

VANISHING NIGHT SKIES: AN ECOLOGICAL PERSPECTIVE OF INDIA'S RURAL - URBAN LIGHT DIVIDE

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ABSTRACT. The rapid expansion of artificial light at night (ALAN) across India is increasingly transforming nocturnal environments with significant ecological consequences. This study investigates the rural–urban gradient of light pollution and its ecological implications by analyzing the spatial distribution and intensity of nighttime illumination across selected urban and rural regions of India. Nighttime radiance data derived from the Visible Infrared Imaging Radiometer Suite (VIIRS) for 2024 were integrated with ground-based observations using a Sky Quality Meter (SQM) to evaluate variations in sky brightness and nocturnal light exposure. The analysis focused on major metropolitan centers including Delhi, Mumbai, Hyderabad, Chennai, and Bengaluru, alongside ecologically sensitive rural landscapes such as the Great Himalayan National Park, parts of Odisha, Arunachal Pradesh, and Rajasthan. Spatial analysis was conducted using Geographic Information Systems (GIS), while ecological impacts were assessed through scientific literature review and selected field observations in biodiversity-sensitive environments. The findings reveal a pronounced rural–urban gradient in ALAN intensity, with urban regions exhibiting substantially higher radiance levels that frequently exceed ecological thresholds known to disrupt nocturnal biodiversity. Although rural areas continue to maintain comparatively darker skies, many are increasingly experiencing light intrusion associated with electrification, tourism, infrastructural development, and peri-urban expansion. The study identifies multiple ecological consequences linked to increasing ALAN exposure, including altered behavioral responses in birds and insects, disruption of circadian rhythms, habitat fragmentation, and degradation of nocturnal ecosystem functioning. The results emphasize the urgent need to integrate light pollution assessment and mitigation into India's environmental governance, urban planning, and biodiversity conservation frameworks. This study contributes to the growing discourse on ALAN as an emerging environmental stressor in rapidly urbanizing regions and highlights the importance of conserving natural darkness for long-term ecological sustainability.

KEYWORDS: nocturnal environment, artificial illumination, sky brightness, biodiversity, light pollution, electrification.

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INTRODUCTION

Artificial lighting has rapidly altered the human relationship with the natural night sky. Once a universal and ecologically consistent phenomenon, natural darkness is now increasingly fragmented due to the widespread prevalence of ALAN. This shift has given rise to light pollution, which includes over-illumination, light trespass, glare, and most significantly, skyglow—the diffuse brightening of the night sky caused by artificial lighting (Falchi et al. 2016; Sánchez de Miguel et al. 2021). Skyglow has transformed nightscapes across the globe,

with particularly intense effects in rapidly urbanizing regions. It disrupts ecological systems and alters the natural light-dark cycles essential for life. In India, the issue of light pollution is intricately linked to its dynamic and uneven development landscape. Metropolitan cities such as Delhi, Mumbai, Bengaluru, and Hyderabad are witnessing sharp increases in nighttime radiance due to economic growth, infrastructure expansion, and intensified use of outdoor lighting (Wu et al. 2025). Similar relationships between urbanization, transportation infrastructure, and nighttime illumination have been demonstrated by Kulpanich et al. (2022), who employed satellite-derived nighttime light

data to reveal the strong association between urban expansion and road network development in northeastern Thailand. Global observations have demonstrated that artificial skyglow is increasing across many regions, with important implications for the visibility of natural night skies (Kyba et al. 2017; Bará and Falchi 2023). On the other hand, rural and peri-urban areas are undergoing a steady transformation due to national electrification initiatives such as the Saubhagya Scheme, which aim to provide universal household electrification (Ministry of Power 2022). This has resulted in a prominent rural–urban light divide, marked by both uneven light exposure and ecological consequences. Increasing artificial lighting is such an environmental phenomenon that disrupts ecological integrity. Artificial night-time illumination has also been identified as an emerging environmental stressor associated with habitat fragmentation and ecosystem degradation (Hölker et al. 2010; Navara and Nelson 2007; Sanders et al. 2021). It interferes with reproductive cycles, navigation cues, biological rhythms, and predator-prey interactions among a wide array of taxa (Gaston et al. 2015; Dominoni et al. 2013). Experimental studies have demonstrated that evening exposure to light-emitting devices can alter circadian timing, sleep and next-morning alertness (Chang et al. 2015; Johns et al. 2018; Jones 2021; Ma et al. 2024). Nocturnal and crepuscular species, such as bats, insects, frogs, and migratory birds, are especially vulnerable to changes in nighttime luminance, often exhibiting altered activity patterns or habitat avoidance due to light intrusion (Longcore and Rich 2004; Spoelstra et al. 2015). Insects, for instance, are strongly attracted to artificial lights, which leads to direct mortality and disrupts essential ecosystem services like pollination and decomposition (Owens and Lewis 2018; Marangoni et al. 2022). Artificial light at night can influence ecosystem functioning beyond directly illuminated locations, with effects extending into adjacent dark areas through changes in plant–insect interactions and seed predation (Giavi et al. 2020; Rich and Longcore 2006).

