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A Quadrat-Based Assessment of Plant Diversity Across Three Land-Use Gradients in Ranchi, Jharkhand, India

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ABSTRACT

Vegetation structure and species diversity were assessed at three land-use monitoring sites in Ranchi District, Jharkhand - Horhap Forest (a relatively undisturbed sal-dominated stand), Lali Village (a mixed forest-edge community bordering settlement), and Ruka Forest / Getalsud Dam (a reservoir-margin forest with high anthropogenic disturbance) - using the standard nested-quadrat method (10 m × 10 m for trees, 5 m × 5 m for shrubs, 1 m × 1 m for herbs; six replicate quadrats per stratum per site). Species were identified in the field, enumerated, and analysed using density, relative density, the Shannon-Wiener diversity index (H'), and Pielou's evenness index (J). Tree-layer diversity ranged from very low at Ruka (H' = 0.27; two species, 92% dominance by *Litsea monopetala*) to moderately high at Lali (H' = 1.55, J = 0.963), reflecting a gradient of disturbance and canopy dominance. Shrub- and herb-layer diversity were consistently higher than tree-layer diversity at all sites, with Ruka herbs recording the highest overall diversity in the study (H' = 2.43, S = 15). Horhap Forest's tree layer was strongly dominated by *Shorea robusta* (66.7% relative density), consistent with the sal-forest climax association typical of the Chota Nagpur plateau. One planned dataset (Lali Village herb layer) was excluded from analysis after a data-integrity check identified that the recorded values duplicated an adjacent site's shrub data; this is disclosed as a limitation rather than substituted with unverified figures. The results indicate an inverse relationship between canopy dominance and understorey diversity and support the use of stratified quadrat sampling as a rapid, low-cost baseline tool for vegetation monitoring in peri-urban forest fragments of the Chota Nagpur plateau.

Key Words -phytosociology; quadrat method; Shannon-Wiener index; Pielou's evenness; species richness; Chota Nagpur plateau; Ranchi; vegetation monitoring

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INTRODUCTION

Terrestrial vegetation underpins ecosystem function, carbon storage, hydrological regulation, and habitat provision, and its quantitative assessment is a foundational task in ecology and environmental management (Odum & Barrett, 2005). Among the range of vegetation-sampling techniques available, the quadrat method - the enumeration of individuals within replicated sample plots of defined area - remains the most widely used approach for characterising plant community composition, population structure, and diversity, owing to its methodological simplicity, statistical tractability, and comparability across sites and studies (Mueller-Dombois & Ellenberg, 1974; Kent & Coker, 1992).

The Chota Nagpur plateau, within which Ranchi district lies, supports tropical dry deciduous forest formations historically dominated by *Shorea robusta* (sal), interspersed with agricultural land, village settlements, and water bodies (Champion & Seth, 1968, as commonly cited in regional forestry literature). Rapid peri-urban expansion around Ranchi city has fragmented and altered much of this forest matrix, creating a mosaic of land-use types - relict forest, village-edge secondary growth, and reservoir-margin vegetation - that differ in disturbance history and are expected to differ correspondingly in community structure and diversity. Quantifying these differences provides a baseline against which future land-use change, restoration interventions, or conservation prioritisation can be assessed.

This study applies the quadrat method and standard diversity indices to three such land-use types in Ranchi - Horhap Forest, Lali Village, and Ruka Forest / Getalsud Dam - across the tree, shrub, and herb strata. The specific objectives were: (i) to enumerate and identify plant species present in each stratum at each site; (ii) to compute density and relative density for all recorded species; (iii) to compute the Shannon–Wiener diversity index (H') and Pielou's evenness index (J) for each site-stratum combination; and (iv) to compare diversity and dominance patterns across sites in relation to their differing disturbance regimes, to evaluate the quadrat method as a rapid baseline tool for peri-urban forest monitoring.

