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Research on Urban Land Use Change in Ha Noi, Viet Nam Using Remote Sensing and GIS for Planning Oriented Work

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Abstract: Currently, 55% of the world's population lives in urban areas, this proportion is expected to increase to 68% by 2050. In the next 30 years, a large amount of the world's population is predictably concentrated in urban areas in the developing world. Ha Noi is the capital and largest city of Viet Nam which has the average growth rate of approximately 3% per year. Urban development management has become an important issue in Viet Nam since the negative impacts of the urban sprawl on the environmental sustainability, life quality has been increasing as well. Hence, urban planning and management would be pivotal for creating the effective framework conditions for a sustainable development. The objective of our study is to explore the urban growth of Ha Noi using the Landsat images from 1975 to 2020 compared to the city planning. The volatility analysis information from classified urban land maps is considered supportive for urban management and planning oriented work. In addition, the remote sensing data analysis is a useful tool to support planners, managers for urban management and decision. This study results showed the urban land area in study site city has been growing about 3 times and the largest rate (4-6 times) for the Dong Anh, Tu Liem, Gia Lam and smallest rate (10-25%) for Ba Dinh and Hai Ba Trung districts.

Keywords: GIS, urban planning, urban land growth, remote sensing

1. Introduction

According to a new United Nations data urban areas (UN, 2020), the world population expected to increase 68% by 2050 and there is a gradual shift in residence of the human population from rural to urban areas. Based on this growth, the world's population could put into the urban areas 2.5 billion people by 2050. Asia and Africa are the most fast-growing continents with growing rate close to 90% in the next 30 years. Since 1989 Vietnam has been undergoing a process of re-engagement with the world economy. This liberalization process (Doi Moi) has been heavily concentrated on the two main cities of Vietnam (Labbé, Collin et al., 2010, Pham, Yamaguchi et al., 2011) such as Hanoi and Ho Chi Minh city.

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In general, Vietnam urban system has been rapidly developed with the rate of 19.6% of 629 cities in 2009 to 36.6% of 802 cities in 2016. In 2018, Vietnam had 819 cities and the current grow rate was 38.4% (NCIF, 2020). On this Vietnam background, Hanoi is not an exception with a highest rate of urbanization of the country, particularly the grow rates have been surged after each milestone of urban planning or adjustment of the planning (Pham, Yamaguchi et al., 2011). The boom of Hanoi population has put the high pressure on the city infrastructure such as overloaded traffic, lack of schools, water and electricity and hospitals. The most dynamic areas are the outskirts of the new Hanoi (Leducq and Scarwell, 2018) where more new roads and houses and other infrastructure built for the aims of reducing pressure for the core city.

Remote sensing provides information about objects at or near the surface of the Earth and atmosphere based on radiation reflected or emitted from those objects. Remotely sensed data on natural and anthropogenic features such as vegetation cover, land use, topography, and hydrography (Quattrochl, Luvall et al., 2000). Satellite remote sensing is a potentially powerful means of monitoring land-use change at high temporal resolution and lower costs than those associated with the use of traditional methods (Bhandari, Kumar et al., 2012). It is well-known that remote sensing technology has played a very important role in the urban planning and management since 1980s (Somvanshi, Kumari et al., 2020).

Remote sensing is very helpful for dynamical monitoring of the process of urbanization. Land-cover or land-use data can be extracted from the Landsat TM imagery by using a computer-assisted image-processing approach. The remotely sensed data with the aid of a GIS can provide valuable data for both quantitative and qualitative studies on land-cover changes.

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Since 1980s, remote sensing (RS) technology has been applied widely and has vital roles in urban management and planning (Netzband, Stefanov et al., 2007). In Vietnam, RS has been applied for this aims, especially urban mapping for 20 years as the RS technology has advancements of providing timely information in large areas, cost effective, and finer precisions. The modern technology of remote sensing integrating GIS which are enable us to collect a large amount of physical earth surface data rather with less of time and cost consumption as its speed and repetitive time basis (Bhatta, 2010, Rashed and Jürgens, 2010).

