ASSESSMENT OF LAND COVER CHANGES ON SUBI REEF IN TRUONG SA ISLANDS, VIETNAM USING MULTI-TEMPORAL LANDSAT IMAGES

Minh Hang Le[1,*]

[1]*Le Quy Don Technical University*

Abstract

In this article, the author proposes that Landsat images should be pre-processed using the DOS method for atmospheric correction and the Gram-Schmidt method for image enhancement. According to the results, the overall classification accuracy of multi-temporal images achieved over 85%, and Landsat images are suitable for classifying land cover on small islands in Truong Sa Islands, such as Subi Reef.

Keywords: *Land cover changes; Subi Reef; Truong Sa Islands; multi-temporal images; Landsat images.*

1. Introduction

Many atolls and islands constitute the Truong Sa Islands (Spratly Islands). Reconstruction work has been completed on the atolls such as Chau Vien (Cuarteron Reef), Chu Thap (Fiery Cross Reef), Gaven Reef, Tu Nghia (Hugh Reef), Gac Ma (Johnson Reef), Xubi (Subi Reef), and Vanh Khan (Mischief Reef), which are illegal occupation by China [1]. The land cover features in these atolls have been changed drastically over the years.

Currently, the satellite images are the primary data of monitoring the changes of the Earth’s surface. Over the last half-century, optical satellites have revolutionized the way scientists monitor the atmosphere, oceans, lands, plants, and other environmental features of the Earth's surface. The authors use Landsat images which are optical images with the spatial resolution 15 m (pan) and 30 m (multispectral), a 16-day collection period, and 11 spectral bands. The process of detecting changes in the condition of an object or phenomena by monitoring it at different times is known as change detection [2]. In order to encourage effective decision making, it is critical to comprehend relationships and interactions between human and natural phenomena on the surface of the Earth [3]. With the growing availability of historical remote sensing (RS) data, lower data costs, and higher resolution from satellite platforms, RS technology is prepared to get an even greater impact on monitoring land-cover and land-use change at various geographical scales [4]. In order to achieve the data analysis target of using RS for LULC change detection, an appropriate understanding of the study region, the satellite imaging system,

[*] Email: leminhhang81@lqdtu.edu.vn

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and the different methods for change detection is required [5]. Lu, et al. (2004) [3] and Jwan, et al. (2013) [6] reviewed classified the change detection approaches into some categories: Algebra (Image differencing, image rationing, Change vector analysis [7]); Transformation (Principal component analysis-PCA, Tasseled cap-TC), Classification (Post classification comparison [8, 9], spectral-temporal combined analysis, unsupervised change detection [10]).

Many researches in Vietnam have proposed a variety of methods for detecting land cover changes. Luong (2020) [11] suggested using GMO Maximum Entropy and Classification and Regression Tree (CART) classification algorithms, as well as multi-temporal Landsat image data on the GEE platform, to determine changes in land cover in Vietnam's northwest mountainous regions. To assess the land use change in the Mekong Delta, Nguyen (2011) [12] employed ISOdata, an unsupervised classification method, and Landsat, SPOT image data. Thanh (2019) [13] assessed land cover changes in the Hanoi city region from 1989 to 2019 using fractional vegetation cover (FVC) and multi-temporal Landsat data. The effectiveness of Landsat images in monitoring land cover changes has been demonstrated by these research findings.

Stephen, et al. (2020) [14] proved that remote sensing data is currently the most important data in the study of land cover on islands. Landsat, SPOT, and high-resolution images (such as GeoEye, Ikonos, QuickBird, WordView-2) are among the remote sensing data used, in which Landsat images accounting for a higher percentage of research publications than other types of material. Human activities, particularly tourism development, infrastructure construction, and population increase, have resulted in changes in the land cover of the islands, according to research findings. The research focuses on Pacific and near-shore islands. There are still a few studies on landcover of offshore islands, particularly in the Truong Sa Islands, that have not been published yet. Atolls make up the majority of the islands in the Truong Sa Islands. However, during 2014 and now, these islands are being changed into such an artificial island with a variety of features such as plants, barren land, built-up. Hence, in this article the author proposes multi-temporal Landsat images which are used to estimate land cover changes in Subi Reef.

