RESEARCH ARTICLE

The Relationship Between Landscape Metrics and Human Interventions on the Floristic Structure and Composition of the Community Reserves of Meghalaya, India

Sandeep Prabhakaran[1,2], Sharief M.U.[1*], Harif Parengal[2,3], Karunakaran P.V.[2], Kumara H.N.[2] and Babu S.[2]

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Abstract

Community Reserves (CRs) are a unique category of protected areas managed by local communities, playing a crucial role in biodiversity conservation. However, the impact of landscape metrics and human intervention on vegetation in these reserves remains less explored. This study examines the relationship between landscape structure, human interventions, and vegetation in 30 CRs across Meghalaya, India, each associated with local villages and clans. Vegetation data were collected using stratified random sampling techniques, and indices such as Shannon, Simpson, and Evenness were calculated. For spatial analysis, Sentinel-2 imagery was utilized, with land use and land cover classification to gather landscape information by using the QGIS tool. The classified data were further analyzed using landscape metrics in FRAGSTAT software. The data on vegetation composition, landscape metrics, and the human disturbance index were then analyzed for correlations. Canonical Correspondence Analysis (CCA) was performed using R software to explore these relationships. Plant diversity varied significantly, with Shannon indices ranging from 2.147 (Mikadogre CR) to 3.845 (Kur Pyrtuh CR). Simpson indices were generally high (>0.8), indicating low species dominance. Evenness ranged from 0.153 (Sakalgre CR) to 0.557 (Kur Pyrtuh CR). The human intervention index varied from 0 (e.g., Chyrmang CR) to 6 (e.g., Jirang CR), with most reserves showing low to moderate levels of disturbance. CCA analysis revealed that 69.08% of the variation in diversity indices is strongly associated with landscape metrics (Total area, Number of Patches, Patch Density, Least Patch Index, Total Edge, Edge Density, Least Shape Index, Area Mean, Area Range, Landscape Division Index, Effective Mesh Size, Splitting Index, Patch Richness) and human intervention. The results suggest that CRs with more complex patch shapes tend to support higher plant species diversity. These findings have significant implications for CR management.

Keywords: Meghalaya, Community conservation, Floristic diversity, LULC classification, Past management regime.

Highlights:

- Meghalaya has the second-largest number of community reserves in India, but many remain unexplored due to their inaccessibility.
- This study examined 30 community reserves, the highest number ever included in a single research effort in the region.
- It offers an in-depth understanding of the relationship between landscape metrics, human interventions, and the floristic structure and composition of Meghalaya's Community Reserve.
- This study helps to the policymakers and stakeholders to improve the conservation practices in each community reserve in Meghalaya.
- Advanced tools such as GIS, FRAGSTATS, and R statistical packages were utilized to conduct the research.

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Introduction

Forests play an important role in the socio-economic scenario of India and the rural communities have conserved forest patches since ancient times (Paul and Chakrabarti, 2011; Basu and Debnath, 2023). These forests act as an integral part of the life of rural communities, which provide food, fuel, and fodder and are considered essential for their physical and cultural survival (Madegowda and Rao, 2017). Community Reserves (CRs), established through the Wildlife (Protection) Amendment Act 2002, are a more recent addition to India's protected area categories. These areas are managed by local communities in association with the forest department, often involving private or communal land holdings (WLPAA 2002). CRs play a significant role in conserving biodiversity-rich forest patches in Northeast India, where most land is owned and managed by local communities or clans (Dikshit and Dikshit, 2014). The state of Meghalaya has the second-highest number of CRs in India,

[1*]Botanical Survey of India Southern Regional Centre, Coimbatore, Tamil Nadu

[2]Salim Ali Centre for Ornithology and Natural History South India Centre of Wildlife Institute of India, Coimbatore, Tamil Nadu

[3]Centre for Tropical Biodiversity Conservation, Malappuram, Kerala

***Corresponding author:** Sharief M.U, Botanical Survey of India Southern Regional Centre, Coimbatore, Tamil Nadu, Email: shariefbsi@yahoo.co.in

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reflecting the deep interconnection between people and forests through ethnic knowledge, culture, and traditional management practices (Laloo *et al*., 2006). This state is home to three major indigenous tribal communities: the Khasis, Jaintias, and Garos, each with distinct histories, cultural identities, and traditional customs (Ryngnga, 2008; Agrahar and Pal, 2005; Gurdon, 1914).

Public participation in forest conservation is crucial in India to ensure sustainable livelihoods and foster a diverse rural economy (Stoll et al., 2010). Community engagement in forest management has led to the rejuvenation of declined ecosystems and the establishment of biodiversity-rich secondary forests (Paudyal *et al*.,2015). The spatial distribution of landscape elements plays a crucial role in shaping biodiversity (Dauber *et al*., 2003). Land use and land cover changes, coupled with the integration of human and ecological factors, are key drivers of forest landscape dynamics (Amici *et al*., 2015). Human intervention and historical management practices have significantly impacted vegetation diversity in forest patches, as noted by Mir and Upadhaya (2017). While some research has been conducted on this topic, such as Mir *et al*., (2021) study on the effects of human activity and landscape metrics on floristic structure and composition in community-managed reserves remain understudied except in the Khasi Hills. To bridge this knowledge gap, we conducted an extensive study encompassing 30 Community Reserves across Meghalaya, which have been managed under various regimes in the past, such as Community Forest (CF), Sacred Groves (SG) and Private Forest (PF).

