Monitoring of the Human Activities From DMSP/OLS Nighttime Imageries

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Abstract

Here, we illustrate the use of Defence Meteorological Satellite Program-Operational Linescan System (DMSP/OLS) night-time imageries as a dataset to monitor human activities and urban change at regional scale. With the new approach, Compounded Night Light Index (CNLI) was extracted from DMSP/OLS imageries and this process was applied in a special time series from 2000 to 2010. Spatial patterns of CNLI changes showed that human activities such as urbanization and industrialization more dominated in the central-southern parts and coastal areas. In the end, this paper identifies that the mentioned human activities are sharply rising, and its consequences on the environment must be mutually considered.

Introduction

Since the analysis of the digital data of defense meteorological satellite program operational line scanner night-time lights in recent decades, a complex of datasets based on this database have been used to monitor human activities and to detect natural phenomena [7,6,20]. So that visible light images from the DMSP night lights are instruments were originally designed to monitor clouds, weather patterns [10,5] to record city lights manmade, natural fires and natural gas flaring [4], and to map the distribution of human settlements and the spatial distribution of human activities [1]. Data available of DMSP/OLS night-time images can be present by NASA earth observation and national center for environmental information archive from NOAA [3].

[7] reported that popular applications of the DMSP/OLS night time images include measuring impacts of urban growth on the environment, mapping night-time sky brightness and specially evaluating damage from natural disasters and forest fires. In another study, [20] demonstrated the relationship between night-time imageries and greenhouse gases emissions clearly.

Along with the rapid urbanization and dramatic economic growth in Guangdong region in recent decades, some environmental problems, such as air pollution, water pollution, increase in greenhouse gas emissions, and enhanced urban heat islands, are increasing in many parts cities [25]. So, monitoring the dynamics of urbanization levels in study area accurately and quickly plays a fundamental role in understanding the process of urbanization and evaluating its environmental influence [13,14]. However, the authenticity and reliability of China's urbanization level has not reached a consensus. For example, according to the national bureau of statistics, China's urbanization level was 36.22% in 2000, but [19] claimed that it was actually 37.04% in the same year. According to the land use/cover data sets produced by the Chinese Academy of Sciences, the built-up area increased from 31,756 km^2 to 43,852 km^2 during this period [12]. There is no doubt that these changes impress natural resources and environment. But how to monitor and understand the dynamics of urbanization levels quickly and accurately remains a challenging problem in Guangdong region. It was observed that the DMSP/OLS night-time lights data have been utilized in several studies for quantitatively estimating and mapping socioeconomic activities related to urbanization processes from regional to global scales [7].

For example, [21] estimated the global human population using the statistical relationship between night-time lighted area and urban population. Also, [24] adopted multi-temporal DMSP/OLS night-time lights data to estimate regional and global urban growth based on a linear correlation between night light brightness and the urban population. However, using DMSP/OLS data, there were some related studies focused on monitoring the dynamics of urbanization level for the last two decades at multiple scales in Guangdong region, especially the dynamics after 2000. In this way, we tend to develop a quantitative approach by employing the model of CNLI to predict and mapping human activities.

Methodology

Study Area

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Fig. 1, shows the map of World with geographical collation of Guangdong region boundary. Guangdong is a province located in the south of China, and it occupies an area of 179,800 km^2 and bounded by 20º13′-25º31′ North latitudes and 109º39′-117º19′ East longitudes. The Guangdong had 106,440,000 people in 2013.

Fig. 1. Geographical location of Guangdong region, China.

DMSP/OLS, Light Index and CNLI

Mentioned study area was extracted from DMSP/OLS images annually and Mean value of DMSP/OLS was calculated from 2000 to 2010. Then in other to achieve better results, according to Attribute Table and Zonal Statistic operation; was computed original value of Min, Mean, Max, Range, Sum, Standard Deviation and etc of DMSP/OLS images in the study area repeatedly.

