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Quantifying the influence of industries on light pollution within protected areas in the Pearl River Delta, China

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Abstract

Industrial enterprises are the primary sources of nighttime light in urban areas, highly correlated with light pollution in protected areas. This study focuses on the Pearl River Delta region in China, known as the "world's factory," utilizing big data from industrial enterprises to quantitatively analyze the correlation between different types of industrial enterprises and light pollution in protected areas. The analysis reveals variations in enterprise types and their correlation levels at different stages of economic development. In 2000, labor-intensive enterprises exhibit the highest correlation with light pollution in protected areas, approximately 1.4, while in 2016, capital-intensive enterprises demonstrate the highest correlation, around 1.6. Technology-intensive enterprises showed a negative correlation with light pollution in protected areas in both 2000 and 2016. Taking into account the number of enterprises, their proportions, and the degree of correlation with light pollution, we believe that resource-intensive enterprises themselves contribute significantly to light pollution. Therefore, site selection should steer clear of protected areas. The findings aim to serve as a basis for environmental regulations, facilitating the assessment of industrial light pollution's environmental impact and promoting sustainable enhancement of nighttime light environments in protected areas.

Introduction

Artificial light's negative impact on ecosystems, from individual organisms to ecological communities, has been widely acknowledged (Gaston et al., 2013; Bennie et al., 2015; Jiang et al., 2022b; Bon et al., 2011; Knop et al., 2017). Protected areas play a crucial role in ecosystem protection, and the nighttime light (NTL) environment is closely related to the health of the ecosystem. In the past few decades, the NTL of protected areas and surroundings around the world has increased rapidly (Davies et al., 2016; Knop et al., 2017; Xiang and Tan, 2017; Jiang et al., 2023; Zheng et al., 2021). It is worth noting that the degree of deterioration of the NTL in protected areas is independent of its protection level. High conservation status or stringent protective measures do not necessarily correlate with lower levels of light pollution in protected areas (Zheng et al., 2021). This highlights the ineffectiveness of current conservation efforts against light pollution.

Urban lights are the primary pollution sources of protected areas, whose impacts are often greater than the impacts of the internal communities (Kollath, 2009). The reason for that is light pollution can propagate over long distances, reaching tens to hundreds of kilometers (Cinzano and Falchi, 2012; Zheng et al., 2021), often surpassing the distance between cities and protected areas. At present, the protection measures of protected areas mainly focus on the internal human activities. That is why existing protective measures have been effective in addressing traditional ecological disturbances (Wang et al., 2013; Gray et al., 2016; Shao et al., 2012; Li et al., 2013), but fall short in combating the ecological threats posed by light pollution. To enhance the NTL environment in protected areas necessitates identifying key human activities generating light pollution externally and implementing rational planning and controls.

Among various human activities, industrial and commercial sectors are the two most significant contributors to light pollution (Biggs et al., 2012; Cheon and Kim, 2020), with industrial activities showing a stronger correlation with light pollution in protected areas. Mining and oil extraction, for instance, can severely impact protected areas with light pollution (Xiang and Tan, 2017). However, existing research on industrial light pollution in protected areas remains limited to specific representative industrial types, lacking comprehensive quantitative studies to inform the optimization of external industrial layout around protected areas.

This study chose the Pearl River Delta (PRD) region in China as a study area, which is well known as the "world's factory"(Xu and Li, 2009). We utilized big data of industrial enterprises to quantitatively analyze the correlation between different types of industrial enterprises and light pollution within protected areas. The study aims to achieve two objectives: 1) Identify the industrial types causing the most significant light pollution in protected areas to provide scientific insights for optimizing the layout of surrounding enterprises; 2) Advocate for more awareness of the light pollution caused by industrial enterprises, and light pollution indicators to be included in the environmental regulation, which will influence site selection of industrial enterprises and will continuously enhance the NTL environment in protected areas.

Study Area

The study area selected for this research is the Pearl River Delta region, situated along the southeastern coast of China and serving as a vital component of Guangdong Province, the largest economic province in China. Covering an area of approximately 55,369km^2 with a population of around 78 million, the PRD region contributes to over 80% of Guangdong Province's gross domestic product (GDP), making it one of the most densely populated and economically advanced regions in China. Additionally, the region boasts abundant natural ecological resources, hosting 405 protected areas with a total area of 7680km^2. These protected areas are categorized into nature reserves and natural parks, and the latter includes marine parks, forest parks, geological parks, wetland parks, and scenic spots (Fig. 1). Due to the region's developed economic industries and high nighttime activity intensity, protected areas in the PRD are facing significant light pollution challenges (Jiang et al., 2022a).

The PRD region comprises nine prefecture-level administrative units: Guangzhou, Shenzhen, Dongguan, Huizhou, Foshan, Zhongshan, Jiangmen, Zhuhai, and Zhaoqing (Fig. 1). Based on economic development levels and geographical positioning, these nine cities are divided into three tiers. Guangzhou and Shenzhen serve as core cities, contributing to approximately 57% of the entire PRD's GDP, while Dongguan, Foshan, Zhuhai, and Zhongshan are peripheral cities, accounting for 31% of the region's GDP. Jiangmen, Zhaoqing, and Huizhou are categorized as edge cities, constituting around 12% of the region's GDP. These three tiers of cities show significant differences in industrial structures and levels of light pollution in protected areas. This study aims to conduct a correlation analysis between enterprises and light pollution in protected areas for the entire PRD region while also performing

separate quantitative analyses for each of the three city tiers to uncover patterns related to enterprise activities and light pollution in protected areas.

