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Article

Multi-Scale Measurement of Regional Inequality in Mainland China during 2005–2010 Using DMSP/OLS Night Light Imagery and Population Density Grid Data

Huimin Xu [1,*], Hutao Yang [1], Xi Li [2,3,4,*], Huiran Jin [4] and Deren Li [2,3]

[1] School of Economics, Zhongnan University of Economics and Law, Wuhan 430073, China; E-Mail: yanghutao@znufe.edu.cn

[2] State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing, Wuhan University, Wuhan 430079, China; E-Mail: drli@whu.edu.cn

[3] Collaborative Innovation Centre of Geospatial Technology, Wuhan 430079, China

[4] Department of Geographical Sciences, University of Maryland, College Park, 20742 MD, USA; E-Mails: hrjin@umd.edu

* Authors to whom correspondence should be addressed;
E-Mails: xuhuimin1985_2008@163.com (H.X.); li_rs@163.com (X.L.) or lixi@whu.edu.cn (X.L.);
Tel.: +86-27-8838-6464 (H.X.); +86-27-6877-8989 (X.L.); Fax: +86-27-8838-6239 (H.X.),
+86-27-6877-8989 (X.L.)

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Abstract: This study used the Night Light Development Index (NLDI) to measure the regional inequality of public services in Mainland China at multiple scales. The NLDI was extracted based on a Gini Coefficient approach to measure the spatial differences of population distribution and night light distribution. Population data were derived from the dataset of China's population density grid, and night light data were acquired from satellite imagery. In the multi-scale analysis, we calculated the NLDI for China as a whole, eight economic regions, 31 provincial regions, and 354 prefectural cities for the two years of 2005 and 2010. The results indicate that Southwest China and Northwest China are the regions with the most unequal public services, with NLDI values of 0.7116 and 0.7251 for 2005, respectively, and 0.6678 and 0.6304 for 2010, respectively. In contrast, Northern Coastal China had the lowest NLDI values of 0.4775 and 0.4312 for 2005 and 2010, respectively, indicating that this region had the most equal public services. Also, the regional inequality of Mainland China in terms of NLDI has been reduced from 0.6161 to 0.5743 during 2005–2010.

The same pattern was observed from the provincial and prefectural analysis, suggesting that public services in Mainland China became more equal within the five-year period. A regression analysis indicated that provincial and prefectural regions with more public services per capita and higher population density had more equal public services.

Keywords: regional inequality; China; Lorenz Curve; night light; remote sensing

1. Introduction

China has experienced fast economic growth and urbanization since the end of the 1970s when the Reform and Opening policy was officially implemented. Although China's economy is growing rapidly, its uneven spatial pattern is evident. In China, strong contrasts exist between East and West, rural and urban regions, and even between different districts of the same city. Unequal regional development may cause social instability that hinders sustainable development [1,2]. Therefore, it is important to measure the regional inequality of China. Scholars attempted to measure this inequality with socioeconomic indicators such as Gross Domestic Product (GDP), GDP per capita, consumption, and investment [3–8]. A number of studies revealed that China's regional inequality had increased since the 1990s and began to decline after 2004 [9,10]. However, a new study found that much of the apparent increase in regional inequality and the reversal since 2005 is a statistical artifact due to using the registered population rather than the resident population [11].

Recently, researchers have realized that public services are important for sustainable development [12–15], and studies have consequently been carried out measuring regional inequality of public services such as education and health care in China [16–19]. Nearly all the previous studies used regionally aggregated indicators to measure the regional inequality. For example, provincial data were used to measure the regional inequality of China as a whole [10,20], and prefectural or county data were used to measure the intra-provincial inequality [21,22]. This strategy does not account for the intra-regional inequality of the basic unit (e.g. prefectural cities), and therefore the inequality of these units was unknown. It is difficult to get disaggregated data for these basic units, especially at the prefectural scales, thus the intra-regional inequality is unknown.

In contrast to daytime remote sensing which is widely applied in land cover mapping [23–28], climate change analysis [29,30], and disaster management [31], night light remote sensing is an emerging technique that can potentially provide spatially continuous socioeconomic indicators because human activities are strongly correlated to night light [32,33]. Night light remote sensing has been widely used in many fields including socioeconomic parameter estimation [34–36], urbanization evaluation [37,38], fishing boat mapping [39], land cover mapping [40–43], and humanitarian disaster evaluation [44–46]. This technique provides an opportunity to map spatial distribution of GDP [47,48], energy consumption [49,50], and public services [51,52]. For China studies, the night light remote sensing has played an important role for evaluating the urbanization. As brightness of the land surface at night can help to discriminate urban areas from non-urban areas, extracting the urban extent by using a threshold applied in night time imagery has proved effective [38,53]. Therefore, multi-temporal night light images have been widely used to study China's rapid urbanization process.

Based on this approach, Gibson and his colleagues found that the annual expansion rate of China's lit area in 287 prefectural cities during 1993–2012 is 8%, which is higher than 5% from official statistical yearbooks [37]. Yi and his colleagues proposed an Urban Light Index (ULI) to evaluate the urbanization process in 34 prefectural cities in Northeast China. They found that the ULI has increased during 1992–2010, and the urbanization is most significant during 2004–2010 [54]. Huang and his colleagues made use of night light images to evaluate city size and rank in China during 1992–2008, they found that the distribution of city sizes became more even during the period and the greatest change in city size distribution occurred during 2000–2003 [42]. Tan investigated the spatial pattern of China's urbanization during 1992–2010 using night light images. He found that the urban areas expanded much more quickly in the 2000s than the 1990s, and Eastern China had the most rapid urban growth in 1990s, while Middle China had the highest rate in the 2000s [55].

Since night light is an indicator of a number of socioeconomic parameters, the spatial disparity of night light has the potential to reflect the spatial disparity of development. A night light development index (NLDI) has been proposed to quantify the difference between population distribution and wealth distribution, the results of which are used to infer regional inequality [56]. The NLDI has been used to measure the inequality at national, sub-national, and gridded scales. One major advantage of NLDI is that the spatial inequality can be calculated at fine spatial scales. For example, Zhou and his colleagues used aggregated night light and population census data to measure the intra-regional inequality of China's 30 provinces for 2010 [57], and Liu and his colleagues utilized night light images to measure the development disparity of different ethnic groups in China during 2000–2013 [58]. In this study, night light is viewed as an indicator of public services rather than GDP. This is because: (1) the major component of night light is public lighting [59], which can reflect regional public services [51,52], and regions with poor lighting can be viewed as regions with poor public services; (2) although night light is strongly correlated with GDP at large scales such as administrative regions and coarse spatial resolution grid, the relationship at finer scales remains unknown; and (3) GDP in agricultural sectors is poorly related to night light [33,60], as rural areas in developing countries are typically totally dark at night. For these reasons, night light is a good proxy for public services rather than GDP, and thus can help to evaluate public services with regard to their regional inequality. The purpose of this study was to measure the regional inequality of public services inside multi-scale regions and their changes during 2005–2010, using spatially continuous night light and population density grid data.

2. Study Area and Data

2.1. Study Area and Original Data

In this study, we make analysis at four scales, China as a whole, economic regions, provinces, and prefectural cities. China comprises 34 provincial regions, including 31 provinces in Mainland China, as well as Hongkong, Macau, and Taiwan. This study only focused on the 31 provincial regions in Mainland China. Hongkong, Macau, and Taiwan were excluded due to the lack of population density grid data. In China, provinces are the first-level administrative regions, and prefectural cities are the second level. All prefectural regions are included in this study. In China, counties are generally under governance of prefectural cities, but there are some counties that do not belong to any prefectural cities, which are called provincial counties. Therefore, all provincial counties (or the regions at the same level) are viewed as prefectural cities, which compose China's administrative regions at the second level. Four cities of Beijing, Tianjin, Shanghai, and Chongqing, directly under governance of the central government, are viewed as prefectural cities in the prefectural analysis. In total, 355 cities and counties were defined as prefectural cities. However, Ge'ermu City in Qinghai Province with no population density grid data available was excluded from this study. Thus, a total of 354 prefectural cities were used for the analysis.

Eight economic regions have been defined by China's Development Research Center of the State Council [61], and used in existing studies [38]. Table 1 lists the eight economic regions with their provincial members, and Table 2 lists the number of prefectural cities in different provinces. Figure 1 shows the map of the provincial and economic regions, and Figure 2 shows the map of the prefectural cities in China.

Table 1. Eight economic regions and their provincial members.

Economic Region	Provinces
Northeast China (NEC)	Liaoning, Jilin and Heilongjiang
Northern Coastal China (NCC)	Beijing, Tianjin, Hebei and Shandong
Southern Coastal China (SCC)	Fujian, Guangdong, and Hainan, Taiwan, Hong Kong and Macao
Eastern Coastal China (ECC)	Shanghai, Jiangsu and Zhejiang
Middle Reaches of the Yellow River (MRYLR)	Shaanxi, Shanxi, Henan and Inner Mongolia
Middle Reaches of the Yangtze River (MRYTR)	Hubei, Hunan, Jiangxi and Anhui
Southwest China (SWC)	Yunnan, Guizhou, Sichuan, Chongqing and Guangxi
Northwest China (NWC)	Gansu, Qinghai, Ningxia, Xizang(Tibet) and Xinjiang

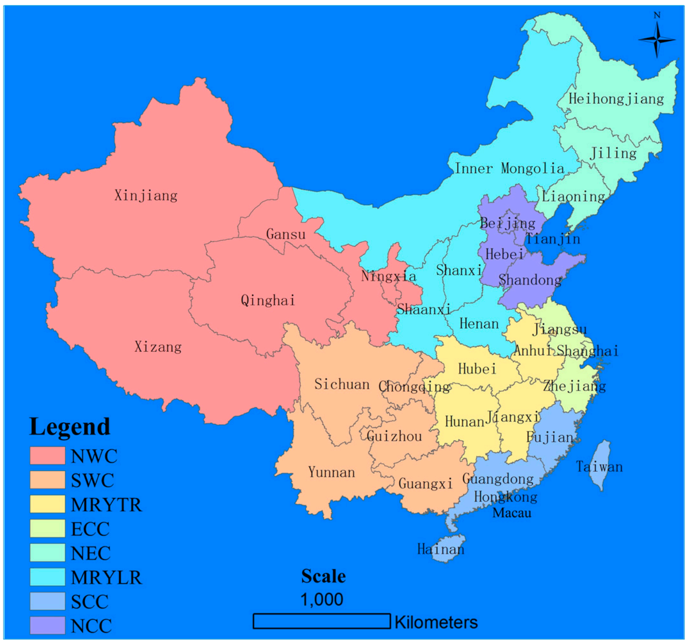

Figure 1. The distribution of provincial regions and economic regions in this study. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

Table 2. Number of prefectural cities in the 31 provinces (excluding Hongkong, Macau, and Taiwan).