There have been wide variations of approaches using remote sensing data for general applications (Quang, 2016, Quang, Tuan et al., 2019) and for urban studies in particularly. Both spectral and spatial information is used for object-based or object-oriented classification (Bhaskaran, Paramananda et al., 2010) which method is widely used in the remote sensing community. In this study, we applied this method for urban classification of some districts of Hanoi, Vietnam using Landsat-X (X is missions of Landsat such as 5, 7, 8) images. We also used tools in ArcGIS for the spatial analyses, changes detection and for mapping purposes. Briefly, we found that Hanoi has been developed very quick since 1993 with most rapidly district of Thanh Xuan and slowest of Hai Ba Trung. The periods of 2000-2015 were the time of booming in urbanization of Hanoi and it was the 1998 urban planning was put into implementation.

2. Study Site and Data

2.1 Hanoi Capital City of Vietnam

Ha Noi is the capital located in the northern region of Viet Nam which is the center for the national government, latitude and longitude coordinates are 21.028511N, 105.804817E (Fig.1.). Hanoi is an important historic, cultural, and economic center of Vietnam which has experienced rapid urbanization and structural transformation (Chu, Nguyen et al., 2017).

We selected 13 districts of Hanoi for the study case as they have difference in growing rates and urban plans. Studying those districts could be representative for the whole Hanoi development in the 1992 to current periods. There are some milestones of Hanoi planning which are: In 1992, the “Master plan to adjust the total area of Hanoi capital up to 2010” regulating Hanoi would be becoming a big city in Asia with area of 8000 ha and population density of 200 capitals per ha. Hanoi plan 2008 flowing the 2008 Resolution No. 15/2008/QH12 on 29/7/2008 which aimed to combine Ha Tay and four districts of Hoa Binh province to the new Hanoi. Hanoi has become the largest city of Vietnam in terms of spatial re-spective. The Hanoi City Master Plan to 2020 and vision to 2050 has been signed by the prime minister which objectives of building up Hanoi “more green, cultural, civilized and modern” with five satellite cities. Therefore, Hanoi have experienced in many plans which changed the Hanoi administration borders, urban development, and population regulation.

