



Mapping the local night-time economy: The spatial role of local coffee shops

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ABSTRACT

Background: Urban economic studies increasingly recognize the significance of night-time activities as indicators of a city's vitality. This research examines how formal small-scale enterprises specifically local coffee shops (*warkop*) contribute to the spatial dynamics of the night-time economy in Banda Aceh, Indonesia, a city characterized by culturally regulated social life. **Methods:** The study integrates spatial and statistical approaches, combining Kernel Density Estimation (KDE), Ordinary Least Squares (OLS), and Multiscale Geographically Weighted Regression (MGWR) to analyze the relationship between local coffee shops density and night-time light (NTL) intensity derived from satellite imagery. **Findings:** The results demonstrate that local coffee shops density has a significant positive correlation with NTL intensity ($\beta = 7.30, p < 0.01$), but the strength of this relationship varies spatially, being strongest in emerging sub-centers with mixed residential and commercial functions and weaker in already illuminated central districts. These findings indicate that local coffee shops serve as micro-scale urban infrastructures sustaining local economic and social vibrancy after dark. **Conclusion:** The study concludes that night-time illumination should not be interpreted solely as an economic indicator, but rather as a spatial manifestation of socio-economic diversity shaped by both formal and informal systems. **Novelty/Originality of this article:** The novelty of this study lies in conceptualizing local coffee shops as culturally embedded urban infrastructures and integrating open-source spatial data with remote-sensing methods to capture the geography of the night-time economy in a Global South city.

KEYWORDS: local coffee shops; night time light; spatial heterogeneity.

1. Introduction

Recent studies on urban economics have expanded beyond measuring daytime economic activities, increasingly emphasizing the dynamics of the night-time economy—the economic and social processes that continue after sunset as cities remain active. The diversity of night-time activities across sectors such as transportation, entertainment, trade, and culinary services (Son et al., 2023) reflects a city's ability to sustain its vitality beyond daylight hours, demonstrating how economic and social life continue after sunset as part of the broader night-time economy. This perspective aligns with the broader urban concept of the 24-hour city, which envisions cities as continuous systems of production, consumption, and mobility operating beyond the conventional daytime economy (Khorsand et al., 2020). One of the most widely used approaches to measure night-time economic activity is through satellite-derived night-time light (NTL) data (Roberts, 2021), which capture the intensity of urban illumination as a proxy for economic and social dynamics after dark (Mellander et al.,

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2015). However, the use of NTL data has so far been predominantly applied at larger spatial scales particularly in metropolitan areas where night-time activities are concentrated in entertainment sectors such as bars, clubs, and restaurants (Abraham et al., 2019).

Meanwhile, in many Eastern or Global South cities, culturally rich societies display distinctive night-time activity patterns shaped by local traditions, religious practices, and social interactions (Son et al., 2023). The medium-sized Indonesian city of Banda Aceh represents a distinctive case where an Islamic-oriented social system shapes night-time activity patterns that diverge from the entertainment-driven urban rhythms of Western cities and even from other Indonesian urban contexts. Within this context, Banda Aceh's night-time economy is presumed to be centered around local coffee shops, locally known as *warkop*, which are culturally legitimate spaces for social interaction and small-scale economic exchange late into the night.

The term "local" in the phrase "local coffee shops" is used to distinguish between modern coffee shops and the traditional coffee shops that form the main focus of this study. In terms of characteristics, local coffee shops are not heavily oriented toward aesthetics as modern coffee shops typically are. The seating arrangements in local coffee shops tend to be denser, with tables placed close together to maximize space, whereas modern coffee shops usually maintain wider spacing to ensure greater comfort and privacy. Moreover, unlike modern coffee shops that are commonly air conditioned or adopt a hybrid indoor setting, local coffee shops generally operate without air conditioning and instead follow a semi outdoor concept that allows natural ventilation. Lastly, in terms of operation hours, modern coffee shops in Banda Aceh are generally open for about fourteen hours, from around 10 a.m. to midnight, whereas local coffee shops typically operate twenty four hours a day, serving as continuous social and economic hubs throughout the night.

These local coffee shops are categorized as formal businesses because they operate in permanent buildings, are subject to taxation, and are regulated by local government policies, such as the requirement to provide a prayer space. Beyond their economic function, local coffee shops hold significant social value as "third places" where people interact (Finlay et al., 2019) such as students completing assignments, employees working remotely, or community members engaging in informal transactions and discussions, as shown in figure 1. Most operate for up to 18 hours a day, and some remain open around the clock. Hence, the prevalence of local coffee shops strongly reflects Banda Aceh's night-time economy, illustrating how formal enterprises can sustain nocturnal urban vitality while remaining consistent with local cultural and religious norms.



Fig. 1. Local Coffee Shops (*Warkop*) as a Space of Social Interaction in Banda Aceh City
Source: Laeis, (2024); Tasya, (2022)

The night-time economy (NTE) represents an extension of economic activity beyond traditional daytime hours, highlighting how cities organize production, services, and leisure across different temporal scales to sustain urban productivity and social vibrancy (Son et al., 2023). In many cities, the NTE tends to emerge as a spatial agglomeration concentrated around central urban areas, where clusters of consumption spaces and night-time activities create distinctive economic nodes. These agglomerations contribute significantly to maintaining the overall vitality and liveliness of urban environments after dark (Aghasafari et al., 2021; Seijas & Gelders, 2021; Wan et al., 2024).

However, the intensity and spatial distribution of night-time economic activity can vary substantially across different parts of a city, depending on factors such as land use, accessibility, and cultural context (Khorsand et al., 2020; Son et al., 2023). From a spatial-analytical perspective, this variation is explained by spatial heterogeneity theory which posits that relationships between urban variables such as business density and economic activity are not uniform across space and therefore cannot be represented by a single global coefficient (Qin et al., 2024). Accordingly, spatial models such as Multiscale Geographically Weighted Regression (GWR) allow these local variations to be analyzed explicitly, revealing how the strength and direction of relationships differ across locations (Liu et al., 2022).

