RIGHT TO STARLIGHT: SCENIC SITES AND OPPORTUNITIES FOR SUSTAINABLE ASTROTOURISM IN BADULLA

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Abstract: The paper studies the opportunities and constraints in utilizing existing scenic areas for astrotourism in Sri Lanka's montane region. Using the Badulla city as a case study, the paper's objective is to identify the current challenges and potentials for establishing dark sky places. The methodology combines the findings of a comprehensive literature review with secondary data from global satellite imagery and field photographic study. The study reveals that scenic places in montane regions offers significant opportunities for astrotourism, increasing light pollution from nearby urban centres induces significant limitation. The paper concludes that the scenic areas which are to be utilized for astrotourism should be located away from urban centres in higher elevations while orienting it's view away from the urban core. The paper concludes setting out policy interventions on lighting malpractices and planning strategies to reduce light pollution in accordance with international standards to overcome the constraints would provide better conditions for astrotourism establishment.

Keywords: *Astrotourism, Light Pollution, Dark Sky Places, Badulla, Sri Lanka*

1. Introduction

The world tourism industry is going through a significant shift in the form of a rising desire for niche and sustainable experiences going beyond generic mass tourism. In this scenario, astrotourism has emerged as a promising niche offering travellers experiences cantered around observation of stars and celestial events under unpolluted night-sky landscapes. It goes beyond sky observation to promoting environmental protection and the importance of preserving the night sky from the adverse effects of artificial light pollution. This has been achieved in the global context via declaration of dark sky places which requires planning,, studies and legal and physical protection (Charlier & Bourgeois, n.d.; Iwanicki, 2022; Pan et al., 2025; Papalambrou & Doulos, 2019). International organizations like the International Dark-Sky Association (IDA) have established criteria and best practices for sites seeking to preserve their dark skies in view of their ecological, cultural, and economic value. The Starlight Initiative, under the La Palma Declaration (Starlight Initiative, 2007), has also crystallized the belief in the "right to starlight" as a global principle and challenged states to preserve their night sky as a shared heritage.

For developing nations with pristine nightscapes, astrotourism provides an opportunity to diversify the tourism initiatives and attract new visitors to the country. Sri Lanka with the significant cultural and natural heritage and unique landscapes can utilize this trend into the growing tourism industry. Notably, the central highlands of the country provide picturesque scenic areas with less populated areas creating suitable conditions for establishment of astrotourism. Studies have suggested protected areas and destinations has the optimal conditions yet some are limited by the accessibility and high sensitivity of the environment (Weerakoon, 2025). Therefore, the paper aims to identify opportunities and constraints to establish dark sky places in existing scenic places within the montane region of the island. The Badulla city and surroundings serve as a suitable case study due to low initial light pollution levels, presence of numerous scenic viewpoints, climate, and accessibility to the facilities and accommodations unlike the protected areas covered in previous studies. The paper will provide insights into the astrotourism establishment in such areas through comprehensive analysis of literature, satellite imagery data, and in-situ observations. This study is significant in establishing sustainable tourism and planning policy to preserve the natural scenic landscapes and the night sky for the future and aligns itself with the growing literature on night sky darkness and well-being (Tanaka et al., 2025) and astrotourism framework establishment (Tapada et al., 2021)

2. Literature review

"Astrotourism" or "Celestial/Astronomical tourism" is the tourism sector that involves travelling for experiencing astronomy related phenomena. For instance, experiencing celestial events such as eclipses, meteor showers during both day and night, visiting observatories or experiencing dark sky parks (Iwanicki, 2022). Astrotourism does not involve only observation or stargazing, it includes astrophotography which is a trend among high end tourists where certain nations has gained significant benefits from astrotourism such as New Zealand and Chile (Weerakoon, 2025). This has attained developing prominence in academic literature with a growing body of work regarding its potential (Tapada et al., 2021).