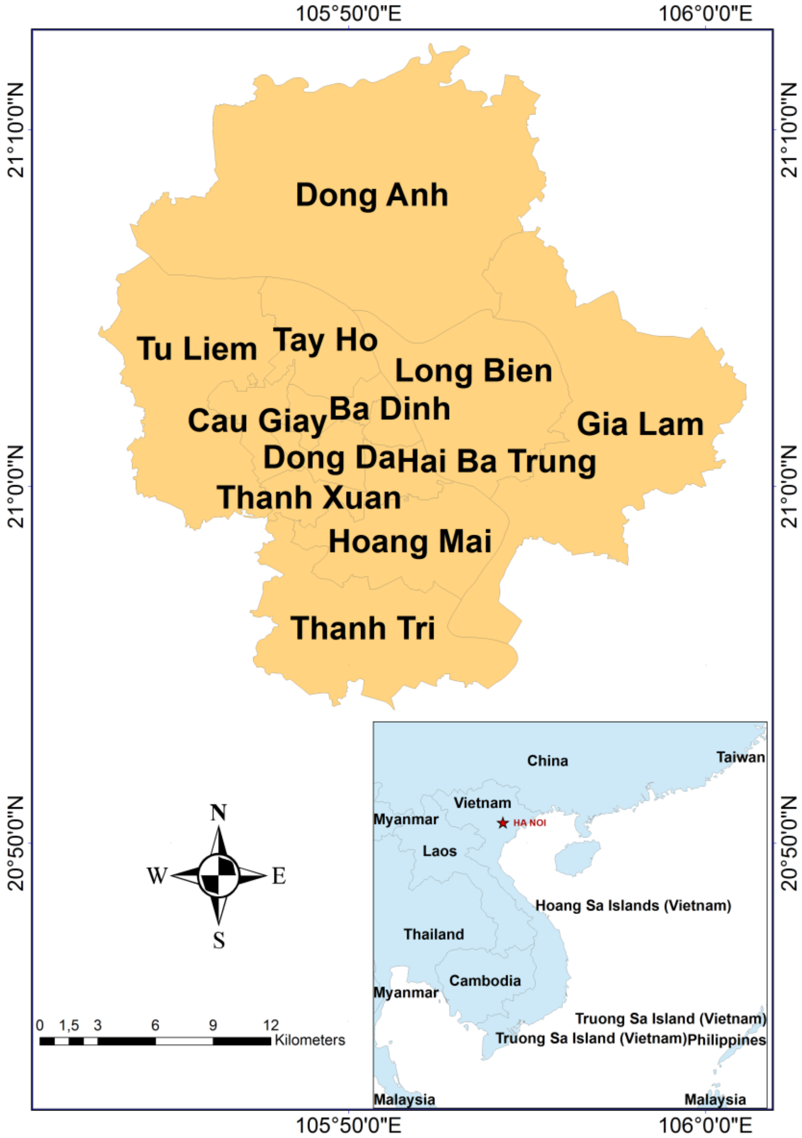


Fig. 1 - Map of study districts of Hanoi

2.2 Remote Sensing Imagery

In order to extract spatial time-series data in nearly 30 years, we collected optical remotes sensing data of Landsat TM, ETM and 8 OLI and TIRS and Sentinel-2 with different spatial resolutions as summarized in the Table 1. We tried to collect the images with minimal cloud cover, hence most the acquisition times were in Winter and Autumn.

Table 1 - Remote sensing collected for this study; TM and ETM stand for Thematic Mapper and Enhanced Thematic Mapper; OLI and TIRS are Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS)

Sensor	Acquisition date	Number of bands	Spatial resolution	Season
Landsat TM	27/12/1993	07	30 m	Winter season
Landsat ETM	17/09/2000	08	30 m	Autumn season
Landsat 7 ETM+	8/11/2007	08	30 m	Winter season
Landsat 8 OLI-TIRS	01/07/2015	12	30 m	Summer season
Sentinel-2	30/07/2020	13	10 m	Summer season

3. Methodology

3.1 Study Work Flow

Fig. 2. presents our steps of image processing, data analyses and result representation including 6 main procedures of: 1) image pre-processing where the Land-sat bands were stacked, georeferenced to the VN2000 coordinate system and subset in the areas of interest (ROI). 2) In the main task of image processing, the urban land is classified into three classes of urban land, water and other applied our rule set. 3) The classified layers will be checked for their accuracy if the errors are still large we adjust the rule set and repeat the task 2 until the result has acceptable of accuracy. 4) Three final steps are classification of the step 3 results, vectorization to convert grid to vector format for spatially analyses (urban land change) and mapping in the results.