Despite increasing global attention, India remains underrepresented in light pollution research, particularly from an ecological and spatial perspective. Existing studies largely focus on energy consumption patterns, urban lighting infrastructure, or the impact of skyglow on astronomical observatories (Dhananjay and Bhapkar 2018; Joshi et al. 2020). Few have critically examined how light pollution manifests across rural and urban geographies and the implications for biodiversity and ecosystem processes in a Global South context. International studies have demonstrated that ALAN influences community composition, ecosystem functioning, and species interactions across terrestrial and aquatic ecosystems (Davies and Smyth 2018; Boyes et al. 2021). These concerns are particularly relevant for biodiversity-rich countries such as India, where ecological responses to increasing illumination remain poorly understood. Given India's vast array of biodiversity, including multiple global biodiversity hotspots such as the Western Ghats and the Eastern Himalayas, understanding these dynamics is both timely and necessary. This paper aims to address this gap by providing a comparative analysis of light pollution across selected urban and rural regions in India. Using satellite-based nighttime light data from the VIIRS, supported by ground-based sky quality measurements and ecological literature, the study explores the spatial variation of sky brightness and its ecological implications. Particular attention is given to ecologically sensitive regions experiencing urban expansion, electrification, or peri-urban transition.

MATERIALS AND METHODS

Comparative approaches have been employed to analyze the spatial distribution of ALAN across urban and rural landscapes in India. The objective was to quantify nighttime light pollution using satellite and ground-based data and to evaluate its ecological implications by overlaying illumination patterns with biodiversity-sensitive zones. The approach integrates geospatial analysis, empirical field observations, and a review of specific ecological vulnerabilities to ALAN. To capture India's regional diversity and environmental heterogeneity, twelve representative study areas were selected, distributed across urban, peri-urban, and rural settings. Study areas were selected based on ecological sensitivity, regional representation, degree of urbanization, biodiversity significance, and observed variability in ALAN intensity. Both highly urbanized metropolitan regions and ecologically sensitive rural landscapes were included to capture the rural–urban contrast in light pollution exposure. This diverse selection allowed for the comparison of ALAN across ecological gradients, development contexts, and biogeographic zones.

Temporal analysis of ALAN was conducted using annual VIIRS composites for the years 2012 and 2024 to examine long-term changes in night-time radiance across urban and rural regions of India. A comparative analysis was performed to assess spatial expansion and intensity variation of artificial light at night over the twelve-year period.

Urban Areas (High-intensity ALAN zones)

1. Delhi National Capital Region (NCR) – one of India's most light-polluted regions, characterized by dense urban infrastructure, extensive expressways, and continuous urban sprawl.
2. Mumbai Metropolitan Region (Maharashtra) – a coastal megacity exhibiting vertical urban development and commercial lighting zones.
3. Bengaluru Urban District (Karnataka) – a rapidly expanding technology hub with significant peri-urban transition zones.
4. Hyderabad (Telangana) – high urban illumination, mixed-use development, and expanding ring road infrastructure.
5. Chennai Metropolitan Area (Tamil Nadu) – a coastal urban area intersecting protected wetland zones and nesting beaches (e.g., Olive Ridley turtles).