REVIEW OF LITERATURE

Development of the quadrat method

Systematic quadrat sampling traces to Pound and Clements (1898), who used fixed-area plots to record species abundance in North American prairie vegetation. Raunkiaer (1934) formalised quadrat-based phytosociology through his "law of frequency," describing the characteristic distribution of species across frequency classes in homogeneous vegetation. Clapham (1932), Cain (1938), and Cain and Castro (1959) subsequently addressed minimal quadrat size and replication number through the species - area curve, establishing the point of diminishing returns beyond which additional sampling adds negligible new species - a consideration reflected in the present study's use of six replicate quadrats per stratum. Curtis and McIntosh (1950) and Cottam and Curtis (1956) introduced the Importance Value Index, combining relative frequency, density, and dominance into a single ranking of ecological importance, later widely applied in tropical and Indian vegetation studies (Whitford, 1949; Phillips, 1959; Misra, 1968). In the Indian context, Misra's (1968) Ecology Work Book and, internationally, Mueller-Dombois and Ellenberg (1974) and Kent and Coker (1992), standardised nested-quadrat protocols of the kind used here (1 m² herb, 25 m² shrub, 100 m² tree quadrats).

Diversity indices

The Shannon–Wiener index has its origin in Shannon's (1948) information-theoretic measure of uncertainty, later adapted to community ecology by MacArthur (1955) and Pielou (1966, 1969) on the premise that species diversity is analogous to the "uncertainty" in predicting the identity of a randomly drawn individual. Simpson (1949) independently derived a dominance-based probability measure, whose complement is commonly reported as a diversity index (Whittaker, 1965; Peet, 1974; Magurran, 2004). Pielou (1966) further defined evenness (J') as the ratio of observed to maximum possible Shannon diversity, a formulation adopted in the present analysis. Complementary richness measures correcting for sample size were proposed by Margalef (1958) and Menhinick (1964), while Whittaker (1965, 1972) distinguished alpha, beta, and gamma diversity as a framework for landscape-level comparison. Peet's

(1974) influential review recommended concurrent reporting of a richness measure, an evenness measure, and a composite heterogeneity index - the approach followed here - and Magurran's (1988, 2004) monographs remain the standard reference for index calculation and interpretation.

Despite the methodological maturity of this field, comparative, multi-site applications along a peri-urban disturbance gradient specific to the Chota Nagpur plateau are limited in the published literature, which this study addresses using field data from three contrasting sites around Ranchi.

MATERIALS & METHODS

Study area

The study was carried out in Ranchi district, Jharkhand, on the Chota Nagpur plateau, at three sites selected to represent a gradient of land use and disturbance: (i) Horhap Forest, a comparatively intact sal-dominated forest stand; (ii) Lali Village, a mixed forest-edge community adjoining agricultural and settled land; and (iii) Ruka Forest, bordering the Getalsud Dam reservoir and subject to higher visitor and grazing pressure. The relative locations of the two northern sites (Horhap and Lali) within Ranchi district are shown in Figure 1.