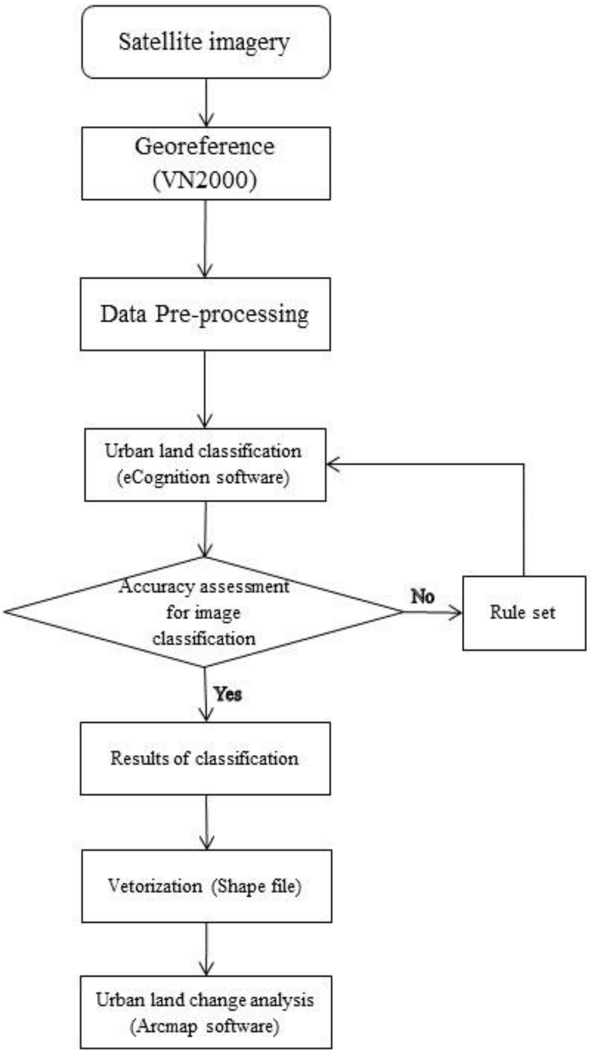


Fig. 2 - Working scheme for achieving the study goals

3.2 Ruling Set

The core process of this work is to set the rules for urban land classification which are based on the different reflectance of solar light on different surfaces received by the optical remote sensing sensors and we used codes for signing the urban land (Code 1), water (Code 2) and others (Code 3) and their definitions in the Table 2. All images were enhanced their quality and classified using the object-based classification in eCognition software. “Object-oriented methods are often more effective than pixel based methods when classifying high-resolution imagery, because as spatial resolution increases, the more variability there may be in the spectral content of individual pixels all belonging to the same class” (Schuckman, Dutton et al., 2015), hence this method was chosen. In the segmentation process, we sur-and change the value of paragraph until to find the best parameters for the satellite image. Finally, we decided to choose the parameters of 10 for the scale, 0.1−0.4 for shape and 0.5 for compact for segmentation process.

We also used the NDVI, SAVI index and the distance-based algorithm for the complex residence areas for the aim of reclassifying the segmentation classification. NDVI and SAVI are the two commonly used vegetation indices, computed using the red and near-infrared bands. NDVI is a measure of surface reflectance and gives a quantitative estimation of vegetation growth and biomass .The NDVI is highly useful in detecting the surface features of the visible area (Bhandari, Kumar et al., 2012). Soil Adjusted Vegetation Index (SAVI) is an index designed to consider soil effects on analyzed images if the land surface is not fully covered by vegetation (Somvanshi, Kumari et al., 2020).

3.3 Accuracy Assessment

In this stage, we calculated confusion matrices for each year of urban extraction using data derived from Google Earth Pro (GEP) application. As It is impossible for us to back the past time to collect in-situ measurement ground-truth data for the task, the GEP allows us to back to the historical images to get set of urban polygons. The producer and user accuracy were calculated in this phase based on the confusion matrices. which are common error indicators in assessing accuracy of remote sensing classifications and described well in the study of Russell (1991) (Congalton, 1991). Hence we would not to re-explain them here.

Kappa statistics (Donner and Klar, 1996) were computed for checking the classified results. The Kappa statistics (K) is solved in the Eq. 1 described in Congalton (1991) (Congalton, 1991).

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_i \times x_{+i})}{N^2 - \sum_{i=1}^{r}(x_i \times x_{+i})} \quad (1)$$

Where is the number of rows in the confusion matrix, xii is the observations in the diagonal of the matrix, x_{i+} and x+i are the marginal totals of row i and column i, respectively, and N is the total number of observations. The coefficient of determination (R2) is employed for the assessing the agreement between extracted areas.

Table 2 - Land use classes and definitions used in this study

(Classes ID)	Classes	Definitions
Code 1	Urban land	Including construction area, commercial area and industrial buildings, residential area and transportation facilities (e.g., airports, parking lots, highways, local roads)
Code 2	Water	Including all water bodies (river, lakes, gravels, stream, canals, and reservoirs).
Code 3	Others	Vegetation(Including all agricultural and others land)