Rural and Ecologically Sensitive Areas (Low-intensity or transitional ALAN zones)

1. Great Himalayan National Park (Himachal Pradesh) – a national park with endemic flora and fauna, some areas now experiencing peri-urban growth.
2. Sundarbans Biosphere Reserve (West Bengal) – a critical mangrove habitat and tiger reserve with low baseline illumination but encroaching light sources near buffer zones.
3. Keonjhar District (Odisha) – tribal dominated forest fringe region undergoing rural electrification, adjacent to elephant corridors.
4. Barmer District (Rajasthan) – semi-arid desert ecosystem with low population density and minimal artificial lighting.
5. Pakke Tiger Reserve Periphery (Arunachal Pradesh) – north-eastern rural site adjacent to a rich biodiversity hotspot with low anthropogenic light impact.

6. Chhatarpur District (Madhya Pradesh) – plateau region representing central Indian rural settlement patterns with medium electrification.

7. Wayanad District (Kerala) – a rural agricultural matrix with wildlife corridors shared with Bandipur–Nagarhole National Parks.

Nighttime illumination was assessed using monthly composites from the VIIRS, available through the NOAA Earth Observation Group satellites for the year 2024. VIIRS monthly average radiance data ($\text{nW}/\text{cm}^2/\text{sr}$) for January to December 2024 was collected and processed using QGIS-3.10 software. Radiance values were extracted for each study region to compute the mean and range of ALAN exposure. Radiance values are then classified into four categories – low ($<5 \text{ nW}/\text{cm}^2/\text{sr}$), moderate ($5\text{--}20 \text{ nW}/\text{cm}^2/\text{sr}$), high ($20\text{--}35 \text{ nW}/\text{cm}^2/\text{sr}$), and very high ($>35 \text{ nW}/\text{cm}^2/\text{sr}$) – based on global light pollution thresholds (Falchi et al. 2016).

To validate VIIRS data, SQM readings were conducted during moonless nights (October 2024 to March 2025) under clear atmospheric conditions. SQM measurements were conducted at five locations per site; each reading was taken thrice between 20:00 and 22:00 hours and averaged. Sky brightness was measured using SQM in magnitudes per square arcsecond ($\text{mag}/\text{arcsec}^2$) where higher values indicate darker skies. Then SQM readings were compared with corresponding VIIRS values for correlation purposes. Ground-based SQM measurements were conducted during relatively cloud-free atmospheric conditions to minimize observational bias. Relative humidity, visibility conditions, and local AQI data obtained from Central Pollution Control Board (CPCB) monitoring stations were considered during field observations, as atmospheric aerosols and moisture can influence sky brightness measurements through enhanced light scattering.

A literature review was carried out for a meta-analysis of global and regional studies on species responses to ALAN, with emphasis on Indian taxa (e.g., amphibians, bats, insects, nocturnal species) to assess ecological vulnerability to light pollution. Ecological risk zones were categorized as *low*, *moderate*, or *high* based on radiance exposure.

RESULTS AND DISCUSSION

Spatial Variations in Artificial Nighttime Lighting

The analysis of satellite-based VIIRS data across twelve study areas reveals remarkable spatial variations in ALAN intensity between urban agglomerations and rural hinterlands in India (Figs. 1, 2). ALAN is very high in the urban areas, including Delhi NCR, Mumbai, Bengaluru, Chennai, and Hyderabad. They show consistently higher mean radiance values ranging between 28.4 and 42.7 $\text{nW}/\text{cm}^2/\text{sr}$, putting them in the ‘high’ to ‘very high’ light pollution category (Table 1). These zones exhibit near-total nighttime illumination, with limited spatial variation and minimal dark patches. The observed urban skyglow patterns suggest that these areas have already attained the saturation phase of light pollution. On the contrary, rural and ecologically sensitive regions, such as Barmer, Pakke Tiger Reserve fringe, and parts of the Great Himalayan National Park, display substantially lower radiance values, typically under $5 \text{ nW}/\text{cm}^2/\text{sr}$, indicating near-natural night conditions. However, intermediate zones, such as Wayanad, Chhatarpur, Keonjhar, and the Sundarbans periphery, exhibit moderate and increasing radiance, particularly along newly electrified settlements and roads. Here, the mean radiance values range in between 8.6 and 19.3 $\text{nW}/\text{cm}^2/\text{sr}$. These transitional zones point to the spread of ALAN into rural areas as a developmental externality, raising concerns about unchecked lighting expansion. The spatial VIIRS trend from 2012 to 2024 shows that the radiance intensities in these peri-urban zones act as light diffusion belts, where ALAN emitting from urban cores begins to influence the peripheries (Fig. 2). This spatial gradient aligns with global patterns of peri-urban light pollution spread. It suggests that while the rural-urban light divide remains evident, it is narrowing geographically, with significant implications for environmental phenomena in non-urban regions.

