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REVIEW

Bibliometric analysis of evolution of night-time light data in urban planning studies

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Abstract
The capability of nighttime light (NTL) data to intuitively detect human activities has made it a crucial tool for urban remote-sensing studies over the past 15 years. There is an urgent need for a thorough assessment of this topic because new data and technology are continually being developed, resulting in an accumulation of research. This study examines the evolution of nighttime light research using a bibliometric analysis. Data were retrieved from Scopus, covering publications from 2015 to 2025. A topic-based search approach was employed to ensure comprehensive coverage of the literature. A total of 962 publications were identified, primarily comprising journal articles and conference papers. The number of publications has shown a steady increase since 2015, with a sharp rise from 2022 onwards, reaching a peak of 165 publications in 2024. The growth trend exhibits a strong positive correlation ($R^2 = 0.9283$), indicating an accelerating trend in research activity. This bibliometric study reveals a steady rise in nighttime light research for urban studies, with a significant surge in 2022. China leads in publication output and international collaborations. This study utilizes VOSviewer to analyze nighttime light research trends, identifying key terms and their evolution over time. Early studies focused on remote sensing fundamentals, while recent research emphasizes urban sustainability and climate impact. Advances in satellite technology, including VIIRS, Luojia 1, UAVs, and SDGSAT-1, have enhanced data quality and expanded the application scope. The shift toward high-resolution, multispectral nighttime light sensors enhances urban and environmental research. By providing a structured overview of research developments, this study serves as a valuable reference for future investigations and the effective management of urban nighttime environments.

Keywords Nighttime light data · Remote sensing · Urban growth · Bibliometric and urban planning

1 Introduction

Bibliographic analysis is a crucial method for assessing evolution, impact, and trends within a particular field of research [1]. This study will provide significant insight into the evolution of research by examining research publications, citations, and institutional contributions. This analysis provides valuable insights into the development of knowledge, key research themes, and influential authors or institutions. This valuable insight can help identify the evolution of nighttime light data in urban planning studies. According to the previous study by the UN Department of Economic and Social Affairs, 56% of the world's population lived in cities in 2020, with a forecast indicating that this percentage will rise to 68% by 2050. Rapid urbanization frequently results in the phenomenon of uncontrolled urban sprawl, which has already affected many large cities and megacities worldwide [2]. This rapid urbanization can cause numerous challenges, such as light pollution [3], inadequate infrastructure [4], environmental degradation [5] and temperature rise [6].

Urbanization can be analyzed through various methods and data sources. Remote sensing and Geographic Information System (GIS) analysis have been widely used to investigate the spatiotemporal dynamics of urban expansion [7]. For the past few years, nighttime light data have been used to analyze urban expansion. Nighttime light images accurately depict lighted areas by strong contrast between light and dark pixels, making it a simple and effective method

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for mapping urban growth [8]. Satellite observations of artificial nighttime light play a unique role in identifying metropolitan locations and activities, unlike other remotely sensed products. Nighttime light images can reveal dynamic patterns of human settlements and economic activities from various perspectives [9].

Urban planning encompasses a broad scope of interdisciplinary research and practice addressing the challenges of urbanization in capitalist societies [10, 11]. The field integrates various disciplines, including urban anthropology, economics, geography, history, politics, and sociology, as well as professional fields such as architecture, engineering, and economic development [12]. Technology integration in urban studies also has significantly transformed in which has supported sustainable urban planning and development by offering previously unheard-of options to investigate human activity and urban dynamics [13]. Sensors, satellite imaging, social media analytics, mobile phone data, and Internet of Things (IoT) devices are now used to collect real-time data about urban systems [14]. Urban researchers now model, simulate, and forecast urban changes with previously unheard-of accuracy because to technological breakthroughs, which offer important insights for sustainable urban planning and development [15]. The integration of urban studies and technology studies presents an effective strategy to understanding and molding the future of cities.

Nighttime light remote sensing advances our understanding of the impact of human activity on the Earth's surface environment, which is becoming increasingly endangered. Satellite-based nighttime lights make significant contributions to understanding the changing world from two perspectives: human activities and environmental changes. Since the late 1990 s, various satellite-based nighttime light remote sensing applications have emerged as a result of nighttime light sensors and data products that are constantly updated and enhanced. These applications contribute significantly to our understanding of urbanization and socioeconomic dynamics, armed conflicts and disasters, fishing activities, greenhouse gas emissions and energy consumption, and light pollution and health consequences [9]. Nighttime light studies have emerged as valuable tools for understanding the influence of urban development on the distribution patterns of urban density. Analyzing nighttime lights provides insights into the spatial arrangement of human settlements and the concentration of activities within urban areas. The intensity and distribution of nighttime lights can be indicative of variations in urban density, serving as a proxy for population density and economic activities [16].

Nighttime light remote sensing provides valuable insights into urban studies and its environmental impacts, but current technologies have limitations. While DMSP-OLS (1 km~) and VIIRS (500 m) sensors improved capabilities, they still have limitations for detailed urban analysis [17, 18]. However, a major breakthrough came with the new satellite with Luojia 1–01, Jilin 1, Eros B and SDGSAT-1, offering high-resolution nocturnal images, enabling more detailed analysis of urban areas [17, 19–21]. With the rapid improvement of nighttime light technologies, satellites will continue to play a crucial role in understanding comprehensive changes on the face of Earth and human activity in the 21 st century.

Recent advancements in nighttime light sensors, algorithms, and products have created new opportunities for understanding contemporary urbanization and associated changes [22]. Research on integrating nighttime light with other multi-source data, such as Machine Learning and Artificial Intelligence, has made it easier to complete timely tasks like evaluating the damage caused by urban disasters and monitoring environmental conditions. The potential uses of nighttime light data have recently expanded due to the merging of machine learning techniques with large-scale urban data, creating a variety of creative study areas [23]. Therefore, these findings are crucial for researchers as they highlight the growing significance of nighttime light data in analyzing urbanization patterns, offering a reliable proxy for human activity and urban density. The integration of advanced sensors and machine learning techniques further enhances the precision and applicability of this data, opening new avenues for interdisciplinary urban research and planning.

