ANALYSIS OF LIGHT INTENSITY DATA BY THE DMSP/OLS SATELLITE IMAGE USING EXISTING SPATIAL DATA FOR MONITORING HUMAN ACTIVITY IN JAPAN

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ABSTRACT:

The main objective of this research is to show how much can be monitored various human activities using night light images by the DMSP/OLS from NOAA/NGDC. In Japan, various human activities can be monitored easily without satellite images because we can use many kinds of detailed spatial dataset and statistics. On the other hand detailed spatial data are not developed adequately especially in developing countries. Night light images by the DMSP/OLS can help to monitor them in such countries.
Therefore we discuss how to use night light images of the DMSP/OLS for this objective in Tohoku region, Japan. Human activates were explained by 3 factors, i.e. road distribution, accumulation of buildings and dynamic population. These data and light images of the DMSP/OLS were resampled into the same aggregate unit and compared with a light intensity of the DMSP/OLS. In addition it is shown which factor of human activates explains the light intensity more clear than other factors by multiple regression analyses using all factors. Results of multiple regression analyses show that impacts by road distribution are strong in urban and suburban areas and impacts by building are strong in rural areas. Impacts by dynamic population are weak in all areas.
Finally estimated images of light intensities were developed using results of multiple regression analysis and they were compared with the actual image of light intensity. The compared result shows that tendency of spatial distribution of the light intensity by the estimated result agrees rather well with tendency by the DMSP/OLS.

1. INTRODUCTION

Monitoring for location and shape of urban areas are very significant task for planning of urban development, disaster prevention, crime prevention and environmental problems in broad metropolitan areas. However, it is often the case that developments of basic spatial data, e.g., distributions of population or infrastructures are poor especially in developing countries (Takashima and Hayashi, 2001). Paucity of basic data is one of the major obstacles to address above problems.

1.1 Previous Studies

There are many previous studies to try to monitor locations and shapes of urban areas without dependence on existing spatial data or statistics. One of such method is to use night light images by the Defense Meteorological Satellite Program's Operational Linescan System (DMSP/OLS) from the National Oceanic and Atmospheric Administration's National Geophysical Data Center (NOAA/NGDC). For example, Imhoff et al. (1997a) and Small et al. (2005) showed distribution and expansion of urban areas in United States and some major cities around the world using DMSP/OLS images. Some studies also tried to monitor various human activities using them. For example, Elvidge et al. (1997b) showed a relationship between spatial distribution of light intensity with business activity or electricity consumption. Likewise, Dobson et al. (2000a) showed a relationship with population distribution and Ghosh et al. (2009) showed with GDP. In addition there are some studies to estimate present state of urban areas using DMSP/OLS images. For example, Takahashi and Hayashi (2001) estimated population distribution and the number of buildings and Kohiyama et al (2000b) estimated distributions of damaged areas by earthquakes.

1.2 Objective

As stated above, many studies have monitored distributions of urban areas and estimate human activities using DMSP/OLS images. On the other hand, there are a few studies to show which kind of human activities are especially reflected in the DMSP/OLS images because of paucity of spatial data which can be used for such verifications adequately especially in developing countries. On the other hand there are many kinds of micro-accurate spatial data in Japan. It was expected to be showed that the DMPS/OLS images reflect which kinds of human activities to compare existing spatial data in Japan with DMSP/OLS images to aggregate by same spatial units.
Therefore we have developed data of human activities by distributions of people, buildings and roads using existing spatial data of Japan and showed correlations between light intensity of DMSP/OLS images with them. In addition we have showed which the most affected factor for light intensity by multiple regression analyses with the light intensity and these 3 factors not only in whole study area, but also in urban, suburban and rural areas. We have already developed same kind of analyses in limited areas (Akiyama et al. (2011a), Sengoku et al. (2010)). In this paper, we have improved data of human activates and expanded study areas.

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2. DATA DEVELOPMENT

Night light images of the DMSP/OLS, road data (lines), building data (polygons) and grid data of dynamic population were aggregated into same spatial units (1km square grid).

2.1 Study Area

A study area is whole area of Tohoku region, Japan (Figure 2). Tohoku region is located in northeast part of Japan. The total area is about 6.69km^2 and population is about 9.2 million. The largest city is Sendai city (population is about 1.05million) and many major cities are connected by the Shinkansen (bullet train). There are relatively broad suburban areas adjoined major cities. In addition there are many small cities (under 10 thousand population). On the other hand, there are broad depopulated rural areas and mountain forest areas. As a result we decided that this area is an appropriate area for our study.

2.2 Aggregate Unit

An aggregate unit is the 1km-square grids called Japanese standard regional mesh (Hyojun Chiiki Mesh in Japanese; It is described the "Regional Mesh" in following text.). Many statistical grid data in Japan are aggregated into this grid. There are 69,814 grids in Tohoku region.