Methodology

Primary Data

The data utilized in this study primarily consist of nighttime light remote sensing data and Chinese customs trade data spanning the years 2000 to 2016.

The light data is sourced from calibrated data by Li et al., published in Scientific Data (Li et al., 2020), with a spatial resolution of approximately 1km. The original data is derived from remote sensing products of the United States' Defense Meteorological Satellite Program (DMSP) and the Suomi National Polar-orbiting Partnership satellite (VIIRS), widely employed in current nighttime light research (Baugh et al., 2010; Liang et al., 2014; Elvidge et al., 2013; Falchi et al., 2016; Zheng et al., 2022).

The enterprise data is obtained from Chinese customs trade statistics, covering each city within PRD and presented in vector data format.

Analysis Scheme

We categorized enterprises into four types: labor-intensive enterprise (LIE), technology-intensive enterprise (TIE), capital-intensive enterprise (CIE), and resource-intensive enterprise (RIE). Labor-intensive enterprises are primarily engaged in the production of textiles, footwear, and umbrellas, while technology-intensive enterprises focus on chemical products and electronic components. Capital-intensive enterprises are involved in activities like steel production and transportation equipment manufacturing, and resource-intensive enterprises mainly deal with livestock, vegetables, and mineral production.

We constructed a quantitative analysis model (1) to examine the correlation between e light intensity (Y) and the four types of enterprise (X) for both 2000 and 2016. The light intensity utilized the mean value of NTL (MNTL) in protected areas, with industrial enterprises restricted to a sensitive distance of 10km (Jiang et al., 2023) from the reserves. After standardization, the two variables underwent correlation analysis.

$$Y_{i,t} = \beta_0 + K_0X_{0,i,d,t}+K_1X_{1,i,d,t}+K_2X_{2,i,d,t+}K_3X_{3,i,d,t+}K_4X_{4,i,d,t} + \varepsilon_{i,d,t}$$

$Y_{i,t}$ represents the MNTL within protected area i in year t; $X_{i,d,t}$ denotes the quantity of the four types of enterprises within the external buffer zone of protected area i; t signifies the study year; d represents the distance, set at 10km; K_1-K_4 are the correlation coefficients between the four types of enterprises and natural reserve nighttime light intensity; $\varepsilon_{i,d,t}$ indicates the residual term; β_0 is a constant. Human footprint data (Venter et al., 2016; Zheng et al., 2021) was used as a control variable X_0.

Results

MNTL in protected areas and their dynamics

Figure 2 illustrates the MNTL and spatial distribution in protected areas of the PRD region in 2000 and 2016. Over the 17-year period, light pollution in protected areas of the PRD region significantly intensified. In 2000, the MNTL in protected areas was 24.9. The core cities of Guangzhou and Shenzhen had a mean of 35.4, the peripheral cities had a mean of 31.5, and the edge cities had a mean of 9.2.

By 2016, the MNTL in protected areas of the PRD region had risen to 32.4, a 30% increase. The MNTL in protected areas of the three city tiers had increased to 43.9, 40.1, and 14.3, respectively. In terms of light pollution levels in the regional protected areas, the core cities' protected areas had the highest intensity, followed by the peripheral cities, with the edge cities exhibiting the lowest levels. However, regarding growth rates, the edge cities showed the highest increase, while the core cities had the lowest.

Industrial Structure and dynamics

Table 1 and Fig.3 presents the quantity statistics of the four types of enterprises in PRD. In 2000, there were a total of 15,779 enterprises within 10km outside protected areas in PRD, which increased to 55,332 by 2016. Labor-intensive enterprises dominated with 46% in 2000, while capital-intensive enterprises were the least at 9%. By 2016, technology-intensive enterprises took the lead with 43%, while capital-intensive enterprises remained at 9%, same as the proportion in 2000 (Fig.3).

Table1 Number of different types of enterprises in Pearl River Delta cities in 2000 and 2016

	Types	PRD 9 cities	Guangzhou GZ	Shenzhen SZ	Dongguan DG	Foshan FS	Zhongshan ZS	Zhuhai ZH	Zhaoqing ZQ	Jiangmen JM	Huizhou HZ
2000	TIE	4590	782	1566	812	329	215	351	87	180	268
	LIE	7275	1286	1998	1299	688	449	580	151	400	424
	CIE	1431	278	341	278	160	98	61	30	97	88
	RIE	2534	561	722	294	224	117	274	78	159	105
2016	TIE	23978	3014	12293	3565	1582	842	1036	170	698	778
	LIE	20756	3499	7568	3854	1993	964	691	179	873	1135
	CIE	5114	719	1758	999	575	307	192	53	314	197
	RIE	5484	784	2228	704	457	309	380	115	338	169

TIE: Technology-intensive enterprise; LIE: Labor-intensive enterprise;
CIE: Capital intensive enterprise; RIE: Resource-intensive enterprise

Regarding the spatial distribution of enterprises（Fig.4）, enterprises in the PRD were predominantly concentrated in the core cities of Shenzhen and Guangzhou, gradually decreasing towards the peripheral and edge cities. In 2000, the total number of foreign trade industrial enterprises in the core cities was 7534, accounting for 48%, while the peripheral and edge cities accounted for 39% and 13% respectively. By 2016, the total number of enterprises in the core cities had reached 31,863, making up 58%, while the peripheral and edge cities accounted for 33% and 9%. It is evident that the core cities' industrial structure heavily influences the PRD region's overall industrial composition.