4. Results

4.1 Hanoi Urbanization Over 1993-2000

Fig. 3 shows the changes in ha of the study districts in the core (Fig. 1A), sub-urban districts (Fig. 1B), suburban districts to districts (Fig. 1C), and all the sub-urban districts (Fig. 1D) in five millstones times from 1993 to 2020 after the Ha-noi plans (explained in section 2.1). It is clearly shown that the minor changes of the four districts in the core of the city with nearly unchanged for the Hoan Kiem (blue line of Fig. 1A) and a moderate increase of Hai Ba Trung in the first 7 years from 1993 to 2000 but remained unchanged to 2020. The Fig. 1A also presents the size of the urban land areas of the districts ranging from 500 ha of Hoan Kiem to 3000 ha of Hai Ba Trung. In contrast, the urbanization of the suburban districts (Fig. 1B) took place more rapidly from 2000-2007 periods with four folds larger of Thanh Tri, Dong Anh and three times bigger of Tu Liem and Gia Lam districts. The urban land areas of all increased slightly of all suburban districts from 2007 to 2020. In the districts which formally were suburban districts (Fig. 1C), there was a sharp rise in urban land areas in the 15 years from 1993 to 2007 with an exception of Cau Giay had a moderate increase. After that all urban land areas have been slowly building up in the transition districts. Finally, the changes in total urban land areas of all the 13 study districts have been presented in the Fig. 1D with the year lines. There were minor changes of all districts from 1993 to 2000. Long Bien, Tu Liem, Dong Anh and Gia Lam were the most urban development districts and Tu Liem and Dong Anh had the largest urban land areas of 4000 ha and 5000 ha, respectively. Hoan Kiem is smallest district with under 500 ha of urban.

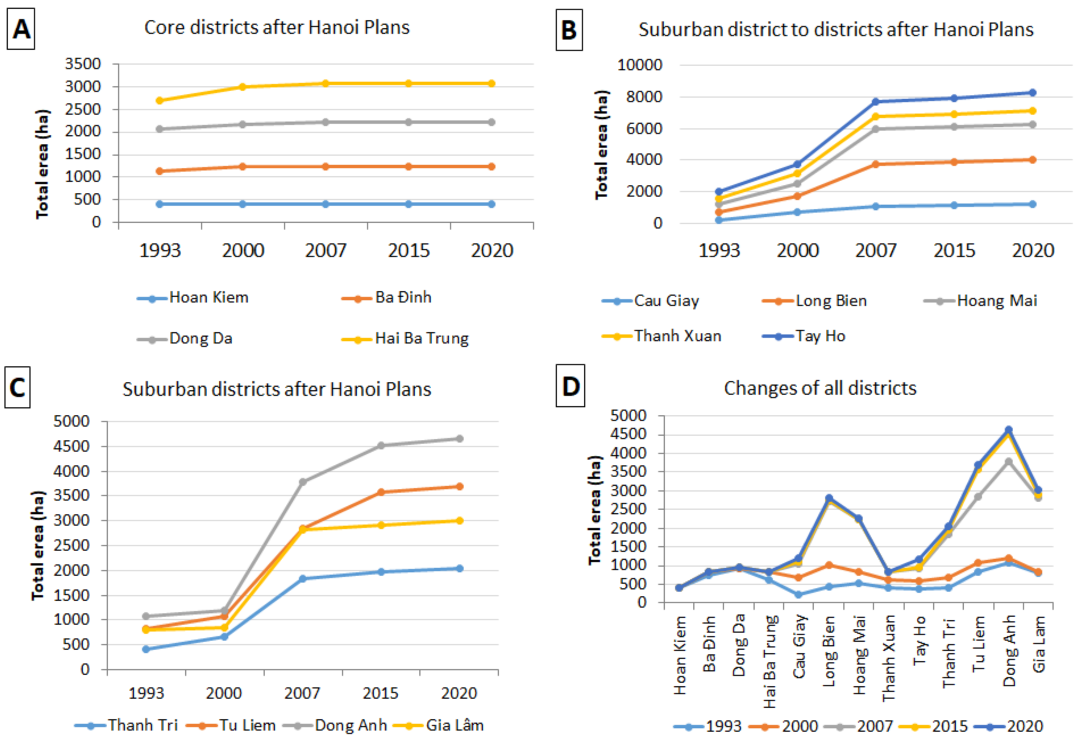


Fig. 3 - Urban land areas change of districts from 1993 to 2020

4.2 Hanoi Urbanization Over 1993-2000

Spatial distributions of urban land and water (for orientation basic) have been mapped for the years of 1993, 2000, 2007, 2015 and 2020 (Fig. 4). In general, the accent city (in red) was there surrounding the West lake (in the middle of the maps) in 1993 and enlarging over the 27 years to current 2020 with the red color was dominant of the 2020 map. Crossing comparison between all the years, although the urban areas were emerging in all districts, the North-East part would have had a higher rate. There were only spread villages in 1993 and a little urban spots in 2000, however after two decades the yellow areas was filled by mostly by the red color.