2. Study area and materials

2.1. Study area

China is currently illegally exploiting the Subi Reef. Subi Reef is a part of the Thi Tu group of atolls. Subi Reef may be located at latitudes of 10°54'47.88"N and longitudes of 114°03'43.2"E. This is a small island approximately 26 kilometers southwest of the Thi Tu Reef (Figure 1).

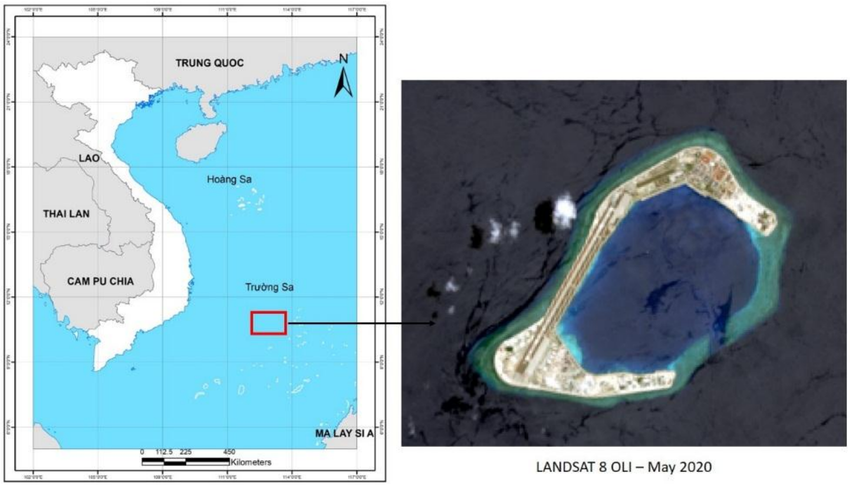

Figure 1. The study area: (a) Location of the study area (a red rectange); (b) Subi Reef in the natural colour image.

Between 2015 and July 2016, China increased its Subi Reef illegal reclamation activities and completed a number of projects. The construction is built on the coral reef. Subi Reef's land cover features have changed year to year. The land use and land cover features of Subi Reef are runway, plants, built-up, barren land, and solar panels, based on the interpretation of high-resolution satellite images and spectral reflectance characteristics.

2.2. Material data and pre-processing

The author uses multi-temporal Landsat 8 OLI data from 2014 to 2020 to assess land cover changes in Subi Reef. The characteristics of material data are shown in Table 1. Using ENVI 5.3 software, multi-temporal Landsat images are pre-processed, including atmospheric correction using the DOS method. The Landsat data are converted to surface reflectance values after atmospheric corrections.

Table 1. The characteristic of material data

Parameters	Descriptions
Acquisition	Landsat 8 OLI
Date	24/04/2014; 11/04/2015; 29/04/2016; 16/04/2017; 24/07/2018; 06/04/2019; 10/05/2020
Path/Row	120/52 and 120/53
Cloud_cover	<10%
Bith depth	16 bits
Projected	UTM/WGS 84
Level	Level 1

3. Methodology

3.1. Image enhancement method of Landsat 8 imagery

A panchromatic band with a resolution of 15 meters and a multispectral band with a spatial resolution of 30 meters are available on the Landsat 8 OLI satellite. Landsat images must be enhanced in resolution by combining with the panchromatic band to increase the spatial resolution of multi-spectral images by pan-sharpening method. The author recommends that the Gram-Schmidt transformation should be used to improve image quality (Figure 2). The essential steps in the Gram-Schmidt pan-sharpening method [15] are as follows: (1) A low-resolution Panchromatic (Pan) band is calculated as a linear combination of *n* multi-spectral (MS) bands; (2) The Gram-Schmidt transform is applied to the simulated Pan image as the first band; (3) The high spatial resolution pan image band is replaced with the first Gram-Schmidt band; (4) The inverse Gram-Schmidt transform is applied to form high-resolution multispectral bands.