Due to variations in economic development levels, the composition of enterprises across the three city tiers exhibited significant differences. In core cities, technology-intensive enterprises had the highest proportion, with 42% in 2000 and 48% in 2016. In peripheral cities, labor-intensive enterprises dominated, with 44% in both 2000 and 2016. Edge cities also had labor-intensive enterprises as the most prominent, accounting for 44% in both years. Capital-intensive enterprises consistently held the lowest proportion across all city tiers, ranging from 8% to 11%.

Correlation Analysis Results

Pearl River Delta region

Table 2 displays the analysis results of the correlation between the four types of industries in the Pearl River Delta region and light pollution in protected areas in 2000. Labor-intensive enterprises showed the highest positive correlation (1.38) with light pollution in protected areas, followed by capital-intensive enterprises (0.74) and resource-intensive enterprises (0.33), while technology-intensive enterprises exhibited a negative correlation.

Table 2 Results of correlation analysis between enterprises and NTL in protected areas in 2000

2000	Pearl River Delta	Core cities	Peripheral cities	Outskirts cities
	9 cities	GZ, SZ	DG, FS, ZS, ZH	ZQ, JM, HZ
TIE	-1.567***	-1.094*	0.134	0.442
	-0.268	-0.55	-0.794	-0.58
LIE	1.376***	0.248	1.410*	1.867***
	-0.324	-0.605	-0.769	-0.685
CIE	0.736***	0.911***	0.271	-0.033
	-0.144	-0.306	-0.293	-0.244
RIE	0.438*	0.575	-0.392	0.679
	-0.233	-0.368	-0.655	-0.509
Human Footprints	0.334***	0.622***	0.366**	-0.071
	-0.074	-0.22	-0.17	-0.076
Constant	0.01	-0.042	0.076	0.060***
	-0.025	-0.084	-0.059	-0.021
Protected areas	405	88	109	208
R-squared	0.448	0.412	0.376	0.494

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

In 2016, there was a significant shift in the correlation between enterprises and light pollution in protected areas (Table3). Capital-intensive enterprises emerged as the most correlated with light pollution in protected areas (1.61), followed by resource-intensive enterprises (1.09). The correlation with NTL intensity for labor-intensive enterprises became insignificant, while the negative correlation between technology-intensive enterprises and NTL in protected areas increased further.

Considering the quantity and proportion of each enterprise type, capital-intensive enterprises produced the heaviest light pollution. The capital-intensive enterprises had the lowest quantity but the highest correlation, indicating a higher level of light pollution from these enterprises. Conversely, technology-intensive enterprises displayed the opposite trend, suggesting lower light pollution levels. After industrial structural optimization in 2016, with an increased proportion of technology-intensive enterprises and a decreased proportion of labor-intensive enterprises, the growing correlation of capital-intensive enterprises with light pollution in protected areas was further highlighted.

Table 3 Results of correlation analysis between enterprises and NTL in protected areas in 2016

2016	Pearl River Delta	Core cities	Peripheral cities	Outskirts cities
	9 cities	GZ, SZ	DG, FS, ZS, ZH	ZQ, JM, HZ
TIE	-2.408***	-1.955**	-2.418*	-2.493
	-0.367	-0.787	-1.39	-1.882
LIE	0.203	0.099	0.676	0.271
	-0.182	-0.331	-0.523	-0.462
CIE	1.606***	1.440*	1.05	0.675
	-0.373	-0.78	-0.774	-1
RIE	1.086***	0.772**	0.845**	2.025***
	-0.168	-0.339	-0.371	-0.433
Human Footprints	0.187**	0.524*	0.098	0.059
	-0.092	-0.306	-0.236	-0.106
Constant	0.103***	0.057	0.194***	0.098***
	-0.03	-0.109	-0.073	-0.03
Protected areas	405	88	109	208
R-squared	0.424	0.354	0.295	0.334

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

Correlation Results of Different City Tiers

In general, the core cities exhibited distinct correlation patterns compared to the peripheral and edge cities, with the latter two tiers showing more similar trends.

In 2000, capital-intensive enterprises in core cities had the highest correlation with protected area NTL intensity at 0.91, while in peripheral and edge cities, labor-intensive enterprises showed the highest correlation with light pollution, at 1.41 and 1.87, respectively.

By 2016, in core cities, capital-intensive enterprises remained the most correlated with protected areas NTL with a correlation coefficient of 1.44, representing a 58% increase from 2000. In peripheral and edge cities, Resource-intensive enterprises became the most correlated with light pollution with correlation coefficients of 0.85 and 2.03, respectively. The latter was 2.4 times higher than the former.

The correlation results in different cities closely align with their industrial structures. In core cities, technology-intensive enterprises dominated, showing a negative correlation with protected area light pollution. As their proportion increased, the correlation with capital-intensive enterprises became more

pronounced. In contrast, peripheral cities relied on lower-end industries utilizing human and natural resources, resulting in a strong correlation between low-end industries and protected areas' light pollution.

