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Investigation and modeling of physical growth of urban areas using night-time light data

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ABSTRACT

The expansion of urbanization and unbalanced urban growth has attracted the attention of many urban planners and decision makers to the issues and consequences of urban population growth. Due to the fact that human activities are accompanied by light during the day and night, so it is possible to study human activities using satellite images that show the light of the city. In this regard, the role of remote sensing techniques and data in identifying changes and urban growth and development in assessing population growth has been more brilliant than other methods. In this study, we will show that night light (NTL) is a way to evaluate the physical growth of cities using NPP images, travel distances and Landsat 7 and 8 images, and using remote sensing and GIS techniques. In this study, we examine population growth and travel distance and urban boundary changes over a 9-year period in two Iranian cities.

1. INTRODUCTION

The process of urbanization and urban growth in different parts of the world is the result of intertwined interactions between various social, economic, political, technological, geographical, and cultural factors. Recently, the development of Quantitative Urbanism and our increasing ability to collect and share data on many aspects of urban life have begun to supply us with better clues to the properties of cities. In this regard, the role of remote sensing techniques and data in identifying changes and population growth has been brighter than other methods. Nighttime light observations from remote sensing provide us with a timely and spatially explicit measure of human activities and therefore enable a host of applications such as tracking urbanization and socioeconomic dynamics, evaluating armed conflicts and disasters, investigating fisheries, assessing greenhouse gas emissions and energy use, and analyzing light pollution and health effects. In this study, we present a new multistage approach that demonstrates that we seek to evaluate the efficiency of night light measurement (NTL) in understanding the extent of urban boundary change and its development over a nine-year period. The purpose of this study is to present the application of satellite remote sensing (NTL) to determine the causes of changes and various factors affecting the development and increase of urban areas and comparisons between several locations.

2.MATERIAL, METHODS AND CASE STUDIES

In this study, the experimental framework for measuring urban growth consists of three stages: land cover production, night light classification, and travel time calculation. Each of these steps has its own processing. Each of these datasets has advantages and disadvantages. If logically combined, the three data sets can provide a more accurate estimate of the city's physical growth. The algorithm used in this study is called the BUNTUS algorithm (built-in, night light and travel time for urban size). In the following, we will show the study area and explain each step separately and we will examine their combination and the final result.

2.1.Case Studies

In this pilot study, we chose two cities (see Figure 1) that test different aspects of BUNTUS. The studies cities are the metropolises of IRAN: Tehran and Tabriz.

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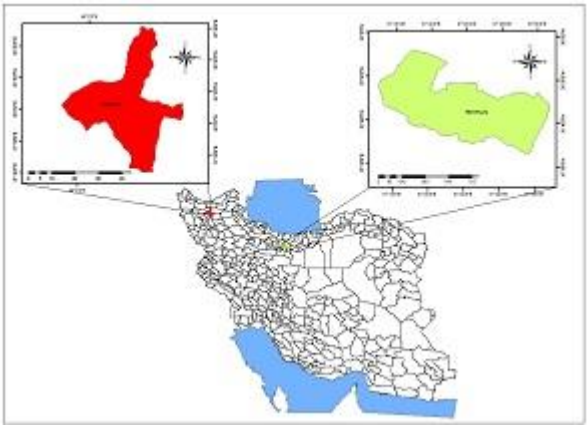

Figure 1. Study area

2.2. Land Cover Classification

For the land cover mapping, Landsat Enhancement Thematic Mapper (ETM), and Landsat Operational Line Imager (OLI)'s products have been used. ETM images were used to produce the ground cover map for 2012 and Landsat 8 images for the rest of the year. First, the necessary preprocessing such as radiometric and atmospheric correction were performed in ENVI image survey software, then the images were classified using the SVM method. At first, each image was classified into four classes, and then we divided those four classes into two classes to identify the built-in and non-created areas. In selecting the training data, Google Earth was used to help classify it correctly.

2.2.1. Accuracy Assessment

An error matrix was used to evaluate the accuracy of land cover produced through classification. The results showed that the accuracy of the four classified classes was between 85% and 90%.

2.2.2. Urban Area Generation

The land cover produced had 4 classes. A higher number of classes minimizes the effect of mixed pixels. We divided the 4 classes into two classes - built and unbuilt. The construct was assigned a value of 1 and everything else was assigned a non-constructed value of 0. Since our main focus was area construction, we re-evaluated the accuracy of the two classes. Our two-class classification was more than 90% successful in all datasets. Finally, Focal Statistics analysis was performed on the two-class image in ArcGIS software and it was ready to be collected with other data.