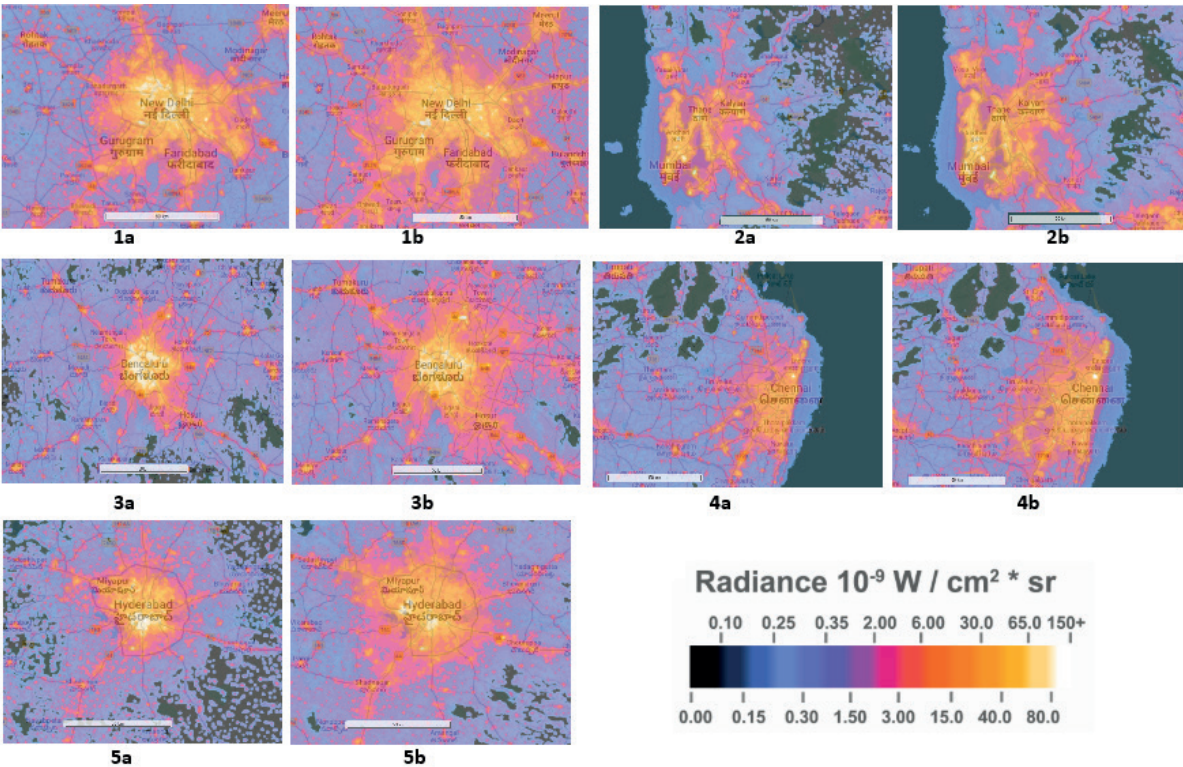


Fig. 1. Spatial expansion and intensification of ALAN from 2012 (a) to 2024 (b) across major Indian urban centers: Delhi (1), Mumbai (2), Bengaluru (3), Chennai (4), and Hyderabad (5)