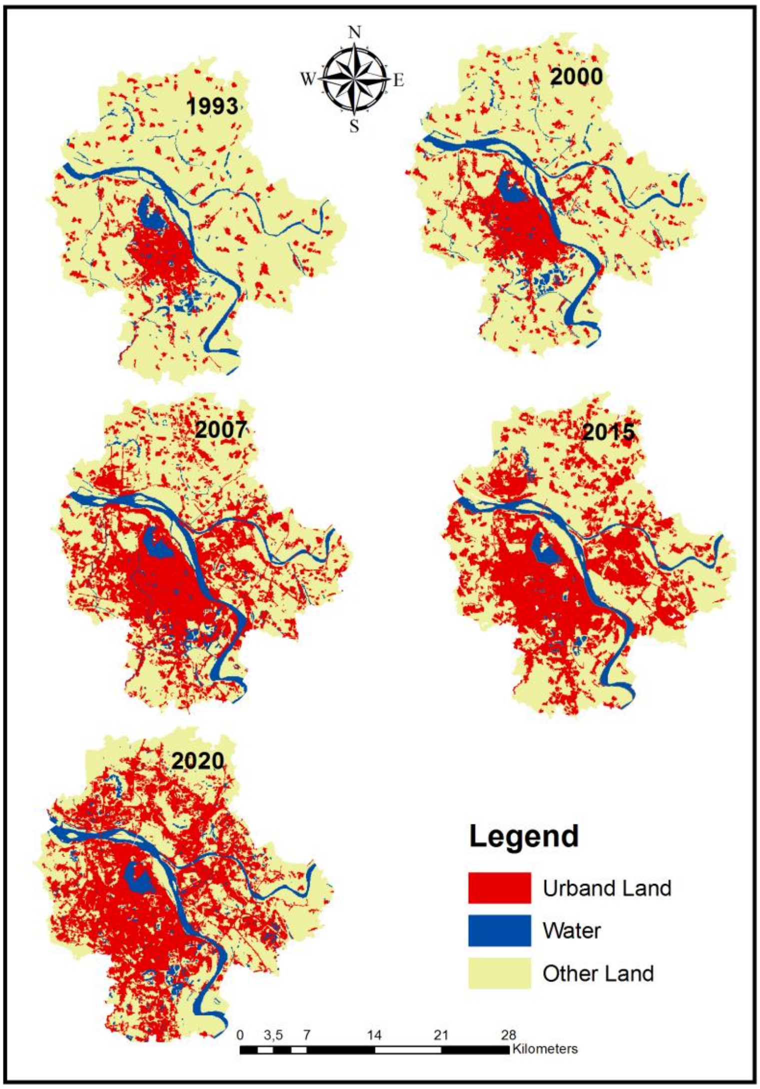


Fig. 4 - Maps of urban areas of study areas from 1993 to 2020

4.3 Hanoi an Emerging City

The Fig. 5 presented a combination remote sensing-based urban extractions for the years from 1993 to 2020 (the urban areas in red). The urban areas have been emerging from the center to the outskirts of the Hanoi city. With the brighter red areas, we could see the new developed urban residences which were expand from the older urban area (core patch). In contrast, darker red areas were the older developed municipality.