2.3. Nighttime Light Data Processing

Nighttime light (NTL) satellite images are a class of remote sensing products, globally available for multiple years. In this research, we use VIIRS images and various strategies. To find the DN threshold for urban areas. For multivariate analysis, we categorized NTL images into five classes to establish the relationship between DN and ground cover. We categorized the VIIRS datasets into five classes at their native resolutions of 742 meters. Using these thresholds, we classified VIIRS data into two classes.

2.4. Travel Distance Raster Creation

The road network provides a third view of urban extent since it measures the connectivity of space. Complete and accurate geospatial road network data is, therefore, a valuable dataset. Open Street Maps (OSM) provides the road network geospatial data at the global level at no cost (Muhammad Luqman & et al,2019). In the present study, OSM data were used which are easily accessible. To do this, a travel time layer was generated in QGIS software using the ORS tools. This tool calculates travel time without any restrictions such as traffic and based on the intended speed in each route. Eventually, it became a roster in ArcGIS software.

2.5. fusion of Datasets

Once three rasters were produced, we proceeded to merge those rasters. A simple sum of three rasters was generated according to the following formula:

$$DNout = DN_B + DN_{NTL} + DN_{TT}$$

Finally, we divided the generated layer into two classes according to the logical threshold. We selected the largest adjacent urban area, which included the urban core, and turned it into a vector polygon of data.

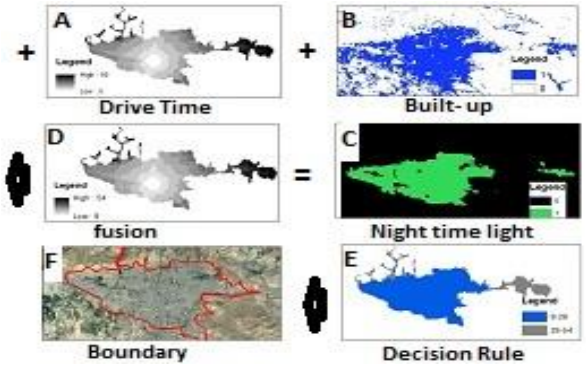

Figure 2. Fusion of three datasets (Tehran in 2020). Plate (A) represents the travel time raster (DNTT), plate (B) represents the built-up area (DNB), plate (C) represents the Nighttime Light classified raster (DNNTL), plate (D) represents the fusion of all three datasets (DNout), plate (E) represents the classified sum with a threshold value 1.5, and plate F represents the largest contiguous urban area boundary.

2. RESULTS

A little direct validation of BUNTUS is difficult. No other dataset has the resolution of time and place for complete comparison. More seriously, the definition of urban sprawl is arbitrary. Based on studies conducted on the two metropolises of Tehran and Tabriz in a period of nine years, the results showed that these two cities have not grown significantly in this period and have grown with a gentle slope.

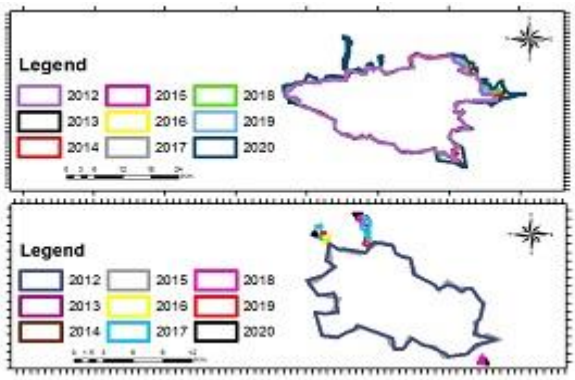

Figure 3. Urban area boundaries of two cities, 2012–2020

3. DISCUSSION

This program should be kept in mind when evaluating the usefulness of a data set such as BUNTUS. This is true for any urban data set because no single definition is sufficient for all applications, even if there is data to determine it. Our task here is to define an algorithm that is strong, consistent, and efficient enough to define global urban dispersion trends for many cities over decades. (Mohammad Loghman et al., 2019). The results of this study showed that the metropolises of Tehran and Tabriz did not experience significant physical growth in this period and had only a slight growth that occurred in different parts of the city. The area of the metropolis of Tehran in this 9-year period is about 66 square kilometers and the city of Tabriz It has increased by about 5 square kilometers.

4. CONCLUSION

The results of these studies show that, by combining Landsat information with night lights and travel time information, urban growth trends can be calculated. Due to the quality and availability of data variables and fully automated and public algorithms, this method makes it possible to achieve the growth of the urban border of all cities with it.

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