

# Diversity and Ecological Significance of Lower Botanical Flora in Lucknow and Adjacent Regions of Uttar Pradesh, India

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## **Abstract:**

Lower botanical organisms, comprising algae, fungi, bryophytes, and pteridophytes, represent foundational components of ecosystem structure and functioning. Despite their ecological importance, regional assessments of these groups remain limited across many urban and semi-urban landscapes of India. The present study investigates the diversity and ecological distribution of lower botanical flora in Lucknow and its adjoining regions of Uttar Pradesh. Qualitative field surveys were conducted across multiple habitat types, including wetlands, riverbanks, urban green spaces, shaded terrestrial substrates, and agricultural environments. Observations revealed substantial taxonomic representation across all major lower botanical groups, with pronounced seasonal variability linked to moisture availability. Algae dominated aquatic and damp terrestrial niches, fungi were primarily associated with decomposing organic substrates, bryophytes exhibited strong colonization of shaded urban surfaces, and pteridophytes were restricted to moist, semi-protected habitats. The findings highlight the ecological roles of lower plants in nutrient cycling, soil stabilization, microhabitat formation, and ecosystem resilience. This study underscores the need for systematic documentation and conservation-focused evaluation of lower botanical diversity within rapidly urbanizing regions of Indian ecosystems.

**Keywords:** Lower botany, Bryophytes, Algae, Fungi, Pteridophytes, Biodiversity, Lucknow, Urban ecology

## **1. Introduction**

Lower botanical organisms – encompassing algae, fungi, bryophytes and pteridophytes – represent some of the most ancient evolutionary lineages of plant life and constitute indispensable components of terrestrial and aquatic ecosystems. These groups perform critical ecological functions, including primary production, organic matter decomposition, soil formation, moisture regulation and nutrient cycling, thereby sustaining key biogeochemical processes and supporting higher trophic levels [1]. Despite their functional significance, lower botanical taxa frequently receive less research attention compared to higher vascular plants, largely due to their cryptic morphology, seasonal growth patterns and taxonomic complexity, which together contribute to persistent documentation gaps in many regions [2].

Recent assessments of Indian biodiversity show that lower botanical groups remain dynamically expanding components of the national flora. In 2024 alone, India added 433 new taxa of flora to its records, including 156 fungi, 63 lichens, 15 bryophytes, 4 pteridophytes and 32 algal taxa, highlighting the ongoing

discovery potential within these lineages. Such additions underscore that algae, fungi, bryophytes and pteridophytes are not only ancient evolutionary lineages but also contemporary contributors to biodiversity patterns, ecosystem functioning and global change responses. At the ecosystem level, bryophytes and other lower plants render multiple services, including soil formation, regulation of moisture and nutrient cycles, carbon sequestration and provision of microhabitats for invertebrates and microbes, which collectively enhance ecosystem stability and resilience [3].

Recent syntheses on bryophyte ecosystem services further emphasize that bryophyte mats support soil formation, nutrient retention, carbon cycling, water storage and erosion control, while acting as microrefugia for seedlings and small fauna. Because of their high surface-to-volume ratio and poikilohydric physiology, bryophytes respond rapidly to changes in moisture regime, atmospheric pollution and substrate chemistry, making them effective bioindicators of environmental quality in both natural and urban landscapes. Consequently, documenting the diversity and habitat associations of lower botanical taxa provides valuable insight into ecosystem health and environmental change [4].

Urban landscapes, once considered biologically impoverished, are now recognized as dynamic socio-ecological systems capable of supporting diverse assemblages of lower botanical flora. Studies from Indian cities have shown that rapid urban growth, land-use change and infrastructure expansion reshape habitat mosaics, alter hydrology and degrade wetlands, thereby influencing the distribution of both higher and lower plants. Within such transforming urban matrices, lower botanical flora colonize natural as well as artificial substrates, including moist soils, freshwater bodies, tree bark, rock surfaces and built infrastructure, where they exhibit remarkable adaptability to fluctuating microclimatic and pollution regimes [5].