Recent studies have utilized night-time light (NTL) data to examine relationships between urban brightness and various dimensions of city development, including urbanization (Li et al., 2021), economic growth (Beyer et al., 2022; Jhamb et al., 2025), and energy consumption (Yue et al., 2020). Yet, these applications rarely address cities where formal economic activities coexist with strong cultural, religious, or moral regulations. Moreover, few studies integrate open-source point of interest (POI) data with NTL imagery to capture micro-scale spatial signatures of urban economic behavior (Zhao et al., 2020).

Despite its importance in sustaining local urban life, the contribution of local coffee shops (*warkop*) to night-time economic intensity has not been quantitatively or spatially examined. Existing literature provides little empirical evidence on how formally regulated yet culturally constrained night-time economies manifest spatially in medium-sized cities of the Global South (Haleem et al., 2021; Seijas & Gelders, 2021). Furthermore, the extent to which the relationship between local coffee shops density and NTL intensity varies across different functional zones such as commercial, educational, and peripheral areas remains largely unknown. This study therefore addresses a dual research gap: (1) an empirical gap, by providing spatial evidence linking formal micro-enterprises with NTL intensity; and (2) a conceptual gap, by extending the notion of the night-time economy beyond entertainment-oriented and metropolitan contexts to include culturally and religiously regulated urban economies.

To fill this gap, the study focuses on the medium-sized Indonesian city of Banda Aceh. It first maps the spatial distribution and clustering of local coffee shops, then examines the global relationship between local coffee shops density and night-time light intensity, and finally evaluates the spatial heterogeneity of this relationship using Multiscale Geographically Weighted Regression (MGWR). Based on existing literature, the study hypothesizes that (H1) local coffee shops density is positively correlated with NTL intensity, indicating that higher densities contribute to greater night-time economic activity, and (H2) the strength of this relationship varies spatially, both in the city center, in the suburban areas, and in other areas with specific characteristics.

By integrating open-source POI and NTL data, this study makes three key contributions. Empirically, it demonstrates how formal small-scale enterprises contribute to night-time urban vitality within a culturally regulated context. Methodologically, it advances spatial analysis of the night-time economy by combining high-resolution remote-sensing data with local economic indicators. Conceptually, it introduces the idea of a religiously regulated formal night-time economy, an urban model distinct from the leisure-driven economies of metropolitan cities. Together, these contributions broaden the understanding of night-time economic diversity in Global South cities and reveal how urban vitality can persist under formal regulation and cultural restraint.

The everyday culture of coffee shops in Banda Aceh further reflects how residents animate urban spaces during the evening hours. Rather than functioning solely as commercial venues, these establishments act as socially embedded gathering points where leisure, mobility, and informal interaction converge. Their spatial presence therefore provides an entry point for understanding how people occupy and energize the city after dark within a regulated cultural environment. By examining these locally grounded practices, the study offers a more nuanced interpretation of how socio-economic activities shape the spatial distribution of luminosity and the lived experience of the night-time city.

2. Methods

2.1 Research design and study area

This study employed a quantitative spatial approach to investigate the relationship between the number of local coffee shops (warkop) and the intensity of night-time economic activity in Banda Aceh City, as measured by the brightness level captured by night-time light (NTL) data. The research utilized open-source spatial datasets, including point-of-interest (POI) data and satellite-derived night-time light imagery. These datasets were subsequently analyzed using spatial regression techniques, namely Ordinary Least Squares (OLS) and Multiscale Geographically Weighted Regression (MGWR), to examine both global and localized relationships while accounting for spatial heterogeneity.

Broadly, the research process consisted of four sequential and interrelated stages. The first stage involved scraping POI data using a specialized web extension to identify and collect the locations of local coffee shops across the city, followed by spatial mapping of their distribution. The second stage involved processing NTL data obtained from satellite imagery. The third stage focused on analyzing the global relationship between local coffee shops and NTL intensity using OLS. Finally, the fourth stage employed the MGWR model to investigate spatially varying relationships and capture the heterogeneity of the association across different parts of the city.

Ontologically, this study is based on the assumption that the intensity of a city's night-time economy can be empirically observed through the brightness levels detected by night-time light imagery and through the spatial distribution of economic activity points such as local coffee shops. Epistemologically, the study adopts a positivist perspective by employing quantitative spatial analysis to objectively investigate the relationship between local coffee shop distribution and urban night-time economic intensity.

