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WEB-GIS for visualizing land use/cover change in mega-cities in developing countries

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Abstract

In connection with the exponential increase of data, the Internet and distributed computing provide the technical framework for processing big data. WEB-GIS provides a gateway to discover and access geographic WEB services, which help to visualize the geographical data for GIS users. In particular, for the mega-cities in developing countries that experienced rapid urbanization in the past decades, the WEB-GIS can help users to understand the urbanization process in a more comprehensive manner.

Key words: data visualization, google earth, LULC data, remote sensing, WEB-GIS

1. Introduction

With the development of computational capability, mobile devices and Internet technology, people around the world generate large amounts of data during every minute of the day. These raw and unstructured data sets are growing exponentially (Wamba *et al*. 2015). An important topic in recent years is how to analyze and extract significant information from these data.

Satellite images are so-called big data consisting of high-resolution optical products which are captured by remote sensing technology. These data sets contain large volumes of information. By using digital image processing techniques, we can now transform the binary data into apprehensible information. The remote sensing techniques play a significant role in observing and analyzing human activities. Based on this background, the present study attempts to visualize satellite images employing WEB-GIS techniques. The technological development of GIS has evolved from the desktop GIS to the wired Internet GIS and to wireless Mobile GIS (Tait 2005). WEB-GIS is a robust way to represent various geographical information (Yin *et al*. 2015).

The raw high-resolution satellite images are unfriendly to the users. In order to obtain the required information such as land use and land cover (LULC) distribution, digital image processing techniques are useful to extract the features from the binary data.

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2. Study areas and methodology

2.1 Target areas

In the past few decades, most of the mega-cities in Asia and Africa have experienced rapid urbanization due to economic globalization (Murayama *et al*. 2015). In this study, we selected 18 mega-cities in Asian and African regions to examine the spatial growth of mega-cities during the 15 years (2000-2014) including Bamako, Bangkok, Beijing, Cairo, Dhaka, Dubai, Hanoi, Jakarta, Kathmandu, Kuala Lumpur, Manila, Nairobi, New Delhi, Pyong Yang, Seoul, Taipei, Tehran and Yangon. The target area is a 100 × 100 km extent for each city.

2.2 Framework of the study

Fig. 1 shows the workflow of this study. In the first phase, data collection and digital image processing are implemented by including generating LULC maps and evaluating energy consumption intensity maps. In the second phase, a WEB-GIS is developed to visualize the changes in land use/cover and energy consumption intensity.

Two types of satellite images are utilized to achieve different requirements. Landsat data are used to process the LULC map, and the DMSP-OLS night-light data are used to construct the energy consumption intensity map. The method developed by Murayama *et al*. (2015) is employed here for the classification of Landsat satellite image data.

The DMSP-OLS data are a global wide night-time satellite images. The NGDC Earth Observation Group (EOG) specializes in night-time observations of lights and combustion sources worldwide (http://ngdc.noaa.gov/eog/index.html). In 1994, the EOG started providing DMSP data and producing a time series of annual cloud-free composites of DMSP night-time lights. With the night radiance light satellite data, the morphology and intensity of the development within human activities can be detected at a moderate spatial scale. The DMSP-OLS data are useful for measuring the intensity pattern of energy consumption.

The anthropogenic heat flux density based on DMSP-OLS night radiance light satellite data has been estimated in many previous studies (Bing and Guang-yu 2012; Chen and Chen 2014; Yang et.al. 2014). From previous results, it is known that a strong linear relationship exists between the energy consumption intensity and the average night-

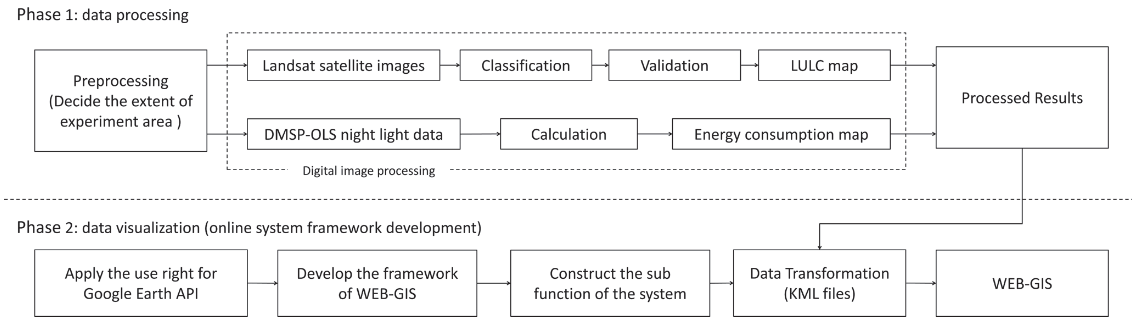

Fig. 1 Workflow of the WEB-GIS development.

time light radiance intensity. Furthermore, the research by Elvidge *et al*. (1999) already indicated that the night-time light data can be used to estimate the power consumption, gas emissions and other economic indicators.