Lucknow, the capital city of Uttar Pradesh, offers a heterogeneous ecological matrix shaped by climatic variability, hydrological features, anthropogenic disturbance and urban green spaces. Recent analyses of urban growth in Lucknow document rapid spatial expansion of built-up areas, conversion of agricultural land and contraction of wetland and open space, processes that collectively affect local biodiversity and environmental quality [6]. The presence of the Gomti River, along with numerous ponds, wetlands, shaded terrestrial habitats and managed urban green spaces, provides a wide range of microhabitats conducive to the growth of lower botanical taxa, while simultaneously exposing them to gradients of disturbance and pollution.

Work on epiphytic and urban bryophytes demonstrates that their richness and composition in cities are strongly shaped by microclimatic conditions, vegetation structure and the urban heat island effect [7]. In particular, higher normalized difference vegetation index (NDVI), presence of old, tall trees and cooler, more humid microclimates are associated with greater bryophyte diversity on urban substrates, indicating that well-managed urban green spaces can function as important refugia for lower plants within densely built environments. However, for many Indian cities, including Lucknow, systematic assessments of lower botanical organisms remain limited compared to higher plant surveys [8].

This knowledge gap is ecologically significant, as lower botanical taxa serve as sensitive indicators of environmental conditions, including moisture regimes, substrate stability, pollution levels and habitat disturbance, particularly in rapidly urbanizing landscapes. The present study aims to address this gap by evaluating the diversity and ecological distribution of lower botanical flora across selected habitats in Lucknow and adjacent regions [9].

Specifically, the study seeks to:

- Document major lower botanical groups present in the region,
- Identify habitat associations and distribution patterns,
- Examine ecological roles and functional significance,
- Highlight implications for biodiversity monitoring and conservation.

By improving regional understanding of lower botanical diversity, this study contributes to broader ecological knowledge, urban biodiversity research and conservation planning within subtropical urban ecosystems.

## 2. Study Area: Lucknow and Surrounding Region

Lucknow, the capital city of Uttar Pradesh, is situated in the central part of the Indo-Gangetic plains and represents a rapidly expanding urban ecosystem characterized by diverse natural and anthropogenic landscapes. Geographically, the city lies at approximately 26.85° N latitude and 80.95° E longitude, with an average elevation of about 123 meters above sea level. The region experiences a subtropical climate marked by pronounced seasonal variation, including hot summers, a monsoon-dominated rainy season, and mild winters [10]. The climate plays a crucial role in shaping lower botanical distribution. Monsoon rainfall, typically occurring between June and September, significantly enhances moisture availability, promoting the growth of algae, fungi, bryophytes, and pteridophytes [11-12]. Temperature fluctuations further influence seasonal proliferation patterns, particularly for moisture-dependent taxa. Hydrologically, the Gomti River forms a major ecological axis within the city, supporting riparian vegetation, wetlands, and semi-aquatic habitats. Numerous ponds, lakes, and artificial water bodies contribute additional microhabitats favorable for lower botanical colonization.

The surrounding region comprises a mosaic of land-use types, including:

- Urban green spaces (parks, gardens, institutional campuses)
- Agricultural fields
- Moist terrestrial substrates
- Disturbed urban surfaces (walls, pavements, shaded structures)
- Semi-natural habitats

Such environmental heterogeneity provides diverse ecological niches that facilitate the occurrence of lower botanical organisms [13]. Moisture-retentive surfaces, shaded areas, decomposing organic matter, and aquatic systems collectively enhance habitat suitability. The combination of climatic variability, hydrological features, and land-use diversity makes Lucknow and its adjoining areas an ecologically relevant site for investigating lower botanical flora and their distribution dynamics within urbanizing landscapes [14].



**Figure 1.** Lower botanical habitats in Lucknow showing algal growth along the Gomti River and bryophyte colonization on shaded urban surfaces.

### 3. Materials and Methods

#### 3.1 Study Design

This investigation employed a qualitative, survey-based observational design aimed at documenting the diversity and distribution of lower botanical taxa across heterogeneous habitat types. The study prioritized ecological representation rather than statistical sampling, focusing on capturing species occurrence under naturally varying environmental conditions [15]. A multi-habitat approach was adopted to encompass the broad ecological niches typically occupied by bryophytes, algae, and associated lower plant groups. Field surveys were conducted across six distinct habitat categories selected for their contrasting moisture regimes, substrate characteristics, and anthropogenic influences [16]:

- Riverbanks (Gomti River)
- Wetlands and ponds
- Urban parks and gardens
- Building walls and shaded artificial surfaces
- Agricultural fields
- Moist soil patches

The study framework emphasized ecological diversity, allowing for the observation of species adapted to aquatic, semi-aquatic, terrestrial, and artificial substrates.