2 Data and methods

The data used for this study were retrieved from Scopus on 9 March 2025. Scopus was chosen as a search tool because Scopus is able to assist in locating a significant number of outstanding citations with more inclusive and wider content coverage [24]. This study first filtered the relevant literature using a topic-based search approach. Understanding that a phrase can have multiple synonyms, this study included as many alternatives as feasible to reduce the amount of pertinent literature that was left out. The finalized search formula was *TITLE-ABS-KEY (((ntl OR "nighttime light" OR "nighttime lights" OR "night time light" OR "nightlight" OR "night light" OR "night lights" OR viirs OR dmsp OR jilin-01 OR "Luojia 1–01" OR sdgsat-1) AND (city OR urban OR urbanisation OR urbanization OR "build-up" OR "build up") AND ("remote sensing")))*. Quotation marks were included in the search term to ensure the reliability of the search results [25]. The timeline was set from 2015 to 2025 to capture the rapid developments of nighttime light technologies and allow for a comprehensive analysis of trends, developments, and key findings within the selected field of study. Research before 2015 heavily

relied on the discontinued DMSP-OLS data, in which the imagery is over-saturated and a lack of calibration, making it less suitable for accurate urban-scale analysis. The search ensures that both foundational research and the most recent advancements are considered, providing a balanced perspective on the topic.

A total of 962 publications related to the evolution of nighttime light data in urban studies were identified, spanning contributions from 264 different journals. These publications encompassed various types, with the majority being journal articles ($n=779$) and conference papers ($n=147$). Other types of publications, such as book chapters and reviews, were also present, but each accounted for fewer than 10 documents.

2.1 Review process

Each publication indexed in the Scopus database includes a comprehensive set of bibliographic information, such as the year of publication, authors' names and institutional affiliations, article titles, abstracts, source journals, subject categories, and reference lists. For this study, bibliographic data from a total of 962 publications related to the evolution and application of nighttime light data in urban studies were extracted from Scopus and exported into Microsoft Excel for initial organization and processing.

The analysis explored multiple dimensions of the publication landscape using a combination of Microsoft Excel and RStudio. Specifically, the study examined trends in publication output and growth over time, patterns of collaboration among authors, the distribution of research across journals, the geographical and institutional origins of the publications, citation performance, and the frequency and co-occurrence of key terms. These aspects provided insight into how the field has evolved, which institutions and countries are most active, and what thematic areas have gained prominence over the years.

To enhance the analysis and visualization of bibliometric relationships, VOSviewer a widely used, open-source bibliometric mapping tool was employed. This software enabled the creation of detailed two-dimensional maps to illustrate the relationships among authors, institutions, countries, citations, and frequently used terms. The VOS mapping technique positioned entities on a map in such a way that the distance between them represented their degree of similarity or relatedness, such as shared citations or co-authorship. In addition, the VOS clustering method was used to categorize related items into thematic clusters, each assigned a distinct color to visually differentiate research areas and collaborative groups. This allowed for a clearer interpretation of research trends and knowledge structures within the field.

Furthermore, Bibliometrix, an open-source R package designed for comprehensive bibliometric analysis, was also utilized to complement the findings generated by VOSviewer. Developed by Derviş in 2020, Bibliometrix offers an extensive suite of functions for analyzing scientific literature and is fully integrated within the R environment. Its flexibility and compatibility with RStudio allow for customizable and reproducible analysis workflows [26]. With access to over 16,000 packages in the R ecosystem, Bibliometrix enables advanced exploration of bibliometric indicators, including publication productivity, collaboration networks, citation impact, thematic mapping, and trend analysis. The combined use of VOSviewer and Bibliometrix provided a robust analytical foundation for the study, facilitating both quantitative and visual insights that are discussed in detail in the subsequent results section.

2.2 Basic statistics and criteria for classification

This bibliometric study spans a period of 11 years, from 2015 to 2025, and provides a comprehensive overview of scholarly activity within the selected domain. A total of 962 documents were identified during this time, sourced from 264 different publications, including journals, books, and other academic outlets. The annual growth rate of publications is recorded at −1.53%, indicating a slight decline in the number of documents published per year over the period studied. Despite this negative growth trend, the average age of documents stands at approximately 3.95 years, suggesting a relatively recent and actively evolving body of literature.

Each document, on average, has received 18.07 citations, reflecting a moderate level of academic influence and engagement with the published works. In total, these documents collectively cite 39,273 references, highlighting the extensive research and foundational literature that underpins the studies. The rich citation base also supports in-depth knowledge accumulation and scholarly connectivity across the field.

Authorship data reveals significant collaborative activity. A total of 3,346 individual authors contributed to the publication corpus, with only 21 of them responsible for single-authored works. The total number of single-authored documents stands at 35, underscoring a strong tendency toward collaborative research in the field. On average, each document has 4.8 co-authors, reflecting interdisciplinary efforts and possibly the growing complexity of research projects that require input from multiple experts. International collaboration also plays a notable role, with 22.97% of the publications involving co-authors from different countries. This international co-authorship percentage indicates a robust global network of scholars contributing to the

field, facilitating knowledge exchange across borders and enhancing the overall impact and visibility of the research.

Together, these statistics provide a foundational overview of the research landscape, helping to classify the trends, productivity, and collaborative behavior of the academic community within the selected timeframe. The combination of quantitative measures with qualitative indicators forms the basis for further classification and thematic analysis in subsequent sections.

3 Results and discussion

3.1 Publication and citation output, and growth trend

The quantity of peer-reviewed publications is a critical metric for assessing the trajectory of a scientific research discipline or topic. As shown in Fig. 1, the number of evaluations of nighttime light data in urban planning studies has increased steadily since 2015. There were limited publications on the evaluation, with only 28 publications in 2015. Publications of the research remain low, with fewer than 100 publications per year up until 2021. However, from 2022, there was a sharp increase in publications, with a 52% increase in the publications ($n=149$). Many research and data acquisition have slowed during the COVID-19 pandemic (2020–2021), which contributed to a rise in 2022, where delayed projects were completed and published [27]. From 2022, a steady increase in publications could be observed every year, with the peak of publications reaching 165 publications in 2024. The publications indicate a strong positive trend with the

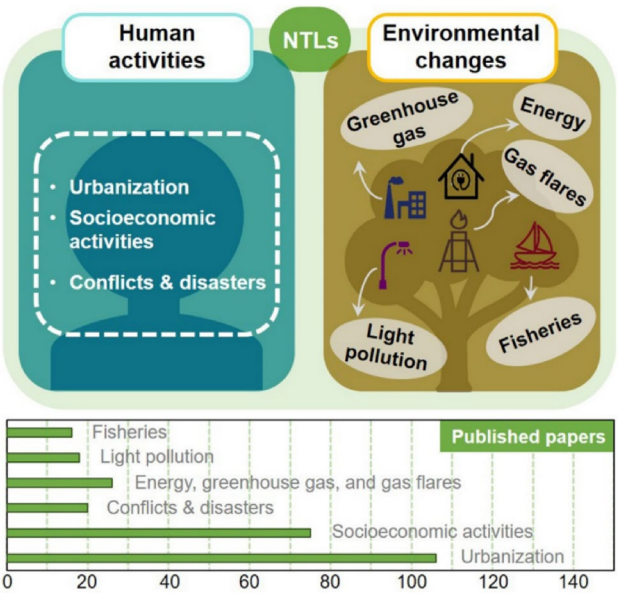

Fig. 1 Application of Nighttime Light Data and a Published Paper [9]