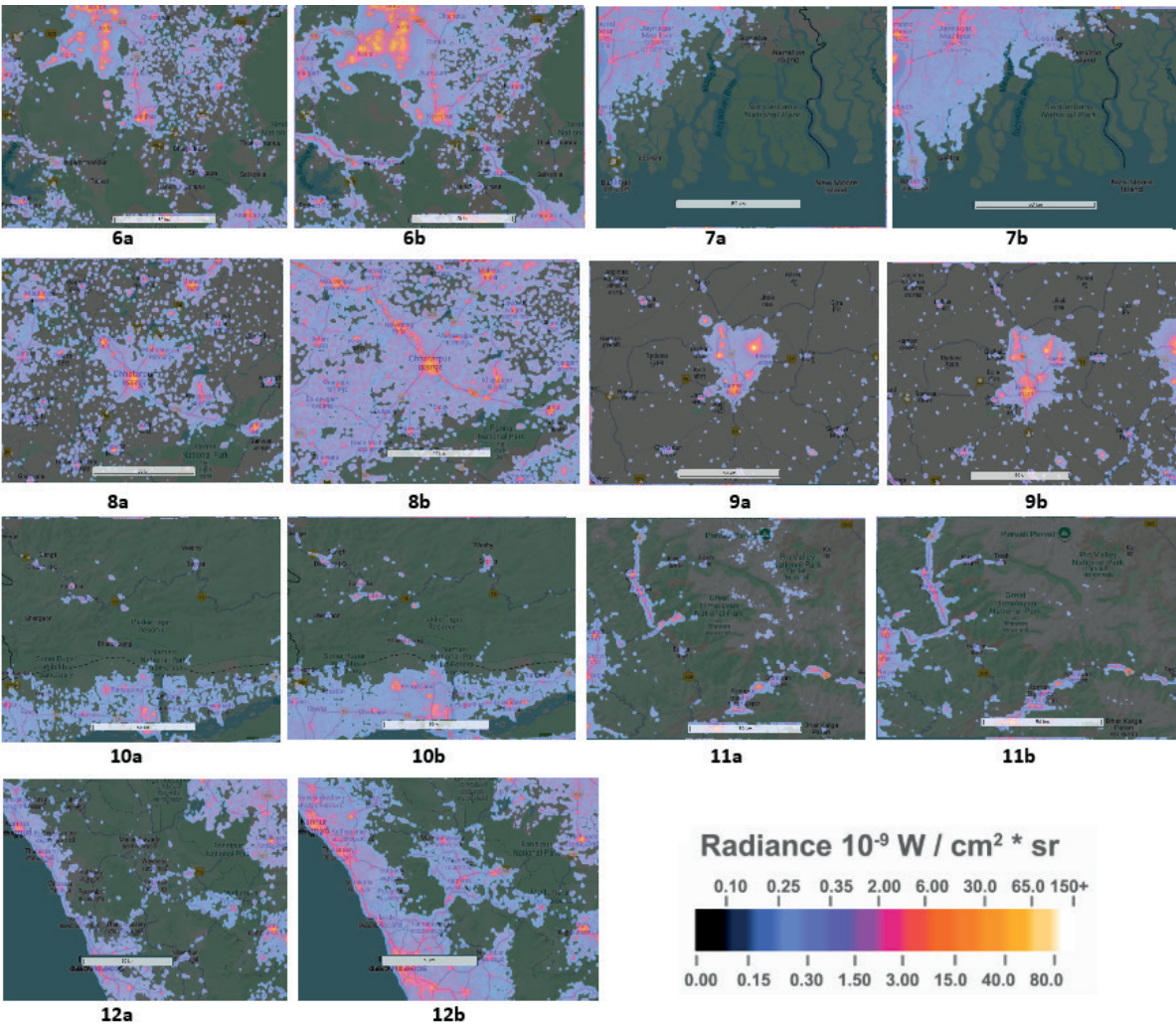


Fig. 2. Spatial expansion and intensification of ALAN from 2012 (a) to 2024 (b) across selected rural and ecologically sensitive regions of India: Great Himalayan National Park (6), Sundarbans Biosphere Reserve (7), Keonjhar District (8), Barmer District (9), Pakke Tiger Reserve (10), Chhatarpur District (11), and Wayanad District (12)