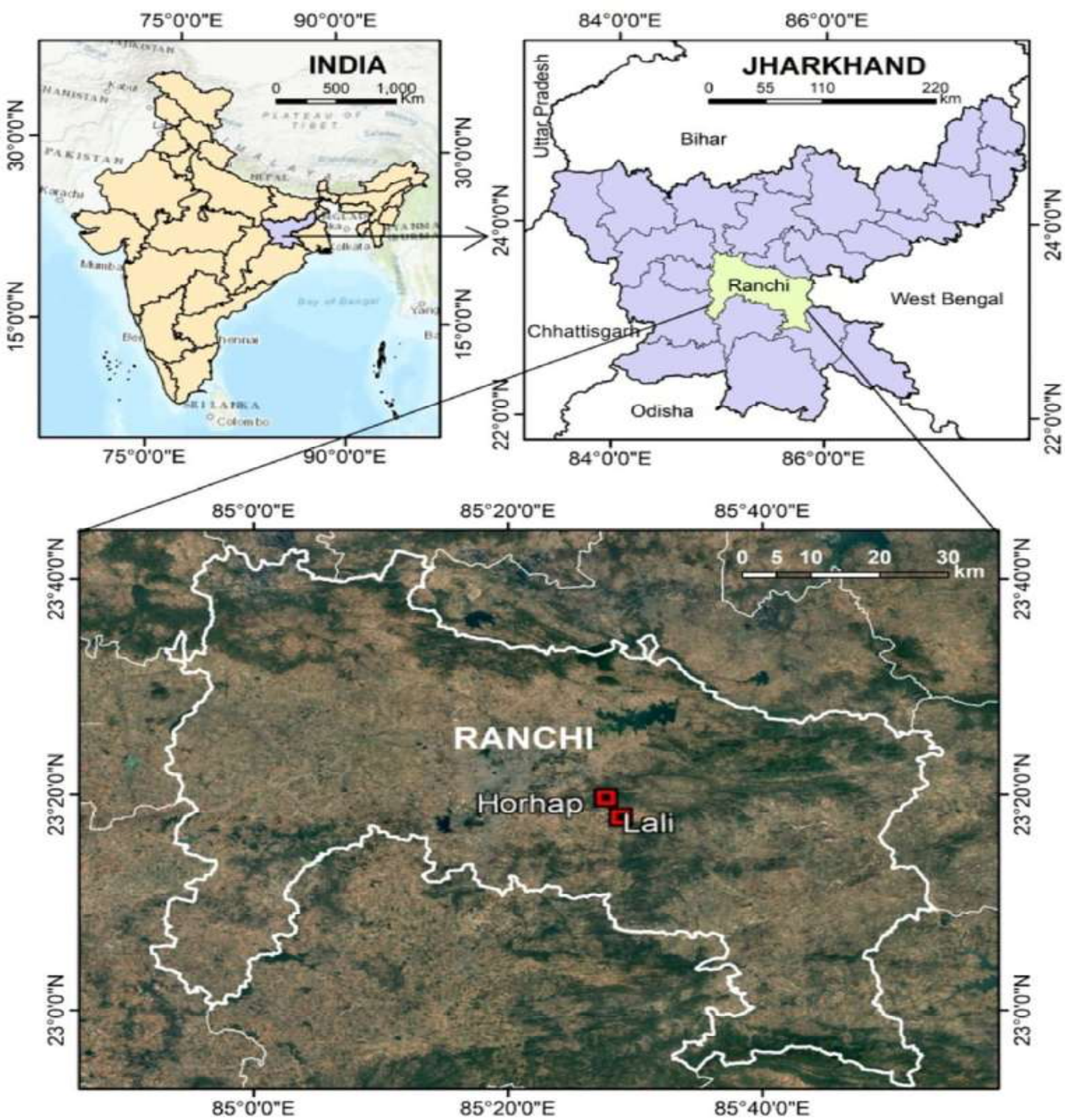

Figure 1. Location map of the Ranchi district study area, showing the position of Horhap Forest and Lali Village monitoring sites (inset: Jharkhand within India; Ranchi within Jharkhand).

Sampling design

A stratified nested-quadrat design was used at each site, with quadrat size scaled to the growth form being sampled: 10 m × 10 m for trees, 5 m × 5 m for shrubs, and 1 m × 1 m for herbs. Six replicate quadrats were sampled per stratum at each site, positioned to capture representative vegetation cover. Within each quadrat, all rooted individuals were identified to species level in the field with the aid of a plant-identification application (PlantNet) cross-checked against standard floras, counted, and recorded in a field notebook together with quadrat number and site coordinates. Representative species and site photographs were taken to support field documentation (Figure 2).

Figure 2. Field data collection in progress at a tree-layer quadrat, Lali Village site.

Data analysis

For each species i in a given site-stratum sample, density and relative density were calculated as:

Density = (Total individuals of species i) ÷ (Number of quadrats sampled)

Relative Density (%) = (Density of species i ÷ Total density of all species) × 100

Species diversity was quantified using the Shannon - Wiener diversity index:

$$H' = -\Sigma (p_i \ln p_i)$$

where p_i is the proportion of individuals belonging to species i (n_i/N). Maximum possible diversity for a sample of S species was calculated as H' max = ln(S), and Pielou's evenness index as:

$$J = H' / H'max$$

J ranges from 0 (a single species overwhelmingly dominant) to 1 (all species equally abundant). All calculations were verified by independent re-computation from the raw species-count data during manuscript preparation.

