

Exploring the Spatial Relationship Between Nighttime Lights and Crime Risk in Districts of Uttar Pradesh

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Abstract

A safe environment is the basic need of all human beings. Safety is the primary concern in developing countries like India. In this research work, a relationship between nighttime light and property crimes such as theft and burglary is analysed. All the districts of Uttar Pradesh are selected as a study area, where crime rate has been rapidly increasing in recent years. For analysis of NTL effect on property crimes, NTL data from NASA's Suomi NPP-VIIRS has been taken, and property crime data of theft and burglary have been taken from the official website of the National Crime Records Bureau (NCRB). Furthermore, a linear regression model has been performed that confirmed that areas with low NTL have a higher incidence of these crimes. For analysis of the spatial relation and patterns of property crimes, Kernel Density Estimation (KDE) and Local Indicator Spatial Autocorrelation (LISA) have been performed. The findings highlight that western, central and northeastern districts have higher incidence of theft and burglary. However, some western UP districts, such as Ghaziabad, Meerut, Shamli, and Gautam Budhh Nagar, with high NTL, also experience high rates of theft and burglary. This result indicates that NTL is not alone the key contributor of crime in a particular region; other factors may include transportation networks, population mobility, and socio-economic conditions.

Keywords: Property crime, NTL,

1. Introduction

The objectives of the UN Sustainable Development Agenda 2030 are a safe environment for every human being. It is increasingly recognised that a sustainable community should be both crime-free and perceived as safe by its citizens (Zhang et al., [2021](#)). The most important fundamental right of humans is to live without ferocity (Kabiraj, [2022](#)). Crimes can occur at any place, at any time, and for different reasons (Lee et al., [2024](#)). The social disorganisation theory explains why certain neighbourhoods have higher crime rates than others (Kubrin, [2009](#)). In regional crime dynamics, the spatial distribution of criminal potential is a crucial factor (Ceccato & Ioannidis, [2025](#); Roy & Chowdhury, [2025](#)). In urban areas, central regions are the hubs of economic activity, so they tend to be brighter than surrounding areas and less

vulnerable to criminal activities (Roy & Chowdhury, 2025). In contrast, peripheral, rural, and remote areas may have higher rates of crimes like burglary, theft, snatching, and robbery due to limited economic opportunities (Mukherjee et al., 2024). According to Routine Activity Theory, there is a positive correlation between nighttime and criminal activities that increase crime rate (Peng et al., 2022).

In order to address problems at the individual, temporal, and spatial levels, traditional data sources are still crucial. However, with the availability of new unconventional data, the differences between these levels of assessment have grown less clear (Krohn et al., n.d.). Remote Sensing data, such as NTL data, is a less explored method of data collection by using satellites and aerial photography (Ceccato & Ioannidis, 2025). Traditional methods of collecting NTL data create major difficulties, especially in temporal analysis (Roy & Chowdhury, 2025). Nighttime light (NTL) is one of the best tools for visualising human footprints from space (Zheng et al., 2022). NTL has been used since the 1970s for mapping human activities such as urban growth, estimating socio-economic development, and assessing natural disaster risks (Zheng et al., 2022). More studies have been done using NTL data from various satellites on urban areas, but very few studies have been done at regional state level, such as district. Analysing crime risk at the district level helps us understand both urban and rural areas. As a result, the purpose of this study is to investigate the relationship between NTL intensity and the pattern of property crime, theft, and burglary in the districts of Uttar Pradesh. VIIRS satellite data have been collected for three years period (2021-2023). This research has examined the pattern of property crime and NTL intensity in the districts of UP. At night, the risk of crimes and fear were higher than during the day (Uttley et al., 2024). In various studies, it has been found that criminals commit crimes mostly at night in dimly lit areas (Lee et al., 2024). The spatial distribution of crime is influenced by factors such as socio-economic, environmental, and political factors. Understanding how these factors influence spatial patterns of crime helps to understand and improve regional planning and policy implications. Significantly, a city's evening economic vibrancy correlates positively with the intensity of its nighttime illumination (Peng et al., 2022).

Previous studies have examined the relationship between night-time light intensity and crime patterns in urban areas such as cities and metropolitan areas. Although very little work has been done on district level, and also analysing remote sensing with crime patterns is also rare in developing countries like India. This research presents a dual impact of NTL on crime. Some research findings indicate a positive relation between NTL and crime patterns, while other

findings indicate a negative relation indicate highly developed areas and well-illuminated city cores have high intensity of crime compared to their surroundings. However, very little research has focused on their contrasting relationship across a large and socially diverse area like Uttar Pradesh.

2. Study area and rationale

For this study, inter-districts analysis of Uttar Pradesh is made. Uttar Pradesh is the most populous state of India, located in the northern part of the country (Figure 1). Uttar Pradesh is characterised by highly urbanised districts, such as Lucknow, Ghaziabad, and Kanpur Nagar, as well as low urbanisation in rural districts in the southeastern and central regions. These districts pose major challenges of urbanization and migration. The districts as a spatial unit have been selected because state-wise crime statistics in India are published by NCRB, and are available at district level. It helped associate NTL with crime data. Uttar Pradesh is characterised by high population density gradient and variation in economic activities and level of urbanisation. People often use the brightness of lights at night as a stand-in for economic activity, urban growth, and human settlements.

In recent years, the cases of theft and burglary at night in low light have been increasing in urban as well as in rural areas (News 18 & Jagran Josh, [2026](#)). Public safety is seriously threatened by this rise in crime rates (Roy & Chowdhury, [2025](#)). Some regions are well illuminated due to proper street lights on highways, residential, and commercial areas, while some regions do not have adequate lights poses serious threats of crimes such as theft, snatching, burglary, and robbery. Uttar Pradesh is characterised by rising urbanising cities with a rural mix, like Noida, Kanpur, Varanasi, Gorakhpur, and Prayagraj. These areas have different degrees of crime in illuminated and non-illuminated areas. Therefore, examining the relationship between NTL and crime provides a clear picture of spatial pattern of crime with respect to economic development across the state.