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The global expansion of astrotourism ventures is linked with the rise of Light pollution levels globally due to increased nighttime lighting and development expansion. This resulted in the loss of the night sky quality and increase of Artificial Sky Glow (ASG) that led people to seek pristine skies(Falchi et al., 2016; Tapada et al., 2021). This detrimental condition led to the establishment of initiatives to declare and preserve dark sky areas with significant night sky quality. Organizations such as UNESCO, ICOMOS, Dark Sky International and Starlight Foundation declares and oversees these sites with their capacities. With the mentioned initiatives of light pollution reduction and night sky preservation, such sites are regarded significant for these ventures, where many countries are identifying and declaring such places to protect night sky and promote astrotourism (Kanianska et al., 2020; Papalambrou & Doulos, 2019). Astrotourism provides other benefits such as economic, educational and sustainable infrastructure development that could benefit countries like Sri Lanka.

In Sri Lanka, the studies on feasibility of astrotourism have been conducted to a certain degree. These studies have prioritized International tourist awareness on the subject and the potential site identification in central highlands. These identified areas are primarily located near protected areas in highlands which are minimal of light pollution (Nimashika, et al., 2024; Weerakoon, 2025). They are Horton plains and surrounding region, Knuckles mountain range and Danigala, which have significant ecological and historical significance (Sumanarathna, 2020; Weerakoon, 2025). Requirements for astrotourism can be listed as clear weather, low light pollution, unobstructed views, primarily found in rural montane regions. Despite certain climatic conditions, tropical regions offer year-round potential for these ventures (Kanianska et al., 2020; Papalambrou & Doulos, 2019).

Light pollution is a major component of the study which is a significant environmental problem in the global and local context. Definition of light pollution can be taken as “any adverse effect or consequence of artificial light” according to Falchi et al., (2016). This includes light trespass, glare, and artificial skyglow, which appears as a diffused glow over urban areas (Utah Community Development Office & Colorado Plateau Dark Sky Cooperative, 2019). This not only affects the visual quality and darkness of night sky but also on ecological functions (Bell, Rebecca et al., 2014; Hao et al., 2024). This is influenced by Weather, Distance from the light source, air quality, presence of moon and elevation are major parameters that affects light pollution induced Artificial sky brightness (Frank et al., 2021, p. 2018; Hänel et al., 2018; Pan et al., 2025). Weather, humidity and particles in the atmosphere, that affect air quality greatly increase the ASG. Moonlight acts as a natural light pollution source in the sky, especially during full moon days. Therefore, astronomical observations should be made during dry periods with clear skies, dry atmospheric conditions and under new moon conditions, ideally in astronomical darkness, where true darkness will be present after dusk. That would ensure better observations than any other conventional date.

The Sri Lankan context has lesser levels of light pollution in comparison to South and Southeast regions of Indian sub-continent. A five-year study conducted by McAvoy & Vadrevu, (2024) using VIIRS satellite data to assess Nigh Time Light (NTL) and population variation confirms these claims. According to the data Colombo shows significantly reduced NTL levels compared to major urban centers in the region. The study suggests that there is a sharp distance-decay effect in Sri Lankan cities in NTL values. This represents the light intensity steeply decline away from the urban center to peripheral areas, suggesting limited sprawl which is in comparison to other countries in the region.

3. Methodology

Methodology of this study is based on the synthesis of the referred literature and analysis of secondary data with the physical observations and data collection conducted on site. To achieve the study objective, cross-referencing of global data and local data collection with literature was conducted.

3.1. CASE STUDY SELECTION: BADULLA CITY SURROUNDINNG, UVA, SRI LANKA

3.1.1 Selection criteria

The case study site was selected based on basic requirements for astrotourism establishment. The presence of a major urban area was to assess the Artificial Sky Glow impact and the availability of facilities for tourists. Based on the criteria below.

- Low light pollution
- Presence of a major urban centre
- Clear climatic conditions
- Higher elevation

The site was chosen as Badulla city and surrounding, which is home to unique natural and cultural destinations and scenic sites. This area consists of major scenic sites such as Dunhinda falls, Narangala peak, Pekoe trail, and other major waterfalls and viewpoints. The city centre is home to significant historic monuments such as Wele Kade market and infamous Sorabora Wewa Pillar Inscription.