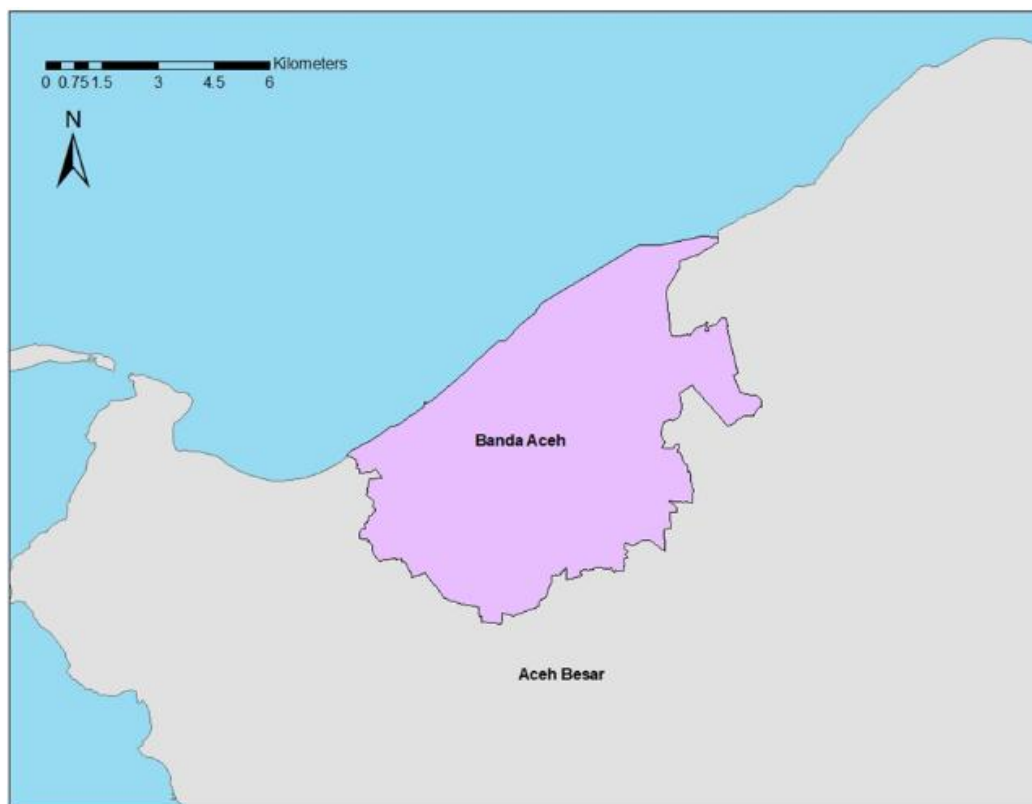


Fig. 2. Location of the Study Area: Banda Aceh City, Indonesia

Banda Aceh, the capital city of Aceh Province, was selected as the study area because it represents a medium-sized city in both the Indonesian context and the broader Global

South. The city is located at the westernmost tip of Indonesia, between 05°16'15"–05°36'16" North Latitude and 95°16'15"–95°22'35" East Longitude, covering approximately 61.36 km² with a population of around 265,000 people in 2024 (Banda Aceh City Statistics Office, 2025). Banda Aceh possesses a unique socio-cultural characteristic due to the implementation of Islamic law (syariah) in public governance and everyday life (Rohidin et al., 2023). This condition significantly influences the structure of economic activity, particularly that occurring at night. Activities commonly associated with nightlife economies in other cities, such as bars, pubs, and nightclubs, are highly restricted or absent. Consequently, the night-time economy of Banda Aceh is largely shaped by local coffee shops, which serve not only as commercial establishments but also as important social spaces. This distinctive context provides an opportunity to examine how religious norms, local culture, and community practices interact with and support urban night-time economic activities.

2.2. Data collection and preparation

The primary datasets used in this study consisted of the number of local coffee shops as the independent variable and night-time light intensity as the dependent variable. The quantity and spatial distribution of local coffee shops were obtained from the Points of Interest (POI) database available on Google Maps using the Instant Data Scraper extension in the Google Chrome browser. This process generated detailed information for each establishment, including business name, category, address, and geographical coordinates.

To ensure that the collected data accurately represented traditional Acehnese coffee shops, a filtering procedure was applied prior to data extraction. In Banda Aceh, traditional coffee shops commonly incorporate local terms such as "warung kopi," "warung kupa," or "warung kupi" in their names, reflecting local linguistic practices. These naming conventions distinguish traditional coffee shops from modern cafés and coffee chains that generally use English terms such as "coffee" or "café." Through this filtering process, only establishments representing the authentic local coffee shop culture were retained. Following data cleaning and the removal of records located outside the administrative boundaries of Banda Aceh, the final dataset consisted of 95 local coffee shops distributed across the city.

The local coffee shop dataset was subsequently converted into shapefile format to facilitate spatial visualization and analysis. To examine the spatial concentration of local coffee shops, Kernel Density Estimation (KDE) was applied to the point data. KDE generated a continuous density surface illustrating the intensity of local coffee shop clustering throughout Banda Aceh. This method is widely used to identify spatial hotspots and clustering patterns of economic activities (Vlad et al., 2023). The resulting density surface provided an initial understanding of the spatial structure of the city's night-time economy. The night-time light (NTL) data were obtained from the 2024 Visible Infrared Imaging Radiometer Suite (VIIRS) dataset accessed through the Light Pollution Map platform (Falchi, 2025). The NTL data were available in raster format with a spatial resolution of 500 × 500 meters and represented the brightness intensity of light emissions detected from satellite imagery. The raster dataset was clipped using the administrative boundary of Banda Aceh City to ensure spatial compatibility with the local coffee shop data. The administrative boundary shapefile was obtained from the Indonesian Geospatial Information Agency.

2.3. Spatial analysis

Following data preparation and harmonization, statistical analyses were conducted to investigate the relationship between local coffee shops and night-time light intensity. The analysis employed a combination of global and local spatial regression techniques. First, Ordinary Least Squares (OLS) regression was used to measure the overall relationship between the number of local coffee shops and NTL intensity across the study area (Yu & Ai, 2014). As a global regression model, OLS assumes that the relationship between variables

remains constant throughout the entire study area and therefore provides a baseline understanding of the general association between local coffee shop distribution and night-time economic intensity.

However, the influence of local coffee shops on NTL intensity may vary spatially across different urban environments. To account for such spatial heterogeneity, this study employed the Multiscale Geographically Weighted Regression (MGWR) model as an extension of the traditional Geographically Weighted Regression (GWR) approach. Unlike conventional GWR, which uses a single bandwidth for all explanatory variables, MGWR allows each variable to operate at its own spatial scale by assigning variable-specific bandwidths (Tan & Bu, 2025). This feature is particularly relevant because the spatial influence of individual local coffee shops is generally localized at a micro scale, whereas the NTL intensity observed by satellites reflects broader illumination patterns at a macro scale.

By accommodating these scale differences, MGWR provides a more flexible and context-sensitive framework for estimating spatial relationships, enabling the identification of both local and global influences of local coffee shops on night-time light intensity. To ensure consistency and comparability between the OLS and MGWR analyses, both models employed the same spatial unit of analysis, namely a uniform grid of 500 × 500 meters covering the entire study area.

All data utilized in this study were derived from publicly accessible open-data sources. No personal or sensitive information was collected during the data acquisition process. Furthermore, all analytical procedures adhered to principles of ethical data use, transparency, and reproducibility. This methodological framework ensures that the study can be independently verified and replicated by future researchers interested in urban night-time economies and spatial economic analysis.

The primary data of this study consisted of the number of local coffee shops, which served as the independent variable, and the intensity of night-time light, which served as the dependent variable. The quantity and spatial distribution of local coffee shops were obtained from the Points of Interest (POI) database available on Google Maps using the Instant Data Scraper extension in the Google Chrome browser. This scraping process produced detailed information for each local coffee shops, including the business name, category, address, and precise geographical coordinates. However, before conducting the scraping process, a crucial step involved the identification and application of boolean filters to ensure that the data collected truly represented traditional coffee shops rather than modern coffee shops, cafés, or restaurants that might differ in their function and target market.