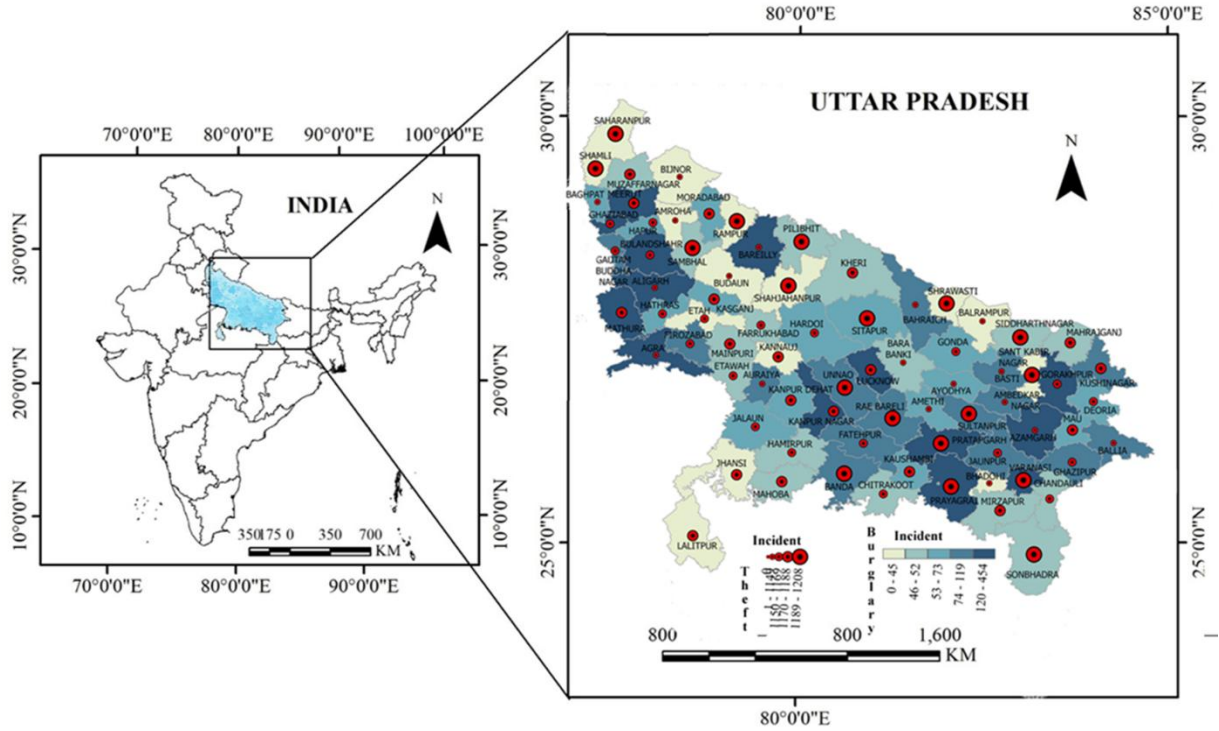


Fig. 1 Location Map of the study area

3. Data and methods

3.1 Nighttime light data

There are three sources from which nighttime light data have been obtained: Defence Meteorological Satellite Program-Operational Linescan System (DMSP-OLS), the Visible Infrared Imaging Radiometer Suite sensor on the Suomi National Polar-orbiting Partnership Satellite (NPP-VIIRS, hereafter VIIRS), and Luojia 1-01 (Zhou et al., 2019). For this study, the nighttime light data from the VIIRS satellite have been obtained and further analysed. The VIIRS sensor, launched in 2011 on the Suomi National Polar-orbiting Partnership (Suomi NPP) satellite, greatly improves NTL data collection with its day/night band (Ivan et al., 2020). There is no universally accepted threshold for defining nighttime crime in the literature (Lee et al., 2024; Coupe and Blake, 2006; Welsh and Farrington, 2008), which presents a methodological challenge. Dominguez and Asahi (2017) identified 7 p.m. to 9 p.m. as the peak risk window. However, Lee et al. (2024) defined nighttime as the interval between civil dusk and civil dawn, when the sun is 6° below the horizon, whereas Flatley (2017) reported that approximately 60% of burglaries and thefts occur between 6 p.m. and 6 a.m.

3.2 Property Crime Data

The crime data of property crimes, particularly theft and burglary, has been taken from the National Crime Records Bureau's annual publication "Crime in India: Statistics", covering the period from 2021 to 2023. The study focused on theft and burglary incidents that occurred especially during dark hours, such as after sunset and before morning, to ensure consistency with the NTL gradient (Roy & Chowdhury, 2025).

3.3 Spatial Pattern Analysis of property crimes and nighttime light

For showing the spatial distribution of property crime incidents over a geographical area using the method of Kernel Density Estimation (KDE), which is a widely used non-parametric method (Roy & Chowdhury, 2025). The following formula is used to calculate KDE:

$$f(x) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x-x_i}{h}\right) \quad (1)$$

where x_i are the observed data points, $f(x)$ is the estimated density at point x , n is the total number of observations (crime incidents, such as theft and burglary), h is the bandwidth, and K is the kernel function.

3.3.1 Spatial relationship between NTL & property crimes: bivariate LISA & Morans'I

In spatial statistics, Moran's I index was examined, which determines the degree of autocorrelation among the nearby objects across a spatial area. Moran's I value ranges from -1 to +1. Moran's I also examined whether the pattern is clustered or randomly distributed. Moran's I is defined (Roy & Chowdhury, 2025) by the formula:

$$I = \frac{n \sum_i \sum_j w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{(\sum_i \sum_j w_{ij}) \sum_i (x_i - \bar{x})^2} \quad (2)$$

where n is the number of the spatial features, x_i is the attribute value of feature i , x_j is the attribute value of feature j , $\bar{x}$ is the mean of this attribute, w_{ij} is the spatial weight between feature i and j ; and $\sum_i \sum_j w_{ij}$ is the aggregation of all spatial weights.

The LISA map helps to analyse the spatial pattern of variables by giving clusters. There are four clusters of crime: H-H cluster, H-L cluster, L-H cluster, and L-L cluster. The following clusters explain how variables are related to each other. For example, the H-H cluster explains high NTL district is surrounded by high-value NTL neighbours.

$$\text{Bivariate LISA : } I_i = \frac{n \cdot [x_i - \bar{x}]}{\sum_i [y_i - \bar{y}]^2} \sum_j w_{ij} [y_j - \bar{y}] \quad (3)$$

Figure 2 shows the whole framework of the present study.

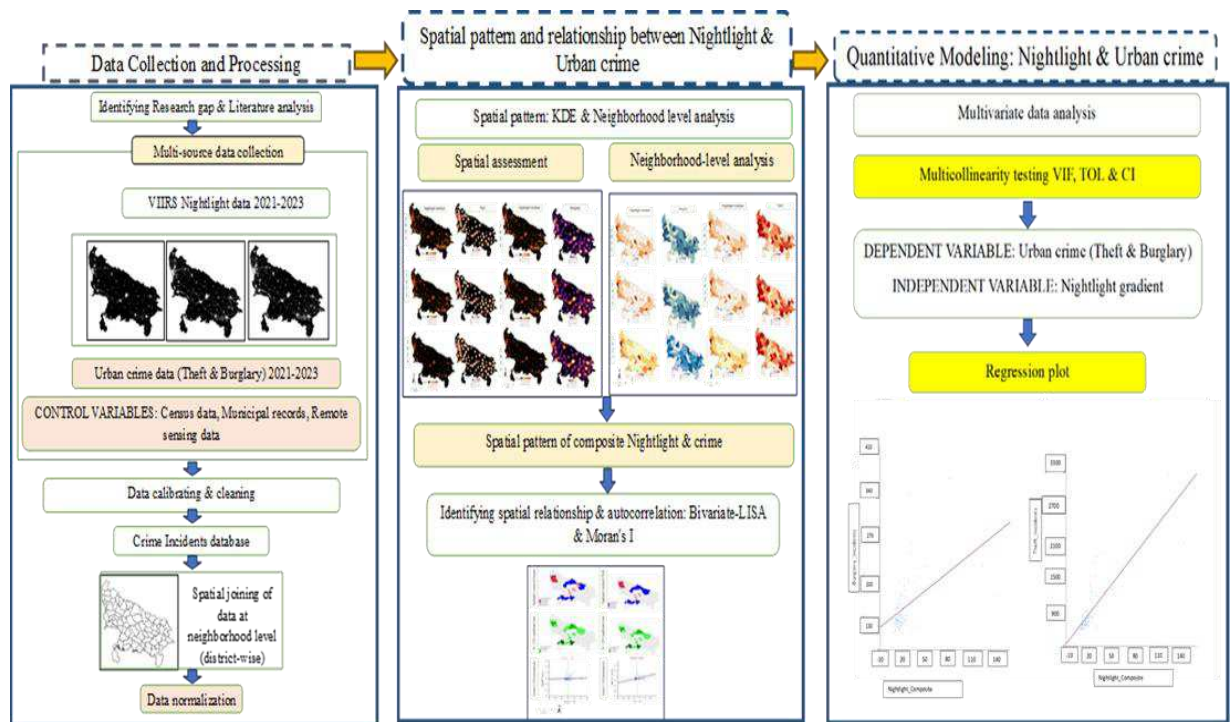


Fig 2. Analytical framework adopted for the present study.

