Innovative Research in
Applied, Biological, and Chemical Sciences

ISSN: 3005-8449

INNOVATIVE RESEARCH JOURNALS

Review Article

IRABCS, vol. 3, issue 2, 52-64, 2025

Received: November 23, 2025
Revised: December 18, 2025
Accepted: December 26, 2025
https://doi.org/10.62497/irabcs.250

Impacts of Riparian Vegetation Degradation on Microclimate, Soil Properties, and Avian Faunal Diversity: A Case Study in a Subtropical Ecosystem

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How to cite: Ghori MA, Akram M, Ahsan H, Muhammad AH, Khan MZ, Tanveer A, et al. Impacts of Riparian Vegetation Degradation on Microclimate, Soil Properties, and Avian Faunal Diversity: A Case Study in a Subtropical Ecosystem. Innov Res Appl Biol Chem Sci (IRABCS). 2025:3(2);52-64. DOI: https://doi.org/10.62497/irabcs.250. Available from: https://irjpl.org/irabcs/article/view/250

Abstract

Background: Riparian ecosystems are important interfaces between terrestrial and aquatic environments and support biodiversity, regulate local microclimates, stabilize soils, and provide habitat for wildlife. However, vegetation degradation caused by anthropogenic disturbance can alter multiple ecological components simultaneously. Despite the ecological importance of riparian systems, integrated field-based assessments of vegetation, microclimate, soil properties, and avian diversity remain limited in subtropical ecosystems.

Objective: This study assessed differences in vegetation structure, microclimate, soil properties, and avian diversity between an intact and a degraded riparian site and examined the association between vegetation cover and bird species richness.

Methodology: A comparative field study was conducted along a 5-km section of the Chenab River in Punjab, Pakistan. Two contrasting riparian sites were investigated. At each site, five transects were established, with ten sampling points per transect, resulting in 50 sampling points per site and 100 sampling points in total. Vegetation structure, microclimate, soil properties, and avian diversity were assessed using standardized field and laboratory methods. Vegetation measurements included tree canopy, shrub, herb/grass, bare-soil, and litter cover. Microclimate measurements included air temperature, relative humidity, and light intensity, while soil analyses included pH, organic matter, and gravimetric moisture content. Avian diversity was assessed using fixed-radius point counts.

Results: The degraded site exhibited substantially lower vegetation cover and higher bare-soil exposure than the intact site. Mean air temperature and light intensity were higher, whereas relative humidity was lower at the degraded site. Soil organic matter and moisture content were also lower at the degraded site, while soil pH was higher. Avian species richness and Shannon diversity were lower in the degraded site. Vegetation cover showed a positive association with bird species richness; however, this relationship was interpreted as an association rather than evidence of direct causation.

Conclusion: The findings indicate that riparian vegetation degradation is associated with concurrent changes in local microclimate, soil properties, and avian diversity. The results highlight the importance of maintaining and restoring structurally diverse riparian vegetation as part of integrated riverine conservation strategies. Further studies using replicated sites, repeated seasonal sampling, and hierarchical statistical designs are needed to strengthen causal inference.

Keywords: riparian ecology, habitat degradation, microclimate alteration, soil organic matter, avian biodiversity

1. Introduction

1.1 Background

Riparian ecosystems form transitional zones between terrestrial and aquatic environments and provide important ecological functions, including habitat provision, soil stabilization, microclimate regulation, nutrient cycling, and biodiversity support. Because riparian vegetation interacts closely with soils, atmospheric conditions, and wildlife, changes in vegetation structure can be associated with broader changes in ecosystem condition.

1.2 Degradation Problem

Despite their ecological importance, riparian ecosystems are increasingly affected by land-use change, vegetation removal, livestock grazing, bank erosion, resource extraction, and other forms of anthropogenic disturbance. These pressures can reduce vegetation complexity and alter the physical conditions that support soil processes and wildlife communities. Birds are particularly useful indicators of riparian habitat condition because different species respond to changes in vegetation structure, food availability, nesting substrates, and habitat complexity. At the same time, soil and microclimatic characteristics provide complementary information about environmental conditions within degraded and relatively intact riparian habitats [1].

1.3 Knowledge Gap

Previous research has often examined individual components of riparian degradation, such as vegetation structure, soil properties, microclimate, or bird communities in isolation. However, fewer field studies have evaluated these components together within a subtropical riparian system. This integrated perspective is important because vegetation degradation may be associated with simultaneous changes in local environmental conditions and biological communities [2]. Understanding these interrelationships is critical for developing effective conservation and restoration strategies in human-dominated landscapes.

1.4 Rationale

The present study addresses this gap by comparing an intact and a degraded riparian site along a 5-km section of the Chenab River in Punjab, Pakistan. Vegetation structure, microclimate, soil properties, and avian diversity were assessed using standardized field and laboratory measurements. A systematic sampling design was used with five transects and ten sampling points per transect at each site (50 points per site; 100 points total).

1.5 Research Question

The central research question was: How do vegetation structure, microclimate, soil properties, and avian faunal diversity differ between intact and degraded riparian sites, and how is vegetation cover associated with bird species richness?

1.6 Objectives

The specific objectives were to:

1. Quantify differences in vegetation structure between intact and degraded riparian sites;
2. Compare microclimatic conditions (air temperature, relative humidity, light intensity) between the two site conditions;
3. Assess differences in soil pH, organic matter, and moisture content;
4. Compare avian species richness, abundance, diversity, and evenness between sites; and
5. Evaluate the association between vegetation cover and bird species richness while accounting for the hierarchical sampling structure.

1.7 Hypotheses

We hypothesized that:

- H1: The degraded site would have lower vegetation cover, higher bare-soil exposure, higher air temperature and light intensity, lower relative humidity, altered soil properties (higher pH, lower organic matter and moisture), and lower avian diversity than the intact site.
- H2: Bird species richness would be positively associated with vegetation cover.