R^2 value of 0.9283, suggesting that the research output in the evaluation is an accelerating

The trend in the citations shows a consistent increase, yet shows an overall declining pattern in recent years, from 2021 to 2024. Total citation shows a relatively stable increase from 2015 to 2021, ranging from 2,500 to 3,500 citations per year. However, there was a constant decrease that can be observed throughout the year from 2022 to 2024. The decreased pattern in R^2 value (0.1338), which signals a dilution of impact. This can also be seen through the correlation between "Mean Citation per Year" and "Citeable Years", where "Citeable Years" decrease, "Mean Total Citation per Year" tends to decrease as well. It implies that because there is more competition for attention and citations within the academic community as the number of publications increases, the average citation impact per publication may decline [28]. This matter has been examined within the framework of multiple disciplines. Across fields, scholars have investigated elements that lead to citation dilution, including modifications in publishing procedures, citation patterns, and the general expansion of academic literature [29].

This citation pattern can be explained by the sudden surge in publications in 2022. The citations consistently favor papers published earlier in the year over those published later due to a bias in their influence, particularly evident in the citations received within the first three years after the publication [29]. This bias is more noticeable with author self-citations than with citations from other authors. Therefore, newer publications may experience fewer citations due to increased competition and citations and dilution, which leads to a temporary drop in citation counts, not due to lesser quality, but rather due to a combination of reduced exposure time and citation dilution caused by the high volume of concurrent publications [30]. This leads to a temporary decline in citation counts for newer entries into the literature.

3.2 Authors and their publication

A total of 3,346 authors contributed to the 962 publications. Only one article on the subject of the evolution of nighttime light in urban studies is attributed to the majority of the writers (80.7%; $n=2{,}700/3{,}346$). At least three publications credit 3.8% ($n=127/3{,}346$), while ten or more publications credit 0.2% ($n=9/3{,}346$). In this research also, only 21 authors out of 3,346 authors have single-authored the publications. Only a small number of productive authors contribute to a considerable percentage of publications on a particular issue, which is in line with findings in another research [31].

Table 2 shows the top 3 most productive authors publishing on the topic of the evolution of nighttime light in urban studies. The ranking is based on the author's total number of publications. Shi Kaifang was identified being the most productive author on the topic of the research, with 34 publications. His research on the evolution of nighttime light in urban studies focuses on carbon emissions and earthquakes. His research contributes to a significant understanding of how nighttime light data impacts urban studies and how it can be utilized to monitor carbon footprint and assess disaster management, especially in reconstruction post-earthquakes.

Followed by Li Xi with 29 publications, his research predominantly covered economic development trends based on nighttime light data. He also utilizes nighttime light data to identify its dynamics during the Covid-19 epidemic. Lastly, Chen Zuoqi has also contributed significant publication, with 21 publications. He also focuses on economic development based on nighttime light data as Li Xi.

The authors' cooperation pattern (i.e., co-authorship) in their urban research in nighttime light publications was examined using a VOSviewer. The network's writers authored at least two publications on the topic. Authors without any relationships with other authors are not included in the network. The results of this author's collaborative network are shown in Fig. 2. The circles' sizes indicate the number of publications, and the line joining two authors indicates their collaboration. The hues stand for the relationship clusters. The cooperation network can be divided into nine major author groupings. The network's lead investigators are Li Xi, Chen Zuoqi, and Shi Kaifang. One of these principal authors has relationships with other authors.

One should be aware of any potential prejudice in the authorship. It was impossible to tell two authors with the same name apart. Additionally, authors who used different names in their publications—for example, because of changes in their marital status—could not be combined. This issue might be resolved by requiring the assignment of a distinct digital identity number (like ORCID) at the time of publishing a researcher's first work, as suggested by others (e.g. van Nunen et al., 2018).

3.3 Journal publication

There was a total of 962 publications regarding the evolution of nighttime light data in urban studies produced by 264 different journals. Out of the 264 journals, 157 (59.5%) journals had published only one publication, and the other 107 journals published two publications or more on the topic. Figure 3 shows the top 5 most active publications on the evolution of nighttime light data in urban studies research. These 5 journals have published more than one-fifth of all the study publications, with this journal publishing 28.2% of this research.

Among these sources, Remote Sensing exhibits the highest number of publications, showing a steep increase after

Table 2 Top 3 productive authors publishing on the evolution of nighttime light in urban studies. (Source: authors, 2025)

Authors	Publication	Journals	Number of Papers	Subtopic
Shi Kaifang	34	IEEE Geoscience and Remote Sensing Letters	8	• Remote Sensing • Carbon Emissions • Earthquake
		IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing	5	
		GIScience and Remote Sensing	3	
		International Journal of Digital Earth	3	
		Building and Environment	2	
Li Xi	29	Wuhan Daxue Xuebao (Xinxi Kexue Ban)/Geomatics and Information Science of Wuhan University	4	• Remote Sensing • Economic Development • Covid-19
		IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing	3	
		Remote Sensing	3	
		Remote Sensing of Environment	3	
		Cehui Xuebao/Acta Geodaetica Et Cartographica Sinica	2	
Chen Zuoqi	21	IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing	4	• Remote Sensing • Economic Development
		National Remote Sensing Bulletin	3	
		Remote Sensing	3	
		International Journal of Geographical Information Science	2	
		Applied Energy	1	
		IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing	4	