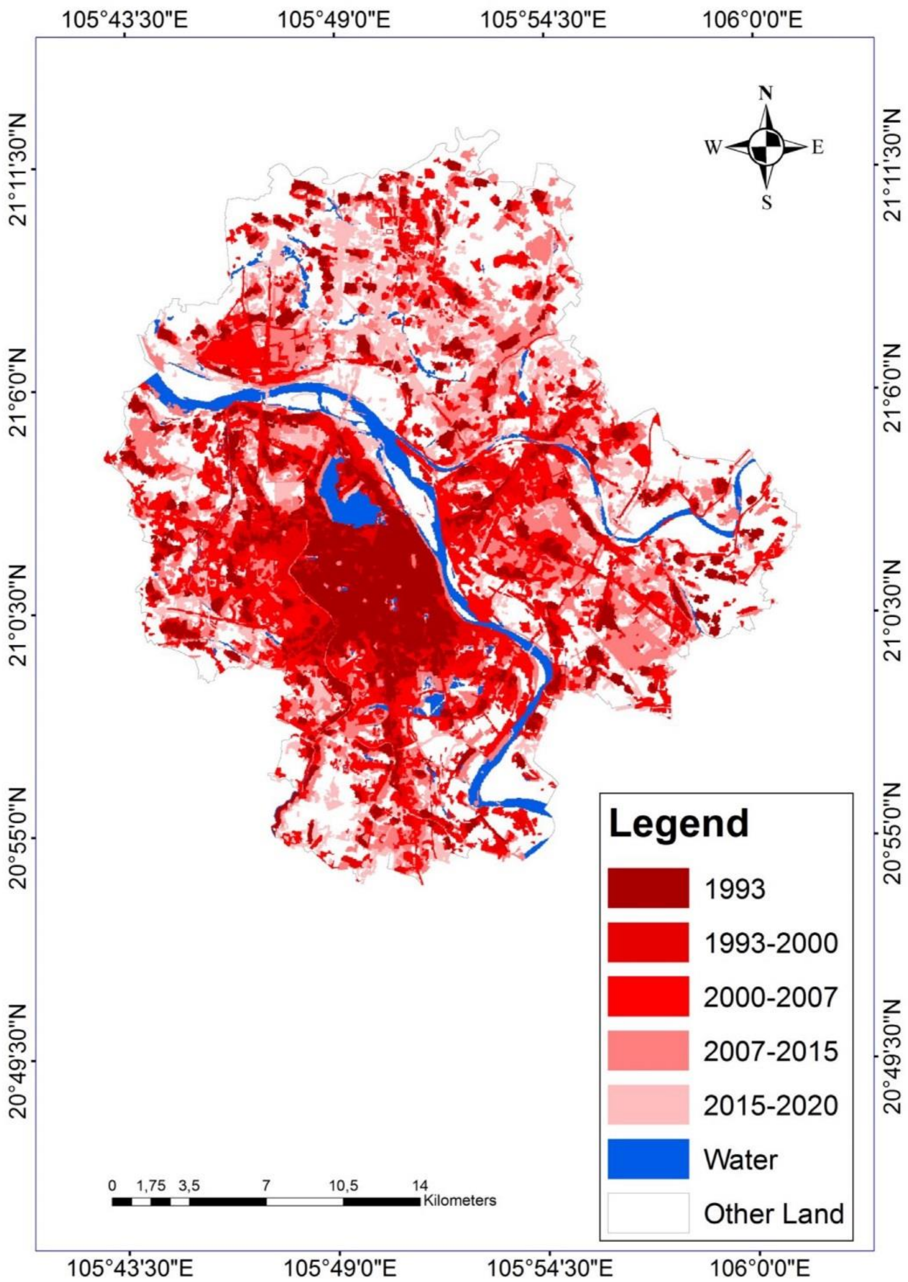


Fig. 5 - Map of urban emerging from 1993 to 2020

4.4 Accuracy Assessment

The producer accuracy, user accuracy (mostly greater than 80%) and Kappa statistics (greater than 0.8) computed and summarized within the Table 3 showed the results of urban areas classifications were at good level. The changes of these accuracy indices over 1993 to 2020 revealed that with newer remote sensing images generating finer results. This might be related to remote sensing technology since we used the same method of image classification for all used images.