Province	Number of Prefectural Cities	Province	Number of Prefectural Cities
Anhui	17	Jiangxi	11
Beijing	1	Jilin	9
Chongqing	1	Liaoning	14
Fujian	9	Ningxia	4
Gansu	14	Qinghai	8
Guangdong	22	Shaanxi	10
Guangxi	13	Shandong	17
Guizhou	9	Shanghai	1
Hainan	18	Shanxi	11
Hebei	11	Sichuan	21
Heilongjiang	13	Tianjin	1
Henan	17	Xinjiang	15
Hubei	15	Xizang	7
Hunan	13	Yunnan	16
Inner Mongolia	12	Zhejiang	11
Jiangsu	13	-	-

Figure 2. The distribution of the prefectural regions of China. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

Population density grid and night light imagery were used to calculate regional inequality. The population grid images with a spatial resolution of 1 km for 2005 and 2010 were downloaded from Global Change Research Data Publisher & Repository [62]. The population grids describe the residential population but not the registered population (Hukou population), so that it represents where people actually live.

The night light images for 2005 and 2010, with a spatial resolution of about 1 km, were derived from the annual composite product of Defense Meteorological Satellite Program's Operational Linescan System (DMSP/OLS), and were downloaded from National Geophysical Data Center [63]. To avoid radiometric problems such as over-saturation that occurs in urban centers [64,65], we used the radiance calibrated product. Compared to the traditional DMSP/OLS stable products [66], the radiance calibrated product provides much better radiometric attributes so that it quantifies the actual night light more accurately. Unfortunately, the radiance calibrated product is not available for 2005. However, the data for 2004 and 2006 are available, so we generated an estimated radiance calibrated product for 2005 by averaging the products from 2004 and 2006. This averaging operation can be viewed as simple linear interpolation to estimate the night light in 2005. It is worth noting that the radiance calibrated product is deemed to be unitless. All the geographic data were projected to the Albers Conical Equal Area Projection.

2.2. Aggregating Night Light Images and Population Grids

A previous study showed that the DMSP/OLS night light images have a spatial error of about 2 km [67]. Although that study did not utilize the radiance calibrated products we used, we should be cautious regarding the potential spatial mismatch between the night light images and population grids. To reduce the spatial mismatch, we aggregated the data using an 8 × 8 pixel window, producing night light and population data on an 8 km grid. Thus the spatial error is likely much less than 0.5 pixel. Although some spatial details are suppressed after the aggregation process, the general difference between the night light and population grid remains, and thus the aggregated data are still effective to measure the regional inequality. The population density grids for 2005 and 2010 are shown in Figures 3 and 4, and the night light images are shown in Figures 5 and 6.

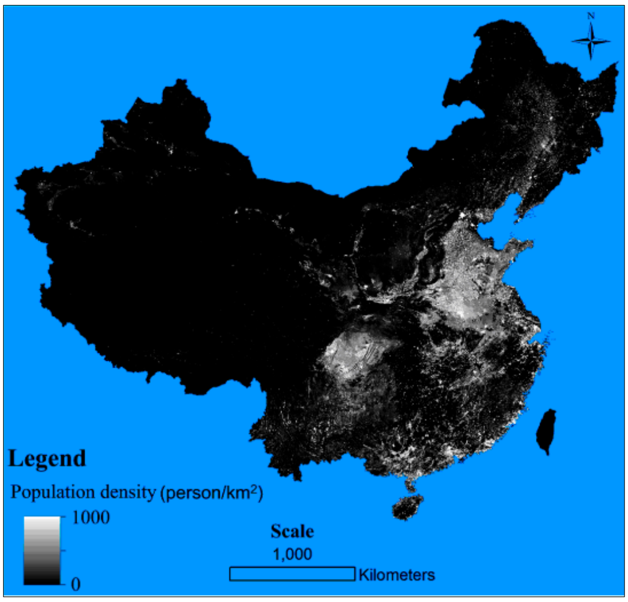

Figure 3. The population density grid data of China for 2005. The population density of 1000 persons/km^2 and larger was assigned the maximum brightness. Taiwan, Hongkong, and Macau are all in black color due to lack of data. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

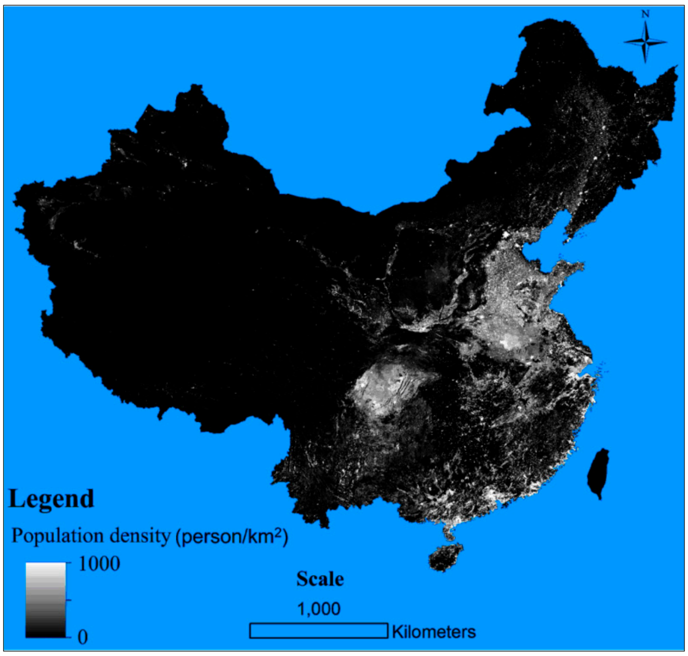

Figure 4. The population density grid data of China for 2010. The population density of 1000 persons/km^2 and larger was assigned the maximum brightness. Taiwan, Hongkong, and Macau are all in black color due to lack of data. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

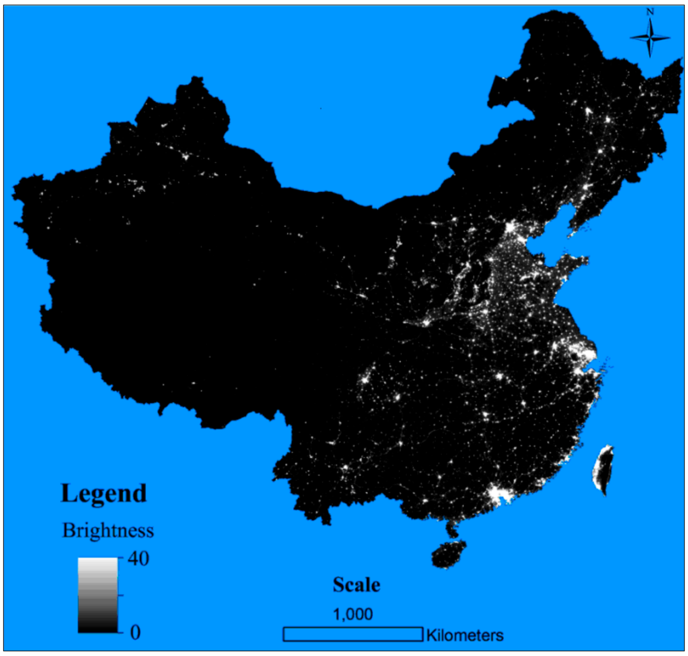

Figure 5. The DMSP/OLS (Defense Meteorological Satellite Program's Operational Linescan System) night light imagery of China for 2005. Note: the brightness of 40 and larger was assigned the maximum brightness. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

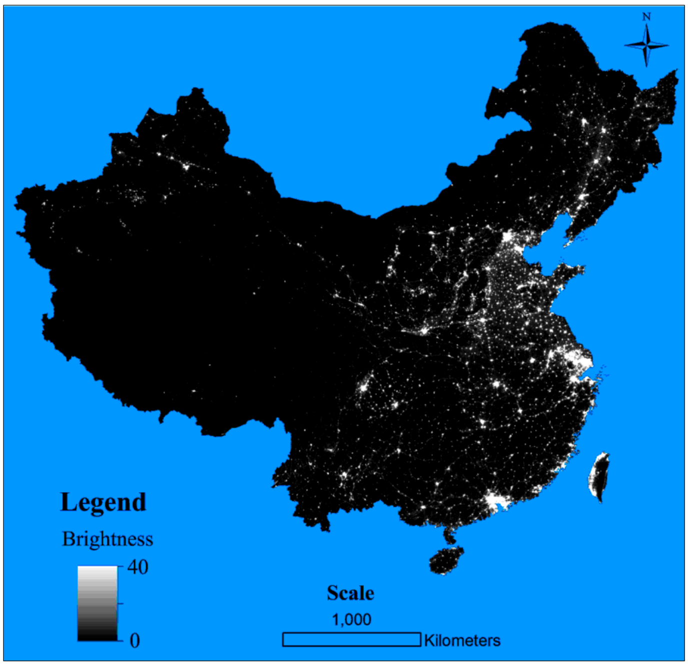

Figure 6. The DMSP/OLS night light imagery of China for 2010. Note: the brightness of 40 and larger was assigned the maximum brightness. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

3. Methodology

We employed the Night Light Development Index (NLDI) to measure the regional inequality of public services from population density grid and night light [56]. The NLDI is based on the concept of the Gini Coefficient that (1) the regional inequality is high if a minority of residents live in an area producing the majority of the night light; (2) the regional inequality is low if the spatial distribution of night light is highly consistent with the spatial distribution of the population density [56]; and (3) the NLDI is between 0 and 1, where 0 represents perfect equality and 1 represents extreme inequality.