Located within the Central Highlands of the Country and has significantly reduced level of Light Pollution among Major Urban centers in Higher elevations. The area falls under the Intermediate Zone, where the defined seasonal variation is present, which is ideal for stargazing. The context morphology also allows a defined distribution of urban expansion, viewpoints and other unique landscape features.

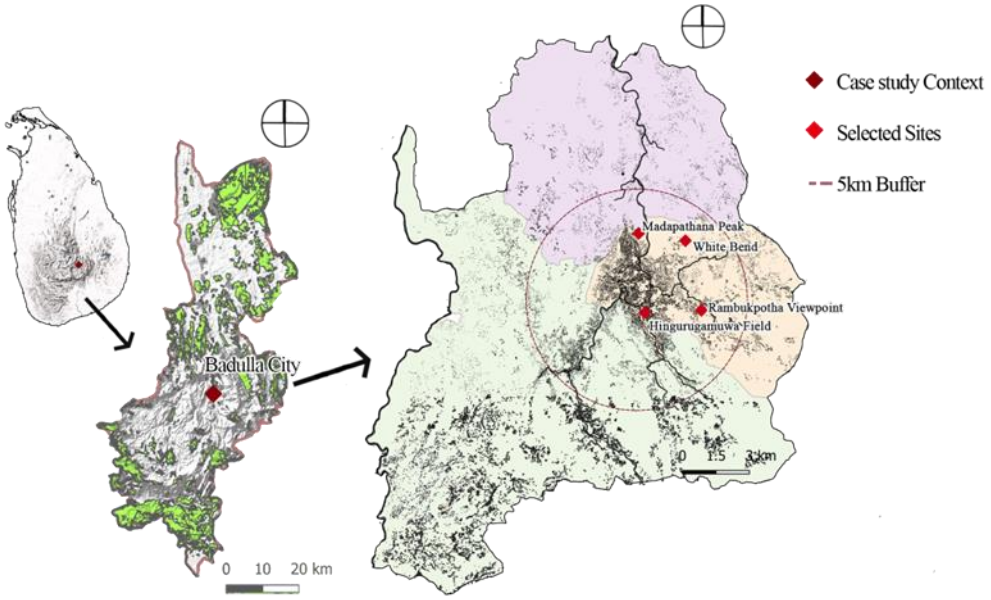

Figure 1: Distribution of Selected sites in relation to the macro & micro context

3.1.2 Site Selection

The Study Area is considered within the 5km buffer zone which was implemented due to the Light pollution Atlas data (Falchi et al., 2016) which shows NSB level of 21.21 mag/arcsec^2 within City Center itself which is Recommended Level of NSB value within Dark Sky Parks according to Dark Sky International.

Selected sites were located radiating from the city center to outwards to the urban fringes and to rural areas, with varying distance and elevation. Elevation variation of the sites is from 654 meters to 1123 meters and Light Pollution Atlas NSB ratings varied from 21.25 mag/arcsec^2 to 21.60 mag/arcsec^2. The details of the selected sites are as given below in the graph.

Table1: Site geographical and NSB information

No	*Site Name*	*Site Character*	*Latitude & Longitude*	*Distance from City Centre (km)*	*Elevation (m)*	*Light Pollution Atlas NSB values for 2024 (mag/arcsec^2)*
1	*Hingurugamuwa Field*	*Paddy field*	*6.97827, 81.06328*	*1.2*	*654*	*21.25*
2	*Madapathana Peak*	*Viewpoint*	*7.01299, 81.05986*	*2.78*	*890*	*21.60*
3	*Rambukpotha Viewpoint*	*Viewpoint*	*6.97933, 81.08627*	*3.15*	*762*	*21.48*
4	*White Bend*	*Viewpoint*	*7.00799, 81.07938*	*3.31*	*1123*	*21.58*

3.2. STUDY METHODOLOGY

The Study was conducted based on the Potential for Astrotourism Development score (PAD) developed by Kanianska et al., (2020), which utilizes different parameters to assess the PAD score of the sites, where higher the score, better the observation conditions. The study utilized the core aspects of the PAD score, focusing on light pollution, distance from the city center, the key potential service provider for the tourists and site significance.