Result

Spatial pattern of NTL and crime (theft, burglary)

The spatio-temporal pattern of theft and burglary crime from 2021 to 2023 with the NTL gradient is depicted in Figure 3. Of the state, the NTL gradient presented in Figure 3 clearly shows that north western region, central, and southeastern regions have a high level of light intensity compared to other peripheral areas. These regions are characterised by higher level of urbanisation and are the hub of economic activities. Cities like Noida, Ghaziabad, Shamli that fall in Delhi NCR has high level of NTL intensity. Other big cities like Lucknow, Kanpur, cities of south eastern region, such as Varanasi, and Prayagraj have more NTL than other areas. These regions are characterised by high population density, rapid population growth, bustling economic activities, and industries. The Bundelkhand region in the south and terai region of north have low NTL intensity and are characterised by a lower level of economic development.

The theft pattern over three years shows a clear, distinct trend (Figure 3a). In all the years, theft crimes have been mostly concentrated in the northwestern region of Uttar Pradesh in districts

like Meerut, Ghaziabad, Shamli, and others. Theft cases remain the same across all three years. However, slight changes might have been observed in burglary crimes. Like theft crimes, burglary is also concentrated in the northwestern districts of Uttar Pradesh. Except for Jhansi, Lalitpur, and Sonbhadra districts, most other districts have a high concentration of burglary crimes according to NCRB data. In 2021, burglary was highly concentrated in Agra, Lucknow, and Prayagraj. Although the pattern shifted in 2022 and 2023, with increased burglary incidents in Gorakhpur in 2022 and Azamgarh in 2023 (Figure3b). This indicates that burglary incidents were mainly concentrated in northwestern UP in 2021, but their presence has expanded eastward in 2022 and 2023. This might suggest an increase in urban infrastructure in these areas. Gorakhpur, Azamgarh, Mau and Varanasi are developed as a regional hub providing urban facilities to their surroundings. Hence, a developed core attracts crimes like burglary.

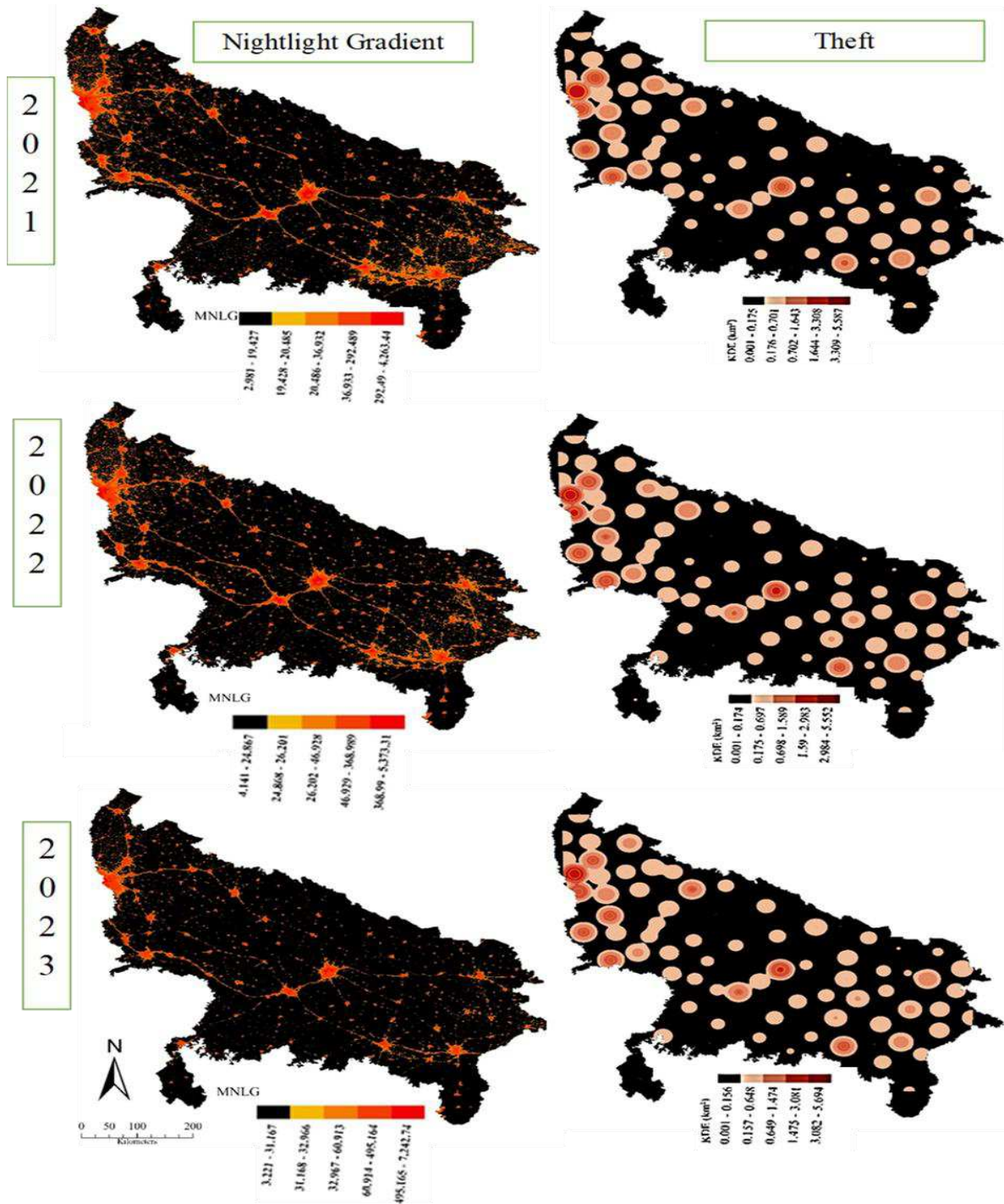


Fig. 1a spatio-temporal pattern of annual Nightlight gradient and Theft density (using KDE) from 2021 to 2023.