In the local context of Banda Aceh, traditional coffee shops typically incorporate words such as “*warung kopi*,” “*warung kupa*,” or “*warung kuphi*” in their names, reflecting the local Acehnese pronunciation of the word “coffee.” These naming conventions distinguish local coffee shops from modern coffee establishments that usually employ English-language names such as “Coffee,” “Cafe,” or other international terms. Through this filtering process, it was possible to isolate and extract only those establishments that authentically represent the traditional coffee shops culture of Banda Aceh. After the completion of data filtering, extraction, and cleaning, including the removal of records that were located outside the administrative boundaries of Banda Aceh City, the final dataset comprised a total of 95 local coffee shops units distributed across the city.

Subsequently, the local coffee shops dataset was converted into a shapefile format to enable visualization and spatial analysis of its distribution within the study area. To better understand the spatial distribution pattern, Kernel Density Estimation (KDE) analysis was applied to the local coffee shops point data. This technique generated a continuous surface that represents the intensity of local coffee shops clustering across Banda Aceh. The KDE analysis is particularly useful for identifying spatial patterns and hotspots where local coffee shops are concentrated (Vlad et al., 2023), such as in the city center or along main commercial corridors. Through this analysis, an initial understanding of the spatial clustering tendencies of local coffee shops was developed, providing insights into the spatial structure of the night-time economy in Banda Aceh.

The night-time light (NTL) data used in this study were obtained from the Visible Infrared Imaging Radiometer Suite (VIIRS) 2024 dataset, which was accessed through the Light Pollution Map platform (Falchi, 2025). The NTL data were provided in raster format with a spatial resolution of 500×500 meters, representing the brightness levels of light emissions visible from satellite imagery. The raster data were subsequently clipped according to the administrative boundaries of Banda Aceh City to ensure spatial alignment with the local coffee shops dataset. The administrative boundary shapefile used for this purpose was sourced from the Indonesian Geospatial Information Agency.

After both datasets had been prepared and harmonized, statistical analyses were conducted using the Ordinary Least Squares (OLS) regression method to measure the general or global relationship between the number of local coffee shops and the NTL intensity (Yu & Ai, 2014). However, because the spatial influence of local coffee shops on NTL intensity is not uniform across all areas of the city, it was necessary to employ a spatially adaptive method to capture localized variations in the strength and direction of this relationship. Therefore, the Multiscale Geographically Weighted Regression (MGWR) model was used as an extension of the traditional GWR approach.

Unlike conventional GWR, which applies a single, fixed bandwidth for all variables, MGWR allows each explanatory variable to operate at its own spatial scale by assigning different bandwidths according to the characteristics of the variable (Tan & Bu, 2025). This capability is particularly important in this study because of the significant difference in scale between the local coffee shops and the night-time light data. The light emitted from individual local coffee shops typically spreads over a very localized, micro-scale area, while the NTL intensity captured by satellites represents a much broader, macro-scale illumination pattern. As such, the MGWR approach provides a more accurate and context-sensitive estimation of spatial relationships, capturing both the local and global influences of local coffee shops on night-time light intensity. To ensure consistency and comparability between analyses, both the OLS and MGWR models used the same unit of analysis: a uniform 500×500 -meter grid across the entire study area.

All data utilized in this study were obtained from publicly accessible open-data sources, and all analytical procedures were conducted in accordance with open-data usage and ethical research principles. No personal or sensitive information was collected during the scraping process, and all data were handled responsibly to protect privacy and data integrity. The overall methodological framework of this study emphasizes transparency, reproducibility, and adherence to ethical standards in spatial data collection, processing, and analysis, ensuring that the findings can be independently verified and replicated by future researchers engaged in similar urban spatial-economic studies.

3. Results and Discussion

Based on the extraction of Point of Interest (POI) data from Google Maps, a total of 95 local coffee shops (*warkop*) were identified and spatially distributed across Banda Aceh City. The data extraction process employed a series of carefully selected keywords to ensure that only traditional coffee shops were captured in the search results, thereby excluding cafés, modern coffee shops, and similar contemporary establishments. The chosen keywords reflected both the common Indonesian term and its Acehnese linguistic variations, such as “*warung kopi*,” “*warung kupi*,” and “*warung kuphi*,” all of which are widely used to describe traditional coffee shops that function as popular social gathering places in Banda Aceh. The resulting spatial dataset of local coffee shops was then converted into shapefile format using geographic coordinates obtained from Google Maps. This conversion was necessary because the spatial dataset served as the fundamental input for subsequent geospatial analyses, enabling further exploration of the relationship between the presence of local coffee and patterns of night-time economic activity across the city.

To provide a more intuitive visualization of the clustering tendencies of these establishments, the spatial point data of local coffee shops were analyzed using the Kernel Density Estimation (KDE) method. This non-parametric technique was applied to examine

spatial aggregation patterns and to identify hotspots that signify high concentrations of local coffee shops within the urban area. The KDE analysis aimed to visually determine whether the spatial distribution of these clusters corresponds with areas of intensified night-time economic activity in Banda Aceh. As illustrated in Figure 3, the results reveal that local coffee shops are most densely concentrated in the city center, which serves as the administrative, commercial, and service hub of the region (Banda Aceh City Government, 2021). Furthermore, additional but smaller clusters were also observed in several sub-center areas, suggesting a hierarchical spatial structure of local coffee shops distribution. This agglomeration pattern indicates that the spatial organization of local coffee shops aligns closely with the city's functional hierarchy, reflecting their role as both social and economic nodes within the urban network (Zhao et al., 2023). Accordingly, the KDE findings suggest that local coffee shops are generally located in areas exhibiting higher levels of night-time brightness, reinforcing the idea that these establishments contribute to localized concentrations of urban vitality after dark. Nevertheless, further quantitative analysis is required to determine whether the observed brightness patterns in these urban centers are significantly influenced by local coffee shops activity or instead dominated by other forms of economic and infrastructural illumination.