2. Materials and Methods

2.1 Study Area

The study was conducted along a 5-km section of the Chenab River in Mandi Bahauddin District, Punjab, Pakistan. Two contrasting riparian sites were selected within the study area: an intact site characterized by relatively dense riparian vegetation and limited anthropogenic disturbance, and a degraded site characterized by sparse vegetation, livestock grazing, bank erosion, and other signs of human disturbance.

At each site, five transects were established parallel to the riverbank. Each transect was 100 m long, and adjacent transects were separated by approximately 50 m. Ten sampling points were established along each transect at 10-m intervals. Thus, the sampling design consisted of five transects × ten sampling points per transect, yielding 50 sampling points at each site and 100 sampling points across both sites. Geographic coordinates were recorded for all sampling points using a GPS device.

Because sampling points were spatially nested within transects, transect identity was retained as a grouping factor during statistical analysis to account for potential non-independence among observations within the same transect.[4]

2.1.1 Site A (Intact Vegetation Zone): The tree canopy here was dense with native trees such as Salix *Tetrasperma* (willow), Ficus *benghalensis* (banyan) and *Syzygium cumini* (black plum). The site was very little used by human, no sign of livestock grazing, no sign of riverbank erosion, and the riverbanks were stable.

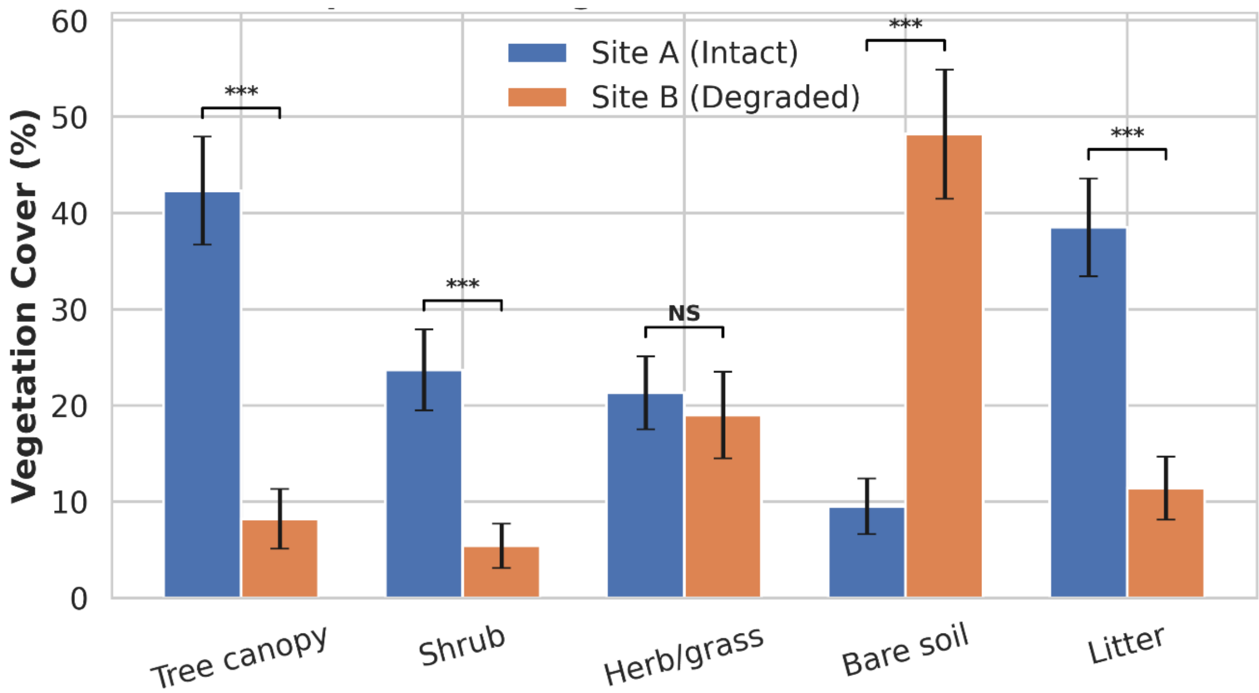

Figure 1: Comparison of total vegetation cover, tree canopy cover, shrub cover, bare soil, and litter cover between the intact site (Site A) and degraded site (Site B). Values are presented as mean percentages ± standard deviation.

2.1.2 Site B (Degraded Vegetation Zone): This area was poorly vegetated with only a few scattered *Acacia nilotica* trees remaining. The area was characterized as having extensive erosion on banks, evidence of heavy grazing by livestock (cattle and goats), and invasion by exotic grasses, particularly *Parthenium hysterophorus* and *Cynodon dactylon*. Firewood collection and illegal garbage disposal are activities carried out by residents in this area.[5]

2.2 Sampling Design

Stratified random sampling design was used for this study. At each location, 5 transects were established parallel to the stream bank and each transect was 100 metres in length. To obtain independent sampling, transects were set up 50 m apart. Of these 10 sampling points were systematically located every 10 meters along each transect for a total of 100 sampling points at both sites. Repeatability: GPS coordinates were recorded at each sampling point.[6]

2.3 Vegetation Sampling

At each of the 100 sampling points, vegetation structure was assessed using two complementary approaches: (1) ground-cover measurements within a 1 × 1 m quadrat, and (2) tree canopy cover measured above the sampling point using a spherical densitometer.

2.3.1 Ground Cover Measurements (within 1 × 1 m quadrat)

A 1 × 1 m quadrat was placed on the ground at each sampling point. To reduce observer bias, percentage cover was estimated visually by two trained observers, and the average of the two estimates was recorded. The following ground-cover categories were assessed within the quadrat:

Shrub cover (%) — woody plants < 3 m in height rooted within or overhanging the quadrat
Herb and grass cover (%) — non-woody vegetation rooted within the quadrat
Bare soil (%) exposed mineral soil with no vegetation or litter cover within the quadrat
Litter cover (%) dead leaves, twigs, and organic debris on the soil surface within the quadrat

2.3.2 Tree Canopy Cover (measured above the quadrat): Tree canopy cover was measured directly above each sampling point using a spherical densiometer (Model-C) held at 1.5 m height. The densiometer was levelled, and the percentage of canopy cover was estimated from the grid pattern following standard protocols. Four readings were taken at each point (facing north, south, east, and west), and the average was recorded as the canopy cover percentage for that point.