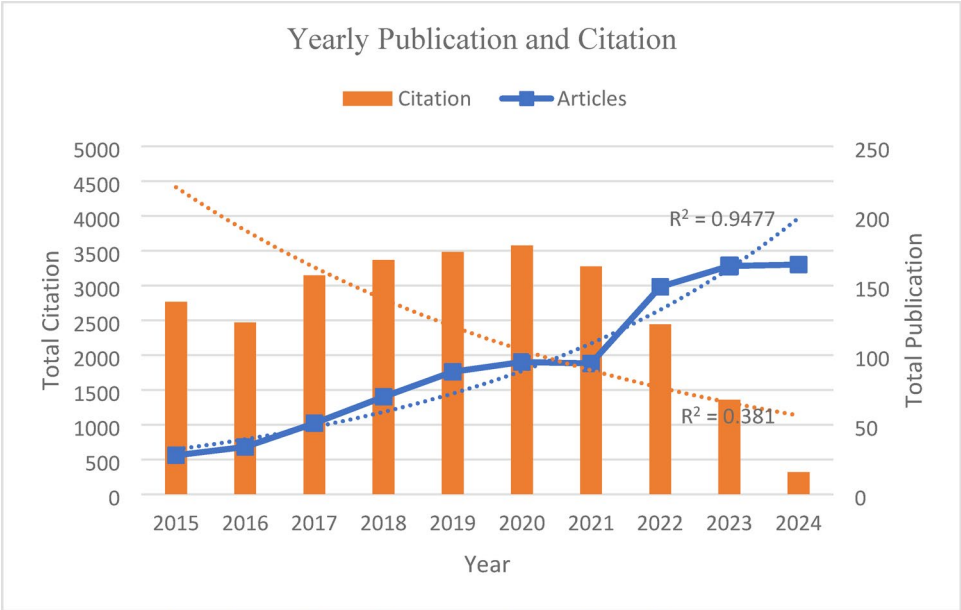

Fig. 2 The annual publication and citation trends in the past 10 years. (Source: authors, 2025)

Table 1 The annual citation trends over time, from 2015 to 2024. (Source: authors, 2025)

Year	Mean Total Citation/ Article	Mean Total Citation/ Year	Citeable Years
2015	62.64	5.69	11
2016	27.76	2.78	10
2017	42.67	4.74	9
2018	23.79	2.97	8
2019	31.38	4.48	7
2020	29.06	4.84	6
2021	16.96	3.39	5
2022	14.01	3.50	4
2023	7.99	2.66	3
2024	2.00	1.00	2

2018 and surpassing 124 publications by 2025. This suggests that the journal has become the leading platform for disseminating research in this domain. Other sources, including the IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Sustainability (Switzerland), Proceedings of SPIE - The International Society for Optical Engineering, and International Geoscience and Remote Sensing Symposium (IGARSS), also demonstrate steady growth. However, their publication numbers remain significantly lower than those of Remote Sensing, levelling off at around 40 publications by 2025.

While the increasing number of publications across diverse journals reflects the growing academic interest in this area, it also presents certain drawbacks. The wide dispersion of articles across 264 journals can lead to the fragmentation of knowledge, making it more difficult for researchers to locate, compare, and synthesize relevant findings efficiently. This diversity in publication sources may also result in inconsistencies in research quality, methodology, and scope, especially when contributions come from journals with varying levels of specialization or peer-review rigor.

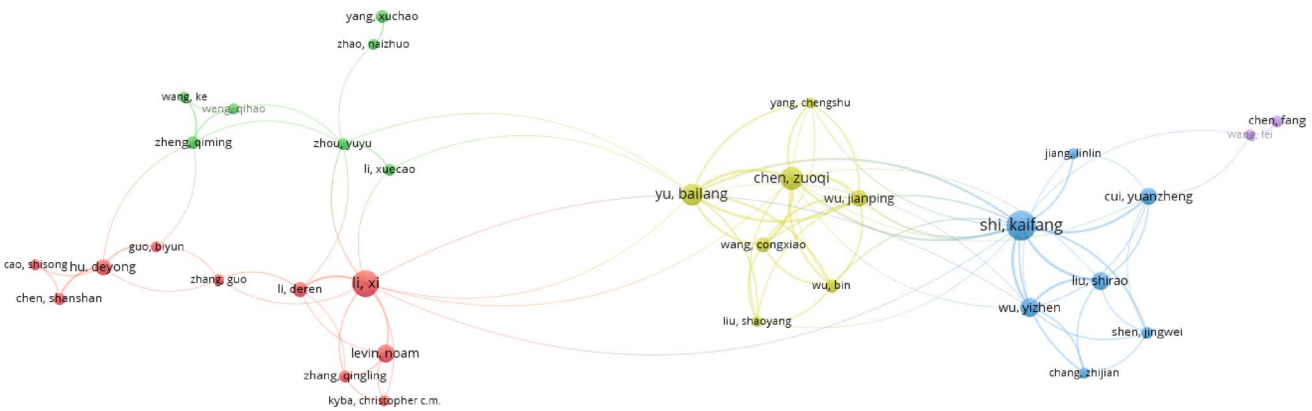

Fig. 3 Authors cooperation network in the research. (Source: authors, 2025)

Table 3 The number of papers by journal (20 Journals). (Source: authors, 2025)

Title of Journal	Range of the publication year	Number of papers
Remote Sensing	2015–2025	124
IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing	2015–2024	45
Sustainability (Switzerland)	2015–2024	40
Proceedings Of SPIE - The International Society for Optical Engineering	2016–2024	35
International Geoscience and Remote Sensing Symposium (IGARSS)	2016–2024	27
Remote Sensing of Environment	2016–2025	24
Science Of The Total Environment	2016–2024	22
International Archives of The Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives	2016–2023	19
Land	2020–2025	17
Journal of Geo-Information Science	2017–2024	16
International Journal of Applied Earth Observation and Geoinformation	2018–2024	15
Ecological Indicators	2016–2025	14
IEEE Geoscience and Remote Sensing Letters	2019–2025	14
ISPRS International Journal of Geo-Information	2016–2024	14
IEEE Transactions on Geoscience and Remote Sensing	2015–2024	12
IOP Conference Series: Earth and Environmental Science	2016–2024	12
Applied Sciences (Switzerland)	2015–2024	11
Journal of Environmental Management	2017–2025	11
Shengtai Xuebao	2021–2025	11
International Journal of Remote Sensing	2015–2024	10

The overall trend indicates a rising interest in remote sensing and sustainability-related research, particularly in the last five years. Based on Table 3, the dominance of *Remote Sensing* as a publication source suggests that it has become the primary choice for researchers in this field, likely due to its technological advancement, open-access nature, and focused scope on geospatial applications. In contrast, while urban planning is inherently linked to sustainability, it has not emerged as the main topic, possibly because it tends to be addressed within broader interdisciplinary studies rather than as a standalone subject. Additionally, urban planning research is often published in region-specific or policy-focused journals, which may not have the same global reach or impact factor as remote sensing-focused outlets. The steady contribution from various other sources further reflects the interdisciplinary nature of this research area, drawing from environmental science, geography, engineering, and policy studies.

