Assessment of land cover/land use change in Hoi An area by using remote sensing and GIS techniques

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Abstract

In recent years, human activities and the pressure of population growth has led to profound changes in urban land cover/land use. Assessment of land use/land cover changes is a very important issue, serving as a foundation for land use planning. In this study, we use Sentinel 2 MSI high spatial resolution image data and GIS technique to build the status maps and land use/land cover change maps in the period 2018 - 2021 in the Hoi An area, Quang Nam province based on object-oriented classification method. Analyzing the results obtained shows that the trend in land use/land cover changes in Hoi An area is the increase in built-up land and the decline in agricultural land, bare land and grass, shurbs in the period 2018 - 2021. The results in this study can also be used to provide important information for sustainable land use planning.

***Keywords*:** remote sensing, land use/land cover change, object-oriented classification, Sentinel 2 MSI, Hoi An area

I. INTRODUCTION

Heritage sites in general, and ancient urban heritage in particular, are invaluable assets of Vietnam, holding profound cultural and social significance. Nevertheless, in recent years, the conservation of cultural heritage has faced numerous difficulties due to the impacts of socio-economic development and human activities. The rapid expansion of tourism, while offering substantial socio-economic benefits, also poses significant challenges to the preservation of ancient structures in Hoi An. Consequently, assessing and detecting changes in the current state of ancient urban heritage areas is an urgent issue, providing essential support for managers in heritage planning and conservation.

Medium-resolution remote sensing data can only detect changes at a generalized level and fails to capture detailed transitions within specific land cover types in heritage-protected zones. These granular changes, in terms of both area and spatial distribution, can be evaluated and analyzed by utilizing high-spatial-resolution remote sensing data (such as Sentinel-2, SPOT 6/7) integrated with GIS technology. Notable studies include those by Close et al. (2021) and You et al. (2020). Research by Elfadaly et al. (2018) employed multi-temporal and multi-sensor satellite data including Corona, Landsat, SPOT, QuickBird, and Sentinel-2A alongside spatial analysis techniques to investigate the ancient Theban temples in Western Luxor (Egypt), which are under severe threat from unplanned urbanization. Such unregulated urban expansion has led to poor drainage networks and high groundwater levels, directly impacting archaeological sites and indirectly accelerating weathering phenomena by altering groundwater tables.

Stubbs and McKee (2006) utilized remote sensing and GIS to analyze and assess both historical and contemporary human impacts on cultural heritage, providing data to develop sustainable tourism and conservation models. Biagetti et al. (2017) applied high-resolution remote sensing to identify anthropogenic signatures affecting the landscape of the central Sahara. Similarly, Agapiou et al. (2016) used high-resolution imagery (QuickBird and GeoEye) to detect "crop marks" a key indicator for identifying buried archaeological remains. In Lucera (Southern Italy), through spectral indices derived from GeoEye imagery, the authors identified several Neolithic ditches. Cerra et al. (2016) implemented surface change detection techniques on high-resolution imagery to identify destroyed cultural heritage sites and objects in the ancient city of Palmyra (Syria) due to the civil war. Maps generated from this data highlighted damaged buildings and high-risk objects, enabling experts to perform timely damage assessments. Beyond optical remote sensing, numerous studies have incorporated SAR (Synthetic Aperture Radar) imagery to analyze, assess, and detect traces and changes at cultural heritage sites (Hernandez et al., 2018; Kwan et al., 2019; Panuju et al., 2020; Phiri et al., 2020).

In Vietnam, prominent research includes the national-level project under the Space Science and Technology Program: "Research on the application of VNREDSat-1 satellite imagery and GIS for the conservation of cultural and natural heritage in Central Vietnam, piloted in Hue City and Phong Nha-Ke Bang National Park" by Pham Van Cu et al. Furthermore, Pham Van Manh et al. (2019, 2021) utilized high-resolution remote sensing data and spatial analysis to evaluate the impacts of urbanization on the Complex of Hue Monuments. The results demonstrated that rapid and extensive urban changes in recent decades have created significant challenges for land-use planning and conservation management, particularly regarding heritage protection in historical areas like Hue. Evidence from both international and domestic studies confirms that remote sensing is a suitable and effective approach for studying land cover/land use dynamics in cultural heritage sites, including ancient urban areas.

II. MATERIALS AND METHODOLOGY

2.1. Remote Sensing Data

The Sentinel-2 mission consists of a constellation of two identical satellites, Sentinel-2A and Sentinel-2B, successfully launched into orbit in 2015 and 2017, respectively. Sentinel-2 provides imagery across 13 spectral bands within the visible and infrared spectrum, featuring a 5-day revisit cycle. The Multi-Spectral Instrument (MSI) sensor onboard the Sentinel-2 satellites facilitates data acquisition in 13 spectral bands; notably, the spatial resolution in the visible and near-infrared (NIR) bands reaches up to 10m, which is highly suitable for small-scale studies.