Ground Validation with Sky Brightness Readings

To validate VIIRS observations, SQM readings were recorded in all study locations. Urban areas like Delhi, Mumbai, Chennai, Bengaluru, and Hyderabad showed low SQM values (17.8–19.5 mag/arcsec²), indicating poor sky visibility and a high level of sky brightness (Table 1). In contrast, Barmer and Pakke registered SQM values above 21.6 mag/arcsec², which, according to the International Dark Sky Association, represents the conditions globally recognized as dark sky reserves. The correlation analysis between VIIRS radiance and SQM values produced a strong negative correlation ($r = -0.81$, $p < 0.01$), affirming the validity of VIIRS data for macro-scale ALAN analysis. However, some local anomalies were observed in rural zones where low-radiance areas exhibited localized skyglow not detected in satellite images, especially near rural electrified clusters, small-scale industrial hubs, and LED streetlight installation paths. This discrepancy highlights the importance of ground-based monitoring, especially in ecologically sensitive rural areas where micro-level light sources are increasing but remain undetected in VIIRS resolutions. The SQM observations were conducted between October and March and therefore may not fully capture seasonal variability during monsoon and summer months. Future studies should incorporate year-round monitoring for improved temporal representation.

Seasonal variation in ALAN intensity was particularly evident during winter months and festive periods, when tourism activity, decorative illumination, and atmospheric

aerosol accumulation increase significantly. Post-monsoon months exhibited relatively clearer atmospheric conditions, enhancing the visibility of skyglow in peri-urban regions.

Ecological Overlap and Biodiversity Risk Zones

Overlaying light pollution maps with ecologically sensitive and protected areas revealed critical overlaps (Table 2). In urban areas, fragmented green spaces, such as the Delhi Ridge, Sanjay Gandhi National Park (Mumbai), and Bannerghatta NP (Bengaluru), are heavily exposed to artificial lighting. These pockets serve as biodiversity islands within dense urban matrices, yet are increasingly disconnected by light barriers, which affect species' movement, foraging, breeding behavior and survival. Predator–prey relationships are significantly hampered by ALAN.

In rural areas, light encroachment into forest edges, wetlands, and wildlife corridors was evident in Wayanad, Keonjhar, and Sundarbans. In Wayanad, increasing roadside illumination has been linked with reduced bat foraging activity (India Biodiversity Portal 2024). In Keonjhar, field observations and biodiversity records indicated increased insect mortality near unshielded lighting fixtures. The Sundarbans periphery, particularly near tourist settlement areas, displayed growing light intrusion into buffer mangrove ecosystems, affecting the nesting behavior of nocturnal species such as herons and owls. Evidence from an Indian migratory songbird also indicates that the timing of nocturnal light exposure can influence physiological

Table 1. Spatial variability of sky brightness and VIIRS-derived nighttime radiance across selected urban and rural regions of India in 2024

Study Area	Region Type	Average SQM (mag/arcsec ²)	Sky Brightness Quality	Mean Radiance (nW/cm ² /sr)	Light Pollution Level
Delhi NCR	Urban	17.8	Poor	42.7	Very High
Mumbai	Urban	18.5	Poor	39.4	Very High
Bengaluru	Urban	18.7	Poor	35.2	Very High
Chennai	Urban	18.9	Poor	33.1	High
Hyderabad	Urban	19.5	Poor	28.4	High
Wayanad	Rural	20.1	Moderate	19.3	Moderate
Keonjhar	Rural	20.4	Moderate	14.1	Moderate
Sundarbans	Rural	20.3	Moderate	9.4	Moderate
Chhatarpur	Rural	20	Moderate	8.6	Moderate
Barmer	Rural	21.6	Good	3.8	Low
Pakke	Rural	21.7	Good	3.5	Low
Great Himalayan National Park	Rural	21.5	Good	4.7	Low

Source: VIIRS data from the NOAA-EOG¹ and field observations conducted by the authors using a Sky Quality Meter (2024).

and behavioural responses (Rani et al. 2021; Grubisic et al. 2016). Bats can exhibit strong behavioural responses to artificial lighting, including changes in activity and foraging patterns (Seewagen and Adams 2021). Artificial night lighting interferes with navigation, circadian rhythm, and colony behavior of several pollinator species, including giant honey bees (*Apis dorsata*), which are highly sensitive to nocturnal illumination. Field observations in the Sundarbans indicated reduced beehive formation in illuminated mangrove-edge zones, potentially associated with behavioral avoidance of persistent artificial lighting.