The following three steps were conducted to calculate the NLDI for a certain region. First, areas with a zero population density were excluded from the analysis, since such areas are not relevant to our study. Second, a Lorenz Curve was extracted, showing the relationship between cumulative population and cumulative night light. Finally, the Lorenz Curve was used to calculate the NLDI, as shown in Figure 7.

The NLDI for Mainland China as a whole, the eight economic regions, the 31 provincial regions, and the 354 prefectural regions were extracted for both 2005 and 2010. As an example, the Lorenz Curve for Mainland China for 2005 is presented in Figure 8.

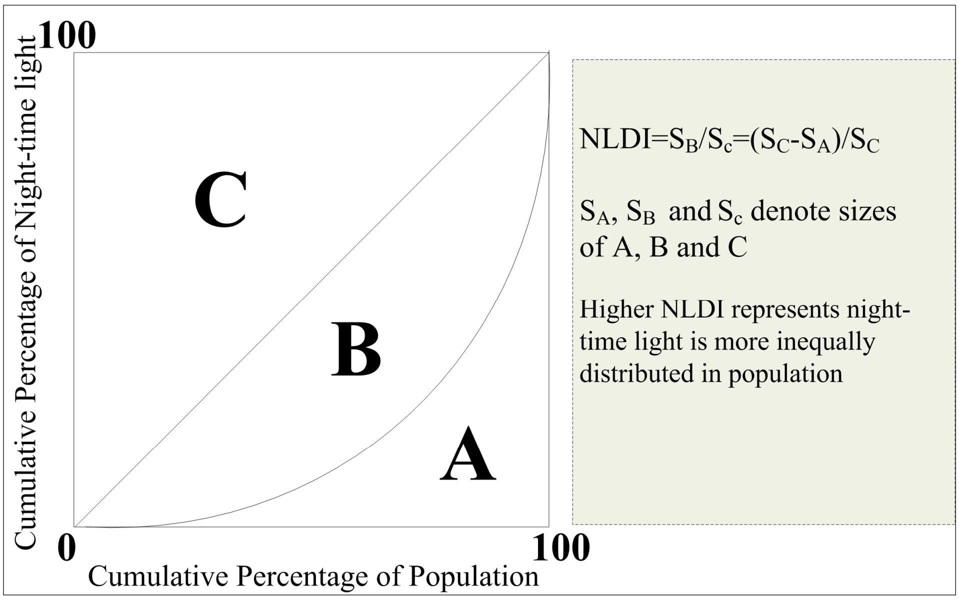

Figure 7. The Night Light Development Index (NLDI) based on the Lorenz Curve.

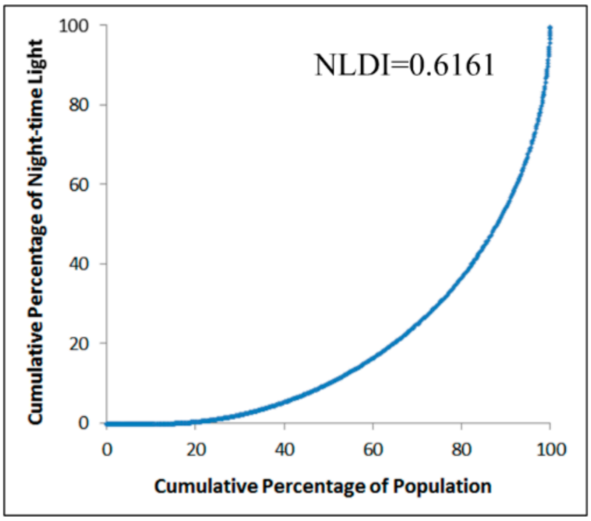

Figure 8. The Lorenz Curve of Mainland China for 2005.

4. Results and Discussion

4.1. Regional Inequality of the Economic Regions

The NLDI for Mainland China and the eight economic regions was derived as shown in Table 3 and Figures 9 and 10. NLDI values of the eight economic regions range from 0.4572 to 0.7251 for 2005 and from 0.4312 to 0.6678 for 2010, showing the regional inequality varies among different economic regions. Southwest China (SWC) and Northwest China (NWC), the least developed regions in China, have the highest NLDI for both 2005 and 2010. Northern Coastal China (NCC) and Eastern Coastal China (ECC) have the lowest NLDI for both 2005 and 2010, indicating these regions have the most equally distributed public services.

The patterns of NLDI change between 2005 and 2010 were summarized by categorizing change in three classes:

$$NLDI_{change} = \begin{cases} \text{increase: } NLDI_{2010} - NLDI_{2005} \geq 0.01 \\ \text{constant: } 0.01 > NLDI_{2010} - NLDI_{2005} \geq -0.01 \\ \text{decrease: } -0.01 > NLDI_{2010} - NLDI_{2005} \end{cases} \quad (1)$$

NLDI decreased in seven out of eight economic zones (*i.e.*, NCC, MRYLR, NEC, MRYTR, SCC, SWC, and NWC), indicating an increase in the equality of public services. Among these regions, Northwest China had the largest NLDI decline, indicating that regional equality was most improved in this region. Eastern Coastal China (ECC) is the only region with an NLDI increase, indicating that the regional inequality increased during the period. For Mainland China as a whole, NLDI declined from 0.6161 to 0.5743 between 2005 and 2010, indicating that public services became more equally distributed over Mainland China during this period.

Table 3. NLDI of Mainland China and the eight economic regions for 2005 and 2010.

Region	$NLDI_{2005}$	$NLDI_{2010}$	NLDI Change
Mainland China	0.6161	0.5743	Decrease
Northern Coastal China (NCC)	0.4775	0.4312	Decrease
Eastern Coastal China (ECC)	0.4572	0.4882	Increase
Middle Reaches of the Yellow River (MRYLR)	0.5548	0.5190	Decrease
Northeast China (NEC)	0.5222	0.4811	Decrease
Middle Reaches of the Yangtze River (MRYTR)	0.5798	0.5421	Decrease
Southern Coastal China (SCC)	0.6639	0.6081	Decrease
Southwest China (SWC)	0.7116	0.6678	Decrease
Northwest China (NWC)	0.7251	0.6304	Decrease

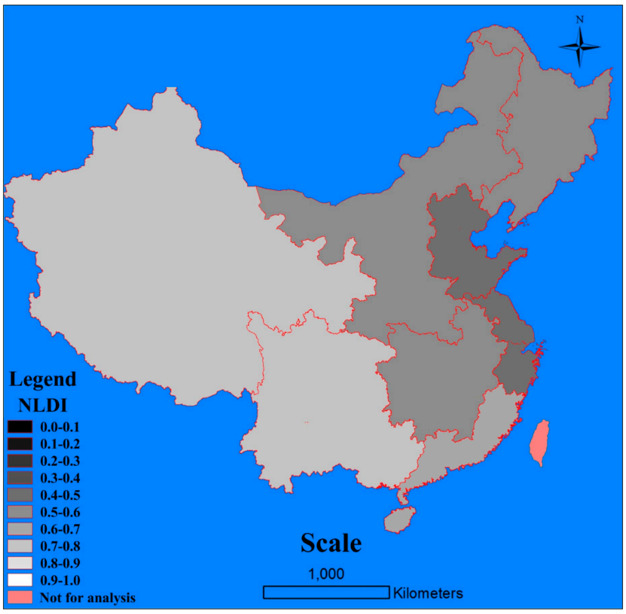

Figure 9. Night light development index (NLDI) of the eight economic zones for 2005. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

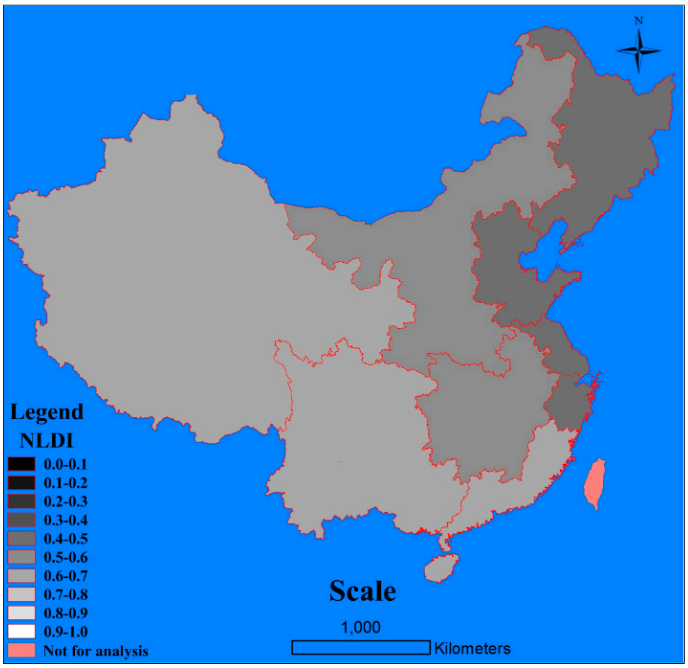

Figure 10. Night light development index (NLDI) of the eight economic zones for 2010. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

4.2. The Regional Inequality of Provincial Regions

The NLDI of the 31 provinces for 2005 and 2010 are shown in Table 4 and in Figures 11 and 12.