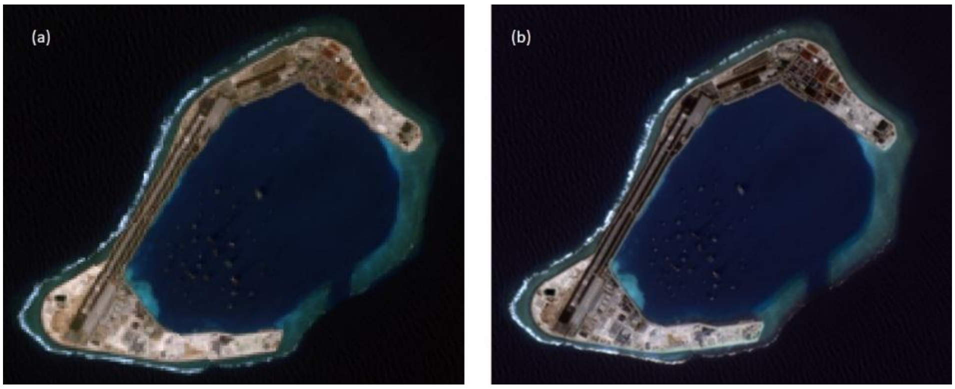

Figure 2. Subi Reef 24/07/2018: (a) The original image;
(b) After image enhancement using Gram-Schmidt tranform.

The advantage of the Gram-Schmidt pan-sharpening method is that there is no restriction on the number of multispectral bands in the image. The multispectral band's processing and spectral reflectance properties are kept in the enhanced image.

The procedure reduces the correlation value (excess value) between the bands by orthogonalizing matrix data or bands of a digital image. To prevent bands with associated values, the revised technique subtracts the average value of each band from each pixel.

3.2. Assessment the change of land cover by using multi-temporal Landsat images

Figure 3 shows the proposed method for classification land cover changes in Subi Reef using multi-temporal Landsat images.

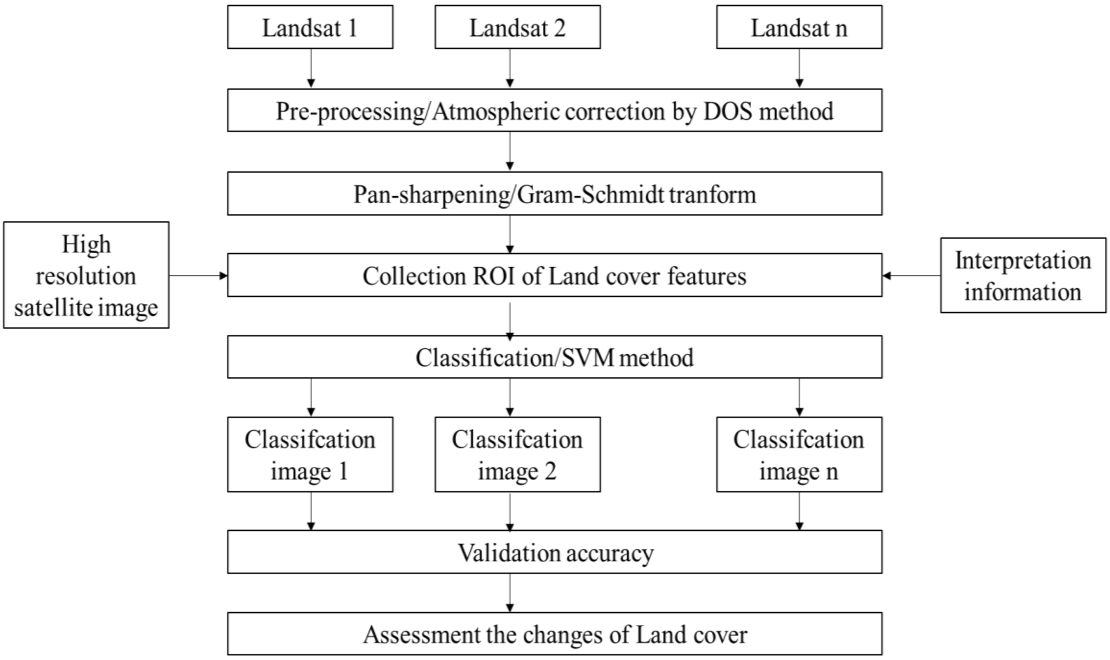

Figure 3. The workflow of the proposed method.

