Assessment of urban land cover change base on Landsat satellite data: A case study from Hanoi, Vietnam

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Abstract. Rapid urbanization process is accelerating the dramatic transformation of urban land cover, creating strong economic, social and environmental impacts. Many studies have achieved significant achievements in the application of Landsat satellite data to assess the land cover change. Remote sensing images of contain the necessary spectral and spatial features of the various objects. The Normalized Difference Vegetation Index (NDVI) is utilized to analyze remote sensing images of landsat satellite data and is one of the most widely used numerical indicator for calculating the visible (VIS) and near-infrared bands (NIR) of the electromagnetic spectrum. In this study, the NDVI based classification has indicated about significant change in land cover in Hanoi, Vietnam from 2001 to 2017. The study results show that a major change has been found in the vegetation cover area where about 56 km² (accounts for 12.3%) area has been lost during the period from 2001 to 2017. This study demonstrates the importance of considering land cover change to improve the quality and optimizing the model of land use in urban areas.

Keywords: Land cover change, Landsat satellite data, Classification, NDVI, Hanoi.

1. Introduction
Vegetation in and around urban environments has been recognized as providing valuable ecosystem services, including the regulating services of climate regulation, water filtration, and air purification [1]. In many cities in the world, urbanization changes the land use practice, usually by reducing the natural land area [2, 3, 4] and simultaneously affected the structure of land cover [5]. Land cover refers to the physical state of the land surface including Built-up land, Crop land, Forest land, Wetland land etc. [6]. Land cover analysis is important in urban planning, land use management and environmental studies [7-10]. Land cover mapping is one of the major important applications of landsat satellite data. The number of remote sensing platforms increased during the past decades and produced more detailed geographical data [11]. In addition, the advancement in the sensor capabilities having better spatial and spectral resolution is a major breakthrough in satellite remote sensing. Sensors can supply accurate and timely information on land cover. In this study, based on land cover mapping from Landsat satellite data to classify images through visual analysis technique are used for mapping.
Urbanization rate in Vietnam reached 35.21% in 2017 [12], and the spatial expansion of urban will increasingly be the main characteristic of land use change in the future in Vietnam [13]. Hanoi is a center of national politics in Vietnam, Hanoi has become one of the most populated cities in the world after expanding significantly in 2008; it is characterized by rapid urbanization and a changing spatial structure of land cover. Therefore, considering land cover change to improve the quality and optimizing the model of land use in urban areas without affecting ecosystem services and at the same time promoting sustainable development is a key challenge for urban planners and manager [14].

2. Study area and methods

2.1. Study area

Figure 1. Location of the study area.

Hanoi is located in the northwest of the center of the Red river Delta, with coordinates from 20°53’ to 21°23’ North latitude and 105°44’ to 106°02’ East longitude. In 2018, Hanoi has a population of 7.78 million and an area of 3358.9 km² and becomes second largest city in Vietnam. The study area is located in the inner city of Hanoi spans 454.9 km² and including 12 districts and 2 rural districts (Figure 1). Hanoi lies on the plain and is far from the sea, it belongs to a tropical region and is greatly affected by the monsoon. The climate in Hanoi is very comfortable and where four common seasons are discernible, sunshine of 1562h per year and annual precipitation of 1,900mm. Currently in urban areas, urban land use structure is seriously imbalanced, green space and social infrastructure are lower than national standards. Urban land use planning and management did not seriously consider the long-term development of the city and the tremendous changes in the ecological environment.

2.2. Data collection

We used 30m resolution Landsat satellite data by USGS (https://glovis.usgs.gov) in 2001, 2007, 2011 and 2017 as the remote sensing imagery for this study, the selected image has less than 10% cloud cover (Table 1).
Table 1. List of landsat satellite data sources

| Data                      | Path/row | Format | Time         | Spatial Resolution |
|---------------------------|----------|--------|--------------|-------------------|
| Landsat 4-5 TM C1 Level-1 | 127/45   | Raster | 2001/04/21   | 30 meters         |
| Landsat 4-5 TM C1 Level-1 | 127/45   | Raster | 2007/05/08   | 30 meters         |
| Landsat 4-5 TM C1 Level-1 | 127/45   | Raster | 2011/07/06   | 30 meters         |
| Landsat 8 OLI/TIRS C1 Level-1 | 127/45   | Raster | 2017/06/04   | 30 meters         |

2.3. Methods

2.3.1. Image preprocessing. All images were atmospherically corrected to surface reflectance. The Landsat 5 and 7 images were processed by the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) [15] and the Landsat 8 images were processed by the Landsat 8 Surface Reflectance (L8SR) system (Landsat 8 Product Guide). Pixels with clouds, cloud shadows, and snow were removed based upon a two-step method. The first step involves use of the Fmask algorithm to identify clouds and their shadows in a single Landsat image [16]. The second step involves use of the Tmask algorithm to further refine the dataset based on the use of multitemporal information [17].