#### 3.2 Study Area and Habitat Characterization

The selected habitats represented a gradient of environmental conditions. Riverbank zones along the Gomti River provided periodically inundated substrates characterized by fluctuating moisture levels, sediment deposition, and organic enrichment. Wetlands and ponds offered permanently or semi-permanently saturated environments conducive to algal mats and hydrophytic lower taxa [17]. Urban parks and gardens were included to assess taxa colonizing managed green spaces, often influenced by irrigation practices, shading, and landscaping activities. Building walls and shaded surfaces served as artificial microhabitats, typically supporting crustose or mat-forming organisms tolerant to intermittent moisture and variable light exposure. Agricultural fields represented disturbed ecosystems with seasonal moisture variation, soil turnover, and nutrient inputs. Moist soil patches, particularly those in shaded or poorly

drained areas, provided stable microclimatic conditions favorable for thalloid and filamentous growth forms [18].

### 3.3 Sampling Strategy

Observations were conducted primarily during high-moisture seasons, namely the monsoon and post-monsoon periods. These seasons were deliberately selected due to their ecological significance, as elevated humidity, precipitation, and reduced evapotranspiration promote peak growth and reproductive activity in lower botanical taxa [19]. Rather than employing fixed quadrats or transects, an exploratory survey methodology was utilized. This flexible strategy enabled comprehensive habitat scanning and targeted sampling of visually distinct colonies. Microhabitats exhibiting visible colonization-such as damp soil, shaded surfaces, submerged substrates, and moss-covered regions-were systematically examined [20]. Repeated visits were performed across sampling sites to account for temporal variability in species appearance and colony development.

### 3.4 Field Observation Protocol

At each location, visual inspections were conducted to identify macroscopic growth forms including mats, patches, crusts, filamentous structures, and thalloid expansions. Key environmental parameters were qualitatively noted, including [21]:

- Substrate type (soil, rock, bark, concrete, etc.)
- Moisture condition (wet, damp, intermittently moist)
- Light exposure (direct sunlight, partial shade, deep shade)
- Associated vegetation or biological colonizers

Photographic documentation was carried out to preserve colony morphology and habitat context. Where feasible, representative specimens were carefully collected using minimal disturbance techniques to maintain structural integrity.

### 3.5 Specimen Identification Techniques

Taxonomic classification was performed using a combination of macroscopic and microscopic approaches.

#### 3.5.1 Morphological Assessment

Initial identification relied on observable characteristics such as [22]:

- Colony texture and coloration
- Growth pattern and organization
- Thallus morphology
- Presence of reproductive structures

Colony structure and thallus organization were particularly important for distinguishing between filamentous algae, thalloid forms, and Bryophytic taxa.

#### 3.5.2 Microscopic Examination

Specimens requiring finer resolution were analyzed under a compound microscope. Microscopic evaluation focused on [23]:

- Cellular organization
- Chloroplast arrangement
- Filament structure

- Spore-bearing or reproductive elements

Microscopy enabled differentiation among morphologically similar taxa and supported accurate classification.

### 3.5.3 Taxonomic References and Validation

Species identification was guided by standard floristic keys, regional taxonomic manuals, and established botanical references. Diagnostic features were cross-validated against published descriptions to minimize misidentification. Where taxonomic ambiguity persisted, classification was conservatively restricted to genus or functional group level [24].

### 3.5.4 Data Recording and Documentation

Observational data were systematically compiled, including habitat association, colony description, and distinguishing characteristics. Emphasis was placed on ecological occurrence rather than abundance quantification. Visual records and specimen notes were archived to ensure reproducibility and reference integrity [25].