Data quality and exclusion criterion

During verification, the herb-layer dataset originally recorded for Lali Village was found to be numerically identical, species-for-species, to the shrub-layer dataset recorded at Ruka Forest, with only the sample-size denominator altered (and altered incorrectly relative to the true species total). This indicates a field-sheet transcription or data-entry duplication rather than an independent herb survey at Lali Village. Rather than reporting a diversity index computed on non-independent data, the Lali Village herb layer was excluded from all downstream analysis and is reported here as a limitation (Section 6). All other eight site×stratum combinations were independently verified against the raw species-count tables and are reported in full.

RESULTS

Diversity indices across sites and strata

Table 1 summarises species richness (S), total individuals sampled (N), Shannon–Wiener diversity (H2), maximum possible diversity (H2 max), and Pielou's evenness (J) for all eight valid site×stratum combinations, which are graphically represented in graphical figures 3,4 and 5.

Table 1. Species richness and diversity indices by site and vegetation stratum.

Site	Stratum	S	N	H'	H'max	J (Evenness)
Horhap Forest	Trees	4	102	0.9163	1.3863	0.661
	Shrubs	3	12	0.96	1.0986	0.874
	Herbs	13	116	2.188	2.5649	0.853
Lali Village	Trees	5	202	1.55	1.6094	0.963
	Shrubs	3	62	0.934	1.0986	0.85
	Herbs	—	—	Excluded*	—	—
Ruka Forest / Getalsud Dam	Trees	2	26	0.2712	0.6931	0.391
	Shrubs	10	65	1.8694	2.3026	0.812
	Herbs	15	214	2.4329	2.7081	0.898

** Lali Village herb data were excluded following the data-integrity check described in Section 3.4.*

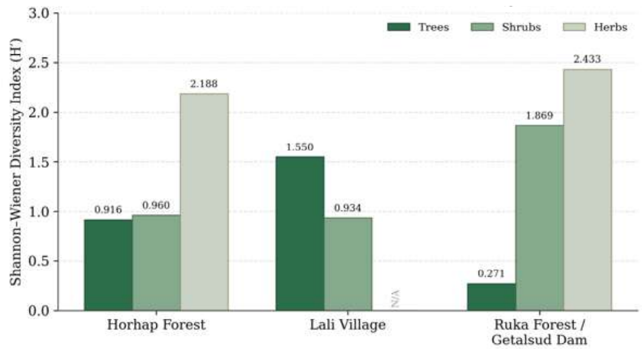

Figure 3. Shannon–Wiener diversity index (H') by vegetation stratum across the three sites.

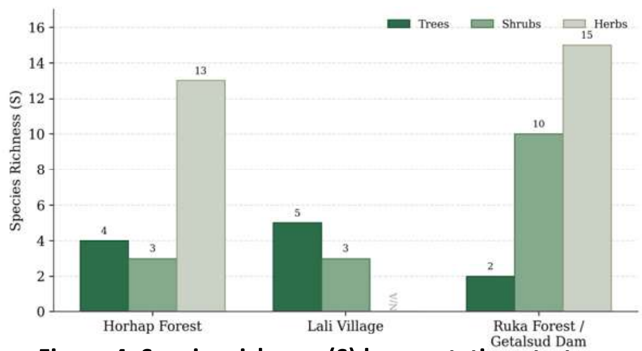

Figure 4. Species richness (S) by vegetation stratum across the three sites.

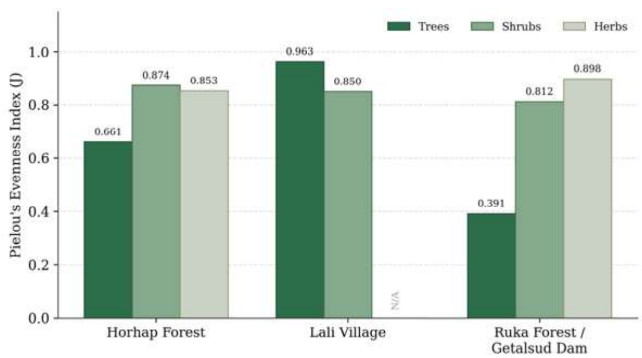

Figure 5. Pielou's evenness index (J) by vegetation stratum across the three sites.