Materials and Methods

Study Area

Meghalaya, a state in Northeast India, is renowned for its rich forest cover, unique biodiversity, geological features, and cultural heritage (Shankar and Tripathi, 2017). Notably, 80% of its forests are traditionally owned and managed by indigenous communities (Ormsby, 2013; Tiwari *et al*., 2010). Located between 24°58′N to 26°07′N latitude and 89°48′E to 92°51′E longitude, it covers 22,429 km², about 0.7% of India's geographical area. Meghalaya comprises three district councils named Garo Hills, Khasi Hills, and Jaintia Hills, which harbors a forest cover of approximately 17,046 sq. km., accounting for 76% of the state's total geographical area (FSI 2021). The reserves encompass a wide variety of forest ecosystems, including tropical evergreen, tropical semi-evergreen, subtropical broadleaved hill forests, tropical moist deciduous forests, grasslands, temperate and subtropical pine forests, secondary moist bamboo breaks, and smaller areas of Very Moist Sal-bearing Forest and Savanna Woodlands (Mir *et al*., 2022; Tripathi and Tripathi, 2010; Roy and Tomar, 2001; Haridasan and Rao, 1985; Balakrishnan, 1981; Champion and Seth, 1968; Kanjilal *et al*., 1934). The richness in vegetation is due to the region's unique ecological conditions, characterized by significant rainfall patterns, temperature regimes, altitudinal gradients, and edaphic factors (Upadhaya *et al*., 2003). The climatic regime of Meghalaya is characterized by a warm-humid summer and cool-dry winter, exhibiting distinct

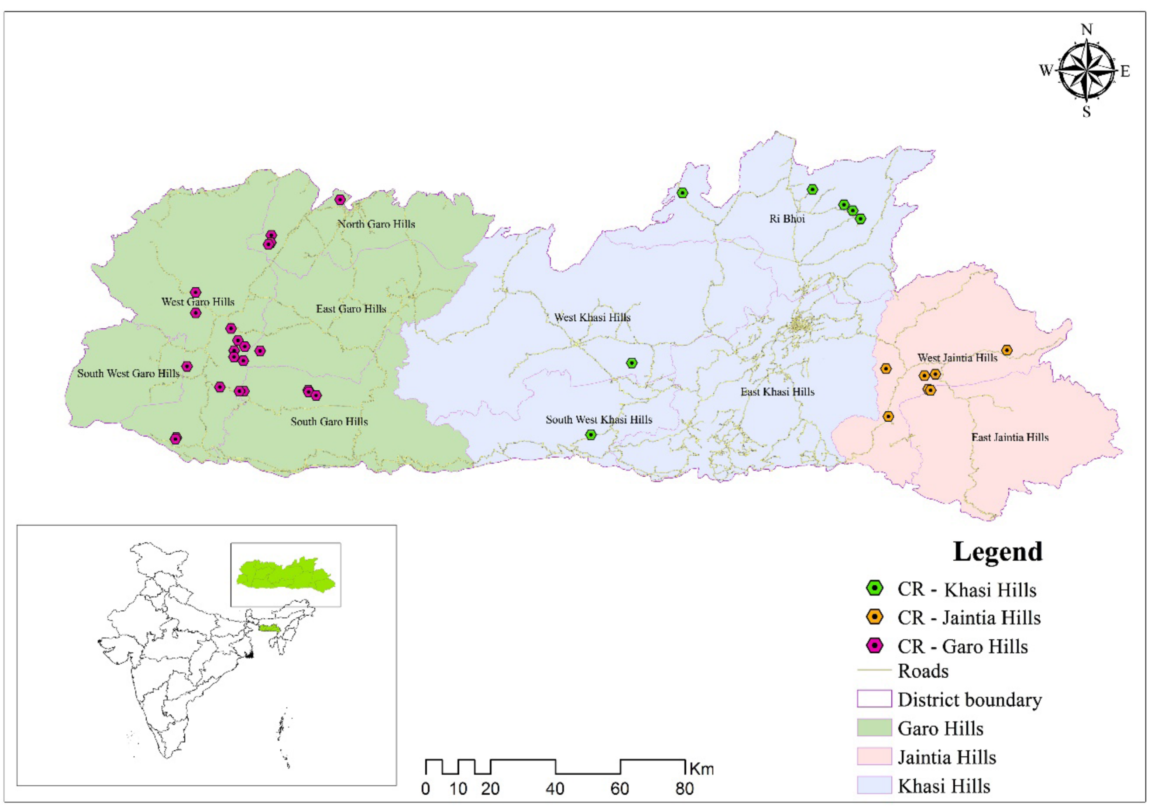

Fig.1: Distribution map of CRs in Meghalaya

mean annual values for precipitation, maximum temperature, minimum temperature, and relative humidity (Mishra *et al*., 2005; Sahoo *et al*., 2021). The edaphic conditions are dominated by lateritic, sandy loam soils with an acidic pH of approximately 5.5 (Tripathi and Barik, 2003; Upadhaya *et al*., 2003). A total of 30 community reserves have been selected for this study: seventeen reserves from the Garo Hills, seven from the Khasi Hills, and six from the Jaintia Hills with varying size and past management regimes (Fig.1).

Methodology

Vegetation Survey

Vegetation data were systematically collected from each Community Reserve (CR) using random sampling, following the nested quadrat method described by Mishra (1968). The size of the reserves varied from 0.5 hectares to 200 hectares, with 2% of the total area sampled in each reserve. For tree species, 10 × 10-meter plots were established. Within each tree plot, a nested 5 × 5-meter plot was designated for shrubs, and five smaller 1 × 1-meter quadrats were used for herbaceous vegetation. Trees with a girth at breast height (GBH) of ≥30 cm were sampled, with data recorded on species name, GBH, height, and GPS coordinates. For shrubs and herbs, the species name and number of individuals were documented (Tripathi *et al*., 2010; Mishra *et al*., 2005; Upadhaya *et al*., 2003). Plant species were identified using reference guides such as Forest Flora of Meghalaya (Haridasan and Rao, 1985, 1987), Flora of Jowai (Balakrishnan 1981, 1983), and Flora of Assam (Kanjilal *et al*., 1934-1940). Unidentified or ambiguous specimens were cross-verified with herbarium records and experts from the Botanical Survey of India, Eastern Regional Centre, Shillong.