Discussion

Industrial production remains one of the most significant human activities generating various forms of pollution (Agency, 2019; Programme, 2019; Organization, 2016; Zhang, 2020). To mitigate the environmental threats posed by industrial production, numerous countries worldwide have established environmental regulations (Zhang, 2020). For instance, in China, major projects like new industrial parks require environmental impact assessments and the formulation of corresponding environmental protection plans (Environment, 2020). Currently, assessments primarily focus on emissions such as waste gases, wastewater, and toxic substances' adverse effects on air, water, and soil, while light pollution has not been included in the assessment checklist. However, the cumulative effects of light pollution may pose a significant threat to reshaping entire ecosystems, thus warranting its incorporation as a crucial aspect of environmental impact assessments.

In the PRD region, capital-intensive enterprises exhibited the highest correlation with light pollution in protected areas. By reviewing of capital-intensive enterprises in the region revealed that ports, shipyards, and electrical enterprises are primary components. Ports are among the brightest places globally, and Shenzhen Yantian Port is the third-largest container terminal worldwide, with high and prolonged nighttime lighting that significantly disturbs coastal protected areas nighttime light environments. Another core city in the PRD region, Guangzhou, hosts capital-intensive enterprises like Baiyun Airport and Nansha Port container terminal, contributing to severe light pollution.

For enterprise types with significant light pollution, thorough assessments should be conducted before construction to evaluate potential light pollution and develop corresponding environmental protection plans. If the enterprise location is not restricted, it is advisable to place highly light-polluting enterprises outside the sensitive distance (10km) of important protected areas. Specialized enterprises such as ports and shipyards requiring specific locations should consider implementing measures like cutoff luminaires, low-angle spotlights, reduced pole heights, increased pole spacing, to enhance lighting efficiency and reduce outward light radiation (Cereghetti et al., 2020), thus minimizing their light pollution impact on protected areas (Elsahragty and Kim, 2015; Kibert, 2016).

Conclusion

Significant correlations exist between industrial enterprises and light pollution in protected areas in the Pearl River Delta region, with the associated enterprises and degrees of correlation varying due to economic development stages and industrial structures. In 2000, labor-intensive enterprises exhibited the highest correlation with light pollution in protected areas, technology-intensive enterprises showed a negative correlation with light pollution in protected areas. By 2016, capital-intensive enterprises became

the most correlated, and the negative correlation coefficient between technology-intensive enterprises and light pollution in protected areas further intensified. The significant shift from labor-intensive enterprises exhibiting the highest correlation to resource-intensive enterprises exhibiting the highest correlation is likely attributed to industrial upgrading in the Pearl River Delta region. Following industrial upgrading, the proportion of labor-intensive enterprises decreased while the proportion of technology-intensive enterprises increased. The latter exhibits a negative correlation with light pollution in natural conservation areas. Hence, this amplifies the correlation of capital-intensive enterprises. The correlation of capital-intensive enterprises was further accentuated.

Based on the patterns revealed by the results of this study, we can infer that in the advanced stages of economic development, capital-intensive enterprises will exhibit the highest correlation with light pollution in protected areas. Conversely, in the early stages of economic and industrial development, lower-end labor-intensive or resource-intensive enterprises show the highest correlation with light pollution in protected areas. The three city tiers in different developmental stages within the Pearl River Delta region also validate this pattern. In core cities dominated by high-tech industries, capital-intensive enterprises emerge as the most correlated with light pollution in protected areas, while in peripheral cities developing supporting industries, industrial enterprises positioned in the middle or lower ends of the industrial chain, such as labor-intensive or resource-intensive enterprises, exhibit a high correlation with light pollution in protected areas.

We hope that the findings of this study can serve as a basis for environmental regulations, facilitating environmental impact assessments of industrial light pollution, thereby promoting sustainable enhancement of nighttime light environments in protected areas.

Declarations

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Data Availability The data of enterprises that support the findings of this study are available from China Customs.

Competing Interest None of the authors have a conflict of interest with the information provided in this review.

References

1. Agency E. E. (2019) Industrial pollution in Europe. Retrieved from https://www.eea.europa.eu/themes/industry/industrial-pollution-in-europe/industrial-pollution-in-europe