To detect and evaluate land cover/land use (LCLU) dynamics in the Hoi An ancient urban heritage area, this study utilized two Sentinel-2A scenes acquired on June 22, 2018, and June 1, 2021 (Figure 1). Both images were captured at nearly the same time of year to minimize seasonal effects on the study area's land cover.

Figure 1. Sentinel-2A imagery acquired on June 22, 2018, and June 1, 2021, of the Hoi An ancient urban heritage area (True Color Composite).

2.2. Methodology

Given the high spatial resolution of the remote sensing data, this study selected the Object-Based Image Analysis (OBIA) method for LCLU classification and change detection in the experimental area. This classification approach has been globally proven effective and suitable for processing high-resolution optical remote sensing data. To process the Sentinel-2 MSI satellite data, eCognition Developer 8.7 software was employed.

The classification criteria, including Scale, Shape, and Compactness, are critical parameters for the image segmentation process. The accuracy of the classification results depends heavily on the precise selection of these criteria. If the image objects are too large, they may encompass multiple land cover types (under-segmentation). Conversely, if the objects are too small, they fail to represent the distinct characteristics of a ground feature (over-segmentation). Based on the characteristics of Sentinel-2 imagery, various parameter values were tested, ultimately leading to the selection of Scale = 50, Shape = 0.1, and Compactness = 0.5. The segmentation results for the Sentinel-2 MSI imagery (June 22, 2018, and June 1, 2021) in the Hoi An area are presented in Figure 2.

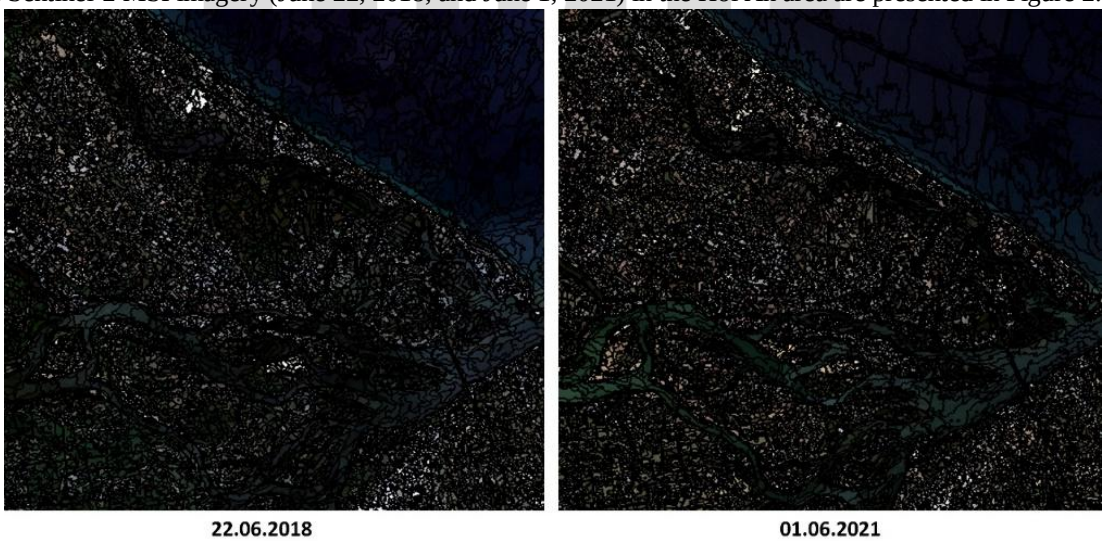

Figure 2. Segmentation results of Sentinel-2 MSI satellite imagery with Scale = 50, Shape = 0.1, and Compactness = 0.5.

III. RESULTS AND DISCUSSION

To classify land cover/land use (LCLU) in the Hoi An ancient urban heritage area using Sentinel-2 imagery, six categories were identified based on spectral and spatial characteristic analysis: (1) water bodies, (2) dense vegetation, (3) grass and shrubs, (4) agricultural land, (5) bare land, and (6) built-up land. For accuracy assessment, 200 random points were sampled using high-resolution Google Earth imagery to construct the error matrix and calculate the Kappa coefficient. The classification accuracies for the 2018 and 2021 LCLU maps reached 82% and 88%, respectively, with corresponding Kappa values of 0.81 and 0.85.

The classification results were subsequently utilized to generate LCLU status maps for the study area. The LCLU status maps of Hoi An (Quang Nam) produced from Sentinel-2 imagery using the object-based classification method are presented in Fig. 3. The areas of LCLU classes determined for 2018 and 2021 are summarized in Table 1.