- Night sky brightness (mag/arcsec^2)
- Elevation
- Proximity to other tourism units

Night Sky Brightness (NSB) level measurements were extracted from the Light Pollution Atlas (Lorenz, 2024) based on publication of Falchi et al., (2016). This reading assesses the nights sky brightness in the astronomical magnitude system introduced by Greek astronomer Hipparchos. Which is measured in magnitude per square arcsecond (mag/arcsec^2) which

is a quantitative measurement of the Night Sky Brightness (Kanianska et al., 2020). To ground truth the Light pollution atlas readings, the Dark Sky Meter App was used to record on site readings of NSB values. 3 measurements were collected from each site, and the average was taken into consideration. To support visualizing the lighting conditions, photographic documentation was done on each site. Both Day and nighttime panoramic images were captured to present the scenic conditions as well as light pollution levels. For visual comparison of the Lighting conditions the paper presents the nighttime panoramic images. The specifications of each method used to evaluate NSB values are listed below in table 2. There, each method's pros and cons are listed along with the technicalities. Based on provided data, each method used to assess NSB in the study would fulfill macro and micro context study and ground truthing respectively.

Table 2: Comparison of Night sky Brightness assessment methods used (Hänel et al., 2018b)

Method	*Pros*	*Cons*	*Technical requirements*
Satellite Data (Light Pollution Atlas)	- *Larger extent* - *Ideal for initial studies* - *Long term data and archive* - *Can model distribution of patterns.*	- *Low resolution* - *Not the actual sky perception* - *Limited temporal resolution due to cloud cover*	- *Access to AIIRS/DMSP data* - *GIS toolkits* - *Ground truthing of Data*
Dark Sky Meter (App)	- *Mobile based platform* - *Visible spectrum record* - *Use of Phone camera and GPS*	- *Only compatible with later iPhone models* - *Not adjustable for exposure* - *Not Suitable for darker skies*	- *iPhone 4s or higher* - *Must be pointed at zenith for readings.*

Elevation and distance to other tourism units were assessed within QGIS software using Digital Elevation Models and mapping the scenic viewpoints and tourism places within the mentioned 5km buffer. And measuring the distance from sites to the tourism places through buffer placement from each site to assess the distance (200m wise displacement of each buffer up to 1 km and proceeding to 2km onwards)

The Data collection was carried out from the first week of August to the second weekend of August 2025. The first week's data was used to adjust the camera settings used to capture the photographs to compare the day, night landscapes and artificial lighting influence over night sky.

4. Results and Discussion

4.1. RESULTS

Data collection for each site was conducted according to the above-mentioned steps and parameters. NSB values were first collected form the Light pollution atlas (Lorenz, 2024) and from Dark Sky Meter App from an iPad Pro 10.5-inch 2nd Gen. Capturing nighttime photographs for panoramas were captured using the camera setup listed in the table 3. The camera settings were kept at same across all four sites to illustrate the intensity of light pollution and ASG. The preliminary data collection setup as used to define the suitable settings for all sites and the intended requirements. Captured images were processed in Adobe Lightroom Suite to create the nightscape panoramas. The develop settings were adjusted to the visibility of Milky Way and same develop settings were used for all sites.

Table 3: Photography equipment & settings

Equipment	*Model*	*Specifications/ Settings*
Camera	*Panasonic Lumix DMC FZ-2500*	*Sensor Size: 1" inch*
Camera Settings		*Image Mode: RAW* *ISO: 800* *Shutter Speed: 30 seconds* *Lens: 24mm f2.8*

4.1.1 Hingurugamuwa Field

Located near the Railway Station of the City, this site placed within the flood plain of the Badulu Oya provides unobstructed views around the Basin. The recorded data is as follows in table 4. This site is placed within the lower elevations at the southern end of Badulla city.