3.4 Geographical and institutional distribution

3.4.1 Countries and continents

Urban studies based on nighttime light publications originate from 40 different countries or territories. Out of those, 40, 19 are located in Asia, 19 in Europe, 3 in America, 2 in Africa, and 2 in Oceania. Figure 4 shows the worldwide distribution of contributing countries and territories. 11 countries or territories (27.5%) produced only 1 publication, 18 countries or territories (45.0%) produced between 2 and 4 publications, and 11 countries or territories (27.5%) have produced over 5 publications on the topic of safety culture.

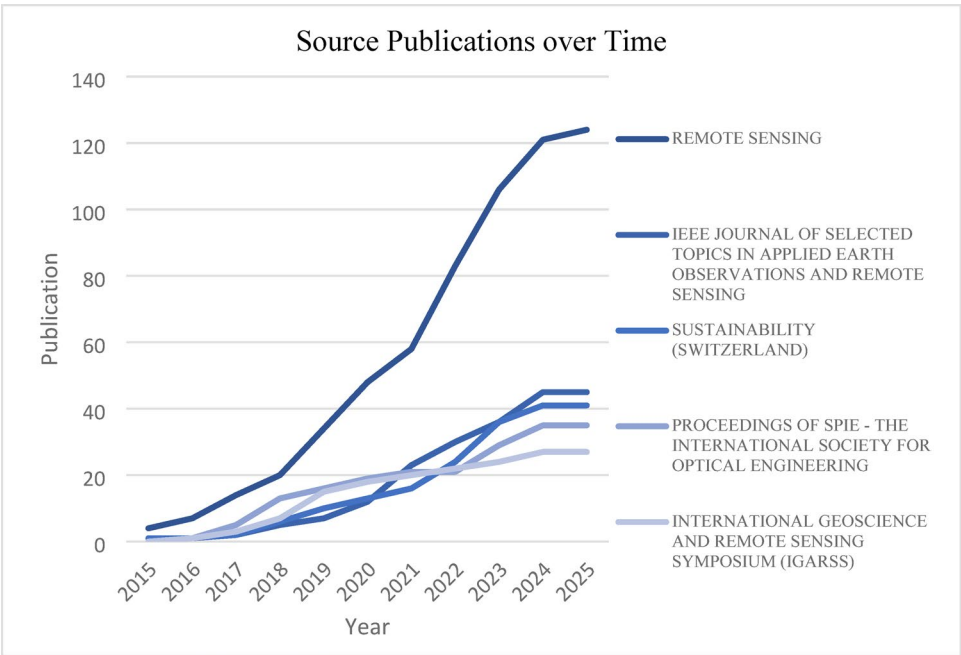

Fig. 4 Active Journals Publications over Time. (Source: authors, 2025)

China produced the most publications ($n=636$), followed by the United States of America ($n=42$) and Indonesia ($n=12$). Figure 5 shows the top 5 most productive countries and territories in urban studies based on nighttime light data research. The dominance of China and several other Asian countries underscores the countries' significant advances in this field. China's significant scientific output can be attributed in part to its active development and deployment of domestic satellite systems tailored to nighttime light monitoring and urban studies. Satellites such as Luojia 1 and the Jilin 1 series offer improved spatial resolution and are specifically designed for capturing fine-grained urban and environmental data. Additionally, SDGSAT-1, launched with a focus on sustainable development monitoring, further reflects China's strategic investments in Earth observation technologies. Recent research indicates that China has made significant strides in scientific output, potentially overtaking the USA as the largest producer of SCI-indexed original research articles since 2018 [32]. However, such concentration poses drawbacks, and it may skew research priorities toward one country's context, reduce global applicability, and limit diverse perspectives. Broader geographic participation is crucial for balanced, inclusive urban studies.

A total of 813 countries and territories were included in the 962 publications that included country or territory information (a publication may be written by multiple authors from different countries or territories, or one author may be associated with more than one country). When examining the continents, geographical inequality is also evident in the extension of the data on nations and territories. A total of 87.95% of the publications ($n=715/813$) were attributed to Asia, 5.66% to America ($n=46/813$), 5.41% to Europe ($n=44/813$), 0.62% to Oceania ($n=5/813$), and 0.37% to Africa.

VOSviewer was used to evaluate the network of collaboration (i.e., co-authorship) across nations that publish urban studies based on data on evening light. At least five publications on the subject were released by the network's member nations. Not included are nations or territories that are not linked to any other nations or territories within the network. Figure 6 displays the outcome of the international cooperation network. The size of the circles represents the number of publications, with China having the largest node, indicating its dominant contribution to the field. The thickness of the links reflects the strength of collaborations, highlighting strong partnerships between China and the United States, as well as between China and Hong Kong. The colors represent different collaboration clusters, with China serving as a central hub for international cooperation. The United States also forms an important connection point, linking to multiple European countries such as Germany, the Netherlands, and the United Kingdom. Additionally, smaller clusters can be seen, such as collaborations involving Malaysia, Sweden, and Iran. The visualization underscores China's pivotal role in urban nighttime light research and its extensive global collaboration network. Similar to other fields of scientific study, countries that collaborate are typically geographically associated and cluster around the countries with the highest publication output [33].

3.4.2 Institutions

This suggests growing academic interest and investment in research across these universities. The publication trends indicate a significant expansion in scholarly output, reflecting the rising importance of their research fields. Based on Fig. 7, among the institutions, East China Normal University leads with the highest number of publications,

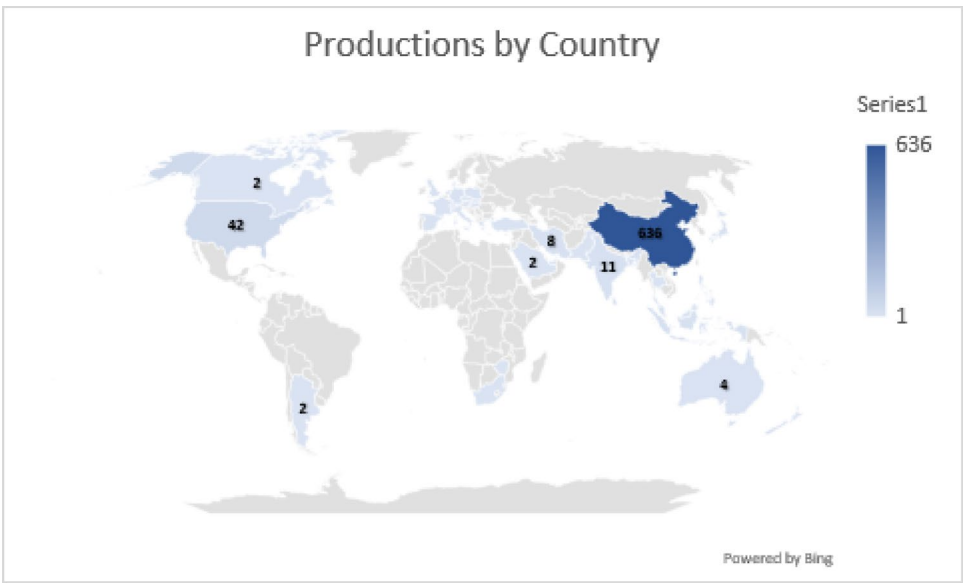

Fig. 5 Productions by Country. (Source: authors, 2025)