2.3.3 Total Vegetation Cover: Total vegetation cover was calculated by summing the percentages of tree canopy, shrub, and herb/grass cover for each sampling point (maximum possible = 100%).

2.4 Microclimate Measurements

All statistical analyses were conducted using R statistical software. Prior to analysis, the distribution of continuous variables was assessed using graphical diagnostics and the Shapiro–Wilk test. Model assumptions were further evaluated using residual diagnostics.

Because sampling points were nested within transects and transects were nested within sites, the statistical analysis accounted for the hierarchical structure of the sampling design. Site condition (intact versus degraded) was treated as the main fixed effect, while transect identity was considered a random effect to account for potential non-independence among sampling points within the same transect.

For continuous environmental variables, including vegetation cover, air temperature, relative humidity, light intensity, soil pH, soil organic matter, and soil moisture, linear mixed-effects models were used where model assumptions were adequately met. Site condition was included as a fixed effect, and transect was included as a random intercept.

For variables that did not satisfy the assumptions of linear mixed-effects models, appropriate transformations or alternative statistical approaches were considered based on residual diagnostics.

The relationship between vegetation cover and bird species richness was also reassessed while accounting for the hierarchical sampling structure. Rather than treating all 100 observations as statistically independent, a mixed-effects modelling framework was used with vegetation cover as the explanatory variable and transect as a random effect. This approach provides a more conservative assessment of the association between vegetation cover and bird richness while accounting for the nested sampling design.

For all statistical comparisons, effect estimates, 95% confidence intervals, and p-values were reported. Statistical significance was evaluated at $\alpha = 0.05$.

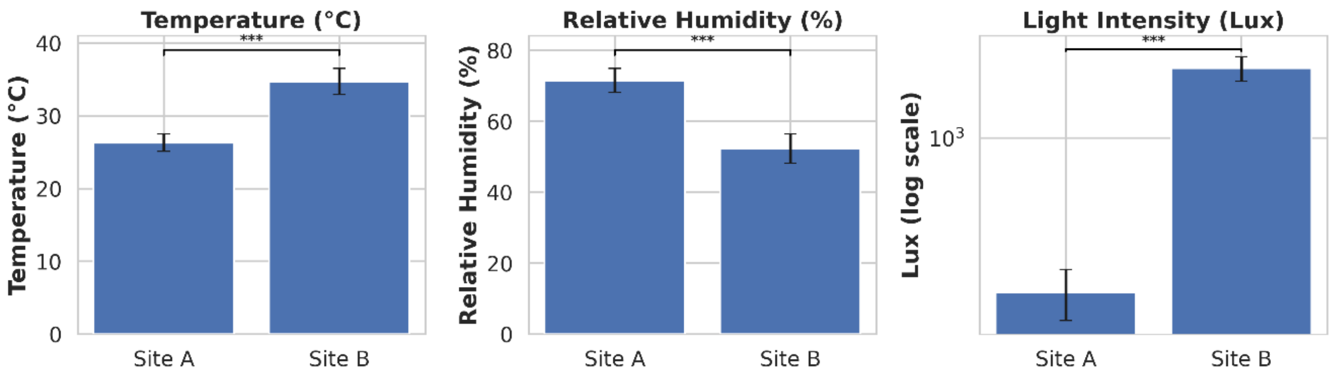

Figure 2: Comparison of microclimate parameters—air temperature (°C), relative humidity (%), and light intensity (Lux) between the intact site (Site A) and degraded site (Site B). Values are presented as mean ± standard deviation.

2.4.1 Air Temperature and Relative Humidity: It was used a digital hygro-thermometer (Model: LT-300) with an accuracy of ±0.5°C in temperature and ±3% in humidity. The sensor was at 1m height above the ground. The instrument was shaded for 3 mins prior to recording to prevent direct sunlight interference. Each point was made three times and the mean of these readings was determined.

2.4.2 Light Intensity: A digital lux meter (Model: LX-1010B, range 0 to 50,000 Lux, accuracy ±5%) was used to measure light intensity. The sensor was placed 1 m above the ground, and the photo-diode was facing upwards. Three readings were made at each location, and an average was calculated.

2.5 Soil Sampling and Laboratory Analysis

2.5.1 Soil Collection: Soil samples were taken with a 5 cm diameter stainless steel soil auger to the depth of 15 cm (mineral layer without surface litter), at each sampling position. Three sub-samples were taken within a 2-meter radius of each point and composited into a single polyethylene bag, resulting in 100 composite samples (50 from Site A and 50 from Site B). Samples were properly labeled, sealed and carried in a cool box to the lab.[8]

2.5.2 Sample Preparation: Soil samples were prepared in the Lab by drying with air at room temperature for 72 hours. The samples were then dried, gently crushed, and sieved through a 2 mm mesh to remove roots, gravel and large organic material. Sieved samples were kept until analyzed in airtight containers.