2.3.2. The Normalized Difference Vegetation Index (NDVI). NDVI is an index based on spectral reflectance of the ground surface feature. Each feature has its own characteristic reflectance varying according to the wavelength. NDVI is calculated as a ratio between the red (RED) and near infrared (NIR) values and the general formula is calculated by (1) [18]:

\[
NDVI = \frac{\text{NIR}-\text{RED}}{\text{NIR}+\text{RED}}
\]

(1)

\[
NDVI = \frac{\text{Band 4} - \text{Band 3}}{\text{Band 4} + \text{Band 3}}
\]

(2)

\[
NDVI = \frac{\text{Band 5} - \text{Band 4}}{\text{Band 5} + \text{Band 4}}
\]

(3)

For Landsat 4-5 data, NDVI is calculated by (2), here band 3=RED and band 4=NIR. For Landsat 8 data, NDVI is calculated by (3), here band 4=RED and band 5=NIR. NDVI value ranges between -1 to +1. A Higher value of NDVI infers the presence of healthy vegetation in the area while its lower value is the indicator of sparse vegetation.

2.3.3. Land cover classification. In land cover classification, multispectral images are used for finding the NDVI values, through which to classify different land cover types such as water bodies, high built-up area, low built-up area, vegetation and dense vegetation in the study area (Table 2).

3. Results and Discussion

3.1. NDVI calculation

![NDVI in the study area from 2001-2017](image.png)

In 2001, the NDVI value calculated ranges from 0.53 to -0.23. The higher value of NDVI was found in the Hoai Duc, Ha Dong, Thanh Tri, Nam Tu Liem, Bac Tu Liem, Long Bien districts and east of
Hoang Mai district (Figure 2.a); the lower values of NDVI were densely distributed in the city center. Compared with 2001, vegetation structure from 2007-2017 showed a significant change across the whole region and their NDVI values were ranges from 0.63 to - 0.29 (2007), 0.65 to - 0.36 (2011) and 0.55 to - 0.15 (2017) (Figure 2.b, c, d). In recent years, the change in urban land use of the area have the tendency of continue to expanded into suburban areas mainly due to swift urbanization in Hanoi and a rural-urban transformation has adverse impacts on the vegetation around urban.

3.2. NDVI classification
In classification of NDVI values, the pixels of the images were manually inspected and a range of values for each land cover types (water bodies, high built-up area, low built-up area, vegetation and dense vegetation) were tailored such as the results (Table 2).

Table 2. Classification of NDVI values for different land cover from 2001-2017

| Type of land cover   | 2001   | 2007   | 2011   | 2017   |
|---------------------|--------|--------|--------|--------|
|                     | Min    | Max    | Min    | Max    |
| Water Bodies        | -0.238 | -0.05  | -0.294 | -0.03  |
| High Built-up       | -0.051 | 0.15   | -0.031 | 0.12   |
| Low Built-up        | 0.151  | 0.25   | 0.121  | 0.27   |
| Vegetation          | 0.251  | 0.4    | 0.271  | 0.45   |
| Dense Vegetation    | 0.401  | 0.534  | 0.451  | 0.63   |

3.3. Urban land cover change in the study area from 2001-2017
Change in urban land cover of study area from 2001-2017 in Hanoi were evaluated through NDVI image classification. The whole area was classified under 5 classes on ArcGIS software. The classes are as follows: water bodies, high built-up area, low built-up area, vegetation and dense vegetation. The results show that a significant change in urban land cover in the study area. In the period from 2001 to 2017, there was a continuous decline in vegetation land area and continuous increase in built-up land area. In addition, water bodie area tends to increase until 2011, then gradually decreases in 2017. The classified image in 2001 shows that area of vegetation land was the most (256.41 km² accounts for 56%), followed by area of built-up land (171.83 km² accounts for 38%) and water bodies area (26.58 km² accounts for 6%). The classified image of the year 2017 shows that area of built-up land was the most (223.84 km² accounts for 49%), followed by area of vegetation land (200.34 km² accounts for 44%) and water bodies area (30.64 km² accounts for 7%) (Figure 3).

Figure 3. Land cover change in the study area from 2001-2017.

A major change has been found in the vegetation cover area where about 56 km² (12.3%) area has been lost during the period from the 2001 to the 2017. The vegetation cover area change is straightforward to explain, as it was directly related to human activities. On the other hand, urban expansion due to swift urbanization in Hanoi also has a negative impact on the vegetation around urban.
4. Conclusion
Through a case study in Hanoi during 2001-2017. Base on Landsat satellite data sources, the NDVI based classification was considered to analyze the change in land cover of the area at spatial and temporal scale. We found that the integration of GIS technology and Landsat satellite data is one of the inevitable trends in the research on urban land cover.

In recent times, rapid urbanization and increased population pressure is accelerating the transformation of natural surface, usually by reducing in a decrease of vegetation land and increasing the impervious cover area. These study results represent an important analysis step for Hanoi municipal government departments have the plans to management and a suitable land use in the future.

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