The workflow of the proposed method consists of four steps:

- Step 1: Multi-temporal Landsat images are pre-processed using the DOS method for atmospheric correction and the Gram-Schmidt transform algorithm for image enhancement.

- Step 2: At the time of image acquisition, based on visual interpretation information on high-resolution satellite images and multi-spectral characteristics to choose ROI (Region of Interest) samples.

- Step 3: Using the SVM algorithm, classify images using a supervised classification method.

- Step 4: Assess land cover changes on multi-temporal Landsat images using the post-classification analysis method.

4. Results and discussion

The land cover features of Subi Reef are classified using the workflow indicated in Figure 3.

The land cover features of Subi Reef have changed from year to year. As a result, the interpretation of the corresponding high-resolution satellite image each year (Figure 4) and the spectral reflectance characteristics of the features (Figure 5) are used to determine the land cover of Subi Reef. Figure 5 shows the difference between the spectral reflectance patterns of barren land and built-up features. The surface reflectance values of the runway, built-up, and under construction (in 2016) features are similar, and the spectral reflectance profiles of coral reefs, grass, and solar panels are all different.

Figure 4. Visual interpretation land cover features of Subi Reef on high resolution satellite image. (A) Runway, (B) Built-up; (C) Under construction [16].

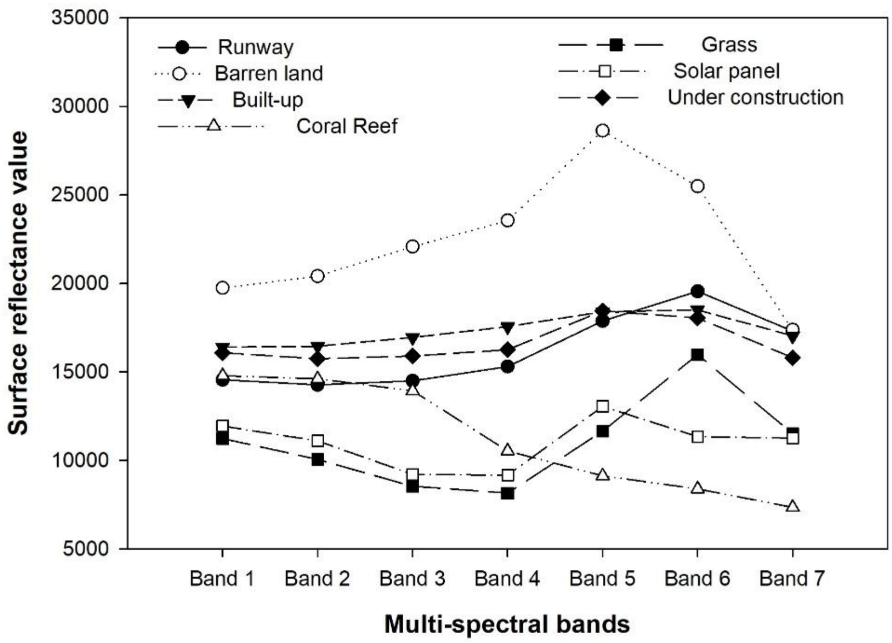

Figure 5. The surface reflectance of land cover features on Subi Reef in Landsat image.