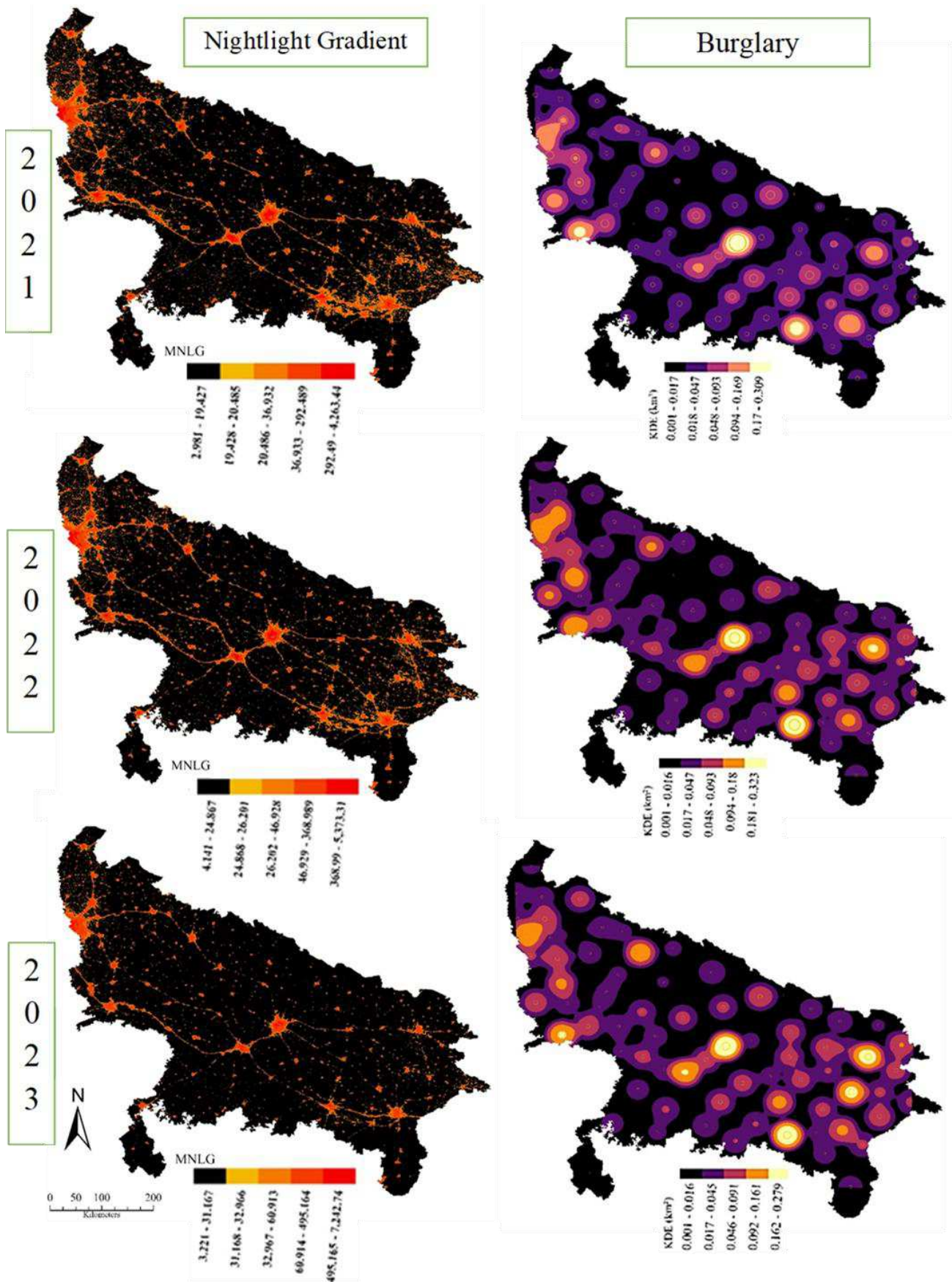


Fig. 2b spatio-temporal pattern of annual Nightlight gradient and Burglary density (using KDE) from 2021 to 2023.

Figure 4a & figure 4b are the district-wise distribution of NTL crime in Uttar Pradesh. The relationship between NTL intensity and crimes such as theft and burglary has been observed. In this figure, the NTL intensity is particularly high in districts such as Lucknow, Baghpat, Ghaziabad, and Varanasi. Other districts show low to moderate NTL intensity. Interestingly, both burglary and theft incidents are higher in northwestern districts like Ghaziabad and Baghpat, and in south-eastern districts like Varanasi and Prayagraj in all three years. This pattern indicates that NTL intensity is positively associated with theft and burglary. Area with high night light has higher crime incidents. In contrast to this, a different pattern is also observed. Areas with a moderate intensity of NTL also have high crime rates. This pattern clearly indicates that NTL has a strong relationship with crime.

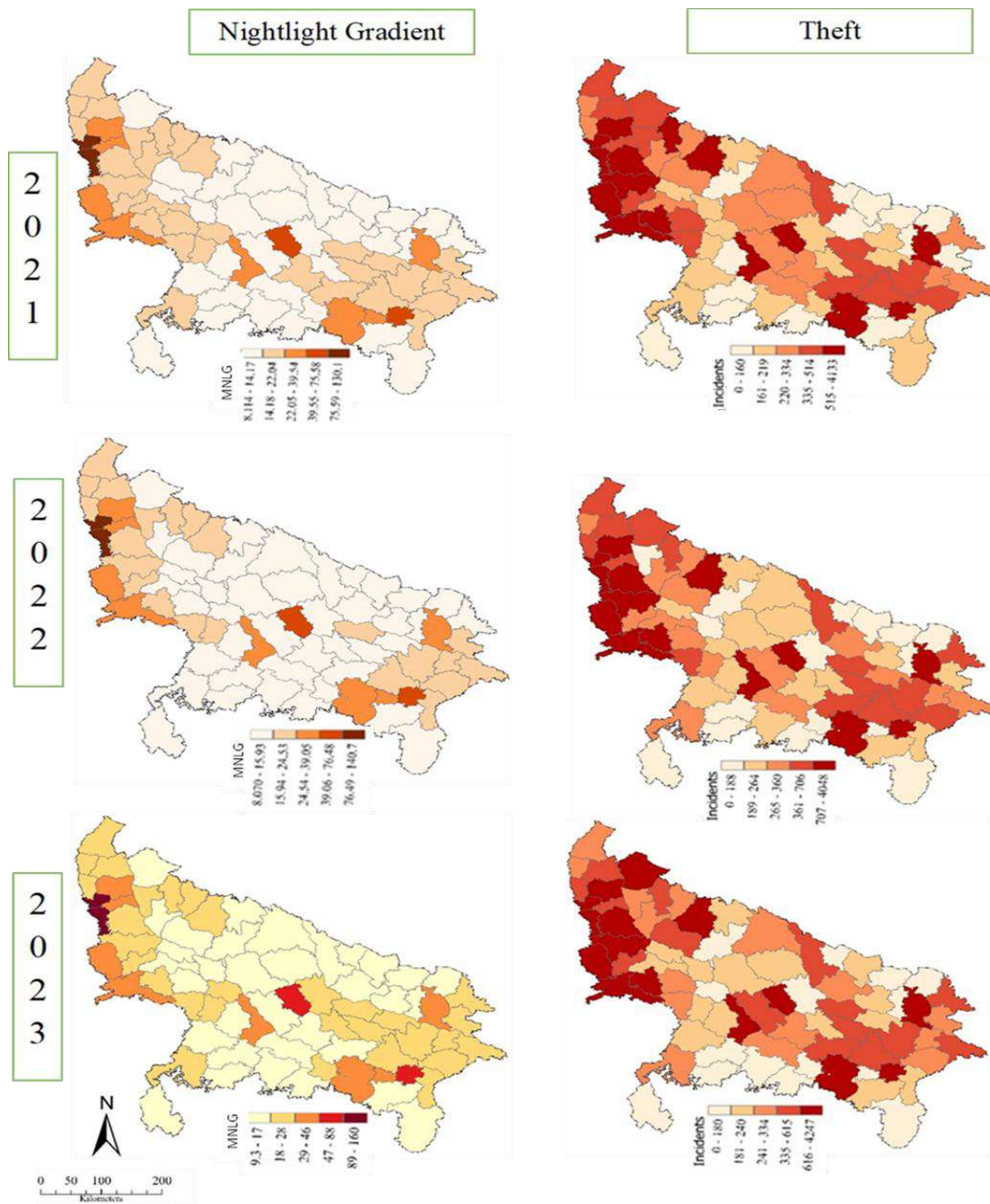


Fig. 3a Neighborhood level Spatio-temporal pattern of annual Nightlight gradient, Theft incidents for the period of 2021–2023.