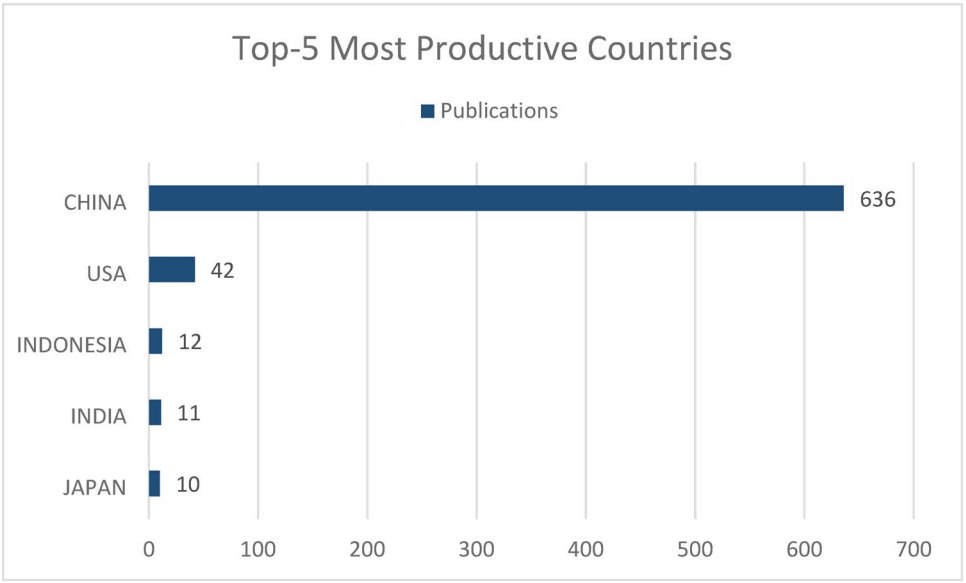

Fig. 6 Top 5 of most productive countries on urban studies based on nighttime light data. (Source: authors, 2025)

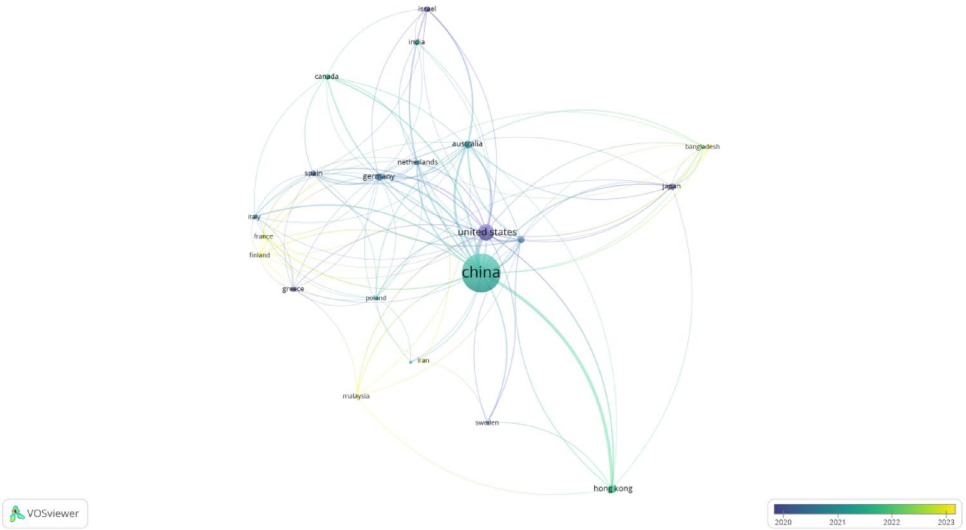

Fig. 7 Cooperation network between countries. (Source: authors, 2025)

demonstrating a consistent upward trajectory, especially from 2020 onward. Peking University follows closely, showing a parallel trend and reaching a similar level of publications by 2025. This suggests that both universities are at the forefront of research in their respective fields, maintaining strong and sustained growth.

It would be intriguing to categorize the 789 institutions involved in safety culture research into three groups: governmental organizations (policy makers), private organizations (such as hospitals and industries), and academic institutions (colleges and universities). This distinction makes it possible to determine if safety culture research is firmly rooted in academia and whether it can provide insight into policy focus and stakeholder involvement [34]. This division takes a lot of effort, though, because each piece of information must be manually sought. After all, it is not listed in Scopus.

3.5 Term analysis

The primary subjects and research trends in the field of nighttime light data evolution in urban studies can be inferred from an examination of the terminology used in the titles and abstracts of publications on the subject.

VOSviewer was used to analyze and visualize the terms. First, all noun phrases were extracted from the titles and abstracts of the 962 urban studies based on nighttime light data publications. Terms with a general meaning, such as ‘article’ and ‘conclusion’, were not included. Terms with different spellings, such as ‘analyse’ and ‘analyze’, were merged. Only terms that occur in at least ten publications were considered. With 909 terms met this threshold. The results of the terms analysis are presented in Fig. 8. The size of the circles represents the frequency of a term, i.e., the larger the circle, the more frequently the term appears in

Fig. 8 Institutions Publication Over Time. (Source: authors, 2025)

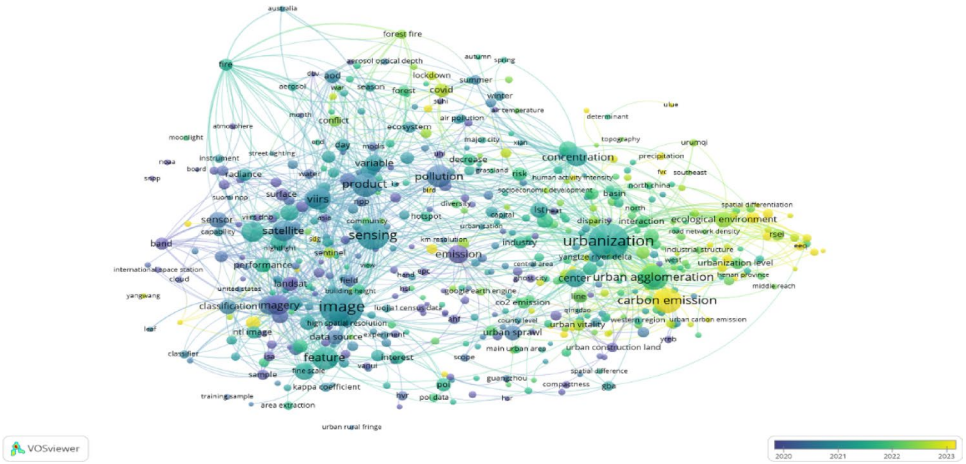

Fig. 9 Term Analysis of Urban Studies Based on Nighttime Light Data. (Source: authors, 2025)

the abstracts and titles of safety culture publications. The overall distance between terms provides information on their relatedness. The shorter the distance between terms, the stronger their relation. The relatedness of terms is determined by counting the number of times that terms occur together in the titles and abstracts [35]. The colors are used to distinguish different clusters.