2.3 Online system

The WEB-GIS based online system is developed through the Google Earth API (GEAPI) version for JavaScript language. With the GEAPI, users can handle the 3D world map through the browser, which means they can easily access the site from mobile devices. Furthermore, as the GEAPI provides a robust way to design the online WEB-GIS, the terrain and 3D building layers can easily be added by using Google Earth.

GEAPI supports the KML language. Therefore, developers can convert geographic data to KML type, and to display the data in Google Earth in various kinds of applications. In this study, the classified LULC maps are converted into the KML format by this way.

The online WEB-GIS consists of two parts, i.e., the map function and accordion control function. If users click the title of each city, the city centre is automatically shown. Then users can select the map to view. The current LULC map remains on the screen even when users jump to map of another city because the layer data are already saved in the browser. With this function, the user can compare two cities easily.

3. Discussion

3.1 Overview of the online system

Recently, users and researchers of spatial information can easily generate various maps by using a robust desktop GIS. However, it is difficult for general users to access geographical data and thematic maps.

To observe and measure how human activities impact rapid urbanization, we created LULC maps based on Landsat satellite images and measured energy consumption intensity maps with the radiance night-time light data. We built an online WEB-GIS to share the data with the public (Fig. 2).

It is important to discuss the relative merits of GEAPI. The good points of using GEAPI are that it reduces the development cycle time cost, and provides many powerful function packages for developers, such as the worldwide administrator boundary layer, terrain layer, 3D building layer, etc. With such functions, the LULC maps can be well represented in the earth model. We can evaluate the cities by thematic maps, terrain and morphology of buildings. One of the weak points of the GEAPI is that if the KML file size is too big, the loading time of data becomes quite long. To solve this problem, separation of the study area into several small tile parts would be an effective method.

3.2 LULC categories

LULC data were categorized into eight classes: urban dense, urban sparse, forest, cropland, grassland, bare land,

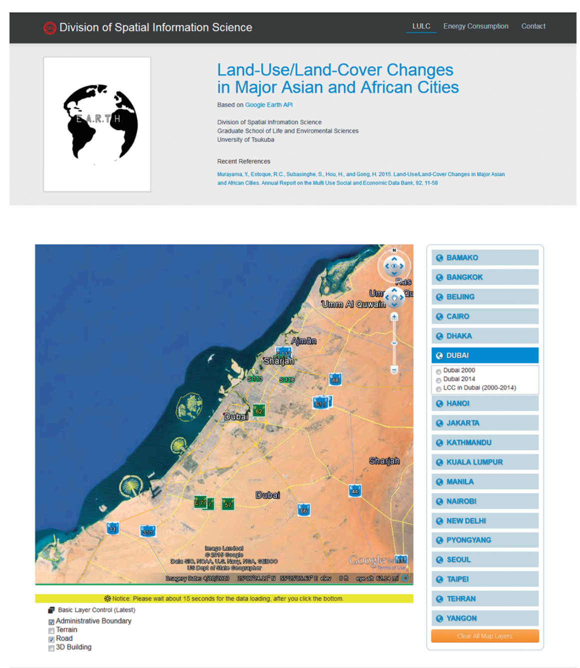

Fig. 2 WEB-GIS developed in this study.
(http://giswin.geo.tsukuba.ac.jp/capital-cities/)