## 3.6 Methodological Considerations and Limitations

Given the qualitative nature of the study, statistical inference regarding species abundance or population density was beyond scope. Seasonal dependency may also influence taxa detectability, particularly for ephemeral or moisture-sensitive organisms. Nevertheless, the adopted methodology provides robust ecological insights into habitat-specific distribution patterns and morphological diversity [26].

## 4. Results

### 4.1 Species Distribution and Habitat Patterns

The survey revealed a heterogeneous distribution of lower botanical taxa across the examined habitat types, strongly influenced by moisture availability, substrate characteristics, and light exposure. Distinct ecological preferences were observed, with certain taxa exhibiting habitat specificity while others displayed broader adaptability. Moisture-rich environments, particularly riverbanks and wetlands, supported the highest visible diversity. These habitats provided stable hydration regimes conducive to both vegetative expansion and reproductive development. In contrast, artificial substrates such as building walls hosted specialized colonizers adapted to intermittent moisture and variable surface conditions. Riverbank zones exhibited abundant growth of bryophytic mats and filamentous algal assemblages. The dynamic hydrological conditions appeared to favor taxa capable of tolerating periodic submergence and sediment disturbance. Wetlands and ponds demonstrated dominance of algal forms, frequently observed as floating, submerged, or attached colonies. These taxa thrived under persistent water saturation and nutrient-rich conditions. Urban parks and gardens displayed moderate diversity, largely shaped by anthropogenic factors such as irrigation, shading, and landscaping practices. Species occurrence in these habitats suggested tolerance to managed ecological conditions. Building walls and shaded surfaces primarily supported crustose and mat-forming organisms, indicating adaptation to limited soil resources and reliance on atmospheric moisture. Agricultural fields showed comparatively lower diversity, likely influenced by soil disturbance, agrochemical inputs, and fluctuating moisture regimes. However, localized moist patches within fields occasionally supported transient colonization.

Moist soil patches emerged as ecologically significant microhabitats, frequently harbouring thalloid and bryophytic taxa benefiting from stable humidity and reduced desiccation stress.

**4.2 Habitat-wise Occurrence Patterns:** Clear habitat associations were evident:

- **Aquatic / Semi-aquatic Dominance** → Algal taxa
- **Terrestrial Moist Substrates** → Bryophytes & thalloid forms
- **Artificial Surfaces** → Crustose & mat-forming taxa
- **Disturbed Environments** → Reduced diversity, opportunistic colonizers

Moisture availability consistently emerged as the primary determinant governing distribution.

Habitat Type	Dominant Taxa	Observed Growth Forms	Ecological Notes
<b>Riverbanks</b>	Bryophytes, Filamentous Algae	Mats, Filaments, Patches	High moisture variability; periodic submergence
<b>Wetlands / Ponds</b>	Algae (Filamentous & Colonial)	Floating colonies, Submerged mats	Stable hydration; nutrient-rich environment
<b>Urban Parks / Gardens</b>	Bryophytes, Mixed taxa	Scattered patches, Thin mats	Influenced by irrigation and shading
<b>Building Walls / Shaded Surfaces</b>	Crustose & Mat-forming taxa	Thin crusts, Surface films	Adaptation to artificial substrates
<b>Agricultural Fields</b>	Opportunistic taxa	Sparse patches	Soil disturbance limits colonization
<b>Moist Soil Patches</b>	Thalloid forms, Bryophytes	Thalli, Dense mats	Stable microclimate; high humidity