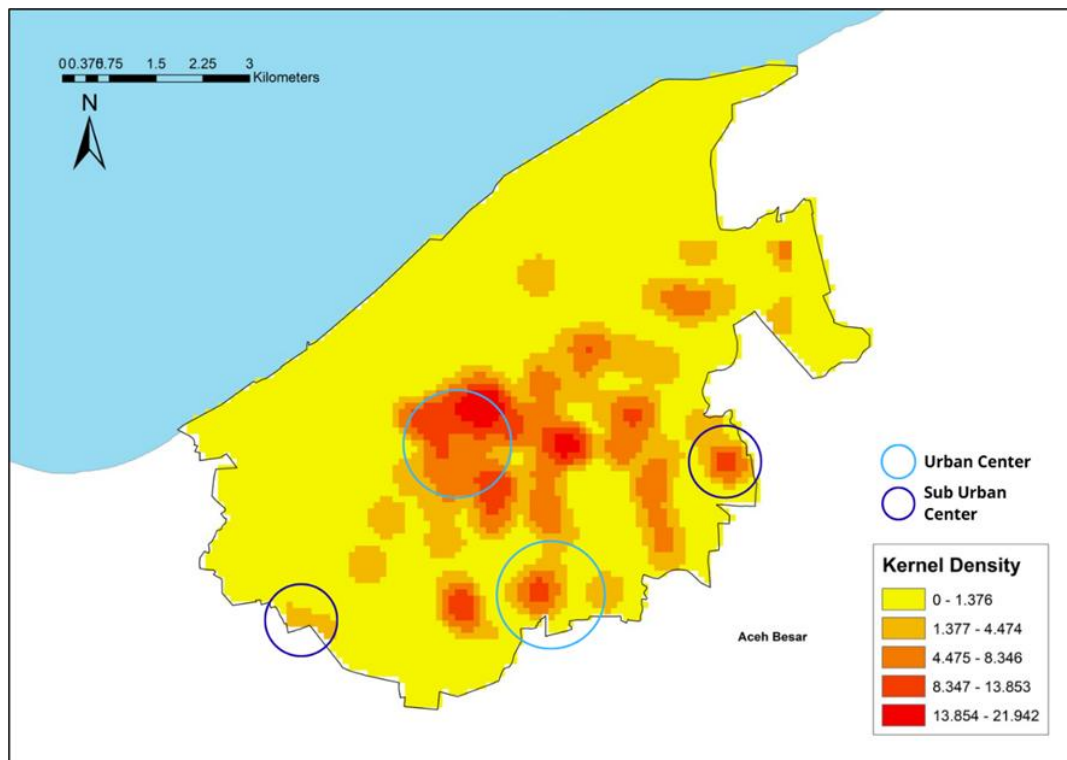


Fig. 3. Kernel Density Estimation (KDE) of Local coffee shops Distribution in Banda Aceh
Source: Author's, based on Google Maps POI data (2024) processed using Arcmap

Figure 4 presents the spatial distribution map of night-time light (NTL) intensity across Banda Aceh City. The map clearly illustrates that the highest NTL intensities are concentrated within the city's central districts, in contrast to the relatively dimmer surrounding areas. This finding substantiates the earlier KDE results, confirming that the largest cluster of local coffee shops indeed coincides with the main service and commercial core of the city. The brightest areas of Banda Aceh correspond spatially with these same central zones, implying that night-time economic activities represented by luminous intensity are spatially aligned with the agglomeration of local coffee shops. This correspondence suggests that the areas characterized by a high level of night social and commercial interaction are also those that contribute most significantly to the city's overall nocturnal illumination. However, it remains uncertain whether this luminous intensity is primarily driven by the presence of local coffee shops or instead by other urban functions,

such as commercial buildings, public facilities, or traffic-related lighting. This uncertainty also applies to other urban sub-centers and peripheral zones within Banda Aceh, where illumination may originate from mixed or unrelated sources.

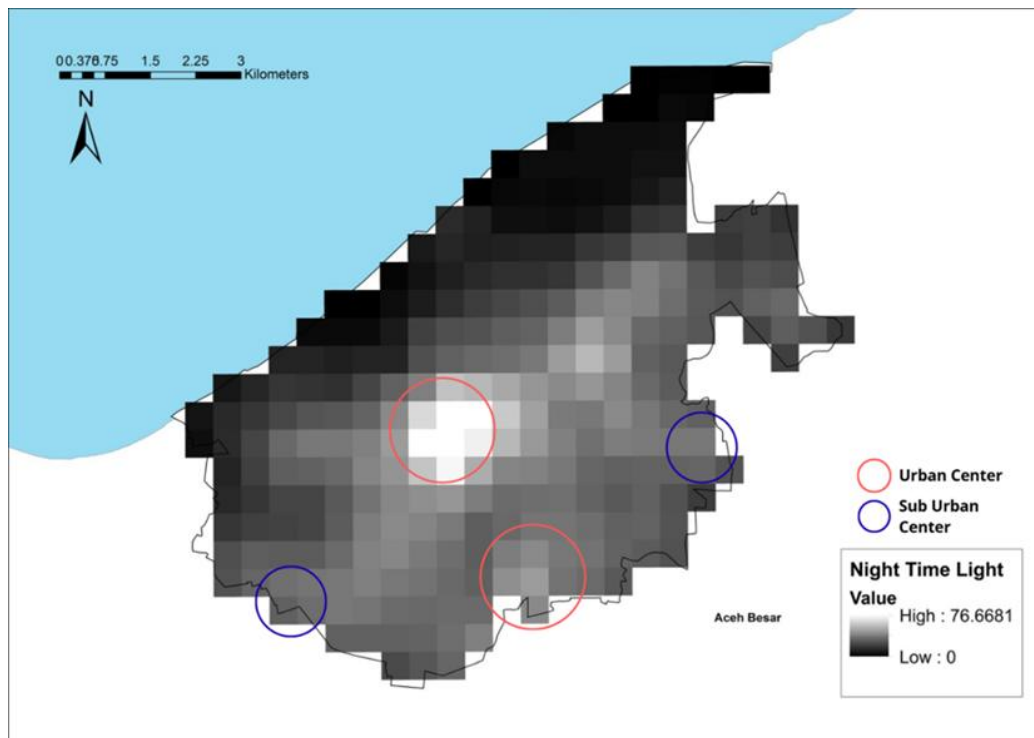


Fig. 4. Spatial Distribution of Night-Time Light (NTL) Intensity in Banda Aceh, 2024
 Source: Author’s, based on VIIRS data (2024)