Table 4: Data from Hingurugamuwa Field

Light Pollution Atlas NSB values for 2024 (mag/arcsec²)	*Dark Sky Meter NSB values (mag/arcsec²)*	*Mean Recorded NSB value (mag/arcsec²)*	*Distance from City Centre (km)*	*Elevation (m)*	*Proximity to other tourism units (km)*
21.25	20.13	20.17	*1.2*	*654*	*<0.6*
	20.18				
	20.2				

Figure 2: Nightscape of Hingurugamuwa field

Site provides picturesque views of paddy fields of the area with the surrounding mountains creates the backdrop. The view is disturbed by the transmission line which extends from south to North as shown in figure 2. At nighttime, the city lights from North and West create heavy Sky glow. The site is disturbed by the streetlights that are not fully shielded, creating glare. This affects less to the Milky Way observation as it can be faintly observed in zenith.

4.1.2 Madapathana Peak

This mountain peak is located at Northern edge of the city creating Dunhinda falls at one of its escarpments, neighboring the Badulu Oya from East. Devoid of the vegetation except for a few trees and grassland at its peak, this offers complete 360^0 views around the region. Also, provides a recreation area for people as a kite flying area, bearing the name “Kite Mountain”. The collected data are as given in table 5.

Table 5: Data from *Madapathana Peak*

Light Pollution Atlas NSB values for 2024 (mag/arcsec²)	*Dark Sky Meter NSB values (mag/arcsec²)*	*Mean Recorded NSB value (mag/arcsec²)*	*Distance from City Centre (km)*	*Elevation (m)*	*Proximity to other tourism units (km)*
21.60	20.62	20.66	*2.78*	*890*	*<0.8*
	20.62				
	20.73				

Figure 3: Nightscape on Madapathana peak

Site is devoid of any obstructions and free to move around. The Night lights from the city below creates Sky Glow from south, affecting the observation. Weather alterations may increase the visibility with sky glow conditions. But with much of the city is closed from the view due to the proximity, the zenith is less affected by lighting issues. Figure 3 shows the ASG

from the city and distant towns and hamlets in the horizon while milky way is faintly visibly above due to development of haze.

4.1.3 Rambukpotha Viewpoint

This viewpoint consists of a tea estate and a natural rock outcrop extending above the vegetation. Surrounded by expanding tea estates towards East and residential areas at West. Located right next to the main roads, this provides easy accessibility to the site. Collected data from the site are listed in table 6 below.

Table 6: Data from *Rambukpotha Viewpoint*

Light Pollution Atlas NSB values for 2024 (mag/arcsec²)	*Dark Sky Meter NSB values (mag/arcsec²)*	*Mean Recorded NSB value (mag/arcsec²)*	*Distance from City Centre (km)*	*Elevation (m)*	*Proximity to other tourism units (km)*
21.48	*20.65*	*20.75*	*3.15*	*762*	*<0.4*
	20.61				
	20.99				

Figure 4: Nightscape at Rambukpotha viewpoint

The view shown above in figure 4 covers major mountains from Madapathana peak from North to Base of Namunukula from South. The key obstruction comes from the transmission lines and light trespass from the residential units.

4.1.4 White Bend

This viewpoint is a significant viewpoint located in Cullen Estate, Badulla. Located above 1100meters, and with the furthest distance, the site provides 180^0 views over the city & surroundings.