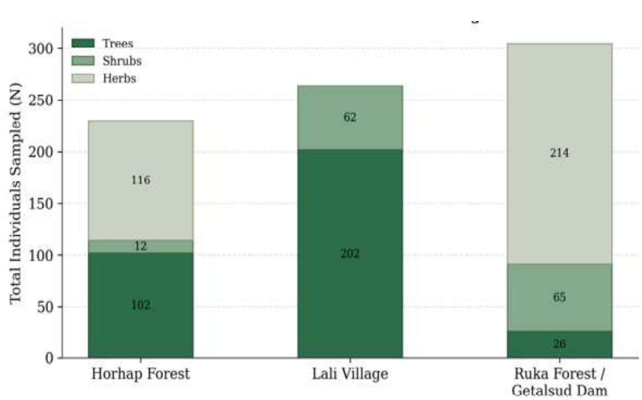

Figure 6. Total sampled abundance (N) by vegetation stratum across the three sites.

Site-wise species composition

Horhap Forest

The tree layer at Horhap Forest (S = 4, N = 102) was strongly dominated by *Shorea robusta*, which accounted for 67.6% of all individuals recorded, consistent with the classical sal-forest climax association of the region; the low tree-layer evenness (J = 0.661) reflects this dominance as shown in Table 2. The shrub layer (S = 3, N = 12) was dominated by *Chromolaena odorata* (58.3%), an invasive weed species commonly associated with forest-edge disturbance as shown in Table 3. The herb layer was markedly more diverse (S = 13, H' = 2.188, J = 0.853) and co-dominated by *Cynodon dactylon* and *Hemidesmus indicus* as shown in Table 4.

Table 2. Horhap Forest - tree-layer species composition.

Species	Common Name	n	Density (ind./quadrat)	Relative Density (%)
Shorea robusta	Sal Tree	69	11.5	67.65
Holarrhena pubescens	Kurchi	21	3.5	20.59
Lagerstroemia parviflora	Laurel	8	1.33	7.84
Butea monosperma	Flame of the Forest	4	0.67	3.92
Total		**102**	**100**	

Table 3. Horhap Forest - shrub-layer species composition.

Species	Common Name	n	Density (ind./quadrat)	Relative Density (%)
Chromolaena odorata	Siam Weed	7	1.17	58.33
Ampelocissus glandulosa	Wild Grape	3	0.5	25
Asparagus racemosus	Shatavari	2	0.33	16.67
Total		**12**	**100**	

Table 4. Horhap Forest — herb-layer species composition

Species	Common Name	n	Density (ind./quadrat)	Relative Density (%)
Cynodon dactylon	Bermuda Grass	26	4.33	22.41
Hemidesmus indicus	Indian Sarsaparilla	23	3.83	19.83
Elephantopus scaber	Elephant's Foot	15	2.5	12.93
Cyperus rotundus	Nut Grass	12	2	10.34
Sida cordata	Country Mallow	11	1.83	9.48
Dioscorea bulbifera	Air Potato	8	1.33	6.9
Curculigo orchioides	Kali Musli	7	1.17	6.03
Commelina diffusa	Spreading Dayflower	4	0.67	3.45
Clerodendrum infortunatum	Bhat	3	0.5	2.59
Carex sp.	Sedge	3	0.5	2.59
Stachytarpheta jamaicensis	Blue Porterweed	2	0.33	1.72
Barleria sp.	Barleria	1	0.17	0.86
Curculigo bulbifera	Bulbous Curculigo	1	0.17	0.86
Total		**116**	**100**	

Lali Village

The tree layer at Lali Village showed the highest diversity and evenness of any tree community sampled (S = 5, N = 202, H2 = 1.550, J = 0.963), with five species present in comparatively balanced proportions (*Shorea robusta* 30.2%, *Croton persimilis* 23.8%, *Magnolia macrophylla* 20.8%, *Melia dubia* 14.4%, *Tectona grandis* 10.9%) as shown in table 5 and 6. This pattern is consistent with a mixed, less canopy-dominated community typical of village-edge secondary growth rather than climax sal forest. The shrub layer (S = 3, N = 62) was dominated by *Dendrocnide cordifolia* (56.5%). Herb-layer data for this site were excluded (Section 3.4).