Household Survey

A household questionnaire survey was conducted across villages associated with community reserves (CRs) to assess human interventions and dependencies. This survey aimed to explore the relationships between local communities and forest ecosystems, providing key insights for management (Agrawal and Gibson, 1999). Using random sampling, 50% of the households in each village associated with the community reserves were surveyed, ensuring balanced representation (Cochran, 1977). The pre-tested questionnaire gathered information on various human dependencies in the reserves (Mir *et al*., 2016; Fowler, 2013; Sunderlin *et al*., 2005), such as collection of Non-Timber Forest Products (NTFPs), harvesting water resources, hunting, road building inside reserve, fishing, and cultivation. In addition to surveys, open-ended discussions and semi-structured interviews were conducted with community leaders and key informants to gather in-depth information about forest use patterns and cultural significance. Informants were selected based on their knowledge of local traditions and land use (Mushove and Vogel, 2005; Grimble, 1998).

Data Analysis

The vegetation structure and composition across the reserves and various diversity indices such as the Shannon–Wiener diversity index, Simpson dominance index and the Species evenness index (Magurran, 1988; Pielou's, 1981; Shannon and Wiener, 1963; Simpson,1949) were assessed to provide insights into the diversity, dominance, and evenness of the plant communities. Species richness was assessed by enumerating the total number of distinct species recorded within each reserve. The diversity indices were calculated by the PAST software (Hammer *et al*., 2001) and the statistical computing environment R studio was utilized for comprehensive data analysis and correlation assessments (Wickham and Bryan, 2023; Kuhn, 2020).

The Human intervention index, a binary scoring system, was used to assess disturbances in the CRs. Each observed disturbance was assigned a value of one, and the total disturbance score for each CRs was calculated by summing the values of all identified disturbances. This method enabled a comparative analysis of human impacts across different CRs, offering a standardized measure to evaluate the intensity and variety of anthropogenic pressures on these protected areas (Mir and Upadhay, 2017; Mir *et al*., 2016).

To analyze landscape metrics, land use/land cover (LULC) derived from Sentinel-2 satellite imagery was used (Marangoz *et al*., 2017; ESA, 2005). The classified data were used as inputs for landscape metrics using FRAGSTATS (McGarigal *et al*., 2012). FRAGSTATS allows for the quantification of landscape structure through various metrics such as total area, number of patches, patch density, least patch index, total edge, edge density, least shape index, area mean, area range, landscape division index, effective mesh size, splitting index, patch richness (Turner, 1990).

Canonical correspondence analysis (CCA), was carried out to understand the interplay between vegetation data, landscape metrics, and past management regimes of CRs (Teer, 1986). This method directly relates floristic structure and composition to environmental and management factors, providing insights into how these variables shape vegetation patterns (Lepš and Šmilauer, 2003). CCA is particularly useful in this scenario as it can simultaneously analyze the response of multiple species to multiple environmental gradients and management practices (Palmer, 1993). By incorporating landscape metrics and human intervention index as explanatory variables, CCA can reveal how past land use and management regimes have influenced current vegetation composition (Borcard *et al*., 2011).

RESULTS

The Vegetation Data

The analysis of diversity indices across Community Reserves (CRs) in Meghalaya reveals a complex and diverse pattern. Using Shannon-Weiner, Simpson, and evenness indices, the study demonstrated varying levels of plant diversity, species dominance, and species equitability (Fig. 2). Diversity peaks in Kur Pyrtuh CR (Shannon: 3.845, Simpson: 0.965) and Daribokgre CR (Shannon: 3.796, Simpson: 0.946), indicating exceptionally rich plant communities. Most reserves exhibit high Simpson indices above 0.8, suggesting low dominance of any single species and high overall diversity. However, evenness varies considerably, ranging from 0.557 in Kur Pyrtuh CR to 0.153 in Sakalgre CR, reflecting significant differences in the distribution of individuals among species. Notable reserves include Kur Pyrtuh CR, which showed the highest diversity and evenness

(0.557), indicating a highly diverse and equitable/homogenous plant community; Daribokgre CR, with high diversity and moderate evenness (0.365); Raid Nongbri CR, demonstrating high diversity (Shannon: 3.546, Simpson: 0.933); Kpoh Elijah CR, with the highest evenness (0.471) in the Khasi Hills region; and Mikadogre CR, which presents the lowest Shannon index (2.147) but moderate Simpson index (0.841) and evenness (0.428). The study reveals significant variability in vegetation diversity across Meghalaya's CRs. While most reserves show high overall diversity, the evenness of species distribution varies considerably, indicating diverse ecological conditions and potentially different management or environmental factors influencing plant communities across the region. This variability underscores the importance of tailored conservation strategies that take into account the unique characteristics of each reserve to maintain and enhance biodiversity in these valuable ecosystems.