Table 4 shows that Beijing, Shanghai, Tianjin, Hebei, and Liaoning have the lowest NLDI values for 2005, indicating public services were most equally distributed in these regions at that time. For 2010, the lowest NLDI provinces were Beijing, Shanghai, Shandong, Hebei, and Henan. In contrast, Sichuan, Yunnan, Guangxi, Gansu, and Xizang (Tibet) have the highest NLDI for 2005. But in 2010, the highest NLDI provinces are Xizang, Sichuan, Guizhou, Inner Mongolia, and Chongqing for 2010. These highest NLDI provinces, except Inner Mongolia, are all located in Southwest China (SWC) and Northwest China (NWC) for both 2005 and 2010, emphasizing the patterns previously found in the economic regions, indicating public services are most unequally distributed in SWC and NWC. Specifically, Xizang is the only provincial region with NLDI larger than 0.8 for both 2005 and 2010. Comparing the NLDI data for 2005 and 2010 using the categorization in Equation (1), we found that nine provinces have increased NLDI, one province has constant NLDI, and 21 provinces have decreased NLDI. This finding shows that the number of provinces becoming more equal is larger than the number of provinces becoming more unequal. Among the ten provinces in Southwest China and Northwest China, nine provinces decreased NLDI during 2005–2010, and only one province (Chongqing) increased NLDI. This trend demonstrates that the regional inequality of Western China was reduced during the period.

We also generated histograms of the NLDI of the provinces to investigate their distribution as shown in Figure 13. We found that the provincial NDLI is concentrated in the range 0.3–0.7 for both 2005 and 2010. By comparing the two histograms, the number of provinces with NLDI between 0.7 and 0.8 has been greatly reduced, from three provinces to zero. This reduction is a major contribution of NLDI reduction over Mainland China.

Table 4. The NLDI of the 31 provinces for 2005 and 2010.

Province	$NLDI_{2005}$	$NLDI_{2010}$	NLDI Change	Province	$NLDI_{2005}$	$NLDI_{2010}$	NLDI Change
Beijing	0.2861	0.3526	Increase	Ningxia	0.5956	0.5833	Decrease
Shanghai	0.3076	0.3045	Constant	Shaanxi	0.5989	0.5708	Decrease
Tianjin	0.3181	0.4087	Increase	Chongqing	0.6248	0.6434	Increase
Hebei	0.3634	0.3854	Increase	Jiangxi	0.6287	0.5817	Decrease
Liaoning	0.3899	0.4419	Increase	Jilin	0.6471	0.4635	Decrease
Zhejiang	0.4047	0.4944	Increase	Inner Mongolia	0.6574	0.6476	Constant
Shandong	0.4186	0.3796	Decrease	Qinghai	0.6657	0.5838	Decrease
Shanxi	0.4422	0.4070	Decrease	Xinjiang	0.6689	0.6045	Decrease
Fujian	0.4504	0.5173	Increase	Guizhou	0.6858	0.6559	Decrease
Jiangsu	0.4628	0.4931	Increase	Guangdong	0.6969	0.6323	Decrease
Henan	0.4703	0.3708	Decrease	Sichuan	0.6998	0.6740	Decrease
Hainan	0.5181	0.4463	Decrease	Yunnan	0.7013	0.6497	Decrease
Heihongjiang	0.5440	0.5171	Decrease	Guangxi	0.7278	0.6233	Decrease
Hunan	0.5475	0.5737	Increase	Gansu	0.7862	0.5979	Decrease
Hubei	0.5629	0.4971	Decrease	Xizang	0.8531	0.8292	Decrease
Anhui	0.5716	0.5048	Decrease	-	-	-	-

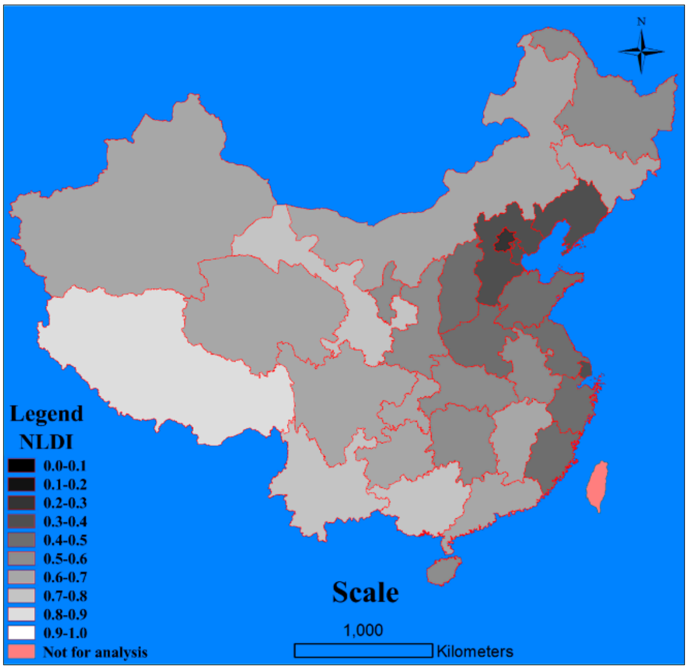

Figure 11. Night light development index (NLDI) of the 31 provinces for 2005. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

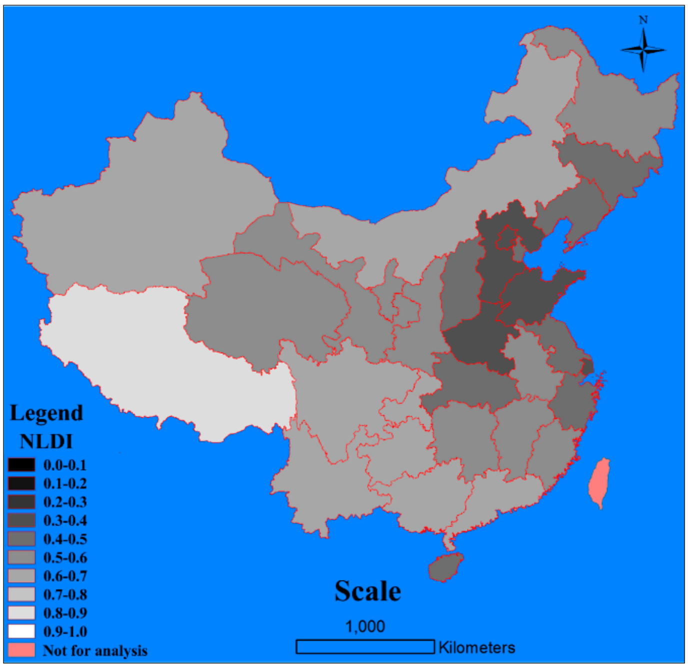

Figure 12. Night light development index (NLDI) of the 31 provinces for 2010. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

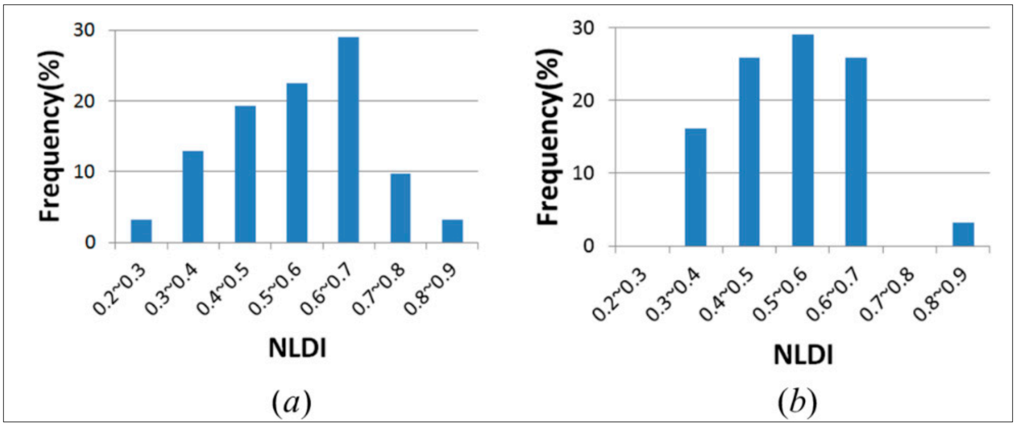

Figure 13. The statistical distribution of NLDI of 31 provinces: (**a**) NLDI frequency for 2005; (**b**) NLDI frequency for 2010.

We hypothesize that the regional inequality at the provincial scale shown in Figures 11, 12 is related to population density variations: Beijing, Shanghai, Shandong, Tianjin, and Henan with low NLDI are all densely populated regions, while Yunnan, Guizhou, Gansu, and Xizang with high NLDI are all sparsely populated regions. Empirical evidence suggests sparsely populated regions in China tend to be less developed. As a consequence, low night light per capita tends to be associated with high NLDI. To test these hypotheses, we regressed population density and NLDI, and night light per capita and NLDI. Areas with no residents were excluded from the analysis. The best function for the regression was found to be a power function. The regression results are shown in Figure 14.