Table 7: Data from *White Bend*

Light Pollution Atlas NSB values for 2024 (mag/arcsec²)	*Dark Sky Meter NSB values (mag/arcsec²)*	*Mean Recorded NSB value (mag/arcsec²)*	*Distance from City Centre (km)*	*Elevation (m)*	*Proximity to other tourism units (km)*
21.58	20.08	20.59	*3.31*	*1123*	*<2*
	21.29				
	20.42				

Figure 5: Nightscape view of White Bend

The mountain peak where the bend is located reduces the full panoramic view only towards the southern part. This also affects the nightscape as the view is directly in line with the city view, resulting in Sky glow covering a significant portion of

the observable area as shown in figure 5. The observable sky is much darker in comparison and zero on site lighting crates a much darker site condition than the rest except Madapathana Peak

The NSB values from Light Pollution Atlas (Lorenz, 2024; Falchi et al., 2016), Dark Sky Meter App readings were first compared. The readings and initial observations reflect an increase in NSB values within the sites in proximity to the city center. Dark Sky Meter App readings reflected a higher level of deviation from Light Pollution Atlas readings. As shown in figure 6, both data sets are compared with each other display the mentioned quality.

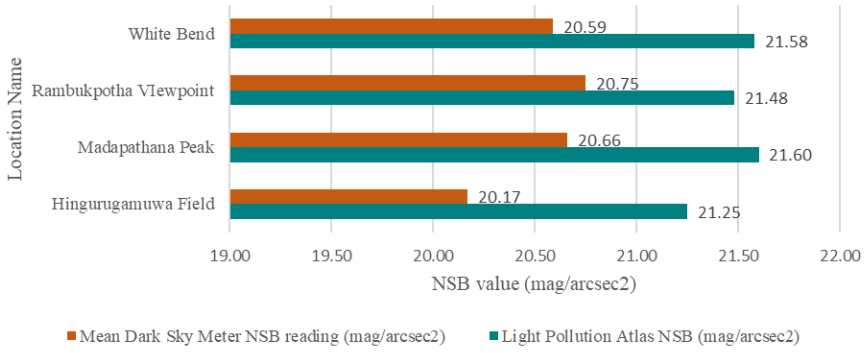

Figure 6: Distribution of NSB readings across sites from Light Pollution Atlas and Dark Sky Meter App

Literature suggests that the NSB value should reflect and corresponding increase with the increase of distance and elevation from the light pollution source. This relationship is evident on comparing Light Pollution Atlas data relationship with distance and elevation when comparing their distribution side by side as in figure 7 and figure 8.

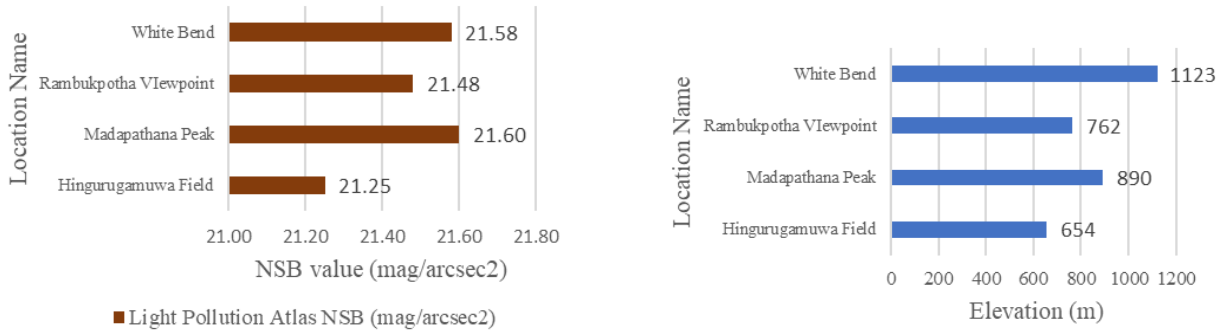

Figure 7: Distribution of NSB readings across sites from Light Pollution Atlas (left) with elevation (right)