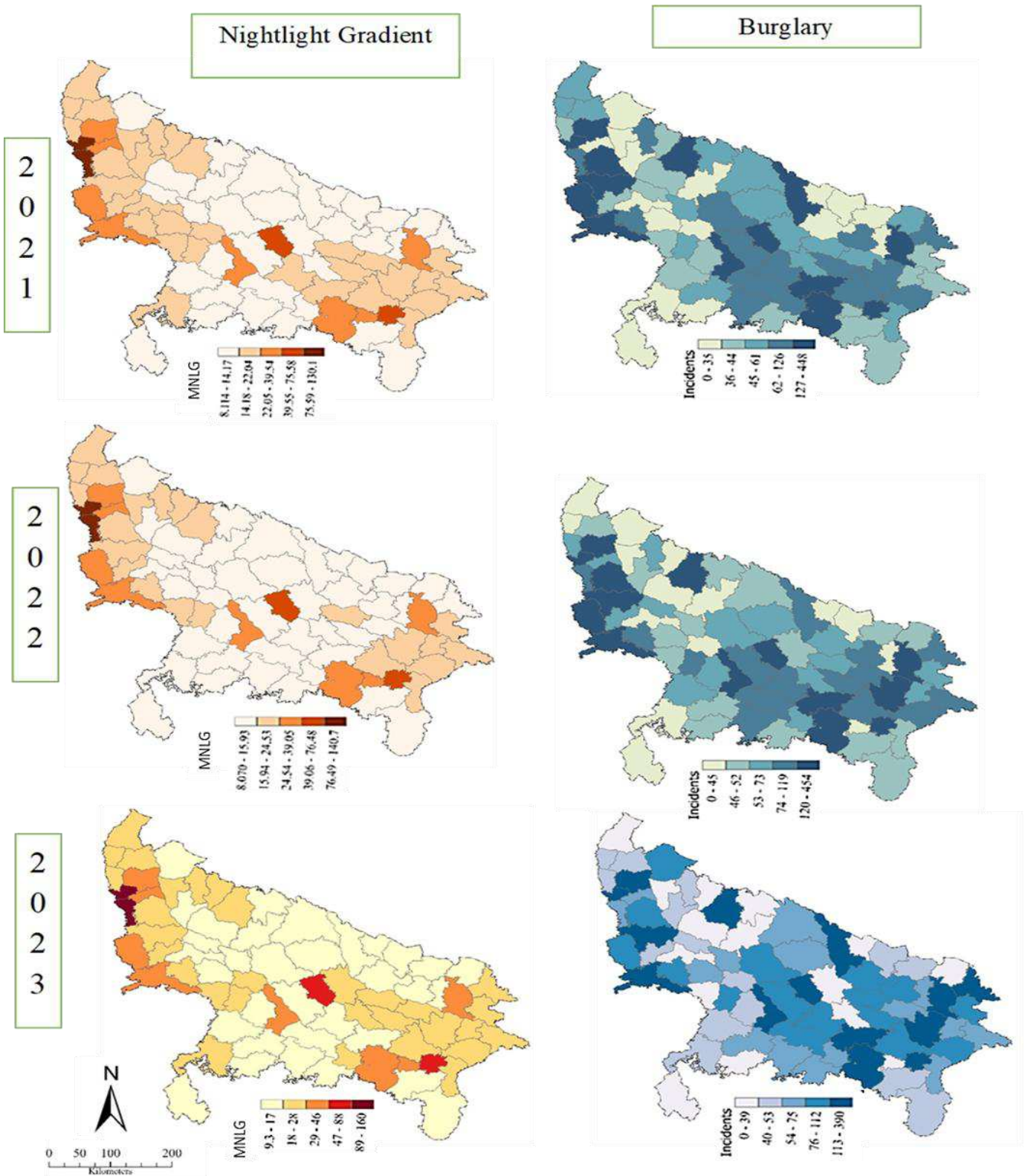


Fig. 4b Neighborhood level Spatio-temporal pattern of annual Nightlight gradient and Burglary incidents for the period of 2021–2023.

Figure 5 displays the overall crime incidents across all three years and the composite NTL gradient. Northwestern, eastern, and central regions exhibit high NTL intensity. These areas are densely populated and serve as major industrial and commercial hubs. Lucknow and Kanpur, situated in the central part, along with Lucknow as the capital of UP, also experience high development rates and are key centres for major commercial and industrial activities. The northwestern regions include districts like Ghaziabad, Baghpat, Meerut, Gautam Buddh Nagar, and Shamli. These districts are part of the Delhi NCR region, providing facilities to India's capital city. Other low NTL regions are southern plateau region, northern terai region, and some of the purvanchal region. These regions are characterised by low level of development. Mostly in districts with a rural nature, low NTL activity has been found.

The composite crime incidents of theft in all three years are higher in the districts of Ghaziabad, Meerut, Gautam Buddha Nagar, Shamli, Lucknow, and Prayagraj. The districts with low NTL are also susceptible to theft. This picture is quite surprising in the case of burglary. The burglary crime is high in the central districts, such as Raebareli, Pratapgarh, Ambedkar Nagar, and the eastern district, such as Gorakhpur, Azamgarh, and Varanasi. Interestingly, the terai districts of Bareilly and Bahraich also have moderate incidents of burglary. These results highlight the link between low NTL intensity and greater susceptibility to burglary in some parts of the state.

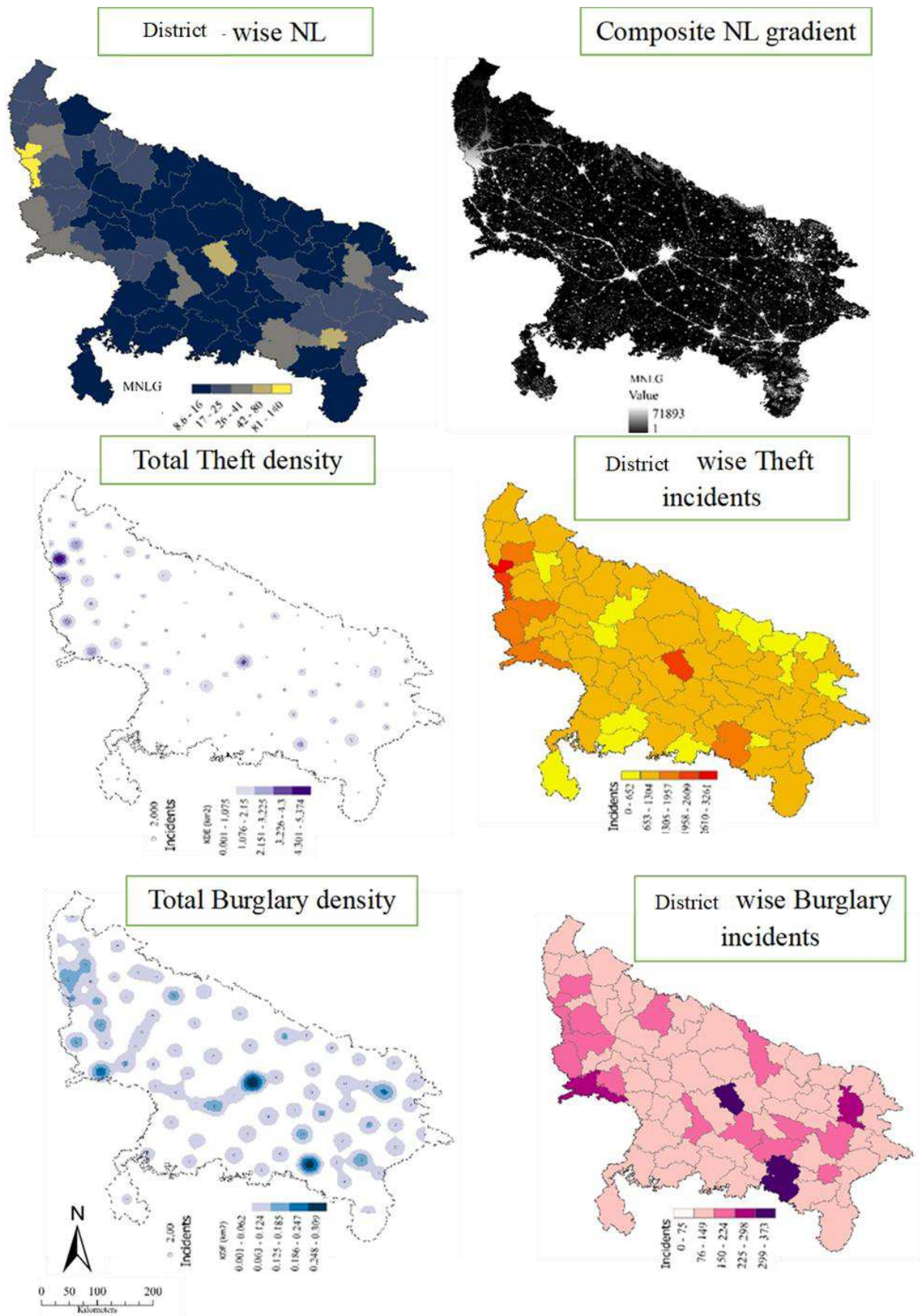


Fig. 5. Composite spatial pattern of Nightlight gradient, Theft and Burglary incidents for the period.