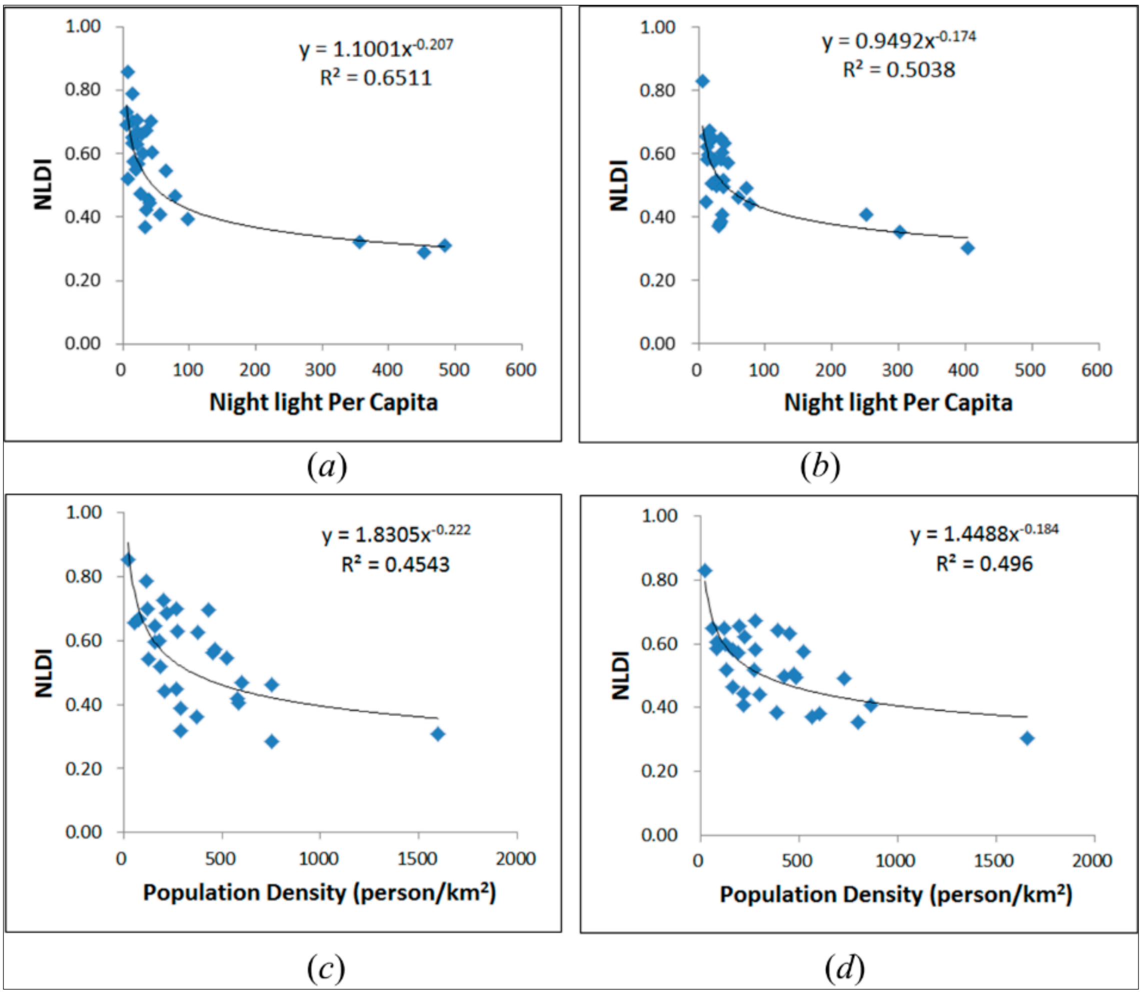

Figure 14. The regression analysis for 31 provinces: **(a)** night light per capita versus NLDI for 2005; **(b)** night light per capita *versus* NLDI for 2010; **(c)** population density versus NLDI for 2005; and **(d)** population density *versus* NLDI for 2010.

From Figure 14, we find that the night light per capita has a strong relationship with NLDI; the regression analyses for 2005 and 2010 have R^2 of 0.6511 and 0.5038, respectively. This analysis suggests that a provincial region with more public services per capita has more equally distributed public services. In addition, the population density also has a relationship with NLDI, suggesting that regions of higher population density have more equally distributed public services, although this relationship is less strong, with R^2 values of 0.4543 and 0.496 for 2005 and 2010, respectively.

4.3. The Regional Inequality of Prefectural Regions

The NLDI of the 354 prefectural cities for 2005 and 2010 is mapped in Figures 15, 16 (see the Appendix of the tabulated data). We found that Jiayuguan City (Gansu Province), Lingshui County (Hainan Province), and Zaozhuang City (Shandong Province) are the three prefectural cities with the lowest NLDI in 2005 and the inferred most equal public services, and these cities have a low NLDI in 2010. Bazhong City (Sichuan Province), Changdu Area (Xizang), and Zhangye City (Gansu Province) are the three prefectural cities with the highest NLDI in 2005 and the most unequal public services. Bazhong City and Changdu Area remain the most unequal in 2010, while the NLDI in Zhangye City was greatly reduced from 0.9456 to 0.5806. Using the definition given by Equation (1), we found that 95 out of the 354 prefectural cities indicate an NLDI increase during 2005–2010, 219 cities indicate an NLDI decrease during 2005–2010, and 40 cities indicate a constant NLDI during the period. This finding shows that the number of prefectural cities becoming more equal is larger than those becoming more unequal during 2005–2010. As shown in Figures 15 and 16, the spatial distribution of NLDI at a prefectural scale is similar to that of the provincial scale as shown in Figures 11 and 12—Beijing, Tianjin, Hebei, and Shandong (all located in Northern Coastal China) have a low NLDI, where the Southwest and Northwest China have a high NLDI for both 2005 and 2010.

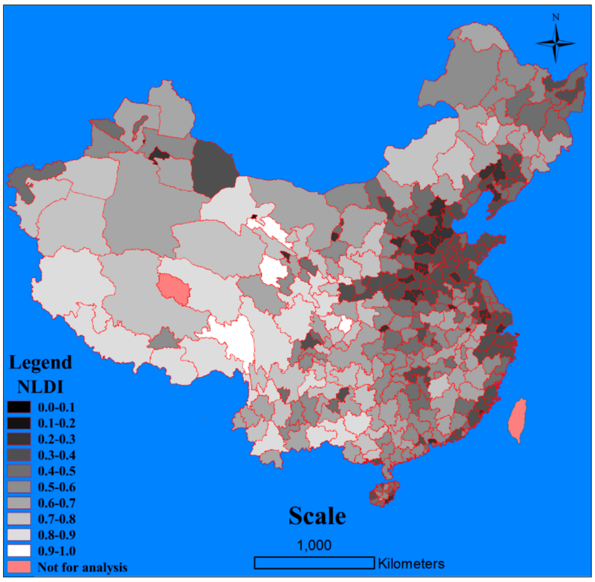

Figure 15. Night light development index (NLDI) of the 354 prefectural cities for 2005. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

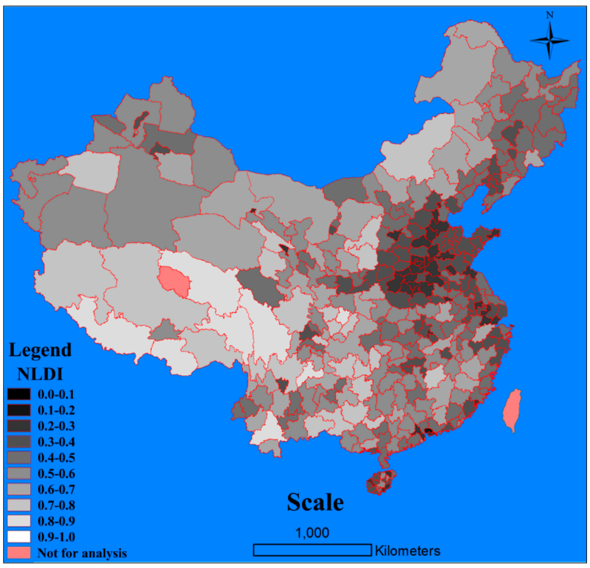

Figure 16. Night light development index (NLDI) of the 354 prefectural cities for 2010. South China Sea Islands are not included in this map as they are excluded from analysis in this study and this map is not a map for the entire regions of China.

To see the statistical distribution of the NLDI of the 354 prefectural cities, histograms were generated for 2005 and 2010, as shown in Figure 17. We found that the distribution of the NLDI at the prefectural city scale is not as concentrated as the results at the provincial scale. The number of prefectural cities with very high NLDI (0.8–0.9 and 0.9–1.0) was notably reduced from 2005 to 2010, which contributed to the reduction of NLDI for most of the prefectural cities.

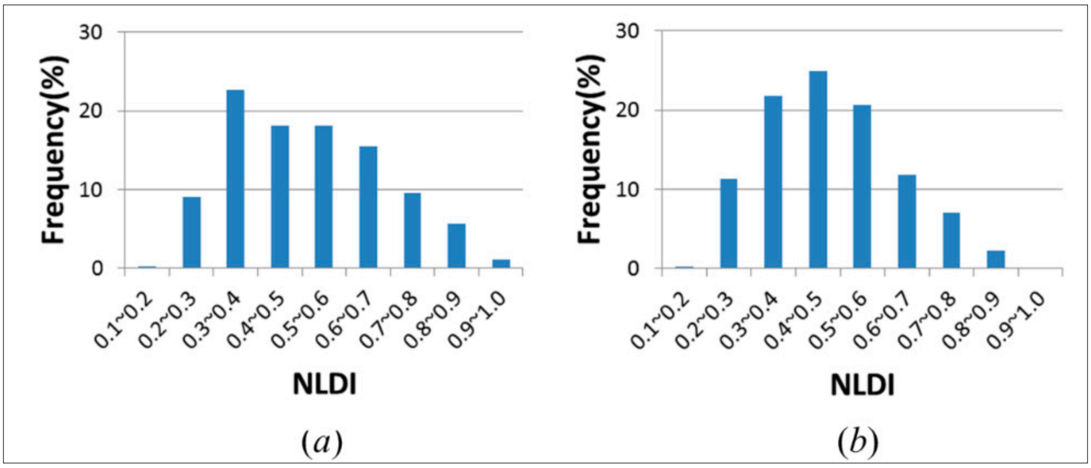

Figure 17. The statistical distribution of NLDI of 354 prefectural cities: (**a**) NLDI frequency for 2005; and (**b**) NLDI frequency for 2010.

As shown in Figure 18, night light per capita and population density is related to NLDI at the provincial scale. From Figure 18a,b we find that the night light per capita is related to the NLDI with R^2 values of 0.4912 and 0.3936 for 2005 and 2010, respectively, suggesting higher public services per capita are associated with more equal public services. Similarly, Figure 18c,d show that the population density is related to NLDI, with R^2 values of 0.3682 and 0.4082 for 2005 and 2010, respectively, again emphasizing the interpretation that regions with higher population density have more equal public services.

