Monitoring land-cover changes using multi-temporal Sentinel-1 data in U Minh Thuong National Park

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SUMMARY

U Minh Thuong National Park is a typical wetland ecosystem in Vietnam. In recently, U Minh Thuong National Park is under pressured to develope economic and protect the forests. According to the ability to observe wide areas and continuous, satellite images are currently the main remote sensing data for monitoring and management of natural resources, especially in monitoring the changes of land cover. SAR (Synthetic Aperture Radar) data, uneffected by the weather, day and night, is being used for environmental management. Sentinel-1 satellite images provided by the European Space Agency is SAR data, with C-band, 12-days a period and free of charge. The changes of land cover object correlate to backscatter values in the time-series of Sentinel-1 data. In this article, the authors proposed to determine land cover objects based on the changes of backscatter values of multi-temporal Sentinel-1. The classification result is assessed by current land use mapping with overall accuracy archieved 85%. In particular, the classification accuracy of built-up land and paddy rice had high accuracy such as 90% and 83%, respectively. According to the results, multi-temporal Sentinel-1 data is helpful for monitoring natural environment.

Rừng quốc gia U Minh Thượng là khu vực có hệ sinh thái ngập nước đặc trưng của Việt Nam. Ngày nay, rừng quốc gia U Minh Thượng đang phải chịu áp lực giữa việc phát triển kinh tế và bảo tồn, khai thác rừng. Với khả năng quan sát diện rộng, liên tục, tư liệu ảnh vệ tinh hiện đang là tư liệu chính trong việc giám sát và quản lý các nguồn tài nguyên thiên nhiên, đặc biệt trong việc giám sát sự thay đổi của rừng. Với ưu điểm không chịu ảnh hưởng của thời tiết, thu nhận cả ngày lẫn đêm, tư liệu ảnh SAR (Synthetic Aperture Radar) đang được nghiên cứu ứng dụng trong nhiều lĩnh vực quản lý tài nguyên môi trường. Tư liệu ảnh vệ tinh Sentinel-1 là tư liệu ảnh SAR, kênh C do Cơ quan hàng không vũ trụ Châu Âu cung cấp, có chu kỳ chụp là 12 ngày và được cung cấp miễn phí. Những thay đổi của đối tượng lớp phủ bề mặt sẽ làm thay đổi giá trị tán xạ ngược trên tư liệu ảnh Sentinel-1 đa thời gian. Trong nội dung bài báo, các tác giả đề xuất xác định đối tượng lớp phủ dựa sự thay đổi của giá trị tán xạ ngược trên tư liệu đa thời gian Sentinel-1. Kết quả phân loại được đánh giá dựa trên bản đồ hiện trạng sử dụng đất với độ chính xác 85%. Trong đó, độ chính xác xác định đối tượng đất đô thị và đất lúa cho độ chính xác cao tương ứng là 90% và 83%. Kết quả nghiên cứu cũng khẳng định khả năng ứng dụng tư liệu ảnh Sentinel-1 trong giám sát tài nguyên môi trường.

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1. INTRODUCTION

U Minh Thuong National Park was recognized as the 8th Ramsar site of Vietnam and 2.228th Ramsar site in the world. U Minh Thuong National Park is one of the last two significant areas of peat swamp forest remaining in Vietnam (the other area is U Minh Ha). Besides, this area is recognized as one of the three highest priority areas for the conservation of wetlands in the Mekong Delta [15]. Due to the impact of human beings over the centuries, the wetland ecosystems and forests in U Minh Thuong have been converted to agricultural land or seafood aquaculture for supporting food. These changes caused ecological imbalance. Over exploitation, forest fires, agricultural production, aquaculture development and other human activities threates the ecosystem of U Minh Thuong area. As a result, land-cover objects changes in a period of year. Hence, monitoring the land cover changes in a year is play an important part in planning biodiversity conservation and economic development of U Minh Thuong area.

Sentinel-1A satellite was successfully launched into orbit by the European Space Agency in December 2014. There are currently Sentinel-1A and Sentinel-1B satellites. The Sentinel-1 satellite carrying microwave sensor with band-C, spatial resolution 10m in IW (Interferometric Wide) mode, is provided free of charge on-line with a 12-day cycle. The advantages of Sentinel-1 data is uneffected by weather conditions, and acquised day and night. These advatages are appropriate for monitoring land use/land cover changes, especially in tropical areas as in Vietnam.

SAR (Synthetic Aperture RADAR) data is used for land cover classification [1-3], rice monitoring [5, 6], [10-12]. The polarization of Sentinel-1 is the main data for mapping land cover by using Support Vector Machine (SVM) [1], decision tree and Random Forest (RF) [2] with accuracy archived 93%. Abdikan.S. *et al* (2016) [1] was used a single Sentinel-1A scence with dual-polarization (VV and VH) for mapping land cover. Waske, B *et al* (2009) classified land cover by multi-temporal SAR images using decision tree and RF method with accuracy 83%. In other while, the multi-temporal SAR data in a few years is applied for mapping rice based on phenology of paddy rice [6], [11].

In Vietnam, there are a few researches to using Sentinel-1 for monitoring environment and land cover mapping [4], [7], [8]. Duy *et al* (2015) proposed to discriminate water area by Sentinel-1 [4]. Luan *et al* (2017) [8] studied flood mapping by RADAR data. Due to free-of-charge with high resolution 10m and short cycle, the time-series Sentinel-1 data allow monitoring the changes of land cover. In this article, the authors propose a method of monitoring the changes of U Minh Thuong Nation Park land cover by using multi-temporal Sentinel-1.

2. STUDY AREA AND MATERIALS

2.1. Study area

The study area is U Minh Thuong Nation Park and located in the Southwest of Kien Giang province. U Minh Thuong national park is the center of U Minh Thuong district. The

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coordinates of U Minh Thuong National Park from $9^031'$ to $9^039'$ North latitude and $105^003'$ to $105^007'$ East longitude (Figure 1).
