additionally, certain species exhibit notable variations in abundance across sites, reflecting potential ecological preferences or responses to site-specific conditions. This pattern can be interpreted in several ways: one species might outcompete the other, or they may simply have different habitat preferences. The population density that a species can reach in a particular area is thought to reflect its tolerance to the environmental conditions specific to that location (Verberk, 2011).

The Biodiversity Assessment for herbaceous species [Figure 2 (A-D)] reveals varying degrees of diversity among the five sites (S1 to S5). Site 3 emerges as the most diverse, boasting the highest number of species and individuals, as well as elevated values across diversity indices such as Simpson, Shannon, and Evenness. Conversely, Site 4 exhibits the lowest diversity, with fewer species, individuals, and lower values across diversity indices. Site 1, 2, and 5 fall between these extremes, showcasing intermediate levels of diversity. This is due to small differences in the environment, various types and levels of species interactions, differences in local climate, or changes in soil conditions (Liu et al., 2019; Xu et al., 2000). Natural ecosystems can be influenced by various factors, including climate and soil characteristics. Additionally, topographic elements like altitude, slope, and orientation are likely to bring about notable shifts in climate, which in turn impact species composition (Onoszko et al., 2024).

The establishment of *Lantana camara*, demonstrates its strong competitive edge over other plant species. Perennial plants have the potential to release allelochemicals into the soil over time, which can gradually build up beneath the trees (Mallik, 1998). These variations likely stem from the combination of environmental factors, habitat characteristics, and human activities. The findings underscore the importance of considering multiple indices to comprehensively assess biodiversity and highlight the need for targeted conservation efforts to preserve herb diversity across different ecological settings.

The Biodiversity Assessment for shrubs [Figure 3 (A-C)] illustrates notable variations in species richness and ecological indices across the five surveyed sites (S1 to S5). Site 3 emerges as the most diverse, hosting the highest number of species and individuals, along with elevated values in diversity indices such as Simpson, Shannon, and Evenness. Conversely, Site 5 exhibits the lowest shrub diversity, characterized by fewer species and individuals, as well as lower values in diversity indices. Sites 1, 2, and 4 demonstrate intermediary levels of biodiversity. Vegetation distribution along altitude gradients is shaped by ecological factors like temperature, precipitation, and nutrient availability in the soil (Cheng, 1981). The findings underscore the importance of comprehensive biodiversity assessments and targeted conservation efforts to preserve shrubs diversity across various ecological settings, as these differences likely reflect diverse environmental conditions, including soil characteristics, microclimates, and anthropogenic influences across the surveyed sites. Topographic characteristics, including slope, aspect, and elevation, can influence local climate and soil conditions, which subsequently affect vegetation structure (Zhang et al., 2006; Zhang and Zhang, 2007; Zhang et al., 2013; Zhang et al., 2016). Soils with a higher sand content retain less water, leading plants to compete more intensely for soil moisture (Toledo et al., 2012).

A higher Shannon entropy, equitability, or evenness value indicates a more diverse or evenly distributed community or dataset (Shannon, 1948). Simpson's dominance index (Simpson, 1949) and its reciprocal form (Whittaker, 1972) are additional measures that help assess the concentration or dominance of individuals within a community. The Menhinick index is widely used in ecological studies to evaluate and compare community diversity or to observe changes in species richness over time, as it considers the relationship between species richness and sample size (Thukral, 2017).

The Importance Value Index (IVI) for various plant species across different sites (S1 to S5). IVI is a measure used in vegetation studies to assess the importance of a species in a particular community or habitat. It is calculated by summing the relative density, relative frequency, and relative dominance of each species. Looking at the IVI values, we can observe that different species exhibit varying levels of importance across the plots. For example, *Lantana camara* stands out as the most important species with the highest IVI value across all plots, indicating its dominance and widespread occurrence. Conversely, species like *Ambrosia cordifolia* and *Solanum nigrum* have relatively low IVI values, suggesting their lesser importance or abundance compared to other species. One of the causes of the low IVI value of *Solanum nigrum* is human activity which has a significant market value of the species. The IVI values provide valuable insights into the composition and structure of plant communities within each site, aiding in ecological assessments and conservation planning.

The NDVI values obtained for the study area, ranging from 0.31 to 0.14, suggest a landscape characterized by sparse to moderate vegetation. Specifically, an NDVI value of 0.31 is indicative of areas with low to moderate vegetation cover, such as grasslands, crops, or scrublands (Tucker, 1979). In contrast, the lower value of 0.14 typically reflects conditions of bare soil or very sparse vegetation, potentially indicating areas that are either under stress from climatic conditions or are subject to human activities, such as agriculture or urbanization.
The observed NDVI values can be attributed to various ecological and anthropogenic factors. For instance, agricultural practices in the region may result in variations in vegetation cover and health, particularly if certain crops are seasonal or if land is left fallow. Furthermore, land degradation, which is often exacerbated by overgrazing, deforestation, or poor land management practices, can lead to significant reductions in NDVI values, reflecting a decline in vegetative health.

In areas with low NDVI values, such as 0.14, it is essential to consider the implications for local ecosystems and the livelihoods dependent on them. These values may indicate areas susceptible to erosion, reduced biodiversity, and limited ecosystem services, including carbon sequestration and water regulation (Pérez-Harguindeguy et al., 2013).

5. Conclusion

The study conducted along the bank of Chessa River has provided valuable insights into the biodiversity, species distribution, and ecological parameters of the area. A total of 41 plant species were identified across five sites (S1 to S5), demonstrating significant variability in species abundance and composition. Among the sites, Site S3 consistently emerged as the most diverse and ecologically balanced, characterized by the highest values of biodiversity indices (Simpson's Index: 0.92, Shannon Index: 2.62, and Fisher's Alpha: 2.95), and a balanced distribution of species. This makes it a critical zone for conservation and ecological study.
Conversely, Site S1 and Site S5 exhibited lower species diversity and higher dominance of fewer species, with Site S5 being particularly constrained in shrub diversity. These sites could benefit from targeted ecological interventions to enhance biodiversity and stability. The Sørensen-Dice similarity index highlighted varying levels of species overlap, with certain site pairs (e.g., S2 and S4) sharing significant commonality, while others (e.g., S1 and S4) showed distinct plant communities. This variation underscores the heterogeneous nature of the study area, influenced by local environmental conditions.

The ecological parameters highlighted the dominance of species such as *Lantana camara*, *Mimosa pudica*, and *Oxalis acetosella*, which play pivotal roles in shaping the plant community's structure. In contrast, species like *Leucas aspera* and *Cyperus compressus* exhibited limited distribution, indicating their niche-specific roles. NDVI analysis reinforced the findings, showcasing areas of robust vegetation with strong chlorophyll content and canopy cover, emphasizing the ecological vitality of certain zones along the river bank.

Overall, the study underscores the importance of Site S3 as a biodiversity hotspot and the ecological significance of preserving and managing this area. Simultaneously, sites with lower diversity, such as S1 and S5, should be prioritized for restoration efforts to enhance ecological balance. The findings contribute to a deeper understanding of the Chessa River bank's biodiversity, paving the way for informed conservation strategies and sustainable management practices.

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Authors' contribution

HB Conceptualized, data collection, the original draft of the manuscript. UD contributed in compilation, manuscript draft, review and final editing. RD in concept guidance and scientific approach. AB in data contribution and writing, concept guidance.

Conflict of interest

Authors have no conflict of interest.

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