As shown in Table 5, we calculated the number of prefectural cities with NLDI > 0.8 in each province as an index to highlight the distribution of cities with highly unequal public services. There were a total of 25 prefectural cities with NLDI > 0.8 in 2005 and 11 in 2010, showing that the number of prefectural cities with very unequal public services was greatly reduced during this period. These cities are distributed in six provinces for 2005 and four provinces for 2010. For 2005, we found that Gansu, Sichuan, Xizang, and Yunnan have more than four prefectural cities with NLDI > 0.8 for each province. It is notably that there was no prefectural city with NLDI > 0.8 in Gansu province in 2010, despite there having been four such cities in 2005. This finding is highly consistent with the observation that the NLDI of Gansu decreased from 0.7862 to 0.5979, as shown in Table 4. All the prefectural cities with NLDI > 0.8 are distributed in Southwest China and Northwest China, which are the regions with highest NLDI as shown in Table 3.

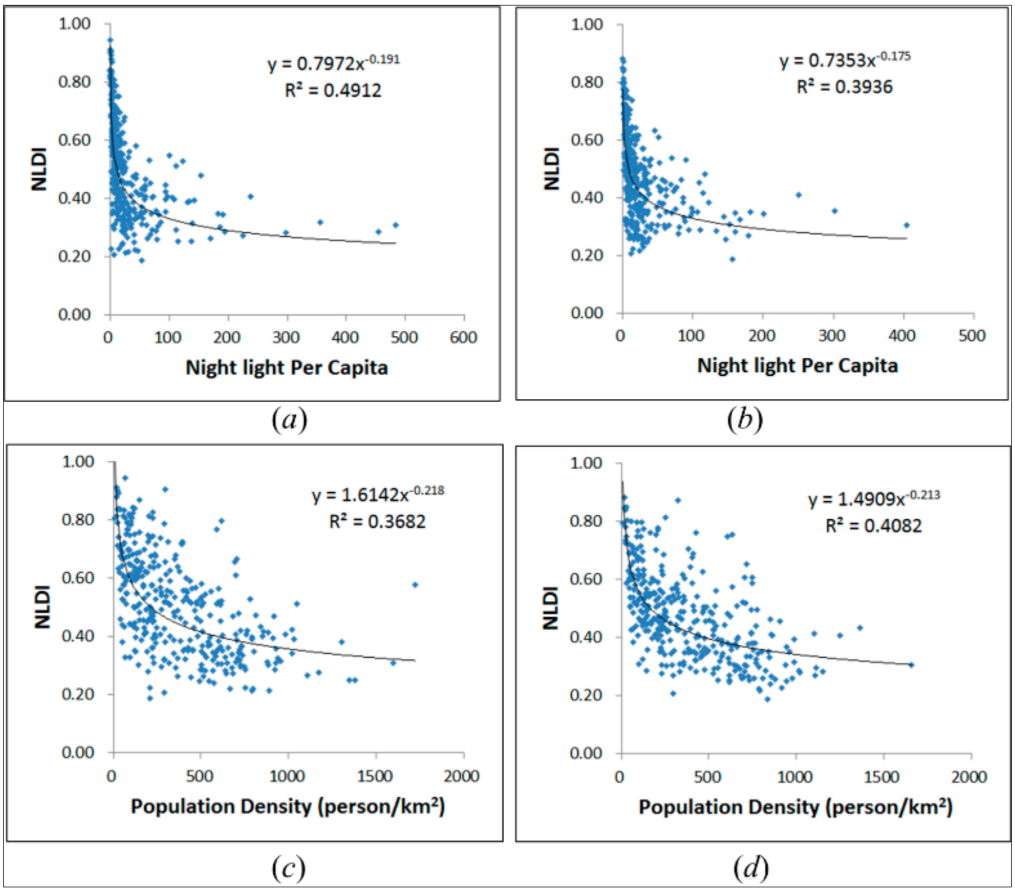

Figure 18. The regression analysis for 354 prefectural cities: (**a**) night light per capita versus NLDI for 2005; (**b**) night light per capita versus NLDI for 2010; (**c**) population density versus NLDI for 2005; and (**d**) population density versus NLDI for 2010.

Table 5. Number of prefectural cities with high NLDI (NPCHN) for 2005 and 2010.

Province	Economic Zone of the Province	$NPCHN_{2005}$	$NPCHN_{2010}$
Gansu	Northwest China (NWC)	6	0
Guangxi	Southwest China (SWC)	2	0
Qinghai	Northwest China (NWC)	2	1
Sichuan	Southwest China (SWC)	5	2
Xizang	Northwest China (NWC)	5	5
Yunnan	Southwest China (SWC)	5	3
	Mainland China	25	11

5. Conclusions

Uneven development in China has brought a number of social problems such as poverty [68] and family separation [69], which are obstacles to China's sustainable development. Measuring the regional inequality of China has long been of interest to the social science community. Most of the researches have focused on inter-regional inequality, such as the disparity among different provinces and disparity between Western China and Eastern China. In contrast, less attention has been paid to intra-regional inequality, especially at the city level, because census data is only available as aggregated data for basic units such as the county or city. This study made use of spatially continuous population data and satellite-observed night light data to calculate the Night Light Development Index (NLDI) as an indicator of intra-regional inequality of public services. Although NLDI has already been used for the world and China [56,57], our study is the first using regions of multiple scales, in particular at the prefectural city scale, and also for change analysis in China.

The overall finding is that the inequality of public services was reduced in China during the period 2005–2010. This finding was observed at all scales of analysis: China as a whole, the eight economic regions, the 31 provinces, and the 354 prefectural regions. The spatial pattern of this reduction in inequality varies by scale of analysis. At all the economic regions scales, Southwest and Northwest China have the highest NLDI indicating the most unequal distribution of public services, whereas Northern Coast China has the lowest NLDI, indicating the most equal distribution of public services. Similar patterns were found at the provincial scale and prefectural region scale. However, strong contrasts in NLDI values are evident within the individual provinces. For example, Southeast China coastal prefectural regions generally have much lower NLDI values than the immediately adjacent regions. Secondly, although there are several factors likely affecting the regional inequality of public services, we found that night light per capita and population density are two important factors, indicating that regions with higher population density and more public services per capita tend to be associated with more equal public services.

As previous studies have shown that the major contributor to night light is street lighting [59], reasons behind the lack of night light in populated areas can be summarized as follows: (1) road networks are absent or sparsely distributed in the area; and (2) there is insufficient street lighting. For example, in the mountainous areas such as Southwest China, the cost of road construction is very high and the road network is limited. Population density is also an important determinant, since investment in the road network is not cost-efficient if there are very few people who can take advantage of the road network. Similarly, a lack of street lighting is very common in many poor areas and especially in rural areas, where local government cannot afford the expense. Where resources are limited, development is likely in only limited areas, suggesting an increased likelihood of spatially unequal infrastructure. Thus higher night light per capita may result in more equality of the night light. These explanations indicate that night light is a proxy for public services, which is likely to be more equally distributed in densely populated regions and developed regions. The multi-scale analysis indicated that Southwest China and Northwest China became more equal in public services. This improvement may be a result of the China Western Development Project in which China's central government invested greatly in the infrastructure, educational, health care, and economy of Western China. This project was designed to reduce the East-West gap and intra-regional gap in Western China. The night light analysis shows that the intra-regional inequality of Western China has been indeed reduced. However, the regional inequality of Southwest and Northwest China is still high, indicating that there is a long way to go for the China Western Development Project.

Due to limit of population density grid data, this study only analyzed the regional inequality for 2005 and 2010, so the comparison analysis can be taken only for these two years. As more population density grid data will be made accessible, the dynamics of the regional inequality of different regions at a different scale can be studied, and a more comprehensive picture on regional inequality of China's development can be drawn in future studies.

Author Contributions

Huimin Xu designed the research, analyzed the data, and wrote the paper, Hutao Yang designed a part of the research, Xi Li collected and analyzed some of the data, Huiran Jin helped to polish the language, and Deren Li designed a part of the research.

Acknowledgments

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Conflicts of Interest

The authors declare no conflict of interest.

Appendix

Table A1. 354 prefectural cities for 2005 and 2010.

Prefectural City	Province	$NLDI_{2005}$	$NLDI_{2010}$
Jiayuguan City	Gansu	0.1871	0.2763
Lingshui County	Hainan	0.2067	0.2069
Zaozhuang City	Shandong	0.2127	0.2394
Zhoushan City	Zhejiang	0.2144	0.2163
Tongling City	Anhui	0.2192	0.3070
Jiaxing City	Zhejiang	0.2216	0.2599
Shennongjia Area	Hubei	0.2245	0.4741
Hebi City	Henan	0.2252	0.2232
Xingtai City	Hebei	0.2394	0.2689
Cangzhou City	Hebei	0.2470	0.2912
Langfang City	Hebei	0.2483	0.2466
Changzhou City	Jiangsu	0.2512	0.3326
Shihezi City	Xinjiang	0.2518	0.4350
Panjin City	Liaoning	0.2586	0.3316
Yingkou City	Liaoning	0.2625	0.3632
Taiyuan City	Shanxi	0.2630	0.2541
Huainan City	Anhui	0.2664	0.2486
Dongguan City	Guangdong	0.2724	0.1868
Zhenjiang City	Jiangsu	0.2736	0.2918
Xiamen City	Fujian	0.2757	0.2956
Fuxin City	Liaoning	0.2789	0.4101
Shenyang City	Liaoning	0.2831	0.3438
Pingdingshan City	Henan	0.2835	0.2538
Wulumuqi City	Xinjiang	0.2841	0.3476
Beijing City	Beijing	0.2861	0.3526