Table 1. Land cover/land use classification results for the Hoi An area (2018–2021)

No.	Land cover/land use category	Area (ha)	
		2018	2021
1	Water bodies	4090.16	3946.03
2	Dense vegetation	63.29	103.53
3	Grass and shrubs	1198.08	1106.90
4	Agricultural land	2590.39	2568.30
5	Bare land	843.93	739.57
6	Built-up land	2975.87	3297.50

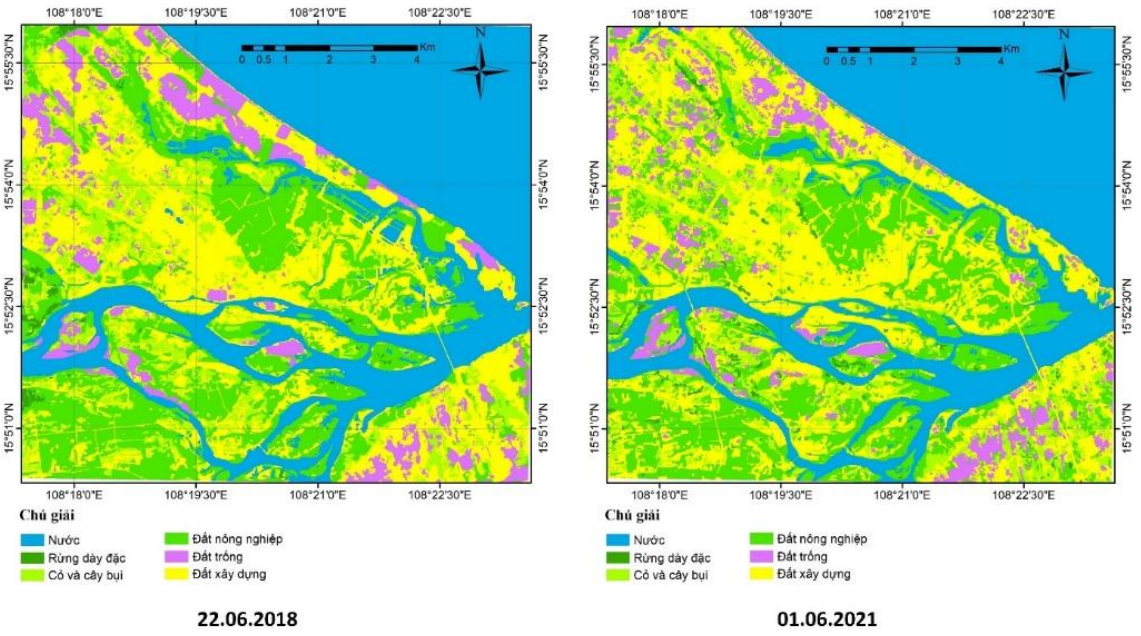

Figure 3. Land cover/land use status maps of the Hoi An area generated from Sentinel-2A imagery acquired on June 22, 2018, and June 1, 2021.

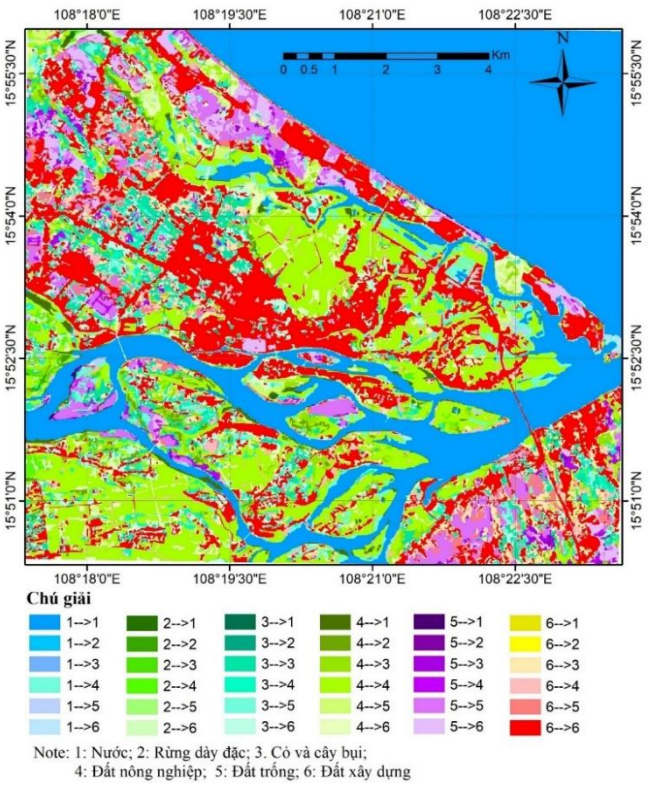

Figure 4. Land cover/land use change map for Hoi An (2018–2021) established using high-resolution Sentinel-2 satellite imagery.