Identifying spatial relationships & autocorrelations

In Figure 6, the bivariate Local Indicator of Spatial Association (Bi-LISA) for NTL gradient and crime (theft and burglary) is depicted. The value of Moran's I shows weak positive spatial clustering. The value of Moran's I progressively declined over the years from 0.25 in 2021, 0.23 in 2022 and 2023. It defines that districts with high theft incidents tend to be near districts with high night light. The Bi-LISA map reveals that the high urbanized districts located in western UP are formed hotspots of theft crime, while low urbanised districts of southern and eastern UP are formed coldspots of theft crime. This map explains that other socio-economic factors are also involved in shaping crime patterns in UP beyond urbanization alone.

The value of Moran's I also shows weak positive spatial dependence in burglary. The value of Moran's I progressively declined over the years from 0.44 in 2021 to 0.18 in 2023. This pattern shows that the spatial clustering of burglary crime declined over the three years. It also shows that there are stable high-crime clusters in urbanised western districts and low-crime clusters that stay the same in less illuminated rural areas. The Bi-LISA suggests the relation between burglary and neighbouring NTL intensity. Bi-LISA analysis shows weak but spatially identifiable links between the amount of light at night and burglary crime in Uttar Pradesh. The high-high cluster indicated high burglary with high NTL intensity in neighbouring districts. H-H spatial clustering is found in the northwestern parts of UP. The L-L cluster suggested low burglary with low neighbouring light at night. This clustering pattern is observed in the southwestern and north-central region. This pattern highlights that low-urbanised, less economically active areas have fewer opportunities to commit crime.

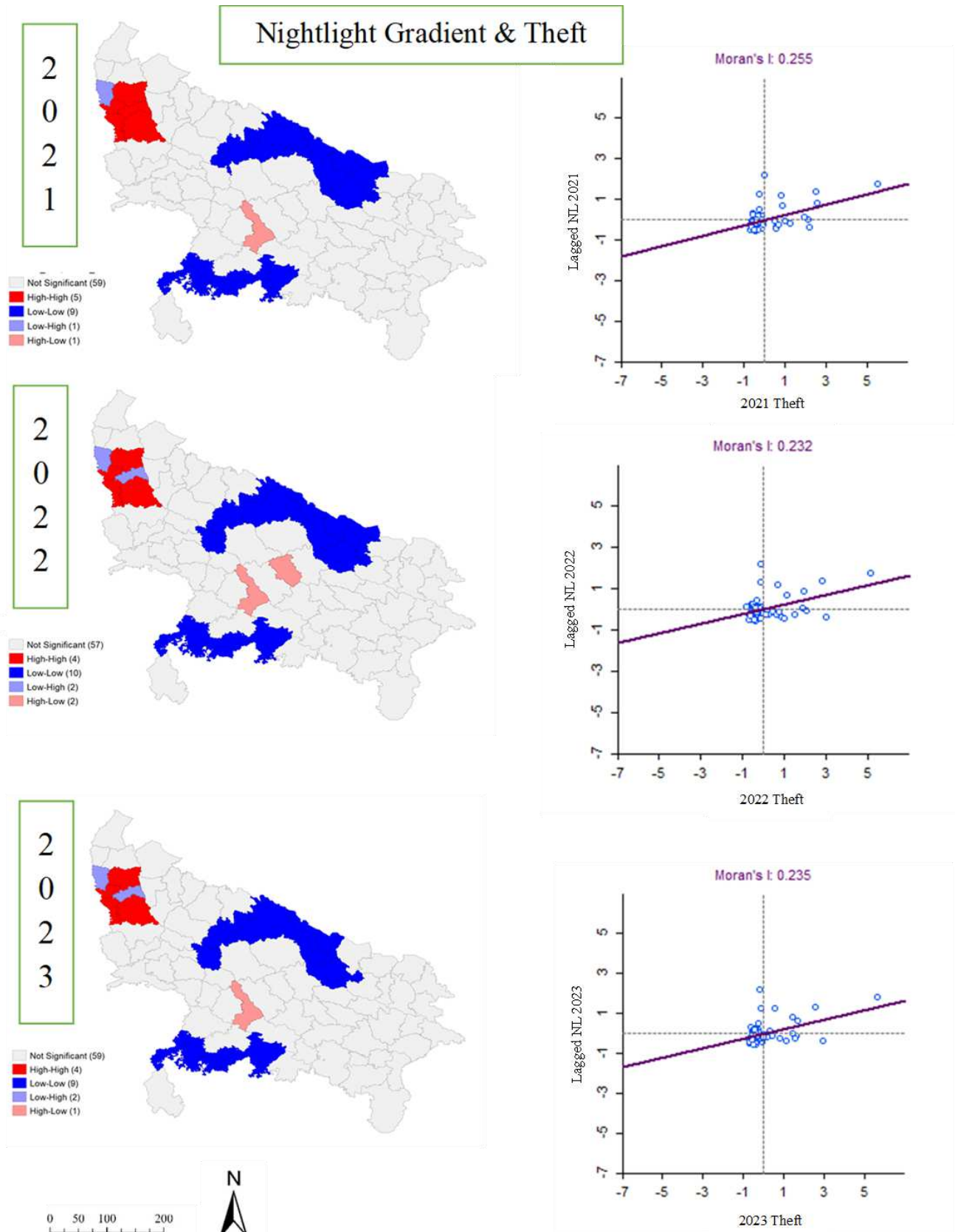


Fig. 6a Spatio-temporal Bivariate-LISA (Local Indicators of Spatial Association) and Bivariate-Moran's I showing the spatial relation between NTL and theft crime