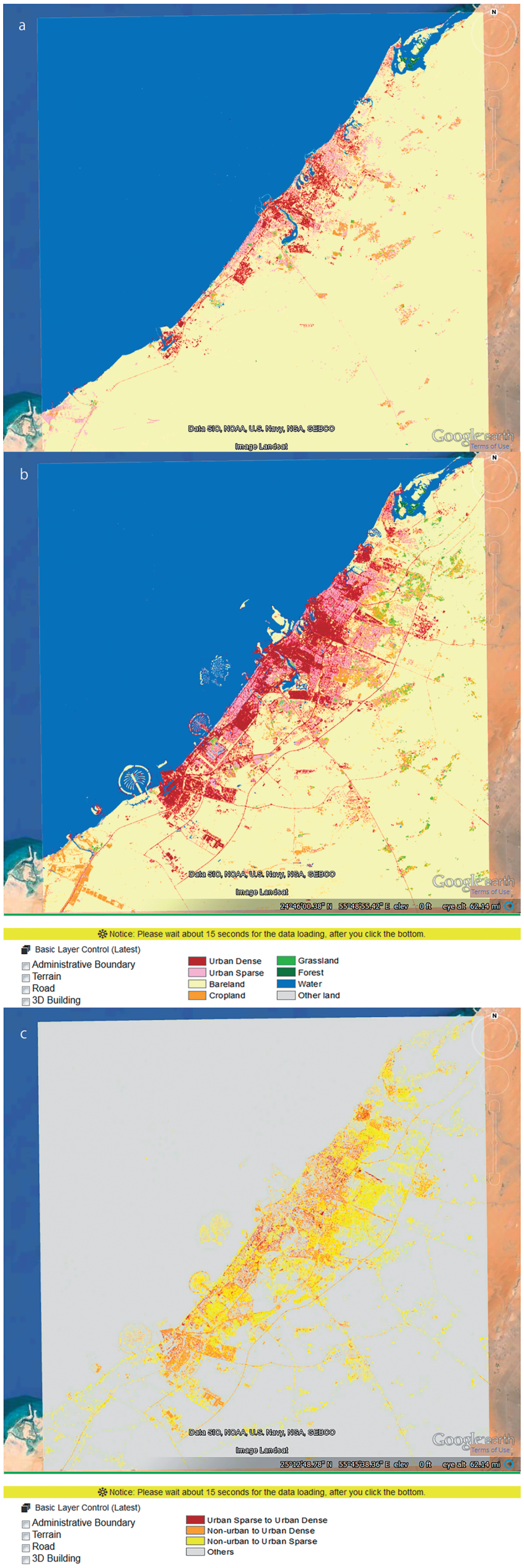

Fig. 3 LULC map in 2000 (a), LULC map in 2014 (b), land cover change map between 2000 and 2014 for Dubai (c).

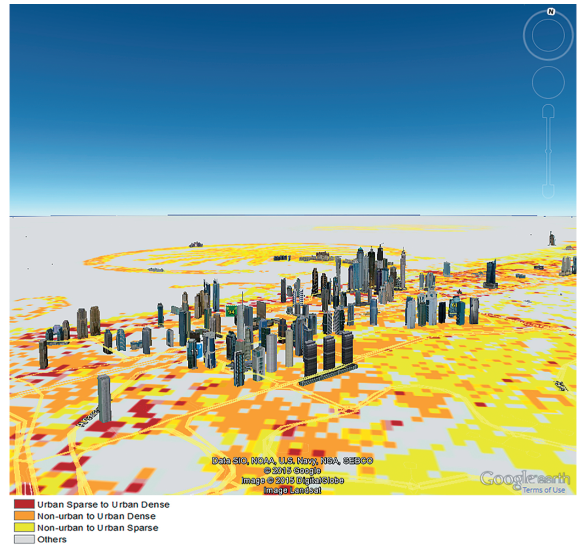

Fig. 5 The LULC change map in 3D view mode.

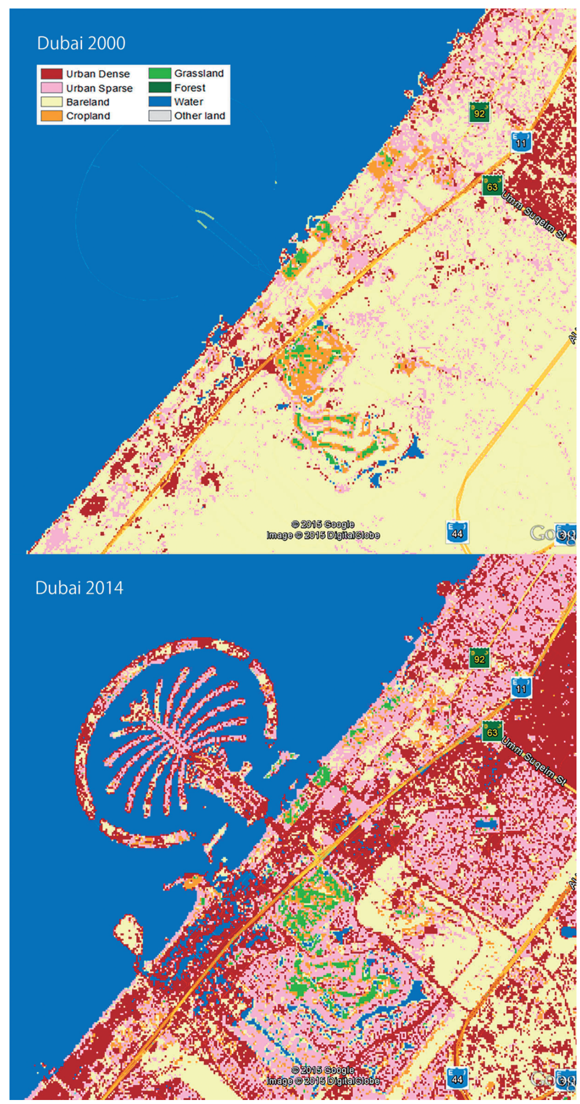

Fig. 4 Center area of Dubai.

water and other land. The class of other land includes clouds, shadow, snow and other conditions. This classification category was followed in Lwin and Murayama (2013).