2. Baugh, K.E., Elvidge, C.D., Ghosh, T., & Ziskin, D. (2010). Development of a 2009 Stable Lights Product using DMSP-OLS data.. (2010) Development of a 2009 Stable Lights Product using DMSP-OLS data. *Proceedings of the Asia-Pacific Advanced Network* 30.
3. Bennie J., Duffy JP, Davies TW, Correa-Cano ME, Gaston KJ. (2015) Global Trends in Exposure to Light Pollution in Natural Terrestrial Ecosystems. *Remote Sensing* 7: 2715–2730. https://doi.org/10.3390/rs70302715
4. Biggs J. D., Fouché T., Bilki F., Zadnik M G. (2012) Measuring and mapping the night sky brightness of Perth, Western Australia. *Monthly Notices of the Royal Astronomical Society* 421: 1450–1464., https://doi.org/10.1111/j.1365-2966.2012.20416.x
5. Bon, D., Ulbrich, I.M., Gouw, J.D., Warneke, C., Kuster, W.C., Alexander, M.L., Baker, A.K., Beyersdorf, A.J., Blake, D.R., Fall, R., Jimenez, J.L., Herndon, S.C., Huey, L.G., Knighton, W.B., Ortega, J.V., Springston, S.R., & Vargas, O. (2011). Measurements of volatile organic compounds at a suburban ground site (T1) in Mexico City during the MILAGRO 2006 campaign: measurement comparison, emission ratios, and source attribution. *Atmospheric Chemistry and Physics*, 11, 2399–2421. https://doi.org/10.5194/acp-11-2399-2011
6. Cereghetti N., Strepparava D, Bettini A, Ferrari S. (2020) Analysis of Light Pollution in Ticino region during the period 2011–2016. *Sustainable Cities and Society* 63. https://doi.org/10.1016/j.scs.2020.102456.
7. Cheon S. and Kim J.-A. (2020) Quantifying the influence of urban sources on night light emissions. *Landscape and Urban Planning* 204. https://doi.org/10.1016/j.landurbplan.2020.103936.
8. Cinzano P. and Falchi F. (2012) The propagation of light pollution in the atmosphere. *Monthly Notices of the Royal Astronomical Society* 427: 3337–3357. https://doi.org/10.1111/j.1365-2966.2012.21884.x
9. Davies, T. W., Duffy, J. P., Bennie, J., & Gaston, K. J. (2016). Stemming the Tide of Light Pollution Encroaching into Marine Protected Areas. *Conservation Letters*, 9(3), 164–171. https://doi.org/10.1111/conl.12191
10. Elsahragty M. and Kim J.-L. (2015) Assessment and Strategies to Reduce Light Pollution using Geographic Information Systems. *Defining the Future of Sustainability and Resilience in Design, Engineering and Construction.* Chicago, CA, 479–488. https://doi.org/10.1016/j.proeng.2015.08.458
11. Elvidge, C.D., Baugh, K.E., Zhizhin, M.N., & Hsu, F. (2013). Why VIIRS data are superior to DMSP for mapping nighttime lights. *Proceedings of the Asia Pacific Advanced Network* 35.
12. Environment M. o. E. a. t. (2020) Opinions on Further Strengthening the Environmental Impact Assessment of Industrial Park Planning. Ministry of Ecology and Environment website: https://www.gov.cn/zhengce/zhengceku/2020-11/25/content_5564093.htm.
13. Falchi F., Cinzano P., Duriscoe D., Kyba C.C.M., Elvidge C.D., Baugh K, Portnov B. A., Rybnikova N.A., Furgoni R. (2016) The new world atlas of artificial night sky brightness. *Science advances* 2: e1600377.

14. Gaston K. J., Bennie J., Davies T. W., Hopkins J. (2013) The ecological impacts of nighttime light pollution: a mechanistic appraisal. *Biological Reviews* 88: 912–927. https://doi.org/10.1111/brv.12036
15. Gray C. L., Hill S, Newbold T., Hudson L. N., Börger L., Contu S., Hoskins A. J., Ferrier S., Purvis A., Scharlemann J. (2016) Local biodiversity is higher inside than outside terrestrial protected areas worldwide. *Nature communications* 7. 12306. https://doi.org/10.1038/ncomms12306
16. Jiang B, Li S, Li J, Zhang Y, Zheng Z. (2022a) Spatio-Temporal Dynamics and Sensitive Distance Identification of Light Pollution in Protected Areas Based on Muti-Source Data: A Case Study of Guangdong Province, China. *International Journal of Environmental Research and Public Health.* 19(19):12662. https://doi.org/10.3390/ijerph191912662
17. Jiang B., Zhang Y., Li S., Li J., Zheng Z., Wang H. (2023) Spatio-temporal dynamics and sensitive distance of nighttime light environment in Pearl River Delta Protected Areas, China. *The journal of applied ecology* 34: 1601–1609.
18. Jiang, F., Ye, Y., He, Z., Cai, J., Shen, A., Peng, R., Chen, B., Tong, C., & Deng, J. (2022b). Revealing the Spatiotemporal Patterns of Anthropogenic Light at Night within Ecological Conservation Redline Using Series Satellite Nighttime Imageries (2000–2020). *Remote Sensing*, 14(14), 3461. https://doi.org/10.3390/rs14143461
19. Kibert C. J. (2016) *Sustainable construction: green building design and delivery*: John Wiley & Sons.
20. Knop E, Zoller L, Ryser R, Gerpe C, Hörler M, Fontaine C. (2017) Artificial light at night as a new threat to pollination. *Nature.* 548, 206–209. https://doi.org/10.1038/nature23288
21. Kolláth Z. (2009) Measuring and modelling light pollution at the Zselic Starry Sky Park. Journal of Physics: Conference Series, 218. 12001pp. doi:10.1088/1742-6596/218/1/012001
22. Li L., Zhang H., Shi A., Li D. (2013) Study on Wetland Landscape Pattern Change in the Ximen Island Marine Special Protected Area based on RS and GIS. *Remote Sensing Technology and Application* 28: 129–136. https://doi.org/CNKI:SUN:YGJS.0.2013-01-020.
23. Li X., Zhou Y., Zhao M., Zhao X. (2020) A harmonized global nighttime light dataset 1992–2018. Scientific Data. 7, 168. https://doi.org/10.1038/s41597-020-0510-y
24. Liang C. K., Mills S., Hauss B.I., Miller S.D. (2014) Improved VIIRS Day/Night Band Imagery With Near-Constant Contrast. *Ieee Transactions on Geoscience and Remote Sensing* 52: 6964–6971.
25. Organization W. H. (2016) Preventing Disease through Healthy Environments: A Global Assessment of the Burden of Disease from Environmental Risks. Retrieved from https://www.who.int/publications/i/item/9789241565196
26. Programme U. N. E. (2019) Emissions Gap Report 2019. Retrieved from https://www.unenvironment.org/resources/emissions-gap-report-2019.
27. Shao J., Zhao W., Xie Z., Duan W., Zhang Q., Lin J. (2012) Population Status of Takin Budorcas taxicolor and Threat Assessmentat Niubeiliang National Nature Reserve,Shaanxi. *Chinese Journal of Wildlife*, 33(02):55–58. https://doi.org/10.19711/j.cnki.issn2310-1490.2012.02.001.