Light Index takes two parameters as night light brightness and lit urban areas into account simultaneously. We computed the Light Index at the scale of our study area using the following formula:

$$Light\ Index = I \times S \quad (1)$$

According to analyze the dynamics of human activities, the CNLI was calculated during 2000 to 2010 additionally. The former is closely correlated with urban population and economic scale and the latter is closely correlated with urban area, Therefore changes in the CNLI can reflect the dynamics of urban population size, economic scale, and urban expansion simultaneously [22]. We computed the CNLI at the scale of our study area using the following formula:

$$Compounded\ Night\ Light\ Index = I \times S \quad (2)$$

Where, *I* is the average night light brightness of all lit pixels in a region. It illustrates as follows:

$$I = \frac{1}{N_L \times DN_M} \times \sum_{i=P}^{DN_M} (DN_i \times n_i) \quad (3)$$

where DN_i is the *DN* value of the *i*th gray level, n_i is the number of lit pixels belonging to the *i*th gray level, *P* is the optimal threshold to extract the lighted urban area from the DMSP/OLS images. DN_M is the maximum DN value, and N_L is the number of lit pixels with a *DN* value between *P* and DN_M. *S* is the proportion of lit urban areas to the total area of a region. It can be showed as follows:

$$S = \frac{Area_N}{Area} \quad (4)$$

where $Area_N$ is the area of lit urban areas in a region and *Area* is the total area of the region.

Results and Discussion

Spatial Patterns of DMSP/OLS and CNLI

The process of urbanization and human economic activities was dynamically determined by calculating CNLI data during the period of the 2000 to 2010 (Table 1). This process is increasing from one period to another and also has upward trend annually. By calculating of DMSP/OLS data, CNLI changes showed that urbanization were more dominated in the central-southern parts and coastal area of the study area (Fig. 2). It is clear that CNLI is closely related with human economic activities such as urbanization, mine, agriculture and it also enables to evaluate population density. This phenomenon led to a decrease of the vegetation coverage on mentioned region's surface, because vegetation coverage is under the influence of urbanization and climatic factors in Guangdong region. CNLI are considered as important indicators for evaluating of the trend of urbanization. Fig. 3 shows dynamics of CNLI clearly.

Table 1: Values change table of DMSP/OLS (Mean), Light Index and CNLI of Guangdong Region in 2000 to 2010.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
DMSP/OLS (Mean)	13.9253	13.6524	14.2343	12.0472	14.0026	13.0026	14.163	14.8716	16.497	17.8646	18.5955
Light Index	6.55	6.57	7.13	6.2	7.7	6.23	7.15	8.26	8.28	7.64	9.88
CNLI	0.1034	0.1008	0.1129	0.0975	0.1222	0.0969	0.1124	0.1298	0.1309	0.1190	0.1564

[2] in a research entitled monitoring forest fires over the Indian region using DMSP/OLS night time satellite data concluded that DMSP-OLS data sets derived fire locations were in good agreement with ground observations and multi satellite data sets with an overall accuracy of more than 98%. It means DMSP-OLS have direct relationship with human activities and it impresses land cover dynamics. For example, when value of DMSP-OLS increases, forest fires will be increased and this process can be threading factor for forest. Present findings are consistent with our result, so that human activities such as urbanization and industrialization are rising annually, and subsequently will have different consequences.

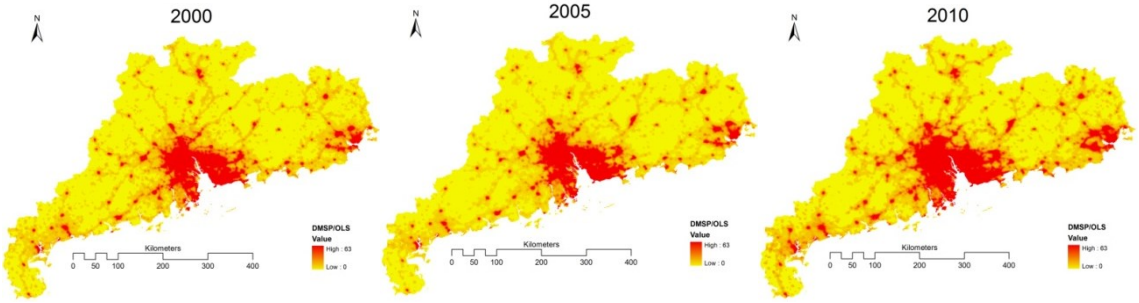

Figure 2: DMSP/OLS value changes during the whole period from 2000 to 2010.