**5. Discussion**

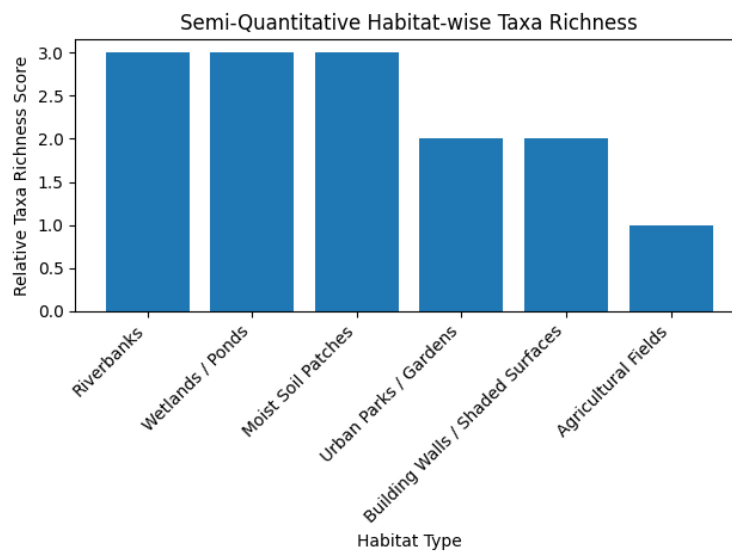
The present study highlights the strong ecological dependency of lower botanical taxa on micro environmental conditions, particularly moisture availability, substrate stability, and disturbance intensity. The observed habitat-wise distribution patterns align closely with established ecological theories governing bryophyte and algal colonization. Moisture-rich habitats such as riverbanks and wetlands demonstrated elevated taxa richness, consistent with the well-documented requirement of lower plants for continuous hydration. Bryophytes, lacking true vascular systems, are especially sensitive to desiccation stress, which explains their pronounced abundance in periodically or permanently moist substrates. Similar moisture-driven distribution patterns have been widely reported in floristic and ecological surveys of non-vascular taxa. Wetlands and pond ecosystems exhibited dominance of algal communities, reflecting optimal hydrological stability and nutrient availability. Aquatic environments provide reduced physiological constraints compared to terrestrial substrates, facilitating rapid vegetative proliferation. This observation corroborates previous studies indicating that algae frequently dominate permanently saturated ecosystems. Urban parks and gardens showed moderate diversity, suggesting that anthropogenic landscapes can function as secondary habitats for lower taxa. Irrigation, shading, and microhabitat heterogeneity likely contribute to this adaptability. Comparable findings have been reported in urban ecological studies, where bryophytes and algae exploit artificially maintained moisture regimes. Artificial substrates, including building walls and shaded surfaces, supported specialized colonizers. These taxa exhibited structural adaptations such as thin crustose growth and compact mats, strategies commonly

associated with tolerance to intermittent moisture and nutrient limitation. Literature on urban bryophyte ecology similarly identifies artificial surfaces as viable colonization niches. Agricultural fields displayed reduced diversity, likely attributable to repeated soil disturbance, agrochemical inputs, and unstable microclimatic conditions. Disturbance-mediated suppression of lower plant communities is a recurring theme in ecological research, particularly in intensively managed ecosystems.

## 6. Semi-Quantitative Statistical Framing

Although the study employed a qualitative observational design, ecological interpretation benefits from semi-quantitative abstraction. Habitat-wise taxa richness was therefore represented using an ordinal scoring framework:

- **High Richness** → **Score 3**
- **Moderate Richness** → **Score 2**
- **Low Richness** → **Score 1**



**Figure 2:** Relative taxa richness across habitats, highest in riverbanks/wetlands/moist soils and lowest in agricultural fields.

This approach does not imply numerical abundance but provides a comparative ecological gradient consistent with visual observations. Such ordinal ecological indices are frequently used in exploratory biodiversity assessments where precise counts are impractical.

## Conclusion

This study demonstrates that lower botanical taxa exhibit clear habitat specificity governed primarily by moisture availability, substrate characteristics, and disturbance intensity. Moisture-rich environments, including riverbanks, wetlands, and stable soil patches, function as biodiversity hotspots supporting diverse non-vascular plant communities, whereas disturbed habitats tend to restrict colonization and persistence. Despite the qualitative nature of the investigation, the study successfully identifies consistent ecological gradients and distributional patterns, offering meaningful insights into habitat–taxa relationships. Future research may build upon these findings through several complementary directions. Quantitative biodiversity assessments incorporating species counts, diversity indices such as Shannon and Simpson metrics, and statistical analyses would enhance ecological resolution. Seasonal dynamics studies examining temporal variation across moisture cycles could further clarify distributional shifts. Integrating

microclimatic measurements, including humidity, temperature, and light intensity, would enable stronger environmental correlations. Functional ecological investigations exploring physiological tolerance limits and adaptive strategies may provide mechanistic understanding. Additionally, conservation-oriented studies evaluating lower botanical taxa as bioindicators of ecosystem health and environmental quality represent an important applied research pathway.

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