Table 2. Assessment of the classification accuracy from 2014 to 2020

Landsat image	**Kappa index**	**Overall accuarcy**
24/04/2014	0.9738	98.86%
11/04/2015	0.9873	98.18%
29/04/2016	0.9602	97.65%
16/04/2017	0.7725	85.52%
24/07/2018	0.9849	99.18%
06/04/2019	0.8597	91.72%
10/05/2020	0.8274	89.82%

Table 2 shows the Subi Reef's land cover classification accuracy from 2014 to 2020. The classification accuracy is calculated by ROI samples selected from the Landsat multispectral image. With a Kappa index of 0.9849, the greatest classification accuracy was 99.18%. The overall classification accuracy of the multi-temporal images are more than 85%.

Figure 6a shows the landcover classification results of Subi Reef using multi-temporal Landsat images from 2014 to 2020. Subi Reef was only an atoll in 2014, with a military building on the island's southwest. China began construction activities on Subi Reef in 2015. A number of constructions were built on the island in 2016. From 2017 to 2020, the island's infrastructure and buildings were still being built.

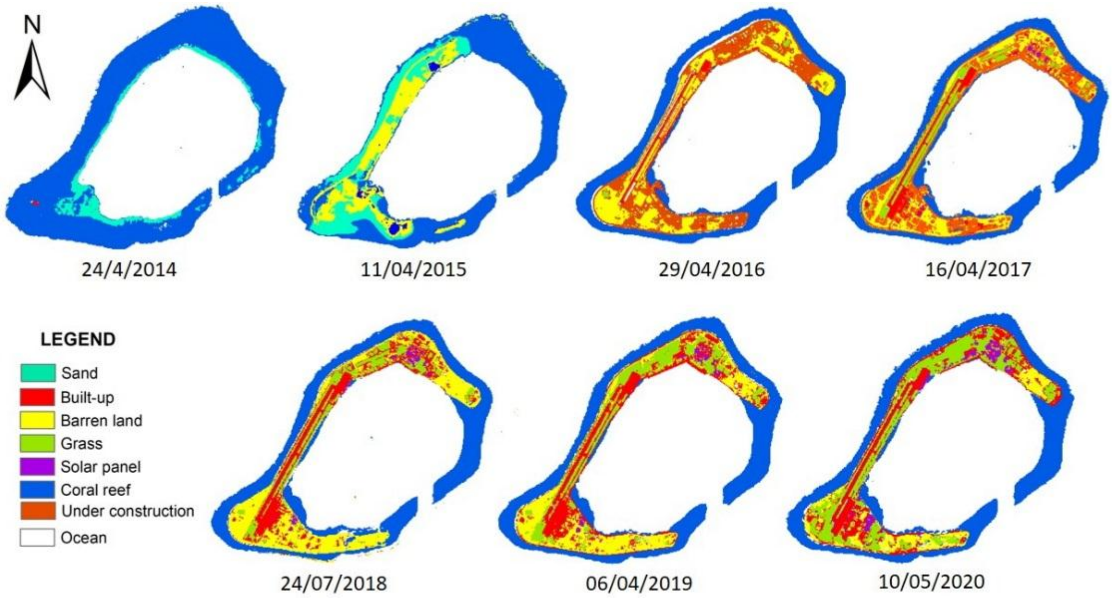

Figure 6a. The landcover classification of Subi Reef from 2014-2020.