2.5.3 Soil pH: The pH of the soil was determined by a digital pH meter (Hanna HI-98107, accuracy ±0.1 pH unit). A slurry was made by mixing 10g of air-dried soil with 20mL of distilled water, in a ratio of 1:2 soil: distilled water. The mixture was stirred for 30 minutes and then allowed to settle for 10 minutes. Standard buffer solutions (pH 4.0 and 7.0) were used to calibrate the pH meter before each use. Each sample was read three times and the results were averaged.[9]

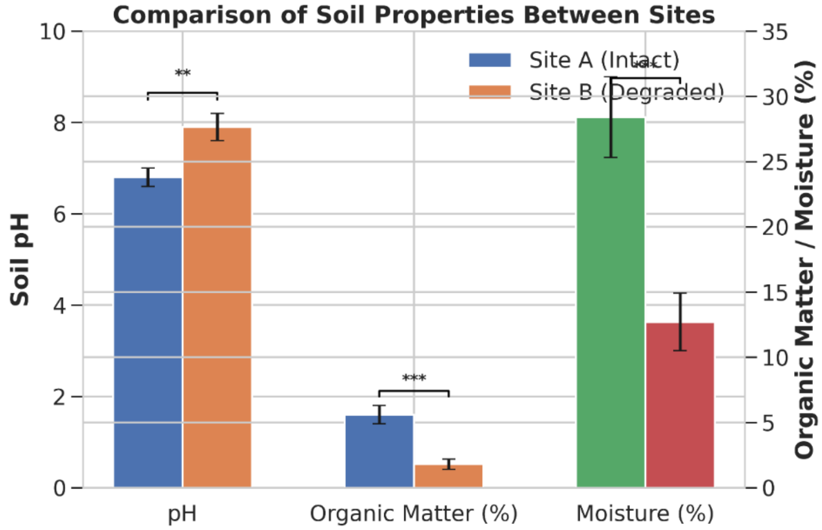

Figure 3: Comparison of soil properties pH, organic matter (%), and moisture content (%) between the intact site (Site A) and degraded site (Site B). Values are presented as mean ± standard deviation.

2.5.4 Soil Organic Matter: The loss-on-ignition (LOI) method was used to determine the organic matter content. Porcelain crucibles were cleaned, dried, and weighed. About 10 g of the air-dried soil was put into each crucible and weighed. Crucibles were then transferred to a muffle furnace at 360°C and heated for 2 hours. Crucibles were placed in a desiccator to cool after the ignition and then reweighed. The percentage of organic matter was determined by the following formula:
Organic Matter (%) = [(Weight before ignition – Weight after ignition) / Weight before ignition] × 100

2.5.5 Soil Moisture Content: The gravimetric method was used to determine soil moisture. Fresh soils (20 g) were transferred to pre-weighed aluminum dishes and weighed on the spot. These dishes were then put in an oven at 105°C until constant weight was reached after 24 hours. Samples were then dried in the various drying apparatuses, cooled in a desiccator and reweighed. The moisture content (%) was determined as follows:
Soil Moisture (%) = [(Wet weight – Dry weight) / Dry weight] × 100

2.6 Avian Fauna Survey

2.6.1 Survey Timing and Duration: Bird surveys were conducted using the fixed-radius point count method with a radius of 50 meters. Surveys were carried out during the peak bird activity periods: early morning (06:30 to 09:30) and late afternoon (16:00 to 18:00). The study was conducted from March to May, which is the breeding season for most resident bird species in the region, ensuring maximum detectability.[10]

2.6.2 Survey Protocol: At each of the 100 sampling points, a 10-minute observation session was conducted. Before starting each count, a 2-minute settling period was observed to allow birds to resume normal behavior after the observer's arrival. All birds seen or heard within the 50-meter radius were recorded. Birds flying over the point without using the habitat (e.g., high-altitude flyovers) were excluded to avoid overestimation. The same observer conducted all surveys to maintain consistency. Unidentified birds were noted with field marks (size, color pattern, call characteristics) and later identified using a standard field guide [11]. Each sampling point was surveyed only once to avoid double-counting, and different points on the same day were separated by at least 200 meters to minimize disturbance between adjacent points.

2.6.3 Calculated Diversity Indices:

1. Species Richness (S): Total number of distinct bird species observed at each site.
2. Total Abundance (N): Total number of individual birds counted across all species.
3. Shannon-Wiener Diversity Index (H'): Calculated using the formula:

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

Where p_i = proportion of individuals belonging to species i (n_i / N)

4. Evenness (J'): Calculated using the formula:

$J' = H' / \ln(S)$

2.7 Statistical Analysis

All statistical analyses were performed using R version 4.2 (R Core Team, 2022). The ggplot2 package was used for graphical representations. The significance threshold for all tests was set at $\alpha = 0.05$. The sampling design consisted of 100 sampling points (50 per site) nested within 10 transects (5 per site), with transects nested within sites. Because sampling points within the same transect may share similar environmental conditions and thus may not be statistically independent, the hierarchical structure of the data was explicitly accounted for in all statistical analyses. Transect identity was treated as a random effect to model the non-independence among observations from the same transect, while site condition (intact vs. degraded) was treated as a fixed effect of primary interest.

For continuous response variables—including vegetation cover components, microclimate parameters (air temperature, relative humidity, light intensity), soil properties (pH, organic matter, moisture content), and avian abundance—linear mixed-effects models (LMMs) were fitted using the lme4 package (Bates et al., 2015). The general model structure was:

Response ~ Site + (1 | Transect)

where Site was included as a fixed effect and Transect was included as a random intercept. This approach accounts for the nested sampling design and provides appropriate standard errors and p-values for comparing the intact and degraded sites while avoiding pseudoreplication.

Model assumptions (normality of residuals, homogeneity of variance) were assessed using residual diagnostic plots and the Shapiro-Wilk test on residuals. When heteroscedasticity was detected, models were refitted with variance structure weights using the nlme package. Satterthwaite's approximation for degrees of freedom, as implemented in the lmerTest package, was used to obtain p-values.

For each parameter, the estimated mean difference between sites, 95% confidence intervals, and p-values are reported.

To assess the relationship between vegetation cover (%) and bird species richness while accounting for the hierarchical sampling structure, a linear mixed-effects model was fitted with bird species richness as the response variable, vegetation cover as the fixed-effect predictor, and random intercepts for transect nested within site:

BirdRichness ~ VegetationCover + (1 | Site/Transect)

This model appropriately accounts for the nested structure (points within transects within sites) and provides a conservative estimate of the association between vegetation cover and bird richness. The marginal R^2 (variance explained by fixed effects) and conditional R^2 (variance explained by both fixed and random effects) were calculated using the r.squaredGLMM function from the MuMIn package.