28. Venter O, Sanderson EW, Magrach A, Allan JR, Beher J, Jones KR, Possingham HP, Laurance WF, Wood P, Fekete BM, Levy MA, Watson JE. (2016) Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. *Nature communications*. 7:12558. https://doi.org/10.1038/ncomms12558
29. Wang W., Pechacek P., Zhang M., Xiao N., Zhu J., Li J. (2013). Effectiveness of nature reserve system for conserving tropical forests: a statistical evaluation of Hainan Island, China. *PloS one*, 8(2), e57561. https://doi.org/10.1371/journal.pone.0057561
30. Xiang W. and Tan M. (2017) Changes in Light Pollution and the Causing Factors in China's Protected Areas, 1992–2012. *Remote Sensing* 9(10):1026. https://doi.org/10.3390/rs9101026
31. Xu X. Q. and Li X. (2009) Research On The Urbanization Of Pearl River Delta (1978–2008): Review And Preview. *Human Geography* 24: 1–6 (in Chinese). https://doi.org/CNKI:SUN:RWDL.0.2009-01-005.
32. Zhang C., Su D. (2020) Environmental regulation, factor endowment, and enterprise location: an interpretation of "Pollution Haven Effect" and “Factor Endowment Hypothesis". *Industrial Economics Research*, (03), 43–56. https://doi.org/10.13269/j.cnki.ier.2020.03.004.
33. Zheng Y., He Y., Zhou Q., Wang H. (2022) Quantitative Evaluation of Urban Expansion using NPP-VIIRS Nighttime Light and Landsat Spectral Data. *Sustainable Cities and Society* 76, 103338. https://doi.org/10.1016/j.scs.2021.103338.
34. Zheng Z., Wu Z., Chen Y., Guo G., Cao Z., Yang Z., Marinello F. (2021) Africa's protected areas are brightening at night: A long-term light pollution monitor based on nighttime light imagery. *Global Environmental Change-Human and Policy Dimensions* 69, 102318. https://doi.org/10.1016/j.gloenvcha.2021.102318.