Table 5. Lali Village — tree-layer species composition.

Species	Common Name	n	Density (ind./quadrat)	Relative Density (%)
Shorea robusta	Sal Tree	61	10.17	30.2
Croton persimilis	Croton	48	8	23.76
Magnolia macrophylla	Bigleaf Magnolia	42	7	20.79
Melia dubia	Malabar Neem	29	4.83	14.36
Tectona grandis	Teak	22	3.67	10.89
Total		**202**	**100**	

Table 6. Lali Village — shrub-layer species composition.

Species	Common Name	n	Density (ind./quadrat)	Relative Density (%)
Dendrocnide cordifolia	Heart-leaved Nettle	35	5.83	56.45
Lantana camara	Lantana	20	3.33	32.26
Pandanus amaryllifolius	Pandan	7	1.17	11.29
Total		**62**	**100**	

Ruka Forest / Getalsud Dam

The tree layer at Ruka recorded the lowest diversity in the study (S = 2, N = 26, H2 = 0.271, J = 0.391), with *Litsea monopetala* accounting for 92.3% of individuals — near-monodominance consistent with a heavily disturbed or regenerating stand at the reservoir margin. In marked contrast, the shrub layer (S = 10, H2 = 1.869, J = 0.812) and herb layer (S = 15, H2 = 2.433, J = 0.898) were the most diverse strata recorded at any site in this study, suggesting that understorey colonisation by a broad range of weedy and ruderal species has proceeded independently of, and inversely to, canopy diversity as shown in table 7,8 and 9.

Table 7. Ruka Forest/Getalsud Dam -tree-layer species composition.

Species	Common Name	n	Density (ind./quadrat)	Relative Density (%)
Litsea monopetala	Kukurchita	24	4	92.31
Citrus jambhiri	Rough Lemon	2	0.33	7.69
Total		**26**	**100**	

Table 8. Ruka Forest/Getalsud Dam -shrub-layer species composition.

Species	Common Name	n	Density (ind./quadrat)	Relative Density (%)
Physalis peruviana	Cape Gooseberry	28	4.67	43.08
Capparis spinosa	Caper Bush	9	1.5	13.85
Stachytarpheta cayennensis	Cayenne Porterweed	6	1	9.23
Randia aculeata	Indigoberry	4	0.67	6.15
Sida rhombifolia	Arrowleaf Sida	4	0.67	6.15
Ziziphus oenoplia	Jackal Jujube	4	0.67	6.15
Duranta erecta	Golden Dewdrop	3	0.5	4.62
Jasminum azoricum	Azores Jasmine	3	0.5	4.62
Tabernaemontana divaricata	Crape Jasmine	2	0.33	3.08
Nauclea latifolia	African Peach	2	0.33	3.08
Total		**65**	**100**	

Table 9. Ruka Forest/Getalsud Dam -herb-layer species composition.

Species	Common Name	n	Density (ind./quadrat)	Relative Density (%)
Ichnocarpus frutescens	Black Creeper	48	8	22.43
Dioscorea bulbifera	Air Potato	23	3.83	10.75
Xanthium strumarium	Cocklebur	21	3.5	9.81
Fagopyrum dibotrys	Perennial Buckwheat	18	3	8.41
Curculigo orchioides	Kali Musli	18	3	8.41
Solanum americanum	American Black Nightshade	18	3	8.41
Alternanthera philoxeroides	Alligator Weed	15	2.5	7.01
Parthenium hysterophorus	Congress Grass	12	2	5.61
Dysphania ambrosioides	Wormseed	12	2	5.61
Cynodon dactylon	Bermuda Grass	9	1.5	4.21
Brachypodium sylvaticum	False Brome	6	1	2.8
Lippia alba	Bushy Matgrass	6	1	2.8
Sphenodesme paniculata	Sphenodesme	3	0.5	1.4
Alternanthera sessilis	Sessile Joyweed	3	0.5	1.4
Erigeron bonariensis	Flax-leaf Fleabane	2	0.33	0.93
Total		**214**	**100**	