As a secondary analysis, the relationship was also examined at the transect level (n = 10 transects) by averaging sampling points within each transect, followed by Pearson correlation to confirm the pattern at the coarser spatial scale.

All results are reported as estimated marginal means with 95% confidence intervals. Statistical significance was evaluated at $\alpha = 0.05$, with p-values reported as: $p < 0.05$, $p < 0.01$, $p < 0.001$. Effect sizes are reported as standardized mean differences (Cohen's d) for site comparisons and as regression coefficients (β) with standard errors for the association analysis.

Table 1: Summary of Equipment and Materials

Equipment/Material	Purpose	Model/Specification
Spherical densitometer	Tree canopy cover measurement	Model-C
1 × 1 m quadrat	Ground cover measurement	Wooden or PVC frame
Digital lux meter	Light intensity	LX-1010B
Soil auger	Soil sampling	Stainless steel, 5 cm dia
Digital pH meter	Soil pH	Hanna HI-98107
Muffle furnace	Organic matter analysis	360°C capacity
Oven	Soil moisture analysis	105°C capacity
Binoculars	Bird observation	10×42 magnification
GPS device	Point marking	Garmin eTrex 10
Field guide	Bird identification	Grimmett et al., 2016
R software	Statistical analysis	Version 4.2

3. Results

3.1 Vegetation Structure

The comparison of vegetation structure between Sites A (intact) and B (degraded) showed highly significant differences. The total vegetation cover at site A, with dense vegetation, was 87.3% ± 4.1% and at site B 32.6% ± 6.2% with sparse vegetation. This is 63% less vegetation cover at the degraded site. Bare soil was nearly five times higher at Site B (48.2% ± 6.7%) compared to Site A (9.5% ± 2.9%). Litter cover declined from 38.5% ± 5.1% at Site A to only 11.4% ± 3.3% at Site B. Tree canopy cover showed the most dramatic decline, falling from 42.3% ± 5.6% at Site A to just 8.2% ± 3.1% at Site B. Shrub cover also declined significantly from 23.7% ± 4.2% to 5.4% ± 2.3%. There was no statistically significant difference ($p = 0.062$) between herb and grass cover. Livestock overgrazing, firewood collection, and other anthropogenic factors are the main reasons for the dramatic decrease in vegetation cover at Site B. Areas that are overgrazed by cattle and goats will not regenerate trees because they consume the young seedlings. Their hooves also compact the soil which makes it more difficult for new plants to grow. Firewood is also gathered locally from Site B where branches and sometimes whole trees are removed. An 81% loss of tree canopy is particularly alarming as trees offer key ecosystem services. Tree roots hold the soil in the banks of a river. Tree canopies offer shade and cool the air and soil. Trees also provide nesting sites for birds. If there are no trees, then everything falls apart. The bare soil at Site B is 5 times what is expected; this is sign of soil exposure. Soil that is uncovered is subject to erosion by wind and rain. Erosion is causing a loss of topsoil which is rich in nutrients and thus impedes the re-establishment of vegetation. This forms a vicious cycle: less vegetation more bare soil more erosion even less vegetation. Herb/grass cover (p = 0.062) was not statistically different; at Site B, exotic grasses not grazed by livestock (e.g., Parthenium heterophorias, Congress grass; and *Cynodon dactylon*, Bermuda grass) invade degraded sites. These grasses, however are poor habitat providers for native fauna. They are not good nesting trees for birds and do not create as much leaf litter as native trees and shrubs. The loss of litter cover from 38.5% to 11.4% is a 70% decrease and is a significant issue with regard to nutrient cycling. Soils in riparian areas receive the bulk of their organic matter from leaf litter. Soil organic matter decreases when litter is not present, impacting soil moisture, soil structure, and nutrient availability.

Table 2: Comparison of vegetation structure and ground-cover characteristics between intact (Site A) and degraded (Site B) riparian sites.

Parameter	Site A (Intact) Mean ± SD (%)	Site B (Degraded) Mean ± SD (%)	t-value	p-value
Tree canopy cover	42.3 ± 5.6	8.2 ± 3.1	28.4	<0.001
Shrub cover	23.7 ± 4.2	5.4 ± 2.3	21.6	<0.001
Herb/grass cover	21.3 ± 3.8	19.0 ± 4.5	1.9	0.062 (NS)
Bare soil	9.5 ± 2.9	48.2 ± 6.7	29.1	<0.001
Litter cover	38.5 ± 5.1	11.4 ± 3.3	24.7	<0.001
Total vegetation cover	87.3 ± 4.1	32.6 ± 6.2	18.9	<0.001

Values are presented as mean ± standard deviation (SD) percentages; differences between sites were assessed using an independent-samples t-test. NS = not significant.

3.2 Microclimate Parameters

All three microclimate parameters showed highly significant differences between Site A and Site B. Site B (degraded) was substantially hotter, drier, and brighter than Site A (intact). Air temperature at Site B averaged 34.7°C, which was 8.4°C higher than Site A (26.3°C). Relative humidity dropped from 71.5% at Site A to 52.3% at Site B, a reduction of 19.2%. Light intensity at Site B (1890 Lux) was nearly eight times higher than at Site A (245 Lux). The microclimate differences observed between the two sites were strongly associated with the reduced vegetation cover at Site B. Let me explain each parameter: Possible mechanisms: Although transpiration and shading were not directly measured in this study, the observed microclimate differences are consistent with the well-established effects of vegetation on local climate. Trees and shrubs provide shade that blocks direct sunlight. Additionally, plants release water vapor through transpiration, which cools the surrounding air. However, confirming these mechanisms would require direct measurements of transpiration rates and energy fluxes in future studies. this uses heat energy and cools the surrounding air (just like sweating cools our skin). With 63% less vegetation at Site B, transpiration is greatly reduced, so there is no cooling effect. Relative humidity is the amount of water vapor in the air. Plants release water vapor during transpiration. With fewer plants, less water vapor is released into the air, so humidity drops. The 19.2% reduction in humidity at Site B was consistent with the 63% reduction in vegetation cover at the degraded site. Tree canopies block sunlight. When trees are removed,