Figures

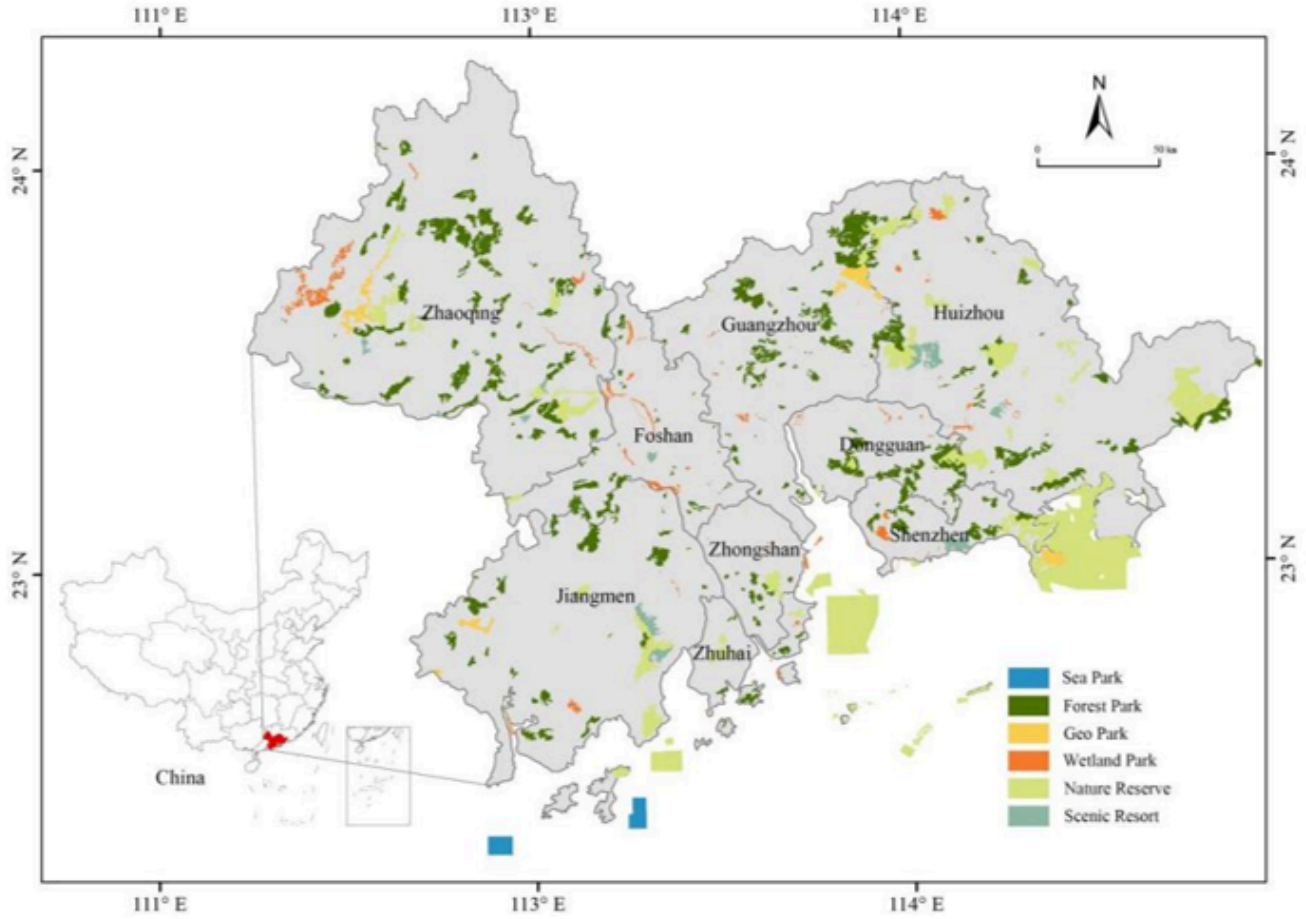


Figure 1

The spatial distribution of the PAs in the Pearl River Delta

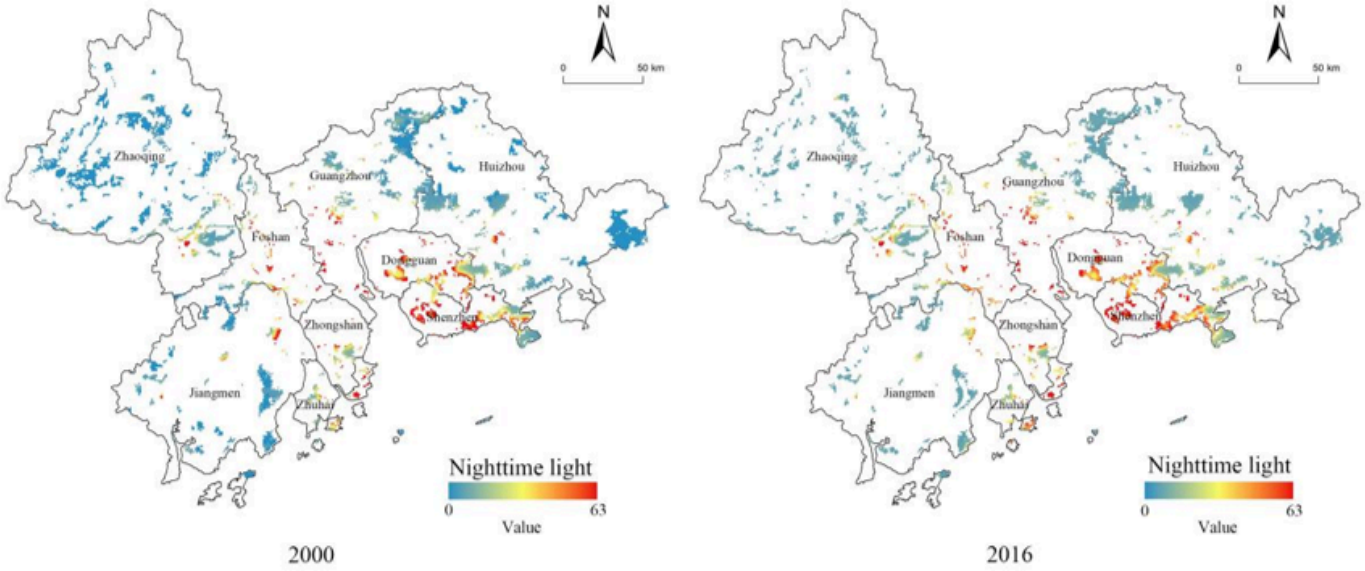


Figure 2

MNTL in protected areas in 2000 and 2016