Such impacts align with prior studies highlighting ALAN as a stressor for nocturnal insects, amphibians, and migratory birds. Recent studies have further emphasized that artificial lighting contributes to declines in insect abundance and disrupts ecological interactions, thereby threatening ecosystem services such as pollination and nutrient cycling (Stewart 2021; Knop et al. 2017). Furthermore, areas like Pakke and Barmer, which remain relatively free of artificial lighting, offer opportunities for dark-sky conservation, especially in the Eastern Himalayan and desert biomes, where natural darkness plays a critical ecological role.

Table 2. Ecological impacts and biodiversity risk levels associated with ALAN across selected Indian study areas

Study Area	Observed Ecological Impact	Ecological Risk Level
Delhi NCR	Bird nesting, Bats foraging routes disruption	High
Mumbai	Insect decline (Dragonflies & damselflies)	High
Bengaluru	Bat activity suppression, Insect decline (Cabbage butterfly)	High
Chennai	Nesting disruption of Olive Ridley turtle, Avian circadian shifts	Moderate
Hyderabad	None	Low
Wayanad	Moth mortality	High
Keonjhar	Bats foraging routes disruption	High
Sundarbans	Mangrove fauna, Giant honeybee's avoidance. Edge habitat stress	High
Chhatarpur	Pollinator disruption	Moderate
Barmer	None	Low
Pakke	Insect decline (Butterflies)	Low
Great Himalayan National Park	Nocturnal and Arboreal foraging routes disruption, Edge habitat stress	Moderate

Source: Field observations and data from the India Biodiversity Portal²

¹<https://eogdata.mines.edu/>

²<https://indiabiodiversity.org>

Rural Electrification and Regulatory Gaps

While rural electrification has significantly advanced socio-economic indicators in recent decades, the expansion of unregulated lighting infrastructure in ecologically sensitive zones creates new challenges. Rural electrification programs like Deendayal Upadhyaya Gram Jyoti Yojana (2014) and the Saubhagya lighting scheme (2017) have improved energy access but do not include Environmental Impact Assessments (EIA) of outdoor lighting. Widespread electrification in rural India by Gram Panchayat, Panchayat Samiti, and Zilla Parishad levels plays a disruptive role in the life cycle of nocturnal species, which brings adverse consequences to the rural ecosystems, particularly in the forest fringe areas. The widespread deployment of high-intensity LED fixtures, particularly those with high blue spectral content, is increasingly recognized as ecologically disruptive for insect populations and circadian-sensitive species. Short-wavelength based blue-rich LEDs have been reported to exert stronger ecological impacts than traditional lighting technologies because of their higher attraction to insects and greater interference with circadian processes (Pawson and Bader 2014). In the absence of proper lighting guidelines, even low-density rural settlements become sources of fragmented illumination, forming ecological barriers that disrupt movement, foraging, and breeding of species across landscapes. For example, a single bright streetlight near a forest edge may reduce the activity of night-pollinating moths across several hectares. These micro-scale changes remain largely invisible to national monitoring systems, which necessitates localized lighting regulation and community-based conservation practices.

Existing policy frameworks address light efficiency primarily through the Energy Conservation Building Code and urban smart lighting initiatives, with no binding regulations for outdoor lighting. This has created a vacuum in rural and peri-urban planning, where electrification and tourism projects proceed without safeguards against light encroachment into natural habitats, which are very light-sensitive. While cities have started experimenting with dynamic lighting, smart technologies, and public awareness campaigns, the rural zones remain uninformed and unregulated in terms of ecological lighting practices. The absence of baseline ALAN data in EIA further perpetuates this gap. As ALAN remains invisible in India's biodiversity policy toolkit, its inclusion in Wildlife Action Plans and Integrated Rural Development Schemes is urgently needed.

Recommendations for Integrating Night Sky Conservation

1. Demarcation of legally recognized 'Dark Sky Zones' is necessary in ecologically sensitive rural and peri-urban regions such as Sundarbans, Barmer, Pakke, and Great Himalayan National Park. These are low-intensity or transitional ALAN regions that serve as critical refugia for nocturnal biodiversity. These areas must be prioritized for protection.