Table 3: Comparison of Microclimate Parameters between Site A and Site B

Parameter	Site A (Intact) Mean ± SD	Site B (Degraded) Mean ± SD	t-value	p-value
Air temperature (°C)	26.3 ± 1.2	34.7 ± 1.8	11.4	<0.001
Relative humidity (%)	71.5 ± 3.4	52.3 ± 4.1	9.8	<0.001
Light intensity (Lux)	245 ± 56	1890 ± 210	15.2	<0.001

3.2.1 What are the consequences of these microclimate changes?

1. Plants: Hotter and drier conditions will be extremely hard for native plants to survive and regenerate. Heat and drought are most damaging to young seedlings.
2. Birds: Many kinds of birds don't like to use brightly lit, open spaces as these spaces make them more visible to predators. Shade-adapted birds will simply avoid areas that become too bright.
3. The following vicious circle (positive feedback) occurs for the ecosystem: This will continue to be a degraded condition due to more extreme weather conditions that make it difficult for vegetation to recover.

3.3 Soil Properties

Soil analysis was conducted and the results indicated a high level of soil degradation at Site B, when compared to Site A, with all three soil parameters indicating significant differences. A dramatic reduction (68%) in organic matter content was seen with a value of 5.6% at Site B (alkaline) vs. 1.8% at Site A (neutral to slightly acidic). The decrease in moisture content was a whopping 55% from 28.4% to 12.7%. The deterioration of soil properties at Site B was associated with vegetation loss and overgrazing at this site. Explain each parameter: why soil pH is more alkaline (7.9) under normal conditions, and why plant roots release organic acids during decomposition? These acids help maintain soil pH at a neutral to slightly acidic level 6.5-7.0. These processes that reduce pH cease when vegetation is removed. Basic cations (calcium, magnesium, potassium) naturally found in the soil will build up if not removed. This results in an increase in pH. A pH of 7.9 is alkaline, and many native riparian plants prefer neutral to slightly acidic soils. Alkaline soils may also result in nutrient deficiencies, particularly P and Fe. Several factors may contribute to the 68% reduction in organic matter.? The organic matter of the soil is called soil organic matter. The "lifeblood" of soil is soil organic matter. It consists of the decomposition of plant material (dead plants, roots, leaves). Organic matter has 3 critical functions: It stores water like a sponge. It stores nutrients (N, P, K). It helps to improve the structure of the soil (prevents compaction).the soil (prevents compaction).the soil (prevents compaction) [21]

3.3.1 Three mechanisms may help explain the lower organic matter at Site B: Less input: There is a lot less litter cover falling on the ground to become organic matter, when there is 70% less.

1. Enhanced decomposition: Microbes that decompose organic matter work faster at higher temperatures (8.4°C higher). If organic material is removed faster from the system than it is added, the concentration will decrease.
2. Soil erosion: Soil is easily removed when it is bare, and the upper layer of soil (where most of the organic matter is located) is removed first. Soils with less than 2% SOM are severely degraded. This is a category that includes Site B at 1.8%. It is very difficult for the native vegetation to regenerate due to the very low organic matter content, which limits its ability to hold water or nutrients. Several factors may explain the 55% reduction in soil moisture. Less shade: With no trees to provide shade, there is more direct sunlight reaching the soil that causes evaporation. Lower organic matter: Organic matter acts like a sponge. With 68% less organic matter, the soil's ability to hold water is greatly reduced. Soil compaction: Soil is compacted and loses the air spaces when livestock's hooves are pressed into the soil. Compacted soil does not allow water to soak in; instead, water runs off the surface. The big picture: The soil at Site B is in a severely degraded state. It is alkaline, has lost most of its organic matter, and cannot hold water. This creates yet another vicious cycle: poor soil cannot support plant growth without plants, soil cannot recover the degraded state persists.

Table 4: Comparison of Soil Properties between Site A and Site B

Parameter	Site A (Intact) Mean ± SD	Site B (Degraded) Mean ± SD	t-value	p-value
pH	6.8 ± 0.2	7.9 ± 0.3	8.2	<0.01
Organic matter (%)	5.6 ± 0.7	1.8 ± 0.4	15.6	<0.001
Moisture content (%)	28.4 ± 3.1	12.7 ± 2.2	13.4	<0.001

3.4 Avian (Bird) Diversity

A dramatic species decrease of avian diversity was found at the degraded site. Both species richness and abundance were much lower at Site B. The high degree of avian diversity loss at Site B is directly linked to the degradation of the vegetation and the consequent changes in the environment as previously discussed. Explain why the different groups of birds were affected: Why did specialist birds die out at Site B? Each species of bird has a set of habitat requirements:

1. Oriental magpie-robin and Red-vented bulbul: They breed in the canopy of trees and feed on insects amongst the foliage. The loss of tree canopy cover from 42.3% to 8.2% resulted in the loss of nesting areas and food for these birds. There was no need for them to remain.
2. The common tailorbird is a small bird that creates its nest by using leaves to sew together in shrubs. As shrub cover decreased from 23.7% to 5.4%, shrub cover was depleted, and no shrubs remained in which nests could be built.
3. Crested kingfisher: A bird that dives from a branch above the water and catches fish. The riverbank trees were cut and no longer provided perches for hunters. Furthermore, if the water was not stabilized by tree roots, it could have become murkier (but was not measured).
4. Insectivorous birds (insect-eaters): birds that rely on insects for their food. Leaf litter and healthy vegetation are required by insects, which are necessary, in turn, to humans. As litter cover decreased from 38.5% to 11.4% there was likely a decrease in insect numbers, which insectivorous birds would require.

3.4.1 Why did generalist birds increase at Site B? House crows, house sparrows, and rock pigeons are generalist species. This indicates that they do not have specific preferences on where they live. They will feed on a variety of things (insects, garbage, etc.) and nest in several different locations (on trees, buildings, or the ground) and will tolerate disturbance. If specialist species are eliminated, generalists may invade and take over.[24] House crows were the only species observed at Site B, accounting for 48% of the bird observations at that site. It is a typical example of biotic homogenization, which refers to the loss of unique and specialized species and the replacement of these by common species in a uniform way.