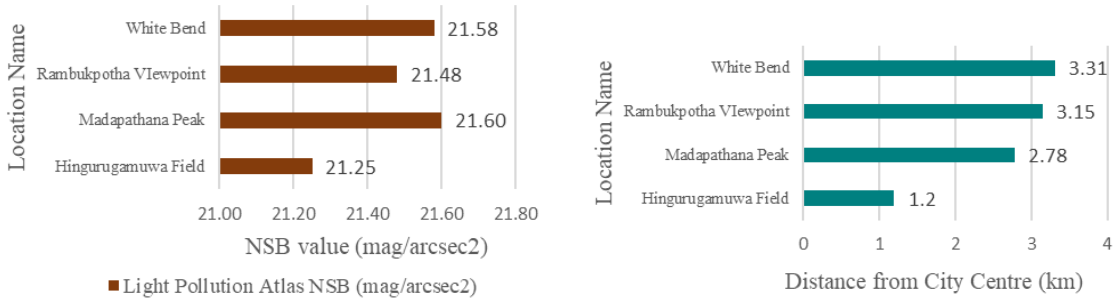

Figure 8: Distribution of NSB readings across sites from Light Pollution Atlas (left) with Distance (right)

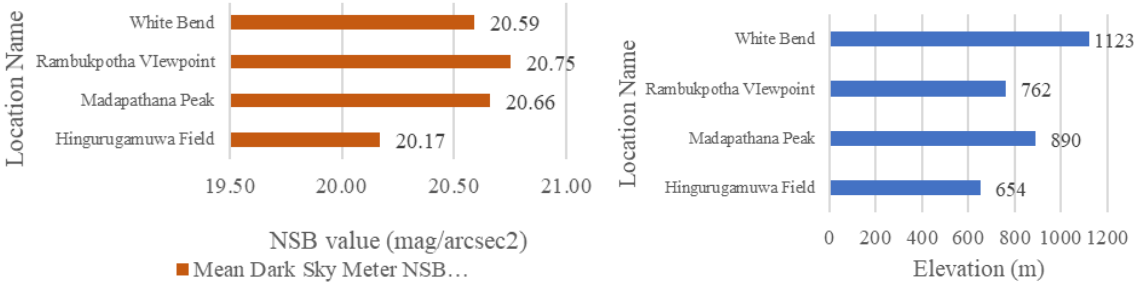

Figure 9: Distribution of NSB readings across the sites from Dark Sky Meter App (left) with Elevation (right)

The comparison of NSB readings with the distance does as in figure 8 does not precisely correlate with the distance variation as shown above. This may be a reason mentioned in observations as the direct view of the city to the site may affect the NSB values. This is more evident with the readings from the Dark Sky Meter App which is significantly lower than the expected readings based on the Light Pollution Atlas. But the progression of NSB values with distance are more similar in this comparison.

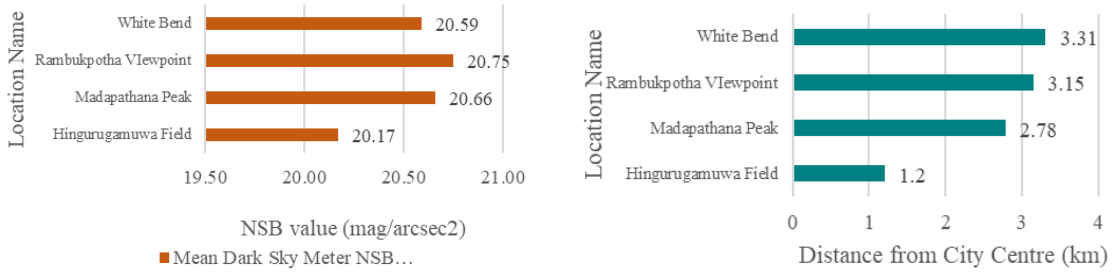

Figure 10: Distribution of NSB readings across the sites from Dark Sky Meter App (left) with Distance (right)

In this comparison in figure 9 and 10, the progression of the NSB readings with distance and elevation is not correlated with each other. Closest relevance only can be observed with distance. And Photographic observations support this progression of NSB readings to a certain extent unlike as shown in figures 7 and 8. The large gap between the Light Pollution Atlas may be the result of the weather and atmospheric conditions and the limited timeframe which the study was conducted. Therefore, conducting a comprehensive study minimum of one year in which the PAD rating (Kanianska et al., 2020) can be utilized properly across all sites.