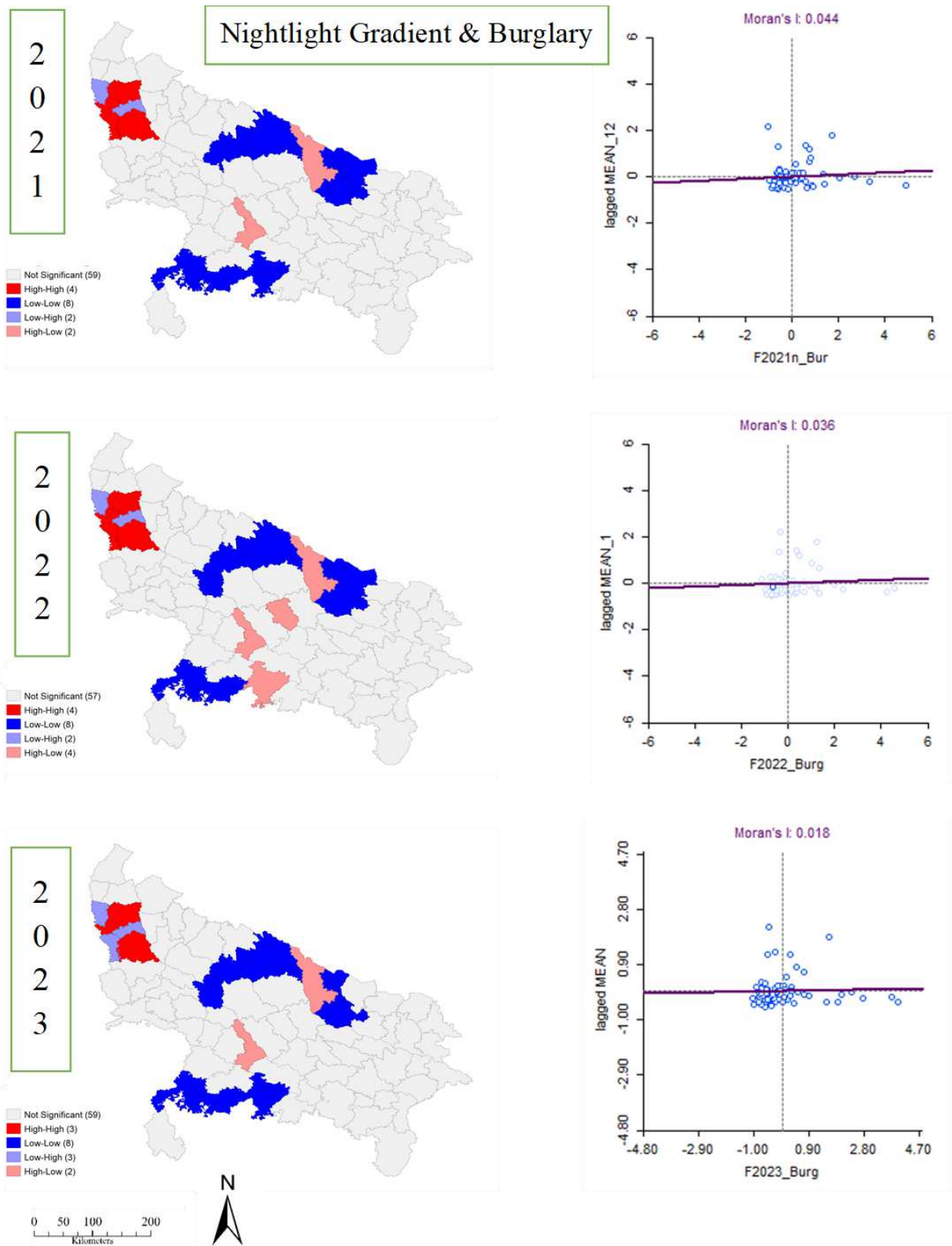


Fig. 6b Spatio-temporal Bivariate-LISA (Local Indicators of Spatial Association) and Bivariate-Moran's I showing the spatial relation between NTL and burglary crime

Figure 7 shows the composite bivariate LISA map and bivariate Moran's I. It reveals a weak positive spatial connection between NTL and theft and burglary. The value of Moran's I for each property crime is 0.24 for theft and 0.00 for burglary. The bivariate LISA map indicates that the western UP districts, such as Ghaziabad, Meerut, Shamli, and Gautam Budhh Nagar, form HH clusters. This suggests that districts with high NTL also experience high rates of theft and burglary. Most southwestern districts, like Jhansi, Mahoba, and Banda, as well as northern districts like Shahjahanpur, Lakhimpur, Shravasti, and Pilibhit, form LL clusters, indicating these districts have low NTL and low crime levels. Kanpur Nagar and Lucknow are two districts that form H-L clusters, meaning high-crime districts are surrounded by districts with low illumination. This pattern is likely because Lucknow and Kanpur are economic and political hubs, providing facilities to nearby less developed districts. More than 50 districts show no significant pattern, suggesting property crime is influenced by factors beyond NTL. Other factors may include urban morphology, transportation networks, population mobility, and socio-economic conditions.

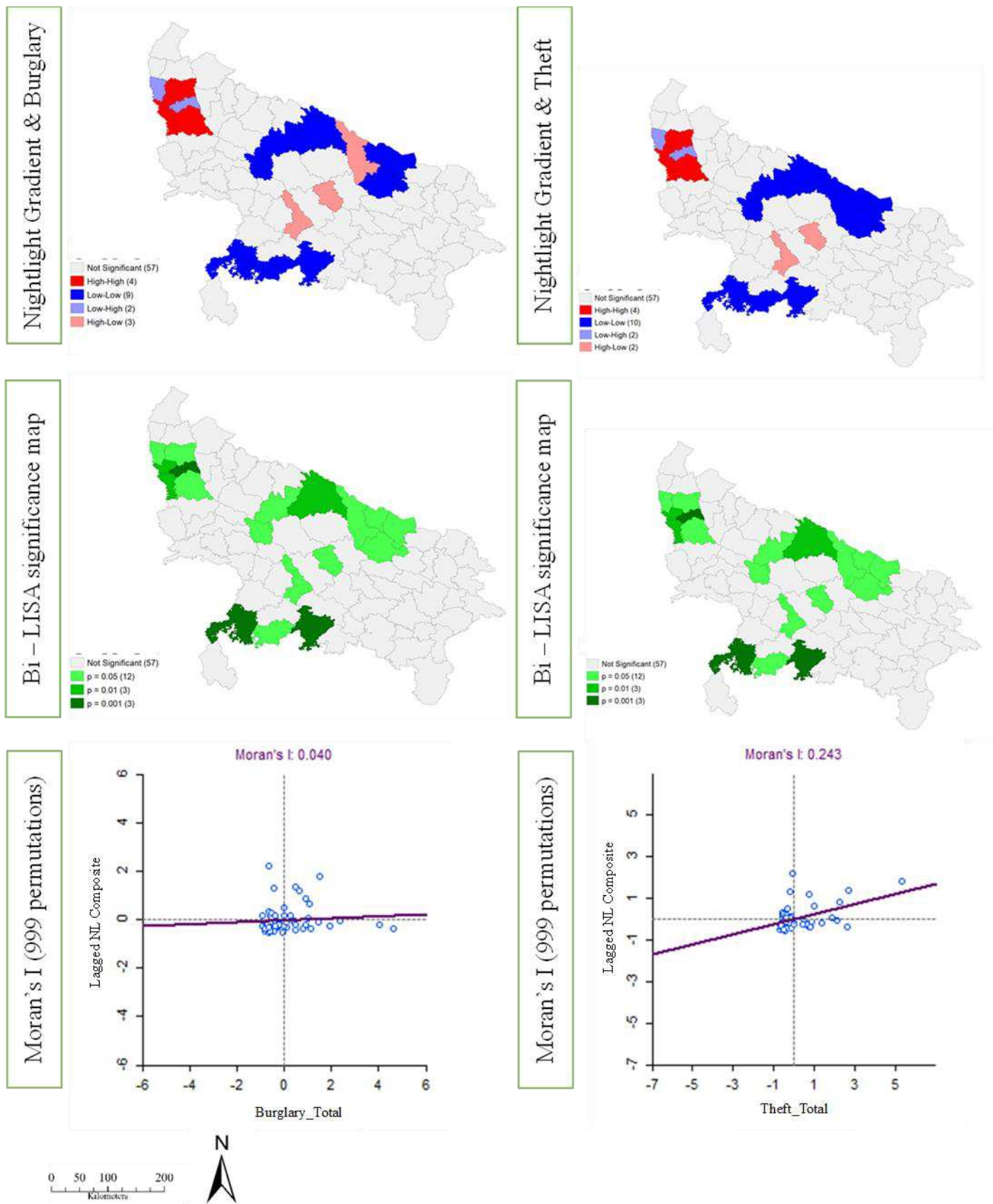


Fig 7. Bivariate-LISA and Bivariate-Moran's I at a 999-permutation level showing the composite spatial relation between Nightlight (NTL) and crime.