To statistically verify the contribution of local coffee shops to the variation of night-time brightness across the city, a correlation and regression analysis was subsequently performed. The first stage of this quantitative analysis involved testing the global relationship between the two variables using the Ordinary Least Squares (OLS) method. This approach was employed to determine whether the presence and density of local coffee shops exert a measurable and statistically significant influence on night-time brightness. The OLS results, presented in Table 1, confirm a positive and statistically significant relationship between local coffee shops density and night-time light intensity ($\beta = 7.30$, $p < 0.01$). This means that, on average, each additional local coffee shops contributes approximately 7.30 units to the overall NTL intensity across Banda Aceh. Nevertheless, the coefficient of determination ($R^2 = 0.24$) indicates that the distribution of local coffee shops explains only about 24% of the spatial variation in night-time brightness, suggesting that other factors such as public lighting systems, vehicular traffic, and nighttime operation of public facilities account for the remaining variation. These findings imply that while local coffee shops play a discernible role in shaping night-time urban dynamics, they are not the sole or dominant factor influencing overall urban brightness. Hence, further spatially disaggregated analysis was required to capture the local heterogeneity of this relationship using the Multiscale Geographically Weighted Regression (MGWR) model. This spatially explicit approach allows for the assessment of how the strength and direction of the relationship between local coffee shops and night-time illumination vary across different parts of the city.

Table 1. Summary of the OLS Model between Local Coffee Shops Count and Night-time Light Intensity

Variable	Coefficient (β)	t- statistic	p- value	R ²	F- statistic (Prob)
Number of Local coffee shops	7.31	8.75	0.000	0.248	78.76 (0.000)

(Author’s analysis using ArcMap 10.8, 2015)

Table 2. Summary of MGWR Model Results

Statistic	Minimum	Mean	Maximum
Local Coefficient	-0.161	0.702	2.976
Local R ²	-3.001	-0.350	0.711

(Author's analysis using MGWR 2.2, 2015)

The MGWR results are summarized in Table 2. The analysis shows that the average effect of local coffee shop density on night-time light intensity across all grid cells is 0.702, with values ranging from -0.161 to 2.976. Spatially, as illustrated in the coefficient map (Figure 5), the influence of local coffee shops on night-time brightness varies widely across the urban landscape. In the city center (grids 1–6), the effect of local coffee shops on NTL intensity is moderate. This pattern suggests that although local coffee shops are highly clustered in the central area, they are not the dominant determinant of illumination, as other urban functions—such as offices, retail centers, and public infrastructure—also contribute substantially to the observed brightness. Conversely, grids with stronger relationships between the two variables are predominantly located in the southern–eastern periphery (grids 7–14) and the northern coastal belt (grids 15–20).

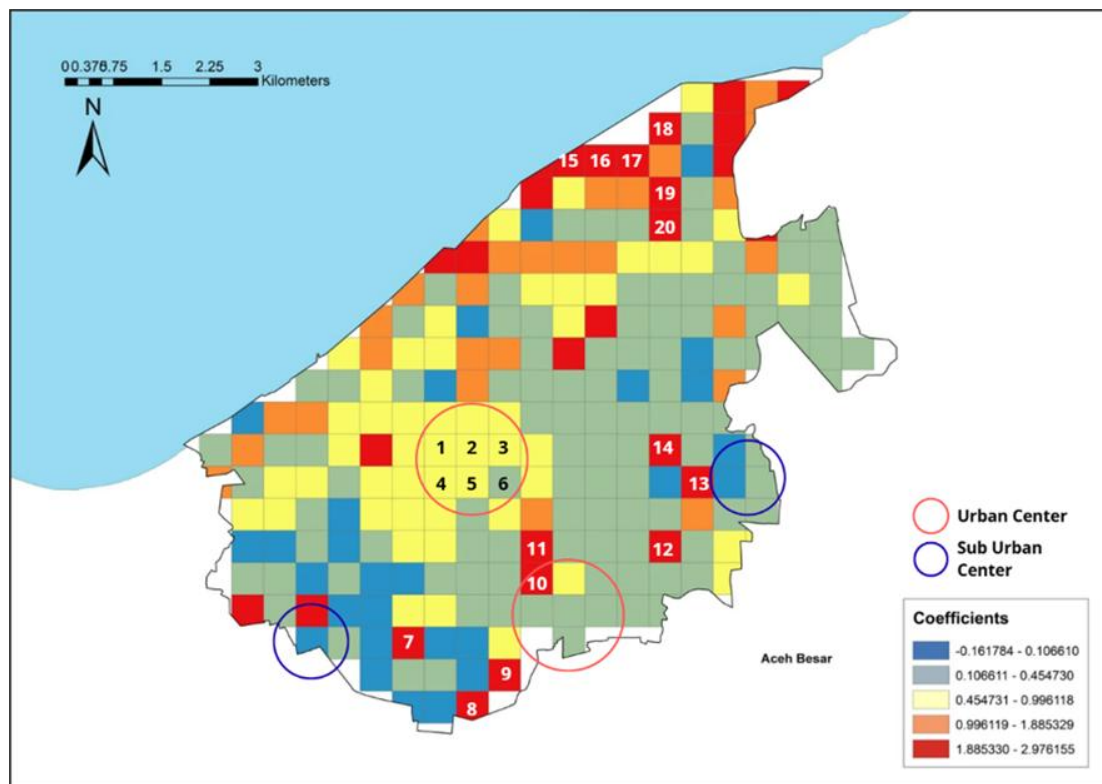


Fig. 5. Spatial Distribution of MGWR Coefficients between Local coffee shops Density and Night-Time Light Intensity

When the spatial pattern of coefficients is compared with land-use characteristics (Figure 6), the central urban zones (grids 1–6) display a highly diverse mixture of land uses, including commercial, residential, governmental, and recreational functions. The relatively moderate coefficients observed in these areas can therefore be attributed to the overlapping effects of multiple land-use types. Meanwhile, the southern–eastern suburban zones (grids 7–14), which are dominated by commercial land use along major road corridors, show stronger coefficient values. This indicates that in these more homogeneous commercial environments, the presence of local coffee shops contributes more strongly to night-time brightness, reinforcing their role as localized nodes of social and economic activity.