With the WEB-GIS, we can compare two time periods for each city. Fig. 3a shows LULC map for Dubai in 2000, and Fig. 3b in 2014. We can understand what kinds of spatial changes have occurred since 2000. Fig. 3c shows the LULC change for Dubai during the last 15 years between 2000 and 2014.

The LULC changes in Dubai are dominant especially in the central area (Fig. 4). The range of the central area is about 4km^2. With the 3D view of WEB-GIS, we can know that the relationship between vertical development and urban land use change is highly correlated. In Fig. 5, the base layer is the LULC change map for Dubai.

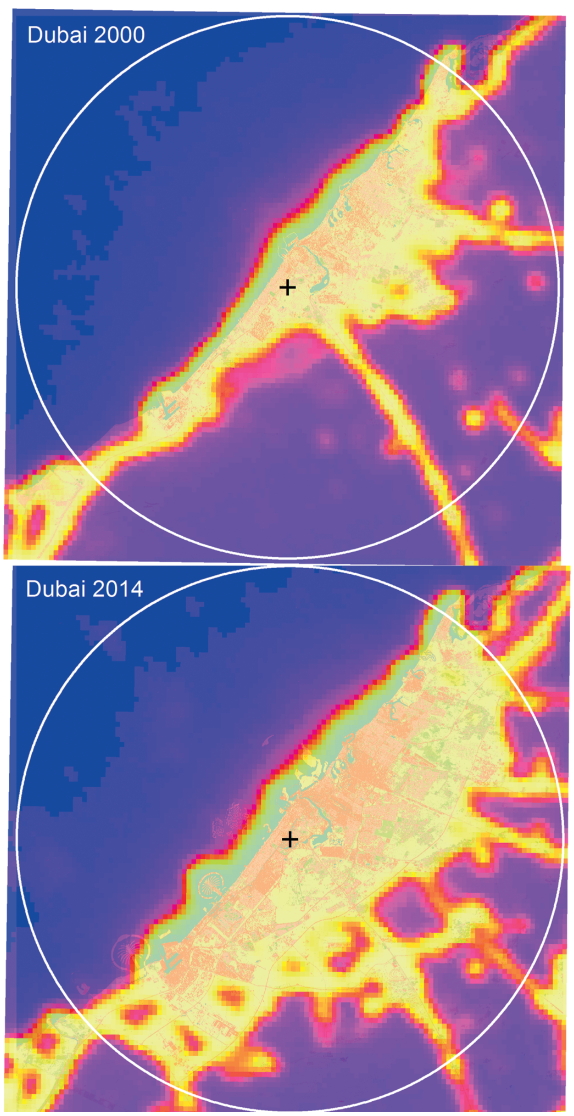

Fig. 6 Intensity map of energy consumption for Dubai in 2000 and 2014.

3.3 Intensity map of energy consumption

The intensity map of energy consumption is derived by the DMSP/OLS radiance night lights data and LULC map. With the overlay of two datasets, Fig. 6 shows a similar spatial distribution with the LULC classification results in this study, and this phenomenon had been proved by many other researches. Furthermore, by using the DMSP-OLS nightlights data, we can monitor the dynamic change of the city, and the night-time data can be used to map the urban fringe (Zhou *et al*. 2014).

On the other hand, the results of the energy consumption intensity map in the WEB-GIS can only perform the pattern, range and intensity of the human activities. The actual values of the energy consumption were not displayed in this study. Thus, Fig. 6 does not indicate the actual values of the energy consumption. The reason is that there is still no appropriate method to measure the actual quantity of energy consumption released into the air by human activities. At any rate, based on the spatial pattern of the energy consumption and degree of urbanization, the user can understand the human activities and urbanization process much better than before.

4. Conclusion

WEB-GIS provides an easy and efficient platform to show geographical pattern to the public. With our GIS services, users can explore the urban changes during the last 15 years. Furthermore, the WEB-GIS can help users to improve urban planning more effectively by comparing with other cities.

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