The basal area (BA) data of the CRs shows significant variation across locations (Fig. 3). Raid Nongbri CR has the highest BA at 36,842.87 square units, while Aruakgre (10 ha) shows the lowest at 204.26 square units. Most reserves maintain BA values between 1,000 and 4,000 square units, representing medium-

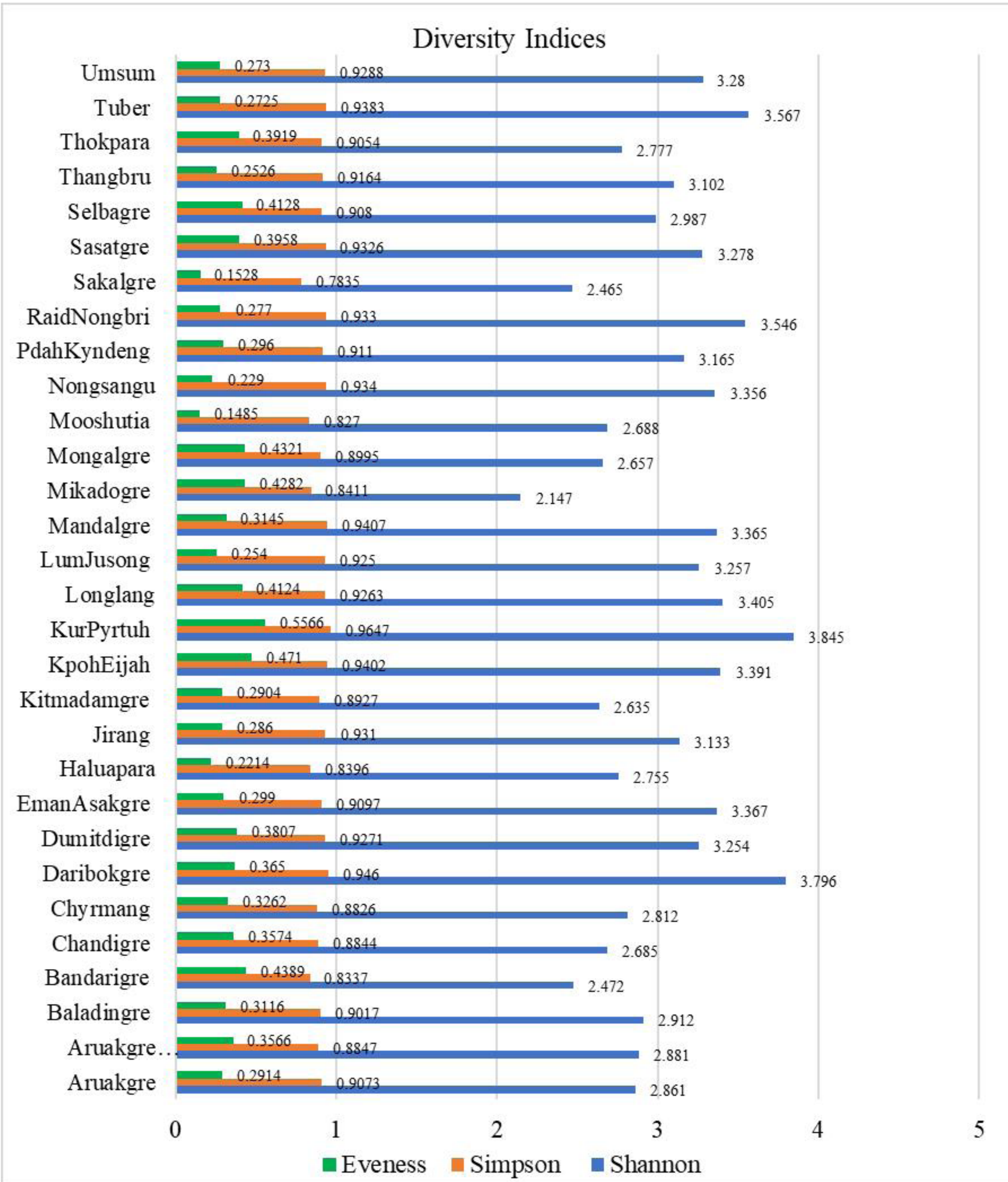

Fig. 2: The diversity indices of the CRs of Meghalaya

sized forest. However, several reserves stand out with notably high BA values: RaidNongbri, Thangbru (29,132.6), PdahKyndeng (15,920.9), Longlang (14,473.1), KurPyrtuh (11,904.8), and Selbagre (8,548.17). Only two reserves, Aruakgre (100 ha) and Umsum (471.01), have BA values below 1,000 square units.

Among the 30 Community Reserves (CRs) studied, human intervention patterns reveal significant variations in both intensity and type of activities (Table 1). The analysis shows intervention scores ranging from 0 to 6, indicating a spectrum from pristine to heavily influenced areas. Chyrmang, Mikadogre, and Umsum CRs emerge as the most undisturbed reserves with no recorded human activities, resulting in an intervention index of 0. This absence of intervention activities suggests these areas maintain high levels of natural integrity or have effective protection measures in place. At the opposite end of the spectrum, Jirang and Nongsangu CRs demonstrate the highest levels of human intervention with index scores of 6. In Jirang CR, this high score reflects diverse activities, including fishing, timber extraction, foddering, NTFP collection, hunting, and road building. Similarly, Nongsangu CR shows intensive use through cultivation, fishing, timber extraction, foddering, NTFP collection, and road building.

The majority of reserves fall into low to moderate levels of intervention (Table 1). Eleven CRs show low intervention levels (scores 1-2), including areas like Eman Asakgre, Kur Pyrtuh, Longlang, Mongalgre, Baladingre, Bandarigre, Chandigre, Sasatgre, Selbagre, and Tuber CRs. Are typically show one or two types of activities, most commonly NTFP collection or foddering. Nine reserves exhibit moderate intervention levels (score of 3), including Daribokgre, Dumitdigre, Haluapara, Kitmadamgre, Kpoh Eijah, Mandalgre, and Sakalgre. NTFP collection and foddering along with one other activity like cultivation or timber extraction. The remaining reserves demonstrate moderately high intervention levels: Pdah Kyndeng and Thangbru (score of 4), and Aruakgre (10 ha), Lum Jusong, and Raid Nongbri (score of 5). Across all reserves, NTFP collection and foddering emerge as the most widespread activities, while fishing and hunting are less common. This pattern suggests that local communities primarily depend on these reserves for basic resource needs, with more intensive activities being limited to specific areas.