Table A1. *Cont.*

Prefectural City	Province	NLDI2005	NLDI2010
Xuchang City	Henan	0.2869	0.2582
Hengshui City	Hebei	0.2870	0.2756
Xining City	Qinghai	0.2874	0.2966
Shijiazhuang City	Hebei	0.2915	0.3036
Yinchuan City	Ningxia	0.2917	0.3518
Wanning City	Hainan	0.2950	0.2692
Anyang City	Henan	0.2953	0.2640
Jiaozuo City	Henan	0.2975	0.2659
Nanjing City	Jiangsu	0.3015	0.3063
Changjiang County	Hainan	0.3030	0.2854
Baoding City	Hebei	0.3031	0.3644
Changsha City	Hubei	0.3042	0.3370
Linyi City	Shandong	0.3054	0.3717
Jinan City	Shandong	0.3065	0.3062
Shanghai City	Shanghai	0.3076	0.3045
Jinzhou City	Liaoning	0.3104	0.4283
Zibo City	Shandong	0.3106	0.3018
Zhoukou City	Henan	0.3108	0.2586
Tieling City	Liaoning	0.3108	0.4303
Ezhou City	Hubei	0.3110	0.2586
Xinxiang City	Henan	0.3113	0.2828
Wuxi City	Jiangsu	0.3159	0.2807
Tianjin City	Tianjin	0.3181	0.4087
Ningbo City	Zhejiang	0.3193	0.4553
Huaibei City	Anhui	0.3199	0.3351
Yantai City	Shandong	0.3226	0.3517
Qionghai City	Hainan	0.3233	0.3077
Luohe City	Henan	0.3251	0.2283
Taizhou City	Zhejiang	0.3264	0.3773
Weihai City	Shandong	0.3268	0.2971
Shuangyashan City	Heilongjiang	0.3285	0.4079
Jincheng City	Shanxi	0.3289	0.3067
Huzhou City	Zhejiang	0.3293	0.2909
Quanzhou City	Fujian	0.3298	0.4969
Wuhan City	Inner Mongolia	0.3299	0.4218
Tangshan City	Hebei	0.3335	0.3366
Xiangtan City	Hunan	0.3370	0.3813
Putian City	Fujian	0.3373	0.4415
Shaoxing City	Zhejiang	0.3378	0.3529
Yuncheng City	Shanxi	0.3413	0.3064
Suzhou City	Jiangsu	0.3433	0.3504
Tai'an City	Shandong	0.3438	0.2551
Qingdao City	Shandong	0.3451	0.3599
Laiwu City	Shandong	0.3458	0.3301
Xian City	Shaanxi	0.3469	0.3258

Table A1. *Cont.*

Prefectural City	Province	NLDI2005	NLDI2010
Dongfang City	Hainan	0.3470	0.3269
Liaoyang City	Liaoning	0.3479	0.3484
Fushun City	Liaoning	0.3482	0.4309
Shangqiu City	Henan	0.3483	0.2610
Weinan City	Shaanxi	0.3512	0.3220
Luoyang City	Henan	0.3516	0.2814
Binzhou City	Shandong	0.3519	0.3379
Hegang City	Heilongjiang	0.3520	0.4583
Hangzhou City	Zhejiang	0.3528	0.6090
Dezhou City	Shandong	0.3551	0.3817
Beihai City	Guangdong	0.3558	0.3237
Handan City	Hebei	0.3566	0.3441
Pingxiang City	Jiangxi	0.3566	0.3373
Chengdu City	Sichuan	0.3571	0.3164
Quzhou City	Zhejiang	0.3609	0.3440
Liaocheng City	Shandong	0.3613	0.2713
Sanmenxia City	Henan	0.3619	0.3524
Benxi City	Liaoning	0.3631	0.4695
Lianyungang City	Jiangsu	0.3655	0.2868
Jining City	Shandong	0.3664	0.3137
Weifang City	Shandong	0.3669	0.3193
Heze City	Shandong	0.3686	0.2983
Jinhua City	Zhejiang	0.3692	0.3998
Shanwei City	Guangdong	0.3718	0.3126
Liaoyuan City	Jilin	0.3767	0.3427
Huaiyin City	Jiangsu	0.3806	0.3955
Lin'gao County	Hainan	0.3810	0.3171
Hami Area	Xinjiang	0.3816	0.5044
Jieyang City	Guangdong	0.3819	0.4081
Xiaogan City	Hubei	0.3837	0.3904
Dalian City	Liaoning	0.3859	0.4614
Zhangzhou City	Fujian	0.3870	0.3723
Jinzhong City	Shanxi	0.3872	0.3969
Xuzhou City	Jiangsu	0.3874	0.4959
Guiyang City	Guizhou	0.3879	0.4405
Kaifeng City	Henan	0.3907	0.3581
Foshan City	Guangdong	0.3915	0.2867
Zhengzhou City	Henan	0.3942	0.2837
Baoji City	Shaanxi	0.3942	0.3560
Wenzhou City	Fujian	0.3965	0.4286
Yangzhou City	Jiangsu	0.3976	0.3826
Huhehaote City	Inner Mongolia	0.3978	0.4516
Tongchuan City	Shaanxi	0.3992	0.4539
Anshan City	Liaoning	0.4015	0.3501
Rizhao City	Shandong	0.4024	0.3711

Table A1. *Cont.*

Prefectural City	Province	NLDI2005	NLDI2010
Wuhan City	Hubei	0.4024	0.3511
Suqian City	Jiangsu	0.4058	0.3775
Shenzhen City	Guangdong	0.4061	0.2684
Chaozhou City	Guangdong	0.4062	0.4119
Nanchang City	Jiangxi	0.4063	0.3765
Lanzhou City	Gansu	0.4076	0.4328
Yangquan City	Shanxi	0.4091	0.4486
Suihua City	Heilongjiang	0.4091	0.4108
Dandong City	Liaoning	0.4108	0.5060
Wenzhou City	Zhejiang	0.4137	0.3942
Qitaihe City	Heilongjiang	0.4143	0.4648
Chaoyang City	Liaoning	0.4144	0.4607
Puyang City	Henan	0.4163	0.2677
Jingzhou City	Hubei	0.4186	0.4027
Zhongshan City	Guangdong	0.4211	0.2874
Deyang City	Sichuan	0.4216	0.4158
Taizhou City	Jiangsu	0.4243	0.4569
Shuozhou City	Shanxi	0.4286	0.4449
Dongying City	Shandong	0.4288	0.3553
Huangshi City	Hubei	0.4289	0.3465
Baoting County	Hainan	0.4290	0.4251
Huludao City	Liaoning	0.4292	0.4694
Jixi City	Heilongjiang	0.4331	0.4561
Nantong City	Jiangsu	0.4343	0.4620
Bo'ertala Autonomous Prefecture	Xinjiang	0.4352	0.4296
Kelamayi City	Xinjiang	0.4412	0.3844
Jiamusi City	Heilongjiang	0.4421	0.5360
Xinzhou City	Shanxi	0.4426	0.4413
Baotou City	Inner Mongolia	0.4448	0.5317
Chenzhou City	Hunan	0.4452	0.4917
Mudanjiang City	Heilongjiang	0.4455	0.4848
Sanya City	Hainan	0.4507	0.3051
Tunchang County	Hainan	0.4513	0.3039
Ledong County	Hainan	0.4520	0.3939
Yancheng City	Jiangsu	0.4526	0.4531
Changzhi City	Shanxi	0.4526	0.3848
Hefei City	Anhui	0.4534	0.4001
Ningde City	Fujian	0.4542	0.4886
Longyan City	Fujian	0.4557	0.5416
Haikou City	Hainan	0.4565	0.2833
Kezilesuke’erkezi Autonomous Prefecture	Xinjiang	0.4599	0.5100
Zhuzhou City	Hunan	0.4619	0.5062
Nanyang City	Henan	0.4632	0.3494
Datong City	Shanxi	0.4645	0.4074
Qinhuangdao City	Hebei	0.4682	0.4144

Table A1. *Cont.*

Prefectural City	Province	NLDI2005	NLDI2010
Bozhou City	Anhui	0.4687	0.4128
Fuxin City	Anhui	0.4706	0.3957
Siping City	Jilin	0.4708	0.4402
Zhumadian City	Henan	0.4726	0.3962
Maanshan City	Anhui	0.4741	0.3683
Hengyang City	Hunan	0.4797	0.5201
Ha'erbin City	Heilongjiang	0.4798	0.4239
Panzhihua City	Sichuan	0.4822	0.3600
Suizhou City	Hubei	0.4843	0.5640
Danzhou City	Hainan	0.4844	0.3926
Xianyang City	Shaanxi	0.4895	0.4091
Yichang City	Hubei	0.4896	0.4910
Ding'an County	Hainan	0.4920	0.5511
Anshun City	Guizhou	0.4938	0.4960
Wenchang City	Hainan	0.4953	0.4317
Shizuishan City	Ningxia	0.4959	0.4537
Zhangjiakou City	Hebei	0.4987	0.5158
Wuzhong City	Ningxia	0.5029	0.5830
Linfen City	Shanxi	0.5036	0.3662
Qiqiha'er City	Heilongjiang	0.5045	0.5095
Zhangjiajie City	Hunan	0.5054	0.6257
Loudi City	Hunan	0.5087	0.4735
Yingtan City	Jiangxi	0.5089	0.5391
Chuzhou City	Anhui	0.5111	0.4282
Yueyang City	Hunan	0.5116	0.4855
Bengbu City	Anhui	0.5122	0.4813
Guangzhou City	Guangdong	0.5125	0.4152
Yichun City	Heilongjiang	0.5126	0.5218
Yuxi Area	Yunnan	0.5136	0.4943
Yongzhou City	Hunan	0.5159	0.5414
Zhanjiang City	Guangdong	0.5167	0.4431
Lishui City	Zhejiang	0.5174	0.5472
Jingmen City	Hubei	0.5183	0.5223
Maoming City	Guangdong	0.5185	0.5104
Changde City	Hunan	0.5192	0.5071
Huaihua City	Hunan	0.5218	0.5869
Suzhou City	Anhui	0.5231	0.3689
Jiangmen City	Guangdong	0.5233	0.4115
Bayannaoer League	Inner Mongolia	0.5270	0.4277
Kunming City	Yunnan	0.5279	0.4816
Heihe City	Heilongjiang	0.5281	0.5378
Neijiang City	Sichuan	0.5297	0.4966
Zhuhai City	Guangdong	0.5302	0.5229
Lvliang Area	Shanxi	0.5323	0.4662
Xinyu City	Jiangxi	0.5355	0.5220