2.3 Resampling of DMPS/OLS Images

In this paper, we only explain how to resample night light images of the DMSP/OLS (image opportunities of Japan are approximately 20:00~21:00 in 2008) into the Regional Mesh. Details about images of the DMSP/OLS were showed in previous studies (e.g. Elvidge et al. 1997b). Pixel size of the DMSP/OLS images is 30 arcseconds. The average length of 1 degree of longitude and latitude around the centroid of Tohoku region (E140.62, N39.17, wgs1984) is approximately 98784.40m, and 30 arcseconds is approximately 823.20m. The pixel size and the pixel shape of the DMSP/OLS discord the Regional Mesh. Therefore light intensity of the DMSP/OLS was resampled as Equation 1.

$$NV_i = \sum_{k_i=1}^{n} \frac{SD_{k_i}}{SR_i} V_{k_i} \tag{1}$$

where SR_i is area of the Regional Mesh i, SD_{ki} is divided areas of DMSP/OLS pixels by the Regional Mesh i, V_{ki} is DMSP/OLS light intensity in each divided areas of DMSP/OLS pixels, and NV_i is the resampled light intensity of the Regional Mesh i. In the case of figure 1, NV_i is calculated as equation 2.

$$NV_i = \frac{SD_1V_1 + SD_2V_2 + SD_3V_3 + SD_4V_4}{SR_i} \tag{2}$$

Figure 3 shows a grid map of resampled light intensity by NV_i.

2.4 Development of Road Grid Data

Road line data of highway, main road and other road in Tohoku region was developed by the national census map data in 2005 provided by Center for Spatial Information Science, The University of Tokyo. Total road length of 3 kind of road in each Regional Mesh was calculated to divide all road line data by the Regional Mesh polygons. Average luminance of road surface in Japan is set as Table 1 by Japan Road Association (2007). R_A in table 1 means road with continuous light,

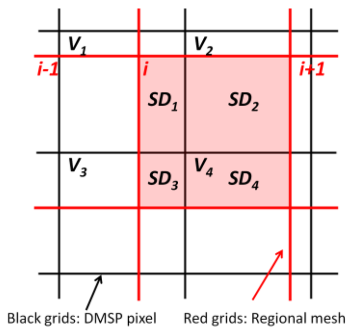

Figure 1. Spatial gap between DMSP/OLS pixels and the Regional Meshes

R_B means with intermittent light, and R_C means with few light affecting road traffic. Values in parentheses are road with light blocking structures on median zone. Values in Table 2 are decided by Table 1. In urban area, this value set as large as possible and in rural area, it set as small as possible.*1 in Table 2 are 0 in Table 1, however they are set 0.1 in this study because it is expected that they emit a weak light from street lamps in some intersections. Estimated light intensity by road in each Regional Mesh is defined as equation 3 based on road length in each Regional Mesh and values in Table 2.

$$L_n = R_H LH_n + R_M LM_n + R_O LO_n \tag{3}$$

where R_H (R_M / R_O) are luminance of road which were changed by region types, LH_n (LM_n / LO_n) is road length of highway / main road / other road in mesh n, and L_n is estimated light intensity by road in mesh n. Figure 4 shows a road grid map of road distribution in Tohoku region.

Road type	External condition (cd/m^2)		
	R_A	R_B	R_C
Highway (R_H)	1.0	1.0 (0.7)	0.7 (0.5)
Main road(R_M)	1.0 (0.7)	0.7 (0.5)	0.5 (0)
Other road(R_O)	0.7 (0.5)	0.5 (0)	0.5 (0)

Table 1. Average luminance of road surface in Japan

Road type	Region type		
	Urban	Suburban	Rural
Highway (R_H)	1.0	1.0	0.5
Main road(R_M)	1.0	0.7	- (*1)
Other road(R_O)	0.7	- (*1)	- (*1)

Table 2. Luminance of road in this study

2.5 Development of Building Grid Data

Digital residential maps in 2008 (ZmapTOWN II, by ZENRIN CO., LTD) were used as building distribution data. Locations, shapes, areas and kinds of building everywhere in Japan can be collected using this data. The kinds of building means an application which contains residential buildings, multi-tenant buildings, shop and office buildings, warehouses and car garages. In addition, we can monitor applications of each floor or room (shops and offices, residential rooms and others which contain vacant rooms) in the case of multi-tenant buildings.

At first, point data of all building centroids in Tohoku region were developed. Secondly, warehouses and car garages were removed because it is considered that these kinds of buildings are not illuminant. Finally areas of illuminant building in each grid are defined as Equation 4.