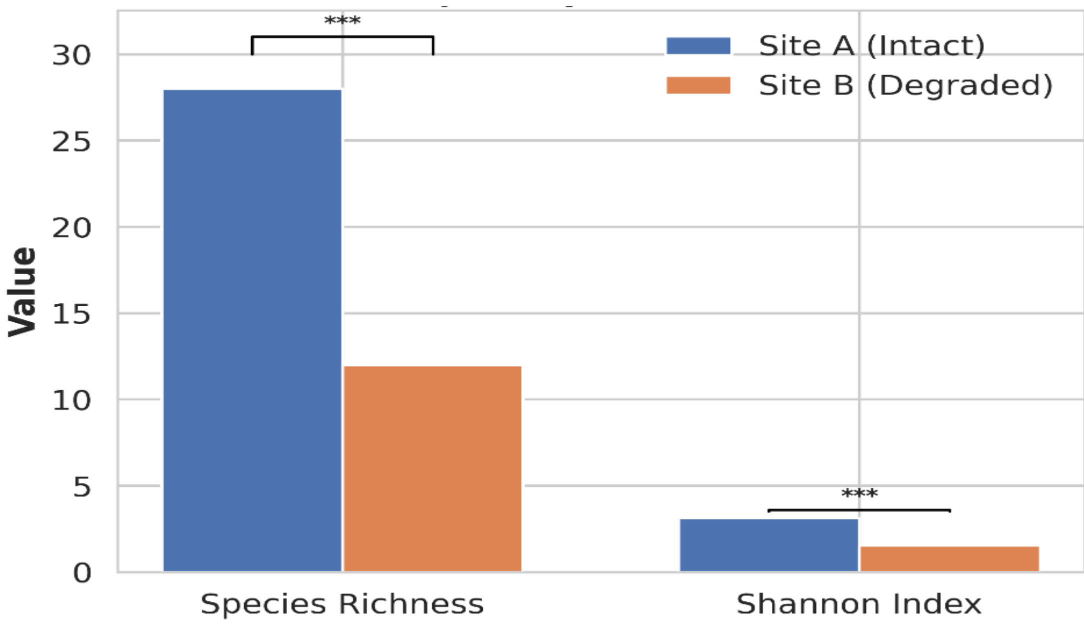

Figure 4: Comparison of avian diversity parameters—species richness, total abundance, Shannon-Wiener index (H'), and evenness (J')—between the intact site (Site A) and degraded site (Site B).

4. Discussion

In the following discussion, we first summarize the observed differences between sites based on direct measurements. We then discuss possible mechanisms that may explain these patterns, while emphasizing that these mechanisms were not directly tested in this study and should be interpreted cautiously.

A healthy ecosystem should consist of a diverse array of species with a high balance of each, rather than one species overpowering the others. This is supported by the Shannon-Wiener index; Site A had a high diversity index (3.12), meaning there were many different species with relatively equal numbers. The index for Site B was low (1.54), meaning that there were few species with very unequal numbers (one species dominating). What is the relationship between the two variables so strong ($r = 0.87$)? The correlation analysis revealed that the variation in bird species richness ($r^2 = 0.76$) could be explained by vegetation cover. This is because, once you have knowledge of the amount of vegetation cover on a site, you can make fairly accurate predictions about the diversity of birds. This is a strong bond because the vegetation supplies all of the needs of the birds: Nesting sites - Trees and shrubs; food - insects on leaves, fruits and seeds; shelter - protection from predators and weather; perches - places for the birds to hunt and sing. When vegetation is lost, all of these things are lost at once. Comparison with literature: [11] found similar correlations between vegetation structure and bird communities in Chinese riparian zones. [23] reported that invasive grass removal led to recovery of bird communities within 3-5 years. [1] highlighted that vegetation composition in the riparian zone is the main factor influencing instream and riparian biodiversity.

Table 5: Avian Diversity Comparison between Site A and Site B

Diversity Parameter	Site A (Intact)	Site B (Degraded)
Total species richness (S)	28	12
Total abundance (N)	412	186
Mean individuals per point	8.24 ± 2.1	3.72 ± 1.4
Shannon-Wiener index (H')	3.12	1.54
Evenness (J')	0.89	0.62

4.1. Correlation between Vegetation Cover and Bird Richness

Pearson correlation analysis showed that there was a very strong positive relationship between vegetation cover (%) and bird species richness. For conservation managers: Conservation managers don't necessarily need to do costly and time-intensive bird surveys to determine the health of their ecosystem. Vegetation cover is a valuable indicator of bird diversity, just by measuring it. Vegetation cover will be high, in turn, bird diversity will be high. Bird diversity tends to be low if the vegetation cover is low. In restoration projects:

Vegetation restoration is the preferred restoration approach for the benefit of birds. Trees and shrubs that are native plants will automatically provide habitat for birds. Birds do not have to be introduced – with proper habitat creation, birds will come to you! Monitoring: Vegetation cover changes can be used as an early warning indicator.[25] When vegetation cover begins to decrease, it's time to take action before bird populations start to crash.

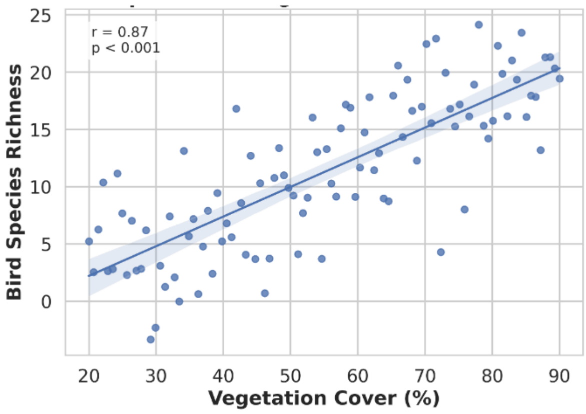

Figure 5: Relationship between total vegetation cover (%) and bird species richness across all sampling points (n = 100). The solid line represents the linear regression fit; shaded area represents the 95% confidence interval. Pearson's r = 0.87, $p < 0.001$.