Figure 8 presents a term analysis of nighttime light research publications incorporating time-based information. The color of each term represents its average publication year, calculated by averaging the publication years of all articles containing that term in their title or abstract. Terms associated with earlier research (around 2020) are shown in blue, while more recent terms (closer to 2023) appear in yellow. Early research, around 2020, focused on remote sensing fundamentals, with key terms such as "satellite," "imagery," "data source," and "classification" dominating the field. Around 2021, there was a shift towards applications in environmental monitoring, with terms like "pollution," "emission," and "concentration" becoming more prominent. The most recent studies (2022–2023) emphasize urbanization-related topics, including "urban agglomeration," "carbon emission," "ecological environment," and "infrastructure." This trend indicates a growing integration of nighttime light data into urban sustainability, environmental assessment, and climate impact studies.

Over time, nighttime light data from various satellite sources has been extensively used in urban studies using term analysis. The distribution of publications by year for the names of the nighttime light accusation devices, DMSP/OLS, SDGSAT-1, VIIRS, Luojia 1, Jilin 1, UAV, and EROS-B is displayed in Fig. 9.

The DMSP/OLS dataset has been primarily used in studies published in the early stages of nighttime light research, as DMSP/OLS was the only reliable satellite-derived data source available before 2013. The DMSP/OLS dataset remains the primary source used in studies published between 2018 and 2020, reflecting its long-standing

historical role in nighttime light research. Despite the availability of improved nighttime light data from VIIRS with a spatial resolution of 500 m since 2012, researchers continue to use DMSP-OLS data because of its longer time series (1992–2013) for socio-economic studies (Sahoo et al., 2020, despite its lower spatial resolution of 1000 m. The VIIRS dataset shows a more recent median publication year, around 2022, with a broader range extending into 2024, suggesting its growing importance in contemporary research, as it benefits from its higher sensitivity compared to DMSP/OLS.

VIIRS and Luojia 1 have a median publication year around 2021, emphasizing their growing role in nighttime light studies. The Luojia 1–01 satellite provides high-resolution (130 m) nighttime light imagery, offering significant advantages over previous sensors, such as SNPP-VIIRS [36, 37]. However, due to its availability limitations, VIIRS and Luojia 1 show similar popularity. Next, the unmanned aerial vehicle (UAV) observations show a relatively recent median year, indicating the rising importance of drone technology in high-resolution nighttime light monitoring. UAVs offer significant benefits for nighttime light monitoring and analysis. They can capture high-resolution images with hourly temporal resolution, providing detailed insights into urban light dynamics that satellites cannot match [38]. Through this study also highlights the rise of the latest satellite systems, which is SDGSAT-1, the world's first satellite dedicated to supporting the UN's 2030 Sustainable Development Agenda, which was successfully launched on November 5, 2021 [39–41],. SDGSAT-1 has a median publication year closer to 2024, highlighting the increasing adoption of high-resolution nighttime light sensors. The satellite carries three key instruments: a multi-spectral imager (MSI), a thermal infrared spectrometer (TIS), and a glimmer imager, which has made its data desirable in recent years [42]. (Fig. 10).

On the other hand, EROS-B has the earliest median publication year, around 2016, suggesting its earlier application in nighttime light studies; however, its recent use is limited due to restricted accessibility and a narrow spectral range, as shown in Table 4, which makes it unsuitable for urban studies. The overall trend in nighttime light satellite imagery indicates a shift toward modern, high-resolution, and multi-spectral nighttime light sensors, enhancing the accuracy and applicability of nighttime light research in urban and environmental studies.

Landsat and MODIS, which were utilized in this research, played a crucial role in Land Use Land Cover (LULC) classification by providing multi-temporal and high-resolution satellite imagery. Landsat, with its long-term data archive, enables detailed monitoring of urban expansion, vegetation changes, and water bodies, making it a valuable tool for historical land cover assessments. Meanwhile, MODIS, with its high temporal resolution, bring insights into urbanization patterns, deforestation, and climate-related impacts. Nighttime light remote sensing, utilizing Landsat and MODIS data, provides unique insights into human activities and environmental changes. These observations enable applications in urbanization monitoring, socioeconomic dynamics tracking, and impervious surface mapping [43]. The integration of these datasets enhances the accuracy of classification models, providing comprehensive spatial and temporal analyses for urban studies based on nighttime light.

Early research relied heavily on DMSP-OLS, which, despite its long historical record and free access, offered low spatial resolution. The emergence of VIIRS-SNPP as the dominant satellite provided better resolution and consistent monthly data, enhancing research potential. More recent additions, such as Luojia 1 and Jilin 1, have introduced higher-resolution imagery, although they are limited by short lifespans or commercial access. Meanwhile, satellites like EROS-B and SDGSAT-1 have brought specialized