The landscape metrics data covers 30 CRs, each with different patch characteristics (Table 2). The total area of these reserves varies widely, from as small as 0.67 hectares (Bandarigre) to as large as 203.66 hectares (Jirang). The number of patches within each reserve also shows significant variation, ranging from just 1 (Sakalgre) to 65 (Nongsangu). The patch density indicates the number of patches per 100 hectares, which varies greatly across reserves. Bandarigre has the highest patch density at 597.10, while Sakalgre has the lowest at 0.82. The Largest Patch Index, representing the percentage of the total area encompassed by the largest patch, ranges from 14.98% (AruakgreB) to 100% (Sakalgre). Edge density shows considerable variation. KpohEijah has the highest edge density at 792.76 m/ha, while Sakalgre has the lowest at 62.53 m/ha. The Shape Index, which measures the complexity of patch shapes, ranges from 1.63 (Chyrmang) to 8.70 (LumJusong). The mean patch area varies from 0.17 hectares (Bandarigre) to 122.17 hectares (Sakalgre). The landscape division index, which represents the probability that two randomly chosen points in the landscape are not situated in the same patch, ranges from 0 (Sakalgre) to 0.91 (Aruakgre B). Effective Mesh Size, an indicator of the degree of landscape fragmentation, varies from 0.53 hectares (Bandarigre) to 160.34 hectares (Daribokgre). The Splitting Index, which is the number of patches with a constant patch size when the landscape is subdivided into sub-patches, ranges from 1 (Sakalgre) to 11.21 (AruakgreB). Lastly, patch richness, representing the number

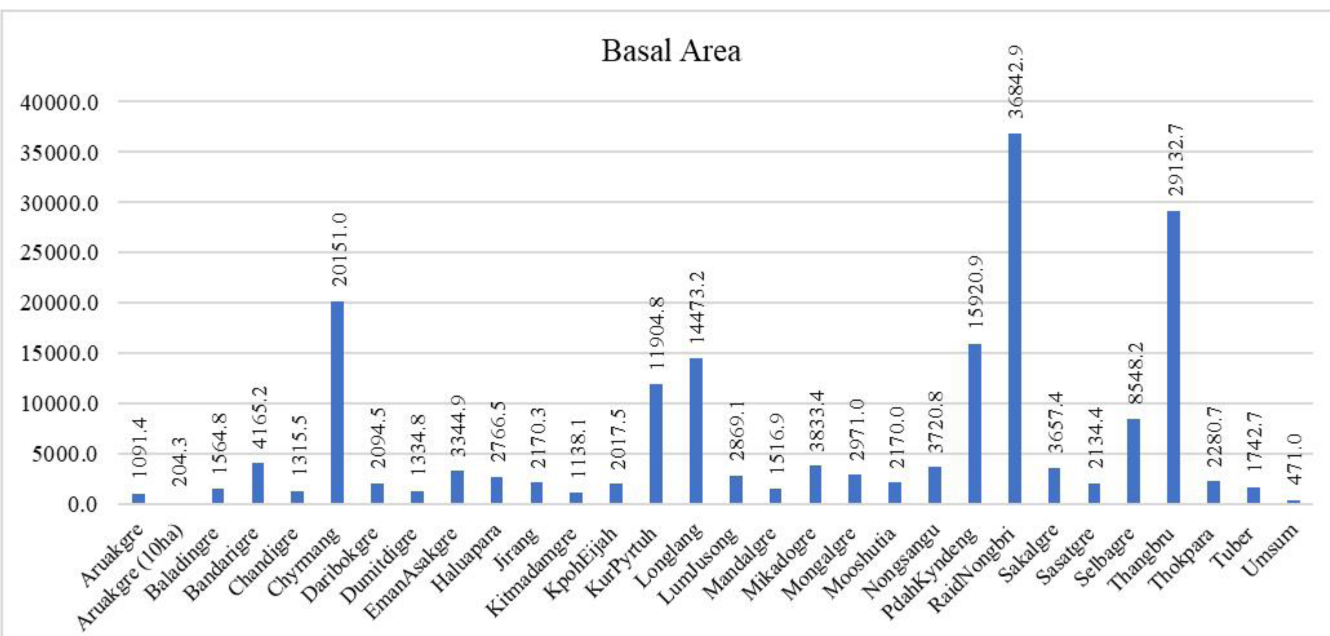

Fig. 3: The Basal area chart of the Community Reserves of Meghalaya.