Analysis of the results in Table 2 indicates that the LCLU change trend in Hoi An during the 2018-2021 period was characterized by a rapid expansion of built-up land (an increase of 321.61 ha, averaging over 100 ha/year). Conversely, agricultural land, bare land, and grass/shrubs experienced a decline. This shift can be attributed to the conversion of these land types into built-up areas, particularly for the "grass and shrubs" class, as these zones are predominantly designated for urban development in local planning. Furthermore, the water surface area decreased by approximately 144 ha, while dense vegetation increased by over 40 ha.

Based on the 2018 and 2021 LCLU status maps of Hoi An, Quang Nam Province, a land cover/land use change map for the 2018–2021 period was established (Figure 4).

IV. CONCLUSION

Sentinel-2 MSI satellite imagery, with its high spatial resolution and open-access availability, serves as an effective resource for generating LCLU status and change maps in heritage-sensitive areas such as Hoi An. For these remote sensing data, the object-based image analysis (OBIA) method proved highly suitable, yielding classification accuracies of nearly 90%.

This study successfully developed LCLU status maps for 2018 and 2021, as well as a change map for the 2018–2021 period, for the Hoi An ancient urban heritage area. These maps reveal a general trend characterized by a rapid decrease in agricultural land, bare land, and shrubs, making way for an increase in built-up and residential land at a rate of approximately 100 hectares per year.

The findings of this research provide valuable information for authorities in monitoring land-use dynamics and implementing timely measures to ensure the efficient and sustainable use of land resources in heritage areas like Hoi An.

References

[1] C. V. Pham, "Research on the application of VNREDSat-1 satellite imagery and geographic information systems for the conservation of cultural and natural heritage in Central Vietnam, piloted in Hue City and Phong Nha-Ke Bang National Park," National Project under the Space Science and Technology Program, 2016 (in Vietnamese).
[2] V. M. Pham, N. T. Nguyen, Q. T. Bui, V. D. Pham, and M. H. Pham, "Impact of urban expansion on cultural heritage: A study in the Complex of Hue Monuments," J. Geodesy and Cartography, no. 40, pp. 34–41, 2019 (in Vietnamese).
[3] A. Agapiou, S. Lysandrou, R. Lasaponara, G. Masini, and D. Hadjimitsis, "Study of the variations of archaeological marks at neolithic site of Lucera, Italy using high-resolution multispectral datasets," Remote Sensing, vol. 8, no. 9, p. 723, 2016.
[4] S. Biagetti et al., "High and medium resolution satellite imagery to evaluate late holocene human–environment interactions in arid lands: A case study from the central Sahara," Remote Sensing, vol. 9, no. 4, p. 351, 2017.
[5] D. Cerra, S. Plank, V. Lysandrou, and J. Tian, "Cultural heritage sites in danger-towards automatic damage detection from space," Remote Sensing, vol. 8, no. 9, p. 781, 2016.
[6] O. Close, S. Petit, B. Beaumont, and E. Hallot, "Evaluating the potentiality of Sentinel-2 for change detection analysis associated to LULUCF in Wallonia, Belgium," Land, vol. 10, no. 1, p. 55, 2021.
[7] A. Elfadaly, W. Attia, M. Qelichi, and R. Lasaponara, "Management of cultural heritage sites using remote sensing indices and spatial analysis techniques," Surveys in Geophysics, vol. 39, pp. 1347–1373, 2018.
[8] M. Hernandez, U. Huth, and G. Schreier, "Earth observation from space for the protection of UNESCO world heritage sites: DLS assisting UNESCO," Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., vol. XXXVII, Part B8, Beijing, 2008.
[9] K. Kwan et al., "Change detection using Landsat and Worldview images," Proc. SPIE 10986, Algorithms, Technologies, and Applications for Multispectral and Hyperspectral Imagery XXV, 1098616, 2019.
[10] D. Panuju, D. Paull, and A. Griffin, "Change detection techniques based on multispectral images for investigating land cover dynamics," Remote Sensing, vol. 12, no. 11, p. 1781, 2020.
[11] D. Phiri et al., "Sentinel-2 data for land cover/use mapping: A review," Remote Sensing, vol. 12, no. 14, p. 2291, 2020.
[12] J. Stubbs and K. McKee, "Applications of remote sensing to the understanding and management of cultural heritage sites," Remote Sensing in Archaeology, pp. 515–540, 2006.
[13] V. M. Pham, S. V. Nghiem, C. V. Pham, L. T. P. Mai, and Q. T. Bui, "Urbanization impact on landscape patterns in cultural heritage preservation sites: A case study of the Complex of Hue Monuments, Vietnam," Landscape Ecology, vol. 36, pp. 1235–1255, 2021.
[14] Y. You, J. Cao, and W. Zhou, "A survey of change detection methods based on remote sensing images for multi-source and multi-objective scenarios," Remote Sensing, vol. 12, no. 15, p. 2460, 2020.