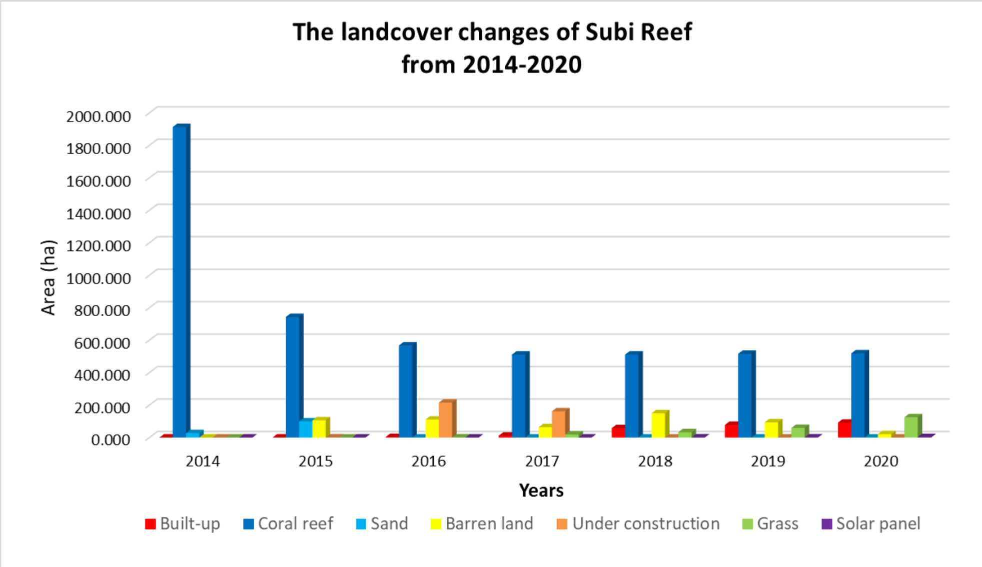

Figure 6b. The landcover area changes of Subi Reef from 2014-2020.

Figure 6b illustrates the land cover area changes of Subi Reef from 2014 to 2020. Subi Reef's area in 2014 was mostly coral reef with 1912.8 ha. The coral reef area was decreased to 742.4 ha in 2015. Simultaneously, land cover features such as sand and barren land increased approximately 99.8 ha and 106.16 ha, correspondingly. In 2015, China began work on the Subi Reef. China had completed the runway and certain building elements with a total size of 3.2 ha by 2016. In 2016, the area of coral reef declined to 567.4 ha, while barren land and under construction features expanded. The built-up area increased significantly from 2017 to 2020 with 80 ha and the coral reef's area remains unchanged at 510.8 ha. In 2020, the area of barren land was be decreased to 20.4 ha, and increased the area of grass feature of 125.1 ha and solar panel.

According to that, China has seized Subi Reef and rebuilt it into an artificial island. This will have a significant impact on regional security while also affecting the maritime ecosystem of the Truong Sa Islands.

5. Conclusion

Consequently, China's illegally occupied Subi Reef is currently mainly an artificial island. Since 2015, China has been reclaiming the island. During 2014 to 2020, the land cover features of the island changed with each step of the island's reclamation. According to study, Subi Reef was just an atoll in 2014. However, different land cover features such as built-up, barren land, and grass will be founded in 2020. China is increasing human activity on Subi Reef, as evidenced by the appearance of man-made features on the island.

According the classification result, Landsat satellite images are significant data for classifying land cover features on offshore islands, especially atolls and artificial islands in the Truong Sa Islands. To classify the land cover on small islands in the Truong Sa Islands, Landsat images should be pre-processed, which includes atmospheric effecting correction using the DOS method and image fusion using Gram-Schmidt method to enhance images. Land cover classification results using multi-temporal Landsat images have an accuracy of more than 85%. Additionally, the classification results are consistent with the results of a high-resolution satellite image evaluation of construction activities at Subi Reef.

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ĐÁNH GIÁ BIẾN ĐỘNG LỚP PHỦ TRÊN ĐẢO ĐÁ XU BI TẠI QUẦN ĐẢO TRƯỜNG SA, VIỆT NAM SỬ DỤNG ẢNH LANDSAT ĐA THỜI GIAN

Lê Minh Hằng

Tóm tắt: *Trong bài báo này, tác giả đề xuất tư liệu ảnh Landsat sẽ thực hiện bước tiền xử lý ảnh gồm hiệu chỉnh khí quyển bằng phương pháp DOS và tăng cường chất lượng ảnh bằng phương pháp Gram-Schmidt. Kết quả cho thấy độ chính xác phân loại trên ảnh đa thời gian đạt trên 85% và tư liệu ảnh Landsat phù hợp để phân loại lớp phủ trên các đảo nhỏ tại quần đảo Trường Sa như đảo đá Xu bi.*

Từ khóa: Biến động lớp phủ; đảo đá Xu bi; quần đảo Trường Sa; ảnh đa thời gian; ảnh Landsat.

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