DISCUSSION

A consistent pattern emerges across all three sites: tree-layer diversity and evenness vary markedly with apparent disturbance and successional status, while shrub- and herb-layer diversity remain comparatively high regardless of canopy condition. Ruka's near-monodominant tree layer (J = 0.391) alongside its highly diverse shrub and herb layers (J = 0.81–0.90) illustrates a pattern reported elsewhere in disturbed tropical forest fragments, where canopy simplification following selective removal or regeneration failure of climax species is accompanied by understorey colonisation by fast-growing, often weedy or invasive, shrub and herb species (cf. Whittaker's (1972) discussion of disturbance and beta diversity). The prevalence of *Physalis peruviana*, *Parthenium hysterophorus*, and *Xanthium strumarium* — all recognised colonisers of disturbed ground — in the Ruka shrub and herb layers supports this interpretation.

Horhap Forest's tree layer, by contrast, shows the classical signature of a sal-climax community: high dominance of a single, shade-tolerant, long-lived species (*Shorea robusta*, 67.6% relative density) with moderate evenness (J = 0.661) among a small number of associated species. Lali Village's tree layer, with five co-occurring species in comparatively balanced proportion (J = 0.963), is consistent with a mixed, edge-of-settlement stand shaped by selective historical extraction and planting (*Croton persimilis, Melia dubia,* and *Tectona grandis* are all species with local utility value) rather than by natural climax succession alone.

Applying Peet's (1974) recommendation to interpret richness, evenness, and a composite index jointly rather than in isolation is informative here: Ruka's tree layer has both the lowest richness and the lowest evenness of any stratum sampled, indicating true ecological impoverishment of the canopy rather than merely a small-sample artefact, whereas its shrub and herb layers combine moderate-to-high richness with moderate-to-high evenness, indicating a genuinely diverse and balanced understorey assemblage rather than dominance by a single coloniser.

LIMITATIONS

Three limitations should be noted. First, as described in Section 3.4, the Lali Village herb-layer dataset was found on verification to duplicate the Ruka shrub-layer dataset and was excluded rather than reported; a genuine herb survey at Lali Village remains outstanding and is recommended as a priority for follow-up fieldwork. Second, sampling was restricted to six quadrats per stratum per site and to a single field season, which is adequate for a first baseline characterisation but does not capture seasonal turnover in the herbaceous layer or inter-annual variability; a species–area curve was not independently constructed to confirm sampling adequacy, and this should be addressed in future replications. Third, species identification relied on a smartphone plant-identification application cross-checked against field observation rather than herbarium voucher confirmation; while adequate for common regional species, this introduces a small risk of misidentification for morphologically similar taxa, and voucher specimens are recommended for any future publication-grade dataset from these sites.

CONCLUSION

This study demonstrates that stratified nested-quadrat sampling, combined with standard diversity indices, is an effective and low-cost method for characterising vegetation structure across a peri-urban land-use gradient in the Chota Nagpur plateau. Tree-layer diversity and evenness declined sharply from the mixed, balanced stand at Lali Village through the sal-dominated stand at Horhap Forest to the near-monodominant stand at Ruka Forest, while shrub- and herb-layer diversity remained consistently moderate to high across all sites, indicating that understorey and canopy diversity are not simply co-varying but can respond in opposite directions to local disturbance. These findings provide a baseline for future vegetation monitoring, restoration prioritisation, and biodiversity conservation planning in the peri-urban forest fragments surrounding Ranchi, and underline the value of routine data-verification steps — such as the one that identified the excluded Lali Village dataset in this study — in maintaining the integrity of field-based ecological datasets.

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AUTHOR CONTRIBUTIONS

P.K., S.P., D.P., A.S., A.K., S., M. S. A., R. M. I.K., A.B.K and M. K., conducted field sampling, species identification, and primary data recording. S.P. (Sandeep Prasad), R. M. (Rashmi Mishra) and P. M. (Prasanjit Mukherjee) verified the dataset, identified and corrected the data-quality issues reported in Sections 3.4 and 5.4, performed the statistical re-analysis, generated the figures, and prepared this manuscript for submission. All authors reviewed and approved the final version.

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