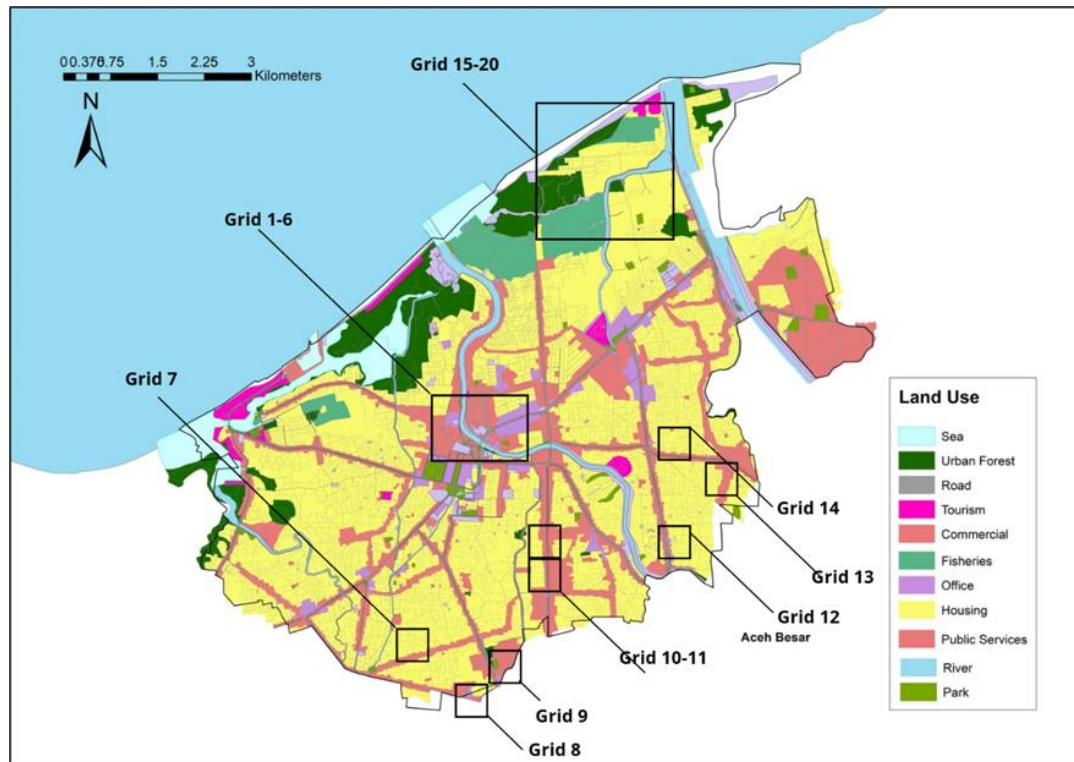


Fig. 6. Land Use Map of Banda Aceh City
Source: Author's, based on spatial plan (2024)

However, the northern coastal areas (grids 15–20) exhibit an anomalously high coefficient pattern that does not align with the actual spatial distribution of local coffee shops as observed in the KDE analysis (Figure 3). According to the KDE results, this area contains no local coffee shops at all, as it is primarily composed of mangrove forests, fishery zones, and small portions of residential and coastal tourism land uses (Figure 6). This apparent anomaly arises from the spatial mechanics of the GWR model itself. Because local regressions in MGWR incorporate spatially weighted data from surrounding cells (Wu et al., 2023), coastal grids may inherit the correlation structure of adjacent urban areas characterized by higher local coffee shop density and brighter nighttime illumination. Consequently, the elevated coefficients in these regions should not be interpreted as genuine causal effects but rather as manifestations of spatial spillover or diffusion artifacts within the satellite radiance data. Moreover, the northern coastal belt also contains alternative sources of light such as ports, mosques, major road infrastructure, and sea-surface reflections that contribute to stable illumination independent of commercial activity (Gao et al., 2025). In areas where both variables exhibit low variance, even minor fluctuations in brightness may appear statistically amplified (Mansour et al., 2023), a phenomenon commonly referred to as spatial sensitivity. Therefore, these coastal anomalies should not be regarded as modeling errors but rather as reflections of contextual illumination dynamics unrelated to local coffee shops activity.

Overall, the analytical results reveal that local coffee shops contribute to Banda Aceh's night-time economy in a spatially uneven and context-dependent manner. Their influence is strongest in emerging sub-centers, where social and commercial interactions continue late into the night, while it diminishes both in the oversaturated brightness of the urban core and in peripheral residential zones characterized by limited evening activity. This pattern reflects the differentiated role of small-scale enterprises within the broader urban illumination landscape supporting local vitality yet constrained by spatial, structural, and environmental contexts. Rather than acting as uniform drivers of nocturnal brightness, local coffee shops form part of a multifaceted urban assemblage where informal economies, infrastructure systems, and socio-spatial dynamics intersect. These findings underscore the importance of interpreting night-time light not merely as a static economic indicator but as

a dynamic spatial manifestation of urban diversity, shaped by both formal and informal systems of human activity.