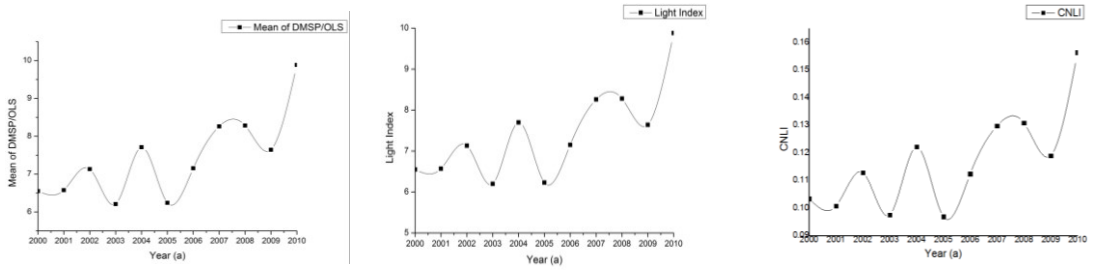

Figure 3: Dynamics of DMSP/OLS (Mean), Light Index and CNLI in Guangdong Region from 2000 to 2010.

Correlation of CNLI and Urbanization Index

Urbanization is a simultaneous process associated with demographic dynamics, socio-economic growth and land-use change and it is a salient human-induced force on environment and ecosystems [18,13]. We tried to find the association between remotely sensed index such as CNLI and endogenous urbanization variables. Table 2 show result of single correlation analysis between CNLI and urbanization index such as built up%, non-agriculture% and urban people% [8,13,16].

We observed that the urban people% and CNLI have relatively strong correlation with the trend of built up% on the whole area of Guangdong region. On the other hand, correlation coefficients of 3 factors with the built up% are relatively large especially in urban people% and CNLI. Again, table 3 presents total trend of three urbanization indexes with CNLI annually. In general, the trend is increasing and with increasing amounts of urbanization index, values of CNLI increase. Thus it can be concluded that urbanization index such as urban people%, non-agriculture% and built up% are connected with CNLI. For example, Table 3 shows that the amounts of buid up%, non-agriculture%, urban people% and CNLI are 7.946035%, 0.908174561%, 0.31185087% and 0.1034 in 2000 respectively.

These amounts with more increasing are 10.285029%, 0.950297155%, 0.5215% and 0.1564 in 2010. In fact quantitative relationships between CNLI and urbanization index indicate diverse responses of DMSP/OLS night-time light signals to anthropogenic dynamics in urbanization process in terms of demographic and economic variables. On the other side, in recent studies, [13] were concluded that using three regression models between night-time weighted light area and four urbanization variables such as population, gross domestic product (GDP), built-up area and electric power consumption; night-time light brightness could be an explanatory indicator for estimating urbanization dynamics at the city level. Therefore expanding human population and human economic activities, by CNLI model using DMSP/OLS data to estimate urbanization dynamics is patterns of urbanization, particularly for cities experiencing rapid urban growth.

Table 2: Correlation between CNLI and three urbanization index.

	Built-Up%	Two Third%	Urban People %	Light Index
Built Up%	1			
Non-agriculture %	0.783206156	1		
Urban People %	0.715862175	0.520838687	1	
CNLI	0.880536569	0.683332326	0.6112	1

Table 3: Review process of urbanization index with CNLI dynamically.

Year	Built Up%	Non-agriculture%	City People %	CNLI
2000	7.946035	0.908174561	0.31185087	0.1034
2001	8.246380	0.917865316	0.483484	0.1008
2002	7.723105	0.924822365	0.31131984	0.1129
2003	8.449690	0.932284987	0.45898521	0.0975
2004	9.367759	0.933813138	0.46808091	0.1222
2005	8.136325	0.936682778	0.45834674	0.0969
2006	8.490129	0.942373107	0.49219358	0.1124
2007	9.226987	0.946642	0.51791855	0.1298
2008	9.570085	0.946380	0.51387329	0.1309
2009	9.875050	0.949085	0.5209	0.1190
2010	10.285029	0.950297155	0.5215	0.1564