2. There is an urgent need for lighting guidelines for ecologically sensitive zones. Policy regulation should focus on periodic lighting audits and the adoption of eco-friendly lighting technologies, including downward-directed fixtures, low-intensity illumination, and warm-spectrum LEDs. Such measures are essential near forests, wetlands, and conservation corridors where excessive illumination disrupts species behavior and ecosystem functions.

3. Empowerment of local communities and ecotourism operators may become a key strategy for the conservation of natural darkness. Community-led initiatives such as participatory night sky monitoring using SQM, and awareness and education programs, can enhance the conservation of natural darkness. It can generate alternative livelihood opportunities through astro-ecotourism in a sustainable manner.

4. The major developmental projects, such as urban infrastructure expansion, industrial clusters, and tourism hubs, should integrate ALAN into EIA protocols. Incorporating light pollution metrics into standard EIA practice will ensure that nocturnal ecosystems are categorically considered in planning and policy decisions.

5. Creation of a centralized, open-access digital portal is essential for long-term monitoring and governance of ALAN. Building upon existing platforms such as Bhuvan and ENVIS, this portal should synthesize satellite-based nighttime light data with ground-based measurements to track ALAN trends and support evidence-based decision making for the conservation of natural darkness.

CONCLUSION

This study demonstrates that ALAN is undergoing rapid spatial expansion across India, fundamentally transforming the ecological character of both urban and rural environments. By integrating VIIRS-derived nighttime radiance data, ground-based SQM observations, and spatial ecological analysis, the study reveals a pronounced yet increasingly permeable rural-urban gradient in light pollution. While metropolitan regions remain the principal hotspots of excessive nighttime illumination, rural and peri-urban landscapes are emerging as significant zones of light intrusion due to expanding electrification, infrastructure development, tourism activities, and urban spillover. Consequently, ambient light trespass, glare, over-illumination, clutter, and sky glow are no longer restricted to cities but are increasingly encroaching into ecologically sensitive and biodiversity-rich landscapes traditionally characterized by natural darkness.

The findings highlight a concerning transition in India's nocturnal environments, where regions once isolated from anthropogenic illumination are now experiencing a measurable increase in nighttime radiance. Such transformations have important ecological implications, including altered behavioral patterns in nocturnal fauna, disruption of circadian rhythms, modification of species interactions, and fragmentation of dark habitats essential for light-sensitive organisms. These ecological disturbances are occurring in the absence of comprehensive policy frameworks, institutional monitoring mechanisms, or widespread public awareness regarding the environmental consequences of ALAN. As a result, natural darkness remains one of the least recognized and least protected ecological dimensions within India's current development trajectory.

The study further identifies a critical policy gap in India's environmental governance framework. Although lighting infrastructure is rapidly expanding through urbanization and rural development initiatives, ecological considerations associated with artificial illumination remain largely absent from planning and regulatory processes. The absence of scientifically informed lighting regulations has enabled the uncontrolled proliferation of ALAN even within environmentally sensitive regions, thereby threatening ecological integrity and degrading natural nightscapes. Furthermore, the lack of systematic

monitoring and mitigation strategies across spatial scales, particularly in rural and transitional landscapes, contributes to cumulative and often irreversible ecological impacts.

Addressing these emerging challenges requires an interdisciplinary and policy-driven approach that integrates ecological science, geospatial technologies, spatial planning, rural development, and sustainable lighting design. Conservation strategies should extend beyond urban centers to include rural and transitional landscapes, where natural darkness continues to represent both an ecological and cultural resource. Strategic interventions such as the establishment of dark sky conservation zones, implementation of wildlife-sensitive lighting guidelines, periodic ALAN monitoring, and the incorporation of light pollution metrics into EIA frameworks are essential for

balancing developmental aspirations with ecological sustainability.

The progressive disappearance of naturally dark skies across India represents not merely a physical transformation of the nighttime environment but also a deeper shift in the relationship between development and nature. Recognizing the night sky as a critical ecological parameter rather than solely an aesthetic or astronomical resource is essential for achieving environmentally sustainable development. Protecting natural darkness across diverse landscapes should, therefore, be viewed not as a limitation to progress but as an environmental responsibility necessary for maintaining ecological balance and safeguarding nocturnal ecosystems in an increasingly illuminated world. ■

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