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How Environment and Urbanization Shape Bird Diversity in Sri Lanka

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1. Introduction

- Birds are highly effective **bioindicators** of environmental change — they are sensitive to habitat structure, climate shifts, pollution, and human disturbance, making them ideal proxies for ecosystem health.
- Sri Lanka is a global **biodiversity hotspot** hosting 429 species across rainforest, scrubland, and wetland ecosystems, yet faces rapid urbanization and land-use transformation.
- Existing studies rarely combine **habitat structure, climate, air pollution, and artificial light at night (ALAN)** in a single national-scale analysis with effort correction.
- **Objective:** Identify which environmental factors most strongly predict bird species richness across Sri Lanka using multi-source satellite data and citizen-science observations.

2. Research Questions & Hypotheses

- **RQ1 / H1:** Does land-cover type explain cell-level richness better than NDVI or climate predictors alone? — Categorical habitat outperforms continuous greenness in hold-out rank agreement.
- **RQ2 / H2:** Is ALAN (urbanization) associated with reduced diversity or biotic homogenization? — ALAN linked to reduced district evenness; Jaccard tests for community convergence.
- **RQ3 / H3:** Are these associations consistent across 2, 5, and 10 km grid scales? — Inventory size remains stable; richness patterns broadly reproduce across resolutions.

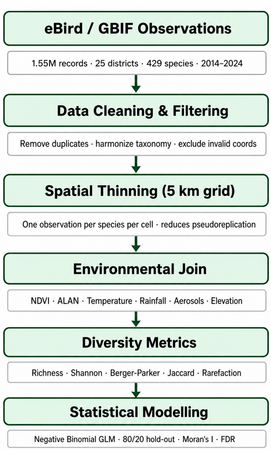
3. Data Sources

Dataset	Purpose & Details
eBird / GBIF	Bird observations 2014–2024; cleaned for taxonomy & coordinates
MODIS NDVI	16-day vegetation greenness composites (MOD13A1)
MODIS Land Cover	Habitat type — 17 IGBP classes (MCD12Q1)
VIIRS ALAN	Night-light radiance as urbanization proxy (VNP46A1)
MERRA-2	Monthly temperature, rainfall, and aerosol optical depth
SRTM	90 m elevation; correlated with temperature gradient

1.55 million records • 429 species
25 districts • 2014–2024

Observation density peaks in the Central Highlands and Western Province. The dry-zone north is systematically under-sampled, underscoring the need for effort correction via **rarefaction** and **checklist density** as a covariate.

4. Methodology



Why 5 km grids? Balances spatial detail against observer-location clustering in citizen-science data. Finer grids (<2 km) amplify pseudoreplication; coarser grids (>10 km) mask habitat variation. Species inventory (429) remained stable across 2, 5, and 10 km.

Bias & effort control:

- Spatial thinning — one obs. per species per grid cell
- Rarefaction with 300 resampling draws to equalise effort
- Yeo–Johnson transform on NDVI and ALAN before modelling
- Checklist density as an explicit effort covariate in all GLMs

5. Statistical Modelling

Why Negative Binomial GLM? Poisson GLM showed severe overdispersion $\left(\chi^2/\mathrm{df} \approx 38.5\right)$. The Negative Binomial distribution absorbs extra-Poisson variance from unmeasured spatial heterogeneity.

$$\log\Big(\mathbb{E}[\text{Richness}]\Big) = \beta_0 + \beta_1\,\text{NDVI} + \beta_2\,\text{LandCover} + \beta_3\,\text{Temp} + \beta_4\,\text{ALAN} + \beta_5\,\text{Elevation} + \cdots$$

- **Response:** species richness per 5 km cell (count data); $n = 1{,}736$ cells
- **Reference class:** Evergreen Broadleaf Forest for land-cover contrasts
- **Evaluation:** 80/20 stratified hold-out; Spearman ρ, RMSE, MAE
- Moran's $I = 0.28$ on residuals — mild spatial autocorrelation; findings are *associational*

6. Results

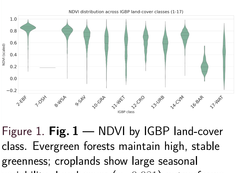


Figure 1. **Fig. 1** — NDVI by IGBP land-cover class. Evergreen forests maintain high, stable greenness; croplands show large seasonal variability. Land cover (ρ=0.081) outperforms NDVI alone (ρ=0.033) as a richness predictor — supporting H1.

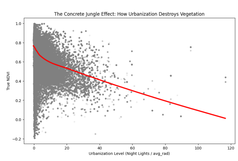


Figure 2. **Fig. 2** — LOWESS regression of NDVI against ALAN. Brighter (more urbanized) areas show consistently lower vegetation greenness, creating a secondary urbanization–richness pathway via habitat degradation.

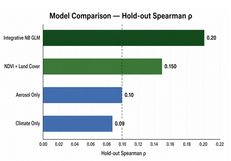


Figure 3. **Fig. 3** — Hold-out Spearman ρ by predictor family. Integrative NB GLM (ρ=0.20) outperforms all single-family models; land cover + NDVI leads among individual families, confirming H1.

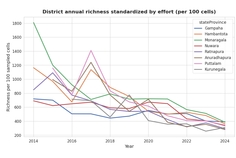


Figure 4. **Fig. 4** — Effort-standardized district richness (per 100 sampled cells) 2014–2024. Most districts show a declining trend, signalling broad-scale habitat pressure.

Key finding	Result
Land cover vs NDVI (marginal ρ)	0.081 vs 0.033 — habitat type wins
Temperature association	Negative: $\beta = -0.046$, p=0.002
Cropland vs Evergreen Forest	$\beta = -0.427$, p=0.011 — lower richness
Woody savanna / mosaics	$\beta \approx -0.19$ to -0.24, $p \leq 0.01$
ALAN after effort correction	β drops $0.066 \rightarrow 0.009$, p=0.60 — not ecology
Jaccard dissimilarity	Turnover, not island-wide homogenization (H2 partial)

7. Conclusions

- ✓ **Land-cover structure** is the strongest environmental predictor of bird diversity in Sri Lanka — categorical habitat type outperforms continuous NDVI, climate, and ALAN in hold-out evaluation.
- ✓ **Urbanization (ALAN)** shapes community evenness and species dominance at the district scale. Its apparent richness association disappears once sampling effort is accounted for — a key methodological finding.
- ✓ The multi-source, effort-corrected framework is **scalable** to other tropical islands and directly supports biodiversity monitoring and conservation prioritization where occurrence data are sparse.

Key References

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Key Numbers at a Glance

Species recorded	**429**	Records cleaned	**1.55 M**
Grid cells (5 km)	**1 736**	Districts	**25**
NB GLM hold-out ρ	**0.20**	RMSE / MAE	**47 / 37**
Land cover ρ	**0.081**	NDVI ρ alone	**0.033**
ALAN β (raw)	**0.066**	ALAN β (effort-corrected)	**0.009**

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