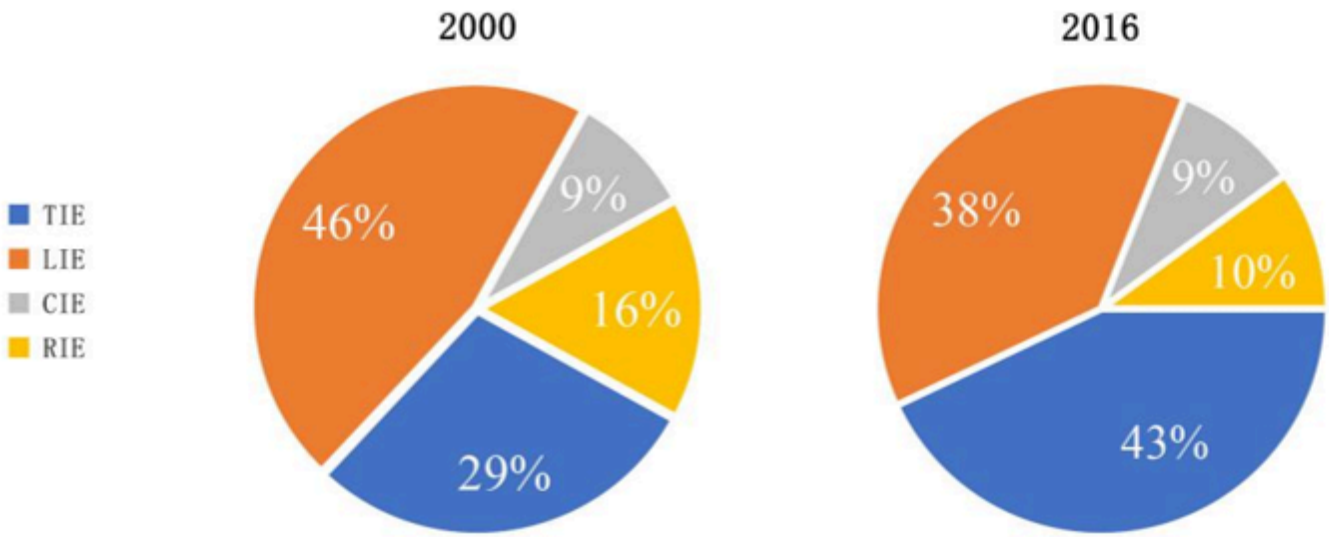


Figure 3

Percentage of number of enterprises in each category

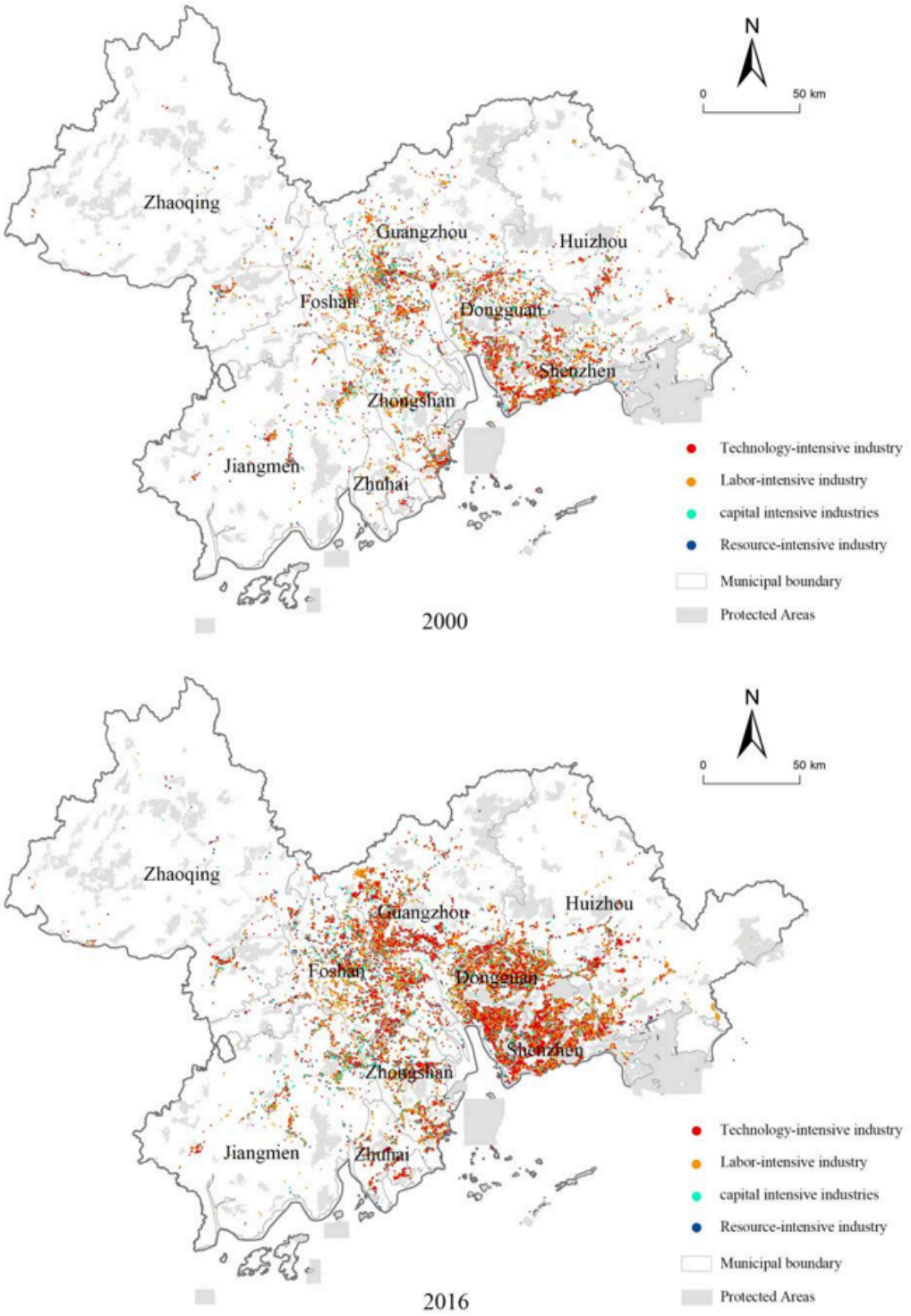


Figure 4

Spatial distribution of enterprises by type