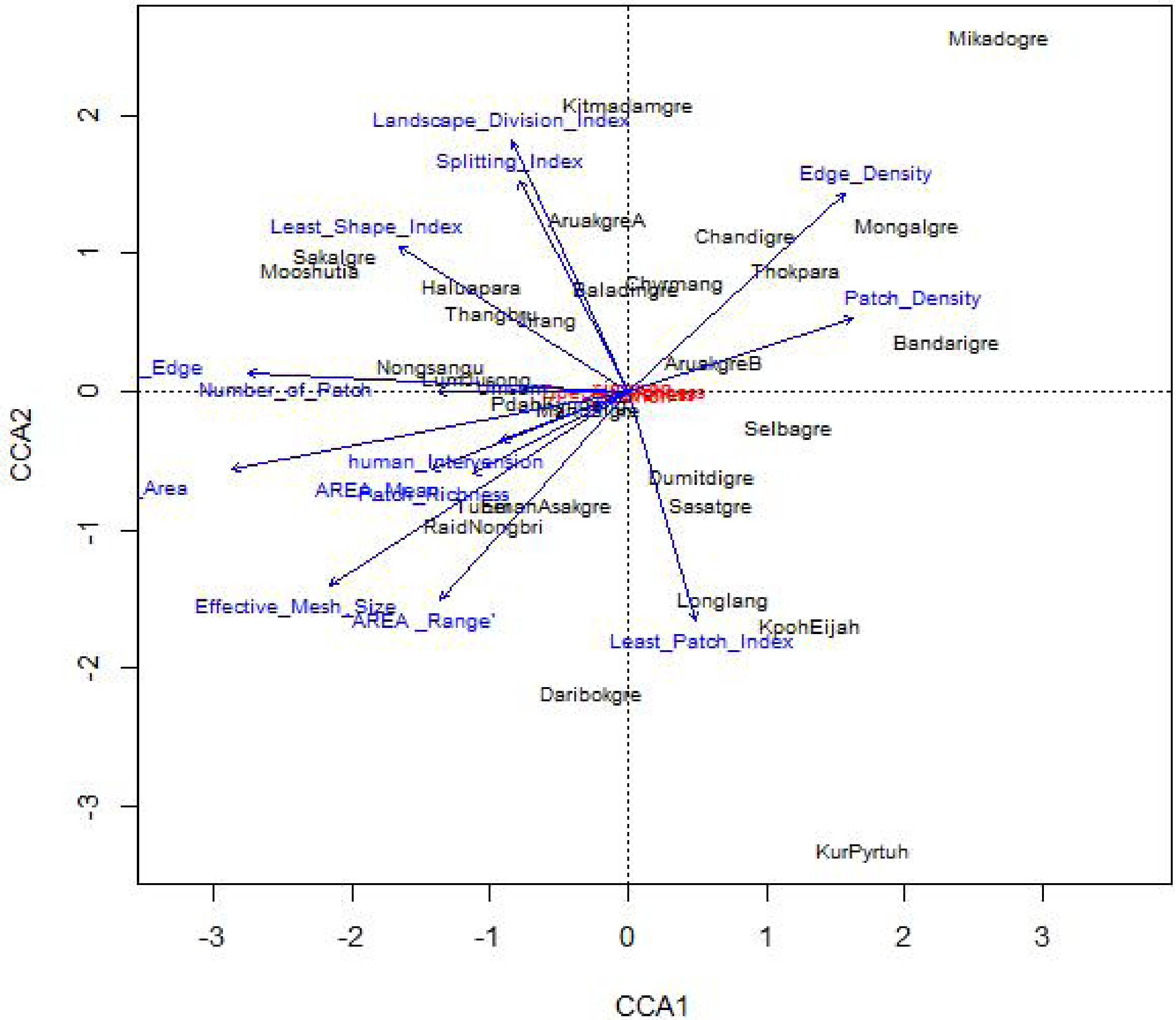

Fig. 4: Canonical correspondence analysis between diversity indices, human intervention and landscape metrics.

of different patch types present, ranges from 1 (Sakalgre) to 8 (Aruakgre B, Mandalgre, and Nongsangu). These metrics together offer valuable insights into how human activities impact the landscape structure, fragmentation, and biodiversity within the community reserves.

The Canonical Correspondence Analysis (CCA) reveals a strong relationship between diversity indices, landscape metrics and human intervention (Fig. 4) in the CRs of Meghalaya. The analysis accounts for 69.08% of the total variation in diversity indices, indicating that landscape characteristics and human interventions significantly influence vegetation patterns. The first canonical axis (CCA1) is particularly informative, explaining 66.56% of the constrained variation and 96.34% of the cumulative proportion for constrained eigenvalues. This suggests that CCA1 captures the primary gradient of landscape influence on vegetation. The second axis (CCA2) adds only 2.32% more explained variation, while the third axis (CCA3) contributes negligibly. The CCA biplot visually represents these relationships, with longer arrows indicating stronger correlations. The landscape division index and splitting index show strong positive correlations with CCA1, suggesting fragmentation impacts vegetation diversity. Edge density and patch density positively correlated with CCA2, indicating the influence of landscape heterogeneity. Human Intervention, closely aligned with area range and effective mesh size, suggests anthropogenic impacts on vegetation patterns. Interestingly, species richness shows a negative correlation with CCA1, potentially indicating that some level of landscape division might support higher species diversity in these reserves. This analysis underscores the complex interplay between landscape structure, human activities, and vegetation diversity in Meghalaya's community reserves, highlighting the need for integrated conservation strategies that consider both ecological and anthropogenic factors.

Discussion

This study revealed a significant relationship between the

Table 1: Details of reserve sizes and human interventions in each Community Reserves

Name of the CR	*Size (Ha)*	*Cultivation*	*Fishing*	*Timber extraction*	*Foddering*	*NWFP*	*Drinking water collection*	*Hunting*	*Road construction*	*Human intervention index*
Aruakgre	100	1			1					2
Aruakgre (10h)	10	1		1	1	1			1	5
Baladingre	26					1		1		2
Bandarigre	0.6					1	1			2
Chandigre	37			1	1					2
Chyrmang	7									0
Daribokgre	173					1	1	1		3
Dumitdigre	70	1		1	1					3
Eman Asakgre	31			1						1
Jirang	200		1	1	1	1		1	1	6
Kitmadamgre	70				1	1		1		3
Kpoh Eijah	17	1			1	1				3
Kur Pyrtuh	15.9				1					1
Longlang	15				1					1
Lum Jusong	130	1		1		1	1	1		5
Mandalgre	33.4						1	1	1	3
Mikadogre	1.2									0
Mongalgre	20		1							1
Mooshutia	33									0
Nongsangu	100	1	1	1	1	1			1	6
Pdah Kyndeng	75	1			1	1		1		4
Raid Nongbri	70	1		1	1	1		1		5
Haluapara	50			1	1			1		3
Sakalgre	122			1		1		1		3
Sasatgre	60					1			1	2
Selbagre	20				1	1				2
Thangbru	19.6		1		1	1	1			4
Thokpara	30	1		1	1	1				4
Tuber	96.6				1		1			2
Umsum	43									0