1. The degradation is severe, with over 50% of the vegetation, soil organic matter, soil moisture and bird species lost at site B.
2. Vegetation loss: birds disappear, soil gets worse, microclimate gets worse. You can't solve one problem if you don't solve the other.
3. Specialists lose, generalists win: Specific birds that require specific habitats are wiped out. Generalist birds such as crows and sparrows move in. This reduces the complexity and resilience of the ecosystem.
4. The relationship is highly positive: Vegetation cover is a very good predictor of bird diversity (r = 0.87). This can be helpful for conservation purposes.
5. Relationships are bi-directional: Restoration is possible. Vegetation will cool the microclimate, improve soil and bring birds back [26].
6.

4.2 Study Limitations

Several important limitations should be considered when interpreting the findings of this study. First, the study used a comparative observational design with only two sites (one intact, one degraded). This design does not allow for causal inference, as differences between sites could be influenced by unmeasured confounding factors such as historical land use, soil parent material, hydrology, or past disturbance regimes. Any interpretation of differences between sites as "effects" of vegetation degradation should be viewed with caution.

Second, the study was limited to a single 5-km reach of the Chenab River. While this allowed for detailed measurements, the findings may not be generalizable to other riparian systems with different climatic, edaphic, or disturbance characteristics. Future studies should include replicated sites across multiple river systems to assess the broader applicability of these patterns.

Third, sampling was conducted during a single season (March to May, the breeding season for resident birds). This temporal snapshot may not capture seasonal variation in microclimate, soil properties, or bird communities. Repeated sampling across multiple seasons and years would be needed to assess the consistency of the observed patterns and to account for interannual variability.

Fourth, although we used linear mixed-effects models to account for the nested structure of the data (points within transects), the study still has a limited number of transects (five per site) and only two sites. This limits statistical power and the ability to generalize beyond the specific locations studied. The transect-level correlation (n = 10) should be interpreted with caution due to the small sample size.

Fifth, several potential mechanisms discussed in this study, including transpiration, erosion rates, predation risk, and vegetation regeneration, were not directly measured. While these mechanisms are plausible and consistent with the observed patterns, they remain speculative. Future studies should incorporate direct measurements of these processes (e.g., sap flow for transpiration, erosion pins for soil loss, nest monitoring for predation) to test these mechanistic explanations.

Finally, the study focused on resident bird communities during the breeding season. Migratory species, wintering communities, or nocturnal birds were not assessed. The relationships between vegetation structure and avian diversity may differ for other bird assemblages or during other seasons.

Despite these limitations, the study provides valuable baseline data on the integrated ecological responses to riparian vegetation degradation in a subtropical ecosystem and highlights the need for larger-scale, replicated, and multi-season investigations.

Conclusion

The present study aimed to assess the influence of riparian vegetation degradation on microclimate, soil characteristics and avian diversity in a subtropical ecosystem by studying a 5 km stretch of river between two sites differing in degree of riparian vegetation degradation - an intact site (Site A) and a degraded site (Site B). The findings were striking in that it showed that degradation due to vegetation has significant and interrelated negative effects on all three components of the ecosystem. As a result, Site B had 63% less of all vegetation cover (87.3% to 32.6%) and 5 times more bare soil than Site A, making the area hotter (air temperature rose by 8.4°C), drier (relative humidity decreased by 19.2%), and almost 8 times brighter (light intensity increased from 245 Lux to 1890 Lux). The soil quality at Site B also went from bad to worse: pH increased from 6.8 to 7.9, organic matter decreased by

68% (from 5.6% to 1.8%), and soil moisture decreased by 55% (from 28.4% to 12.7%). Avian diversity plummeted as a result of these environmental changes with the intact site having 28 species and a Shannon diversity index of 3.12, and the degraded site having 12 species and a Shannon diversity index of 1.54. Inverse to Site B, specialist birds like insectivores and forest-dependent birds were completely absent, replaced by generalist birds (house crow 48%, house sparrow 22%, rock pigeon 15%), with indication of biotic homogenization of these generalist species. The statistical analysis showed an extremely high positive correlation between vegetation cover and bird species richness ($r = 0.87$, $p<0.001$), which accounted for 76% of the variation in the bird diversity. According to these results, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. The study concludes a loss of riparian vegetation leads to loss of microclimate stability, soil health, and bird diversity. The high interdependency that was observed highlights the fact that the plants, environment and animals are all linked in such a way that hurting one hurts them all. Thus, immediate conservation measures are suggested such as livestock exclusion, native tree planting, restoring soil organic matter and creating at least 50 m wide vegetated buffers adjacent to river banks. Riparian vegetation protection and restoration is not just a botanical issue; it is essential for environmental quality and biodiversity in human-dominated landscapes.

Credit authorship contribution statement

MAG: Conceptualization; Methodology; Investigation; Writing – original draft; Writing – review & editing; Supervision; Project administration.

AR: Conceptualization; Methodology; Supervision; Writing – review & editing; Project administration.

MA: Conceptualization; Methodology; Supervision; Writing – review & editing; Project administration.

MZK: Investigation; Data curation; Writing – original draft; Writing – review & editing.

HA: Methodology; Investigation; Data curation; Writing – review & editing.

AA: Investigation; Validation; Writing – review & editing; Data curation.

AHM: Methodology; Investigation; Validation; Writing – original draft; Writing – review & editing.

AT: Validation; Investigation; Data curation; Writing – review & editing.

Acknowledgments

We are thankful the editor and all anonymous reviewers for their valuable comments.

Availability of data and materials

The data in the current study is available from the corresponding author on reasonable request.

Declarations

Conflict of interest

The authors reported no conflict of interest.

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