In consideration of the distance from the city center and the distance to other tourism units, Madapathana Peak emerged as the most suitable scenic area to be utilized as a potential place for astrotourism followed by Rambukpotha viewpoint and the rest. The findings highlight the higher distance and elevation from light pollution source (in this study, the city center) provides the optimal conditions for darker and clearer skies. But view orientation from the light source, geographic character and nearby other tourism places will also affect the potential of these scenic places to be utilized astrotourism destinations.

4.2. OPPORTUNITIES AND CONSTRAINTS FOR ASTROTOURISM IN STUDY AREA

4.2.1 Opportunities

Montane regions such as Badulla city surrounding in Sri Lanka, presents a significant opportunity to establish astrotourism. The central highlands offer many scenic areas that are less populated, creating suitable regions for this venture. With lower light pollution levels compared to other areas in central highlands surrounding the urban area, Badulla also offers numerous scenic viewpoints and location within intermediate zone of the island provides favorable climatic conditions for stargazing. Unlike protected areas, the city provides accommodation and other facilities, making the sites more suitable for the venture. Study suggests that scenic areas away from the city with higher elevations, unobstructed views and oriented areas away from the city provide optimal conditions.

4.2.2 Constraints

Despite the opportunities, the light pollution from the city poses as the major limitation, in-situ lighting issues such as light trespass like in Hingurugamuwa field and Rambukpotha viewpoint also affects the night sky quality. Study also revealed orientation of view towards the city directly impacts the artificial sky glow in the observable area, which was observed within White Bend. Presence of visual obstructions such as transmission lines were an issue in daytime in certain sites. The Night Sky Brightness readings from Dark Sky Meter app did not show precise correlation with distance and elevation data, which might be the influence the readings due to the direct view of the city from site.

4.3. DISCUSSION AND RECOMMENDATIONS

This study highlights the potential of Badulla City and surroundings for astrotourism but emphasizes the limitations posed by short-term data collection. Thus, the study reveals the need for better longitudinal study. Instruments such as Sky Quality Meter (SQM) would provide highly accurate zenith NSB readings than the Dark Sky Meter app, where it is not suitable for much darker skies. (Hänel et al., 2018; Kanianska et al., 2020). Weather variations may have affected the reliability of the readings taken on sites; therefore, a comprehensive longitudinal study is suggested again to increase the accuracy and reliability of the results.

Anthropogenic lighting malpractices poses a significant threat to astrotourism initiatives despite the favourable climate and scenic potential of the region. Adhering to the global standards such as Dark Sky International's guidelines (Charlier & Bourgeois, 2013; Papalambrou & Doulos, 2019) would mitigate ASG and increase the night sky quality. Establishment of a Dark Sky Place, following with Dark Sky International's guidelines may also increase the value of these scenic areas and

would support to retain their characters. And this would also support in reducing light pollution as well. These initiatives would ultimately benefit the rural economy and the sustainability of the city (Nimashika et al., 2024; Tapada et al., 2021)

Finally, the right to starlight is not only concerns itself with tourism niches but also serves as a cultural and environmental need. This would create the montane areas such as Badulla a potential precedent for advancing the sustainable and responsible tourism as well as preserving the fleeting nightscapes of Sri Lanka.

5. Conclusion

The study reveals while Badulla area bears potential opportunities to establish astrotourism utilizing scenic places, with the scenic potential and relative low light pollution levels, artificial lighting from the city act as a constraint. Findings underscore the need of strategic planning, policy interventions to preserve the night sky quality. This also suggests implementing a long-term study with more technical analysis. Working towards establishing International Dark Sky place with sustainable lighting within the region would contribute to reducing light pollution and increase the value of the site as a major astrotourism and scenic destination in the island as well as the region.

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