Table A1. *Cont.*

Prefectural City	Province	NLDI2005	NLDI2010
Chaohu City	Anhui	0.5363	0.4613
Anqing City	Anhui	0.5367	0.4534
Yangjiang City	Guangdong	0.5401	0.4890
Huizhou City	Guangdong	0.5412	0.4439
Yiyang City	Hunan	0.5452	0.5623
Qujing City	Yunnan	0.5466	0.5382
Baisha County	Hainan	0.5470	0.3092
Daqing City	Heilongjiang	0.5490	0.5380
Changji Autonomous Prefecture	Xinjiang	0.5497	0.4867
Xiangfan City	Hubei	0.5504	0.5090
Meizhou City	Guangdong	0.5517	0.4652
Leshan City	Sichuan	0.5523	0.5388
Wuhu City	Anhui	0.5559	0.3541
Shiyan City	Hubei	0.5582	0.5302
Enshi Autonomous Prefecture	Hubei	0.5587	0.4624
Linxia Autonomous Prefecture	Gansu	0.5593	0.4226
Yichun City	Jiangxi	0.5595	0.5324
Lasa City	Xizang	0.5622	0.5703
Huanggang City	Hubei	0.5650	0.4297
Shaoyang City	Hunan	0.5652	0.5763
Xianning City	Hubei	0.5669	0.5235
Guigang City	Guangxi	0.5678	0.4829
Tonghua City	Jilin	0.5707	0.4540
Chengmai County	Hainan	0.5751	0.5190
Shaoguan City	Guangdong	0.5764	0.5525
Qiongzhong County	Hainan	0.5777	0.5398
Qingyuan City	Guangdong	0.5787	0.5553
Hulunbei'er City	Inner Mongolia	0.5788	0.6161
Shantou City	Guangdong	0.5788	0.5098
Meishan City	Sichuan	0.5802	0.4899
Yili Autonomous Prefecture	Xinjiang	0.5896	0.5347
Jingdezhen City	Jiangxi	0.5902	0.4734
Huangnan Autonomous Prefecture	Qinghai	0.5911	0.5179
Yulin City	Guangxi	0.5918	0.4278
Zhaoqing City	Guangdong	0.5944	0.5467
Ya'an City	Sichuan	0.5958	0.6188
Xinyang City	Henan	0.6014	0.5833
Tongliao City	Inner Mongolia	0.6025	0.6029
Hanzhong City	Shaanxi	0.6032	0.5665
Sanming City	Fujian	0.6046	0.6091
Yanbian Autonomous Prefecture	Jilin	0.6049	0.4400
Guyuan City	Ningxia	0.6072	0.5863
Xishuangbanna Autonomous Prefecture	Yunnan	0.6102	0.6191
Guangan City	Sichuan	0.6121	0.6529
Liupanshui City	Guizhou	0.6129	0.5681

Table A1. *Cont.*

Prefectural City	Province	NLDI2005	NLDI2010
Honhhe Autonomous Prefecture	Yunnan	0.6132	0.5939
Tongshi City	Hainan	0.6138	0.4251
Chengde City	Hebei	0.6146	0.6001
E'erduosi City	Inner Mongolia	0.6198	0.6319
Liuzhou City	Guangxi	0.6204	0.5283
Qianxinan Autonomous Prefecture	Guizhou	0.6233	0.5972
Chizhou City	Anhui	0.6236	0.5516
Chongqing City	Chongqing	0.6248	0.6434
Shangrao City	Jiangxi	0.6284	0.5557
Shangluo City	Shaanxi	0.6287	0.6328
Haidong Area	Qinghai	0.6316	0.5469
Aletai Area	Xinjiang	0.6340	0.5874
Dali Autonomous Prefecture	Yunnan	0.6355	0.5109
Xuancheng City	Anhui	0.6363	0.4727
Huangshan City	Anhui	0.6378	0.4996
Hezhou City	Guangxi	0.6380	0.6052
Fuzhou City	Jiangxi	0.6399	0.5919
Xiangxi Autonomous Prefecture	Hunan	0.6400	0.7045
Yunfu City	Guangdong	0.6426	0.5410
Daxing'anling Area	Heilongjiang	0.6427	0.6916
Dehong Autonomous Prefecture	Yunnan	0.6469	0.4674
Baishan City	Jilin	0.6514	0.6348
Jilin City	Jilin	0.6533	0.4464
Ganzhou City	Jiangxi	0.6570	0.6306
Suining City	Sichuan	0.6573	0.6077
Mianyang City	Sichuan	0.6582	0.5722
Songyuan City	Jilin	0.6594	0.4761
Fangchenggang City	Guangxi	0.6600	0.5105
Baoshan City	Yunnan	0.6641	0.4672
Bayinguoleng Autonomous Prefecture	Xinjiang	0.6649	0.5387
Lu'an Area	Anhui	0.6653	0.6058
Zigong City	Sichuan	0.6667	0.5875
Wulanchabu League	Inner Mongolia	0.6725	0.6870
Alashan League	Inner Mongolia	0.6748	0.6006
Heyuan City	Guangdong	0.6769	0.6463
Wuzhou City	Guangxi	0.6773	0.5340
Guoluo Autonomous Prefecture	Qinghai	0.6775	0.4940
Changchun City	Jilin	0.6794	0.3849
Jiujiang City	Jiangxi	0.6829	0.6161
Nanping City	Fujian	0.6842	0.6679
Chongzuo City	Guangxi	0.6857	0.5528
Qiannan Autonomous Prefecture	Guizhou	0.6879	0.6971
Xing'an League	Inner Mongolia	0.6906	0.6015
Tulufan City	Xinjiang	0.6943	0.6139
Tacheng Area	Xinjiang	0.6977	0.5936

Table A1. *Cont.*

Prefectural City	Province	NLDI2005	NLDI2010
Guilin City	Guangxi	0.6979	0.5536
Hetian Area	Xinjiang	0.7001	0.5138
Jinchang City	Gansu	0.7004	0.5537
Xilinguole League	Inner Mongolia	0.7110	0.7365
Haixi Autonomous Prefecture	Qinghai	0.7129	0.6887
Zunyi City	Guizhou	0.7157	0.7018
Chifeng City	Inner Mongolia	0.7164	0.6157
Luzhou City	Sichuan	0.7195	0.6763
Yibin City	Sichuan	0.7201	0.6893
Yan'an City	Shaanxi	0.7213	0.7150
Ankang City	Shaanxi	0.7215	0.6330
Qinzhou City	Guangxi	0.7244	0.6168
Dazhou City	Sichuan	0.7255	0.7617
Ji'an City	Jiangxi	0.7261	0.7555
Bijie Area	Guizhou	0.7373	0.6872
Tongren Area	Guizhou	0.7383	0.7620
Wuwei City	Gansu	0.7434	0.5246
Tianshui City	Gansu	0.7467	0.4599
Laibin City	Guangxi	0.7474	0.7774
Chuxiong Autonomous Prefecture	Yunnan	0.7493	0.6666
Kashi Area	Xinjiang	0.7502	0.5330
Akesu Area	Xinjiang	0.7516	0.7050
Qiandong Autonomous Prefecture	Guizhou	0.7590	0.7480
Liangshan Autonomous Prefecture	Sichuan	0.7666	0.7053
Yulin City	Shaanxi	0.7687	0.7471
Nanchong City	Sichuan	0.7689	0.7490
Lincang	Yunnan	0.7852	0.6714
Nanning City	Guangxi	0.7868	0.5697
Baiyin City	Gansu	0.7886	0.6710
Qingyang City	Gansu	0.7909	0.6750
Haibei Autonomous Prefecture	Qinghai	0.7911	0.7233
Baicheng City	Jilin	0.7925	0.5639
Diqing Autonomous Prefecture	Yunnan	0.7926	0.7251
Naqu Area	Xizang	0.7940	0.7673
Ziyang City	Sichuan	0.7967	0.7536
Linzhi Area	Xizang	0.8080	0.7951
Lijiang Area	Yunnan	0.8082	0.6601
Wenshan Autonomous Prefecture	Yunnan	0.8087	0.7963
Zhaotong City	Yunnan	0.8089	0.8142
Bose City	Guangxi	0.8094	0.7153
Simao Area	Yunnan	0.8128	0.8005
Guangyuan City	Sichuan	0.8137	0.7710
Ganzi Autonomous Prefecture	Sichuan	0.8142	0.8402
Ali Area	Xizang	0.8212	0.7963
Longnan City	Gansu	0.8235	0.6177

Table A1. *Cont.*

Prefectural City	Province	NLDI2005	NLDI2010
Pingliang City	Gansu	0.8265	0.5124
Nujiang Autonomous Prefecture	Yunnan	0.8339	0.6910
Gannan Autonomous Prefecture	Gansu	0.8355	0.6051
Aba Autonomous Prefecture	Sichuan	0.8374	0.7806
Yushu Autonomous Prefecture	Qinghai	0.8390	0.8041
Hechi City	Guangxi	0.8401	0.7748
Dingxi Area	Gansu	0.8446	0.5502
Jiuquan City	Gansu	0.8691	0.6475
Shannan Area	Xizang	0.8807	0.8468
Rikaze Area	Xizang	0.8937	0.8506
Hainan Autonomous Prefecture	Qinghai	0.9021	0.7499
Bazhong City	Sichuan	0.9050	0.8715
Changdu Area	Xizang	0.9123	0.8830
Zhangye City	Gansu	0.9456	0.5806

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