In Figure 8, a simple regression analysis has been performed to find out relation between NTL and property crimes (theft and burglary). This plot illustrates a strong negative correlation between NTL intensity and property crimes, specifically theft and burglary. Both graphs show a decreasing trend between crime and NTL. Crime incidence is high in the low-illuminating areas, and decreasing in the areas where NTL intensity is high. This indicates that brighter areas have lower crime rates. This negative association between NTL and both crimes indicates that lighting plays an important role in shaping the crime dynamics of a region.

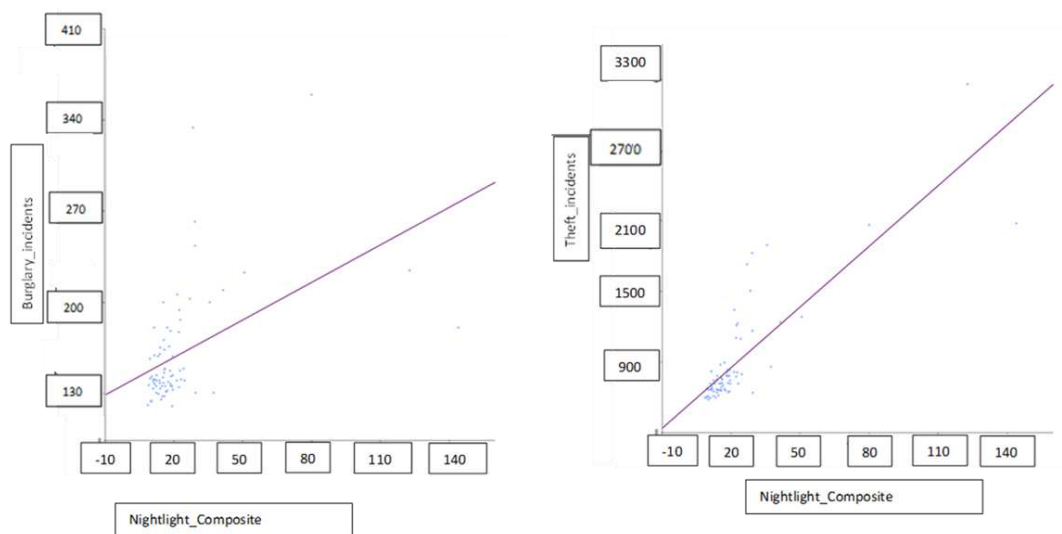


Fig. 8. Regression plot showing association between Composite NTL gradient and Crime (Theft and Burglary).

Discussion

This study explores the spatial relationship between NTL intensity and property crimes in the districts of Uttar Pradesh. Our study finds a negative relationship between nighttime light intensity and crime. This finding is also aligned with other research findings (Chalfin et al., [2022](#); Roy & Chowdhury, [2025](#); Zahed, [n.d.](#)). Some spatial analyses highlight a higher incidence of crime in highly illuminated areas (Peng et al., [2022](#)). These results show that nighttime lighting alone can't fully explain the occurrence of crime. Instead, crime dynamics are shaped by a number of social, economic, environmental, and other factors that work together (Leong and Sung, 2015; Xu et al., 2018). According to crime pattern theory, criminal prefers to commit crimes in familiar environments with ample opportunities (Brantingham and Brantingham, [2013](#)). As a result, the geographical locations, such as the transitional area between rural and urban counterparts, low-lighting areas, provide a perfect location to commit crimes.

The spatial analyses of KDE and Bi-LISA reveal a weak positive association between NTL and property crimes, indicating that highly urbanised and densely populated districts of western UP, including Ghaziabad, Shamli, Gautam Budhh Nagar, Meerut, and Agra, experience higher crime incidents. These results align with earlier studies indicating that regions characterised by elevated economic activity and population density, frequently represented by increased NTL intensity, may encounter higher crime rates due to enhanced opportunities and targets (Peng et al., [2022](#)). This reflects the principles of Routine Activity Theory, where crime occurs when motivated criminals get potential targets in space and time in the absence of capable guardians (Cohen, [1979](#); Kadam et al., [2025](#)).

The presence of both negative and positive relationships indicates that NTL serves as a proxy for more than one underlying process. On the one hand, more light may make things safer by making it easier to watch over things. On the other hand, it also means that cities are growing, businesses are relocating, and people are moving around, which can make it easier for criminals to evade detection. NTL's two roles help explain the difference between regression results and spatial clustering patterns.

This research further highlighted the significant regional disparities within Uttar Pradesh. While the western region consistently emerged as a crime hotspot, the terai and Bundelkhand region have some comparatively lower crime rate suggest that crime patterns are not only influenced by lighting facilities but also by trajectories of regional development, better transport networks, migration inflows, and urban development. The influence of the capital

city, Delhi, can also not be neglected. Ghaziabad, Noida, Baghpat, and Meerut have high impact on Delhi's crime.

Overall, the findings indicate that NTL is a useful indicator of crime. Relying only on improving lighting conditions can't address crime. The findings of this research indicate that policy implications should not rely on NTL, but also address other socio-economic factors that affect crime. However, this research also has limitations. Socio-demographic analyses, such as literacy, migration, and employment rate, have not been analysed. Future research should integrate demographic and economic factors with crime to develop more realistic conclusion of this research.

Policy Recommendations

The findings of this paper reveal a strong policy implication needed for the districts of Uttar Pradesh. The districts that are characterised by low nighttime light intensity and high crime rate should prioritize to improve street light facilities, implementing CCTV surveillance in peripheral zones, villages, and commuter zones of cities. Districts with high nighttime light intensity and higher crime rates should prioritise improving the surveillance system at night. One of the UP-government's initiatives, UP 112, is working well in urban surveillance. The CCTNS system is also practical in reporting crime digitally. The government should focus on implementing more initiatives like this. The regions with H-H clustering need more attention in crime risk reduction. In big cities, the night lightning not only effective in crime reduction. Focus should shift towards addressing socio-economic challenges and other factors. Overall, an integrated approach should contribute to safer and sustainable urban and rural communities across the districts of Uttar Pradesh.

Conclusion

The study has been designed to examine the effect of artificial lights at night on property crime patterns in the districts of Uttar Pradesh, utilising remote sensing data and spatial analysis techniques. The findings indicate a great difference among the regions of Uttar Pradesh. While western region has high NTL, the gradient decreases towards eastern and southern regions. The districts, such as Ghaziabad, Gautam Budhh Nagar, Meerut, and Aligarh, are highly developed compared to their surroundings. Although Varanasi, Gorakhpur, Azamgarh, and Prayagraj have some levels of development, their surrounding districts have a great level of socio-economic disparity. The regression findings indicate a negative association between NTL and property

crimes. In contrast to this, the spatial analysis indicates a weak positive association between NTL and property crimes in the districts of Western UP. This dual role of NTL may be because of variations in regions. Association of NTL with crime is negatively affected at local level because of a low level of development, and the crime hotspots are also very low. In contrast to this, NTL is positively associated with crime in city centres because of a high level of development; crime hotspots are also high. The presence of both criminal activity in high-illuminated areas and criminal activity in low-illuminated areas indicates that studying nighttime light alone can't fully explain the crime patterns of a region. Other factors may include the degree of urbanization, level of economic development, mobility of population, and how well transport networks are developed. Although correlation of these factors with crime has not been shown in this paper. The focus of this paper is to explore the NTL data and evaluate its relation with crime. Future research may include more variables, such as demographic factors, policing strategies, and economic inequality, to make crime prediction and prevention models.

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