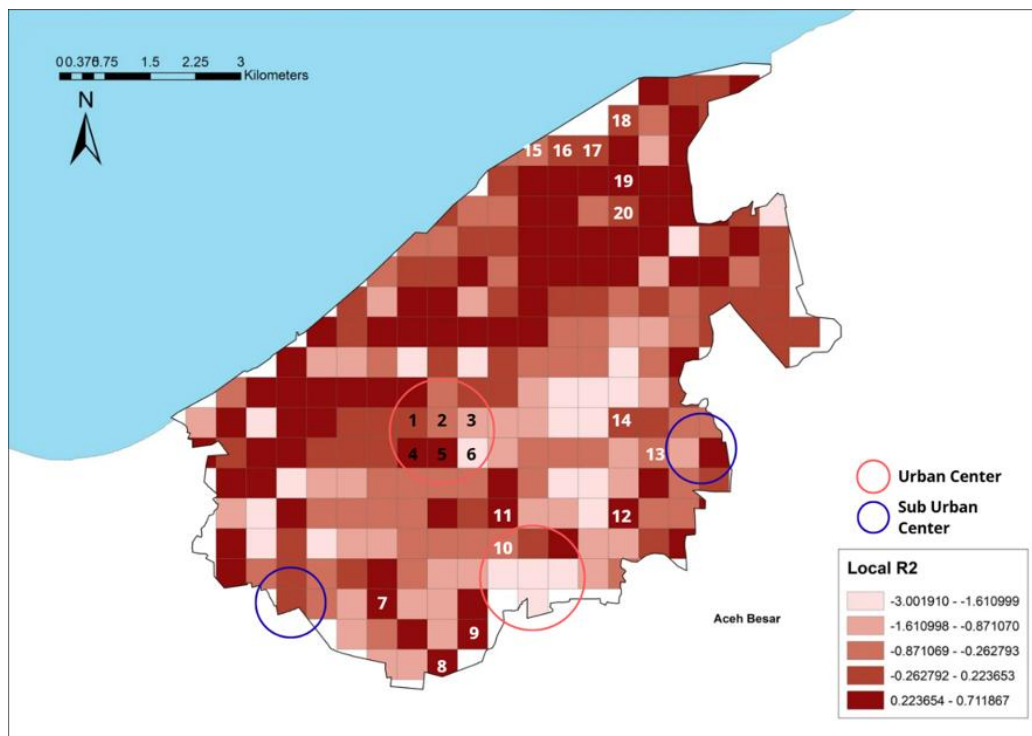


Fig. 7. Spatial distribution of local R2 between local coffee shops density and night-time light intensity

The identification of local coffee shops as active contributors to Banda Aceh's night-time economy also offers broader conceptual insights into how socio-cultural characteristics can shape distinct urban economic patterns. The findings demonstrate that regional identity rooted in cultural norms, religious values, and everyday social behavior can influence not only spatial interactions but also the temporal rhythm of urban economic activity. In this context, the role of local coffee shops in Banda Aceh extends beyond serving as venues for casual socialization or culinary experiences; they represent a culturally embedded form of urban night-time economy that embodies the city's distinctive Islamic and communal character. This distinctive pattern offers new perspectives in urban studies, illustrating how local culture can generate its own form of economic dynamism outside the conventional frameworks of entertainment-oriented nightlife. Furthermore, this cultural-economic uniqueness holds potential as a basis for city branding, positioning Banda Aceh as an exemplar of how regional identity and social values can coexist with and even drive an inclusive and sustainable urban vitality.

Moreover, these findings provide additional implications for the field of spatial and urban planning. The existence of local coffee shops (*warkop*) that demonstrably contribute to Banda Aceh's night-time economic activity suggests that these establishments especially those forming spatial clusters function as temporary centers of urban life after dark. Consequently, this study offers valuable input for the formulation of zoning regulations and spatial planning strategies that acknowledge the socio-economic roles of small-scale urban actors. In addition, the identification and mapping of areas exhibiting strong spatial associations with local coffee shops distribution present an opportunity for the Banda Aceh City Government to strategically harness the presence of these establishments to enhance night-time urban safety, surveillance, and livability. In a broader sense, these insights encourage planners to recognize how informal and culturally grounded economic activities can strengthen urban resilience and contribute to the sustainability of local economies.

4. Conclusions

This study concludes that local coffee shops (local coffee shops) play a vital yet spatially differentiated role in sustaining the night-time economy of Banda Aceh. The combination of KDE, OLS, and MGWR analyses confirms that local coffee shops density significantly influences night-time illumination, but with varying magnitudes across different urban contexts. The strongest associations occur in emerging sub-centers where social and economic activities extend into late hours, while diminishing effects appear in the saturated city core and peripheral residential zones. This pattern highlights that small-scale, culturally embedded enterprises contribute unevenly to nocturnal economic vitality depending on their spatial and functional environments.

The research advances current knowledge by conceptualizing local coffee shops as micro-scale urban infrastructures that bridge informal economic practices with spatial manifestations of urban vibrancy. By linking ground-level social activities with satellite-based luminosity data, it introduces a methodological framework that integrates urban informality and spatial analytics. These findings reinforce that night-time illumination should be interpreted as a spatial representation of socio-economic diversity, not merely as an economic proxy. Consequently, the study contributes to urban planning discourse by underscoring the need to integrate informal and community-run enterprises into strategies for inclusive, culturally sensitive, and sustainable night-time urban development. Taken together, these insights also point to a broader implication: night-time spatial data must be interpreted with sensitivity to local cultural and urban contexts. In many cities—particularly those where evening activities are shaped by cultural norms rather than entertainment-driven markets—the meaning of luminosity can differ substantially from what is assumed in conventional analyses. By showing how small, everyday establishments can generate detectable spatial patterns when viewed through multi-scale models, this research offers planners a way to read light data with greater nuance. It also highlights the importance of recognizing culturally rooted practices that often give shape to urban life after dark.

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Author Contribution

Conceptualization, methodology, software, validation, formal analysis, investigation, data curation, writing – review and editing, visualization, and project administration were carried out solely by G. N.

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Ethical Review Board Statement

Not available.

Data Availability Statement

All datasets used in this research are publicly available. The local coffee shops (POI) data were obtained from Google Maps using the Instant Data Scraper extension, and the night-time light (NTL) data were sourced from the Visible Infrared Imaging Radiometer Suite (VIIRS) dataset accessible via the Light Pollution Map platform. Processed datasets

and analytical scripts are available from the corresponding author upon reasonable request.

Conflicts of Interest

The author declares no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the author used ChatGPT (OpenAI) to refine the academic tone and clarity of the writing and Perplexity AI to assist in the literature search process. After using these tools, the author thoroughly reviewed, edited, and verified the content to ensure accuracy and originality, taking full responsibility for the final version of the manuscript.

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