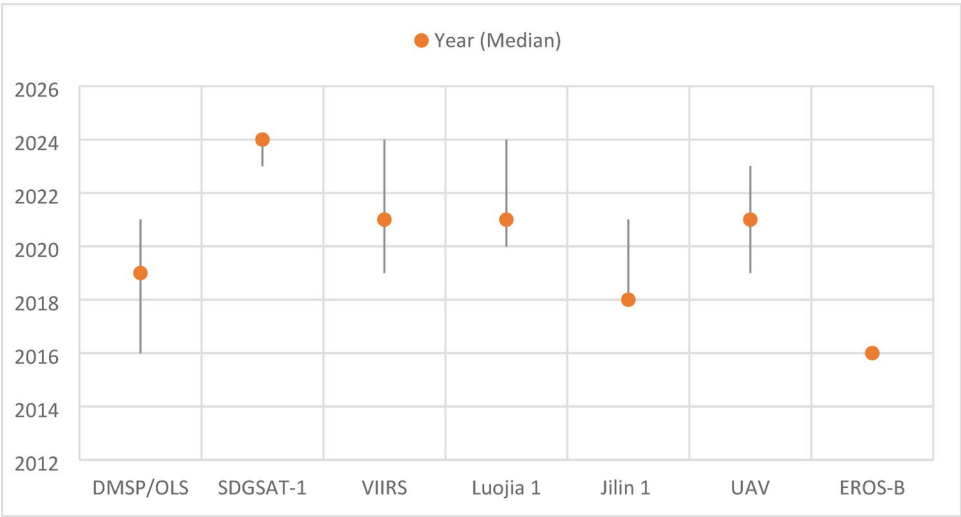

Fig. 10 Nighttime Light Accusation Devices. (Source: authors, 2025)

Table 4 Nighttime light satellite specification [44–49]

DMSP– OLS (Defense Meteorological Satellite Program - Operational Linescan System)	
Occurrence	22
Accessible Periods	1992–2013
Spectral Resolution	0.4–1.1 μm
Spatial Resolution	30 arc seconds (~1 km)
Nighttime overpass time (local time)	~19:30
Radiometric Resolution	6 bits
Minimum illumination detectable (W/cm2/sr)	5.0E-10
Measuring Unit	Relative (0–0.63)
Accessibility	Free
Product Cycle	Yearly
VIIRS– SNPP (Visible Infrared Imaging Radiometer Suite– Suomi NPP)	
Occurrence	**470**
Accessible Periods	2012– now
Wavelength Range	0.5–0.9 μm
Spectral Resolution	15 arc seconds (~500 m)
Nighttime overpass time (local time)	~01:30
Radiometric Resolution	14 bits
Minimum illumination detectable (W/cm2/sr)	2.0E-11
Measuring Unit	Radiation (nanoWatts/ (cm^2sr))
Accessibility	Free
Product Cycle	Monthly
Luojia 1	
Occurrence	**138**
Accessible Periods	2018–2019
Wavelength Range	0.46–0.98 μm
Spectral Resolution	130 m
Nighttime overpass time (local time)	~22:30
Radiometric Resolution	14 bits
Minimum illumination detectable (W/cm2/sr)	-
Measuring Unit	Radiation (nano Watts/ (cm^2sr))
Accessibility	Partially Free
Product Cycle	15 days
Jilin 1	
Occurrence	**6**
Accessible Periods	2015– now
Wavelength Range	Panchromatic: 450–800 nm Blue: 450–510 nm Green: 510–580 nm Red: 630–690 nm Near-infrared: 770–895 nm
Spectral Resolution	3.00 m (Multi-spectral bands) 0.75 m (Panchromatic band)
Nighttime overpass time (local time)	~22:00
Radiometric Resolution	12 bits
Minimum illumination detectable (W/cm2/sr)	-
Measuring Unit	Unitless / W.$sr^{-1}.m^{-2}.\mu\, m^{-1}$
Accessibility	Paid
Product Cycle	3.3 days

Table 4 (continued)

Eros B	
Occurrence	**2**
Accessible Periods	2018– now
Wavelength Range	0.45–0.9 μm
Spectral Resolution	0.65 m
Nighttime overpass time (local time)	-
Radiometric Resolution	15 bits
Minimum illumination detectable (W/cm2/sr)	-
Measuring Unit	Radiation (nano Watts/ (cm^2sr))
Accessibility	Paid
Product Cycle	On-demand
SDGSAT– 1	
Occurrence	**67**
Accessible Periods	2021– now
Wavelength Range	Blue: 430–520 nm Green: 520–615 nm Red: 615–900 nm Panchromatic: 450–900 nm
Spatial Resolution	40 m (Visible bands) 10 m (Panchromatic band)
Nighttime overpass time (local time)	~21:00
Radiometric Resolution	16 bits
Minimum illumination detectable (W/cm2/sr)	-
Measuring Unit	Radiation (Watts/(cm^2 sr))
Accessibility	Available upon request
Product Cycle	11 days

capabilities, such as very high resolution and sustainability-focused spectral data, respectively, even if access is limited or costly. This evolving ecosystem of satellite sensors likely spurred new research opportunities and applications.

Overall, VIIRS remains the most widely used satellite because of its optimal balance of resolution, sensitivity, and free accessibility. SDGSAT-1 is acquiring prominence in 2024, offering higher resolution and enhanced spectral capabilities, making it a valuable tool for sustainability studies. While short-lived satellites like Luojia 1 provide higher-resolution data, their limited availability restricts widespread use. The paid satellites, such as Jilin 1 and EROS-B, are exceptional details but are less frequently used in academic research because of cost constraints. These trends reflect the continuous evolution of nighttime light research, emphasizing the shift toward higher-resolution sensors and expanded spectral analysis to enhance urban and environmental studies.

4 Conclusion

The findings of this study, nighttime light has been a crucial instrument for urban studies, helping to illustrate various urban dynamics, assess natural and man-made disasters, and evaluate urban developments. The current state of urban studies based on nighttime light data was examined using keyword co-occurrence technology, following a rigorous screening of pertinent literature in the Scopus database, which yielded a bibliometric analysis. The hot research countries and hot study locations in China were also retrieved and synthesized in this study. A summary of the new trends, problems, and application themes in urban studies based on nighttime light data was provided. The basic bibliometric analysis showed that urban studies based on nighttime light data have flourished over the years, especially in 2022. China emerges as the most frequently occurring publication, where China recorded the highest production of publications throughout the years. China dominates urban nighttime light research, with strong international collaborations, particularly with the USA and Hong

Kong. Geographical disparities persist, with Asia contributing the majority of publications while other regions remain underrepresented.

Nighttime light research has evolved from the fundamentals of remote sensing to applications in environmental monitoring and urban sustainability. The increasing focus on urbanization and climate impact studies highlights the growing relevance of nighttime light data in contemporary research. This study also highlights that technological advancements have driven this shift, with VIIRS emerging as the dominant sensor due to its higher sensitivity and resolution. The introduction of SDGSAT-1 has further expanded research applications, particularly in the field of sustainable development studies. Landsat plays a crucial role in historical urban expansion analysis, while MODIS supports large-scale environmental monitoring. The integration of multiple satellite datasets enhances the accuracy of classification models, providing more comprehensive spatial and temporal analyses for urban studies. Therefore, the results of this study are important for providing scientific references to inform future innovative research and the management of urban nighttime environments.

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Declarations

Competing interests Not applicable.

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