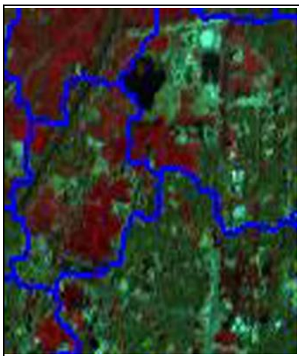
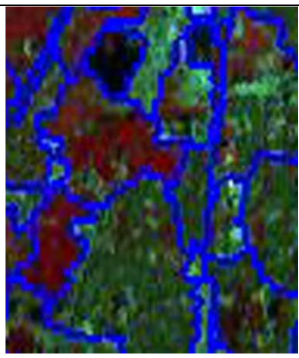
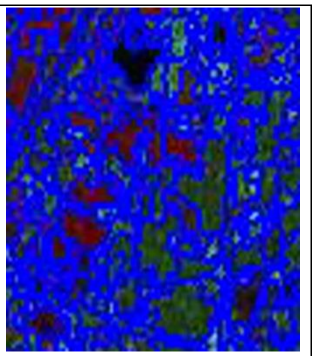
Table 3 - Accuracy indies computed and summarized form confusion matrices

Years	1993	2000	2007	2015	2020
Producer accuracy (%)	81.02	86.76	89.31	92.09	92.68
User accuracy (%)	79.11	84.72	81.01	88.17	88.07
Kappa	0.81	0.84	0.88	0.90	0.915

5. Discussion and Conclusion

First, it would be undeniable the importance of remote sensing data for many purposes of applications (Quang, Quinn et al., 2020), particularly this technology has been state-of-the-art developed, hence the RS data have become increasingly available (Maktav, Erbek et al., 2005). That means we have more options of choosing what data for what purpose and data assimilations would become more important (Kalhor and Emaminejad, 2019) such as in this study we used RS data from Landsat and Sentinel-2 missions. However, for the finer scales related to urban, construction etc. the study goals may not always meet in terms of accuracy requirements, field measurements for validating the RS-based extractions.
Another point which is often put on the table is the uncertainty of results (Xian and Crane, 2005). Using remote sensing data that means we indirectly extract information from solar light reflectance from observed surfaces (optical) or backscatters of radar pulses (active remote sensing), hence users would be keen to know how much extent of the reliability of their outcomes are. There are many approaches for accuracy assessment even so the most common method used in remote sensing community would be uses of confusion matrices (Congalton, 1991) where the user and producer accuracies, and Kappa statistics for each classification are computed. We also applied this accuracy assessment approach in this study. Inversely, a question could be raised is whether the confusion matrices (Congalton, 1991) are perfect? There was a study against this approach and pointed out some limitations of Kappa statistics such as it does not report the correct proportion portion and gives information that is redundant or misleading for practical decision making (Pontius Jr and Millones, 2011). We may need more work on this aspect.
Furthermore, there are dozens of exiting image classifications (Quang, Quinn et al., 2020), commonly divided into pixel-based and object-based methods. The object-based method which has pros and cons compared to the pixel-based classification approach described well in the study of Liu and Xia (2010) (Liu and Xia, 2010). Here, we discuss more on the issues of further steps of segmentation classification of the object-based method as users set their own rules. That is why, the subjective ideas of the rule set developers might affect the categorization results. Here, we provide readers with some our experiences in analyzing the urban characteristics for setting rules of segmentation classification hints (Table 4).

Table 4 - Analyses of choosing indices for setting rules of multiresolution segmentation classification

		
scale parameter: 50; shape: 0.75; compactness: 0.75	scale parameter: 30; shape: 0.5; compactness: 0.5	scale parameter: 10; shape: 0.25; compactness

Finally, how much information derived from remote sensing and GIS could support urban planning and management? It would be a tough question, however in general picture, there are a large number of publications using remote sensing data and GIS analyses and mapping related to urban management (Oh, 2001, Srdjevic, Lakicevic et al., 2013), planning (Wang and Gu, 2020) conservation (Xie, Gu et al., 2020), houses (Sun and Salvaggio, 2013, Wu, Yu et al., 2017, Singh, 2012), traffic (de Luca, Di Pace et al., 2020, Hawas, Sherif et al., 2020, Skabardonis, 2020) and urban tree (Quattrochl, Luvall et al., 2000, Taylor and Hochuli, 2017, Melero, Stefanescu et al., 2020). More studies using such this valuable data sources are expected still to come. The future work of this research we want to modeling urban growth and use the spatial metrics to quantitative and analysis the urban growth of this study area.

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