Human Factors and CNLI

In November 2002, a form of atypical pneumonia called severe acute respiratory syndrome (SARS) broke out rapidly in the Guangdong regions and surrounding areas in 2002, and the outbreak lasted until 2004 and made serious impact local economy in the recent years. At the epicenter of the outbreak was Guangdong, where the outbreak of SARS[1] infected more than 5,300 people and killed 349 nationwide [15,9]. The SARS epidemic was not simply a public health problem. Indeed, it caused the most severe socio-economic crisis for the Guangdong leadership since the 2002 crackdown. Outbreak of the disease fueled fears among economists that its economy was headed for a serious downturn (https://en.wikipedia.org/wiki/Timeline.of.the.SARS.outbreak/). Then Guangdong region was gradually faced with a major shift in its population between the years of 2005 and 2006, So that scientific resources as national bureau of statistics of China (1995-2010) reported that Guangdong had surpassed Henan and Sichuan province to become the most populous province in China in January 2005, registering 79.1 million permanent residents and 31 million migrants, those lived in the province for at least six months of the year (https://en.wikipedia.org/wiki/Guangdong). Thus it can be undoubtedly concluded that increase or decrease population leaded to oscillation in CNLI model (Fig. 4).

In fact in Fig. 4, the trend of CNLI fluctuations has an upward direction in 2005 to 2006, but due to the climate, environment and other mentioned factors, the dynamics of CNLI was completely altered in 2007 to 2008. This is similar to this brochure that [17] were concluded that the logarithm of population density is highly correlated with the deforestation. Frequently, we faced with the most increasing of human activity in 2009 to 2010, and surly this scenario will have consequences for the environment. Due to during the more than 10 years, the population of Guangdong region increased from 85,225,007 people in 2000 to 104,303,132 person in 2010, although this process has been involved other challenges. Totally with the increase of the population, human activities such as urbanization, development of rural areas and land utilization increase additionally and this issue will affect the land vegetation and other components of the environment. But human activities such as agriculture production, ecological construction significantly drove the improvement of vegetation cover [23]. In addition with development of social economy, people become increasingly aware of the importance of environmental protection and sustainable development to restore forestland or grassland [11].

According to Fig. 4, CNLI increased in 2002, 2004, 2006, 2007 and eventually 2009 to 2010. Mutually CNLI decreased in 2001, 2003, 2005 and 2009. According to satellite imageries and land survey, here it can be concluded that since CNLI has been declined, land vegetation has been rising by ecological driven, so where, reforestation and rangelands and other ecological project have been improved in the recent years. Also controlling land use, planting trees and agro-forestry were closely related to expand land vegetation in the Guangdong region. Additionally it cannot be ignored impacts of climatic factors such as drought, flood and also tropical cyclone on CNLI. Here, we prevent the development of discussion.

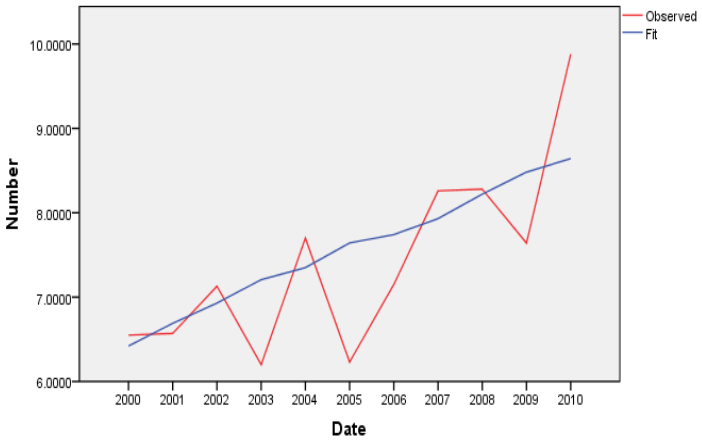

Fig. 4. Fluctuations and Direction model of CNLI

Conclusion

Conclusively, we found that night-time imageries came from DMSP-OLS sensors with identical on board design and continuous space platform, providing a unique and valuable resource for monitoring the long-term dynamics of urbani-

[1] The SARS coronavirus, sometimes shortened to SARS-CoV, is the virus that causes severe acute respiratory syndrome (SARS).

zation and industrialization. In addition, we mapped and analysed spatial patterns of the human activities from 2000 to 2010, and the results of CNLI dynamic was greatly indicated process. We demonstrated that the industrialization and urbanization have sharply expanded form Pearl River (Guangzhou), its delta and surrounding areas. Finally, we agree that the damage to the environment caused by these activities is past the point of no return or that the damage is near the point of no return. By the way, mentioned scenario should to be analyzed to reveal the temporal change of all driving factors.

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