vegetation composition, human intervention and landscape metrics across the community reserves of Meghalaya. To address the management challenges of these reserves, it is essential to study the floristic characteristics of the landscape elements, along with the human interventions. This approach has been successfully applied in various studies examining the effects of landscape heterogeneity and management history on plant communities (Lindborg and Eriksson, 2004; Arozena *et al*., 2019; Honnay *et al*., 1999). The range of Shannon and Simpson indices observed across the CRs indicates significant variability in plant diversity and species dominance (Shankar and Tripathi, 2017; Rad *et al*., 2009). The high biodiversity and highest evenness observed in reserves like Kur Pyrtuh CR, which represents the most healthy and stable vegetation, may be attributed to their past management as sacred groves. CRs that were once sacred groves tend to face fewer disturbances (Mir *et al*., 2017) than community and village forests due to differences in approach to cultural reasons and practices towards their preservation. (Bdoor and Bshar., 2016).

Human disturbances in tropical forests result in habitat loss, reduced biodiversity, and greater landscape fragmentation. (Pablo *et al*., 2023). The CRs are currently experiencing controlled human activities, including logging, cultivation, and the collection of Non-Wood Forest Products (NWFPs), which are influencing the composition and dominance of species within these areas (Majumdar and Datta, 2015; Mishra *et al*., 2004, 2003). Notably, some reserves exhibited high intervention scores (6), like Jirang and Nongsangu could provide insights into the resilience of these ecosystems to human pressures and the patchiness of these reserves also very high (Zhu *et al*., 2019; Seidl *et al*.,2016). Most of the CRs show a medium range of disturbance (2 to 3) with high diversity; this finding supports

Table 2: Landscape metrics values of community reserves

Reserve Name	*Number of Patch*	*Patch Density*	*Least Patch Index*	*Total Edge*	*Edge Density*	*Least Shape Index*	*Area Mean*	*Area Range*	*Landscape Division Index*	*Effective Mesh Size*	*Splitting Index*	*Patch Richness*
Aruakgre	39.00	38.78	55.06	30293.00	301.22	7.55	2.58	55.28	0.68	32.59	3.09	4
Aruakgre	42.00	373.96	14.98	8903.50	792.76	6.64	0.27	1.68	0.91	1.00	11.21	8
Baladingre	13.00	50.51	95.34	7168.00	278.52	3.53	1.98	24.54	0.09	23.40	1.10	3
Bandarigre	4.00	597.10	88.75	745.50	1112.85	2.27	0.17	0.59	0.21	0.53	1.26	4
Chandigre	11.00	29.53	64.95	10527.50	282.62	4.31	3.39	24.14	0.52	17.73	2.10	3
Chyrmang	4.00	80.49	95.47	1454.11	292.59	1.63	1.24	4.71	0.09	4.53	1.10	3
Daribokgre	2.00	1.15	96.13	11021.00	63.62	2.09	86.61	159.82	0.07	160.34	1.08	2
Dumitdigre	16.00	22.53	95.07	9150.00	128.86	2.71	4.44	67.50	0.10	64.19	1.11	4
EmanAsakgre	7.00	21.97	96.79	4411.50	138.46	1.95	4.55	30.77	0.06	29.86	1.07	2
Haluapara	11.00	22.04	35.10	10704.50	214.47	3.79	4.54	17.40	0.75	12.50	3.99	3
Jirang	25.00	12.28	33.94	31708.83	155.70	5.55	8.15	68.92	0.83	33.68	6.05	7
Kitmadamgre	29.00	40.70	33.98	19758.00	277.28	5.85	2.46	24.17	0.80	14.10	5.05	5
KpohEijah	43.00	250.83	85.46	6211.50	362.33	3.75	0.40	14.65	0.27	12.58	1.36	7
KurPyrtuh	9.00	56.59	92.75	4173.17	262.39	2.61	1.77	14.75	0.14	13.71	1.16	4
Longlang	7.00	46.17	98.14	2558.84	168.78	1.64	2.17	14.88	0.04	14.60	1.04	4
LumJusong	63.00	48.52	52.62	39677.55	305.59	8.70	2.06	68.27	0.71	37.10	3.50	6
Mandalgre	44.00	131.73	74.24	13767.22	412.18	5.95	0.76	24.79	0.44	18.56	1.80	8
Mikadogre	3.00	233.81	48.53	1036.98	808.20	2.28	0.43	0.52	0.57	0.55	2.33	2
Mongalgre	6.00	31.19	91.39	3890.00	202.18	2.22	3.21	17.49	0.16	16.13	1.19	2
Mooshutia	19.00	57.13	63.50	12210.25	367.13	5.29	1.75	21.11	0.57	14.25	2.33	7
Nongsangu	65.00	65.24	62.12	27191.87	272.92	6.80	1.53	61.89	0.60	40.02	2.49	8
PdahKyndeng	41.00	54.76	32.08	20674.04	276.14	5.96	1.83	24.02	0.86	10.69	7.00	6
RaidNongbri	43.00	61.14	52.84	17896.94	254.45	5.33	1.64	37.17	0.69	21.69	3.24	7
Sakalgre	1.00	0.82	100.00	7639.13	62.53	1.73	122.17	0.00	0.00	122.17	1.00	1
Sasatgre	12.00	20.01	89.26	10338.86	172.37	3.33	5.00	53.50	0.20	47.93	1.25	5
Selbagre	19.00	93.38	35.63	8310.59	408.43	4.60	1.07	7.20	0.77	4.64	4.38	3
Thangbru	43.00	221.07	34.11	10685.57	549.37	6.05	0.45	6.63	0.83	3.32	5.85	7
Thokpara	13.00	42.48	46.94	10964.80	358.33	4.95	2.35	14.18	0.73	8.27	3.70	3
Tuber	43.00	44.52	87.89	18483.77	191.35	4.70	2.25	84.89	0.22	74.91	1.29	7
Umsum	43.00	98.92	44.37	16495.67	379.46	6.25	1.01	19.29	0.73	11.55	3.76	5

the intermediate disturbance hypothesis, which proposes that moderate levels of disturbance promote the greatest plant species richness (Bendix *et al*., 2017; Mishra *et al*., 2004). Very few CRs reported no human intervention, such as Chyrmang, Mikadogre, and Umsum; these undisturbed sites may serve as important reference sites for understanding natural forest dynamics in the CRs (Mir *et al*., 2021). Out of these three non-disturbed CRs, two are sacred groves.

Studying the landscape metrics provides insights into the spatial configuration and composition of landscape elements, enabling a comprehensive assessment of landscape heterogeneity and fragmentation (Turner, 2005; Wu, 2004; Wiens, 1989). The patch metrics analysis of the CRs shows most reserves have a mosaic of forest types within the reserves, likely contributing to a wide range of ecological niches and resources. Such habitat diversity can support varied floral and faunal diversity, potentially enhancing overall biodiversity (Tews *et al*., 2004). Human interventions are shaping landscape patterns and structures, which, in turn, affect the floristic diversity of an area (Krishnadas and Osuri, 2020). Land use by humans acts as a major barrier to gene flow, impacting genetic diversity and population connectivity (Tassone *et al*., 2020). In Meghalaya, activities such as shifting cultivation, clear-cutting of forests, and mining have fragmented the landscape, resulting in a decline in species composition (Roy and Tomar, 2001). Many CRs, such as Pdah Kyndeng, Jirang, Nongsangu, Lumjusong, Aruvagre, and Kitmandange, contain both abandoned and active *jhum* cultivation lands. These disturbances have also impacted the population of primary species, an abundance of the species thus altering the vegetation structures and affecting the creation of more ecotones between vegetation patches (Lepart and Debussche, 1992).

The patch landscape metrics analysis indicates Sakalgre CR has only one patch and Nongsangu CR has 65 patches. This landscape heterogeneity suggests different levels of fragmentation across reserves (Fahrig, 2003). The largest patch index, ranging from 14.98% (Aruakgre) to 100% (Sakalgre), indicates varying degrees of connectivity across the patches to ensure landscape stability (McGarigal *et al*., 2012). In Aruvagre CR, higher Division and Splitting Indices, combined with a lower effective mesh size, reflect a more fragmented landscape with reduced connectivity (Jaeger, 2000). The LumJusong CR has higher edge metrics, indicating increased landscape fragmentation and potential edge effects on ecosystem processes (Harper *et al*., 2005). The elevated Landscape shape index in LumJusong CR further supports this, with higher values indicating more complex and fragmented landscapes (Patton, 1975). These findings highlight varying levels of landscape diversity across reserves, with potential implications for biodiversity conservation and ecosystem functioning (Cushman *et al*., 2008)

The forest plays an important role in the environment as well as the socio-cultural aspect of the people (Ritter and Dauksta, 2013). Effective management strategies that respect the cultural and spiritual significance of these reserves are crucial to ensure their long-term conservation and management of the diverse vegetation types. The people of this state share a deep connection with the forest, rooted in their ethnic knowledge and cultural traditions, where forest management practices are closely linked to their beliefs and customs (Laloo *et al*., 2006). The diverse forest composition observed in these reserves underscores the need for tailored conservation strategies that account for the specific ecological characteristics of each area. As suggested by Lindenmayer *et al*., (2006), effective forest management should consider the full spectrum of forest types and their associated biodiversity values to ensure desirable conservation outcomes. Involving communities in conservation efforts supports the sustainable use of natural resources and helps to address various conservation challenges and regional disparities (Stoll *et al*., 2010). Community engagement in forest management has also contributed to the restoration of degraded ecosystems and the growth of new, thriving secondary forests rich in biodiversity (Chazdon., 2008).

Conclusion

This study of Community Reserves (CRs) in Meghalaya reveals a complex interplay between floristic diversity, landscape characteristics, and human intervention. The analysis of diversity indices demonstrates significant variability across the reserves, with some areas exhibiting exceptionally high plant diversity while others show more dominance and less equitable species distribution. The landscape metrics analysis further illustrates the spatial structural diversity of these reserves, ranging from small, fragmented to large, contiguous habitats. Notably, the canonical correspondence analysis (CCA) results indicate a strong relationship between floristic diversity, landscape metrics, and human intervention, accounting for 69.08% of the total variation in diversity indices. This suggests that both natural landscape features and anthropogenic factors play crucial roles in shaping the biodiversity of these reserves. The varying levels of human intervention observed across the CRs, from pristine areas to those with significant anthropogenic influence, underscore the need for tailored conservation strategies. These findings highlight the importance of considering both ecological and human factors in conservation planning. Future management of Meghalaya's community reserves should adopt an integrated approach that accounts for the unique characteristics of each reserve, balancing biodiversity conservation with sustainable human activities to ensure the long-term preservation of this network of people's protected areas.

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Author Contribution

All authors provided essential feedback and contributed to shaping the research, analysis, and manuscript. Mr. Sandeep Prabhakaran conducted field data collection, performed data analysis, and wrote the main text of the manuscript. Mr. Harif Parengal assisted with data analysis. Dr. Karunakaran P.V. led the overall study, offering guidance and supervision throughout its duration. Both Dr. Karunakaran P.V. and Dr. Sharief M.U. guided the manuscript writing process, providing their expertise and insights. Dr. Kumara H.N. and Dr. Babu S. contributed to the study's design, data interpretation, and manuscript review, ensuring the quality and accuracy of the research.

Conflict of Interest

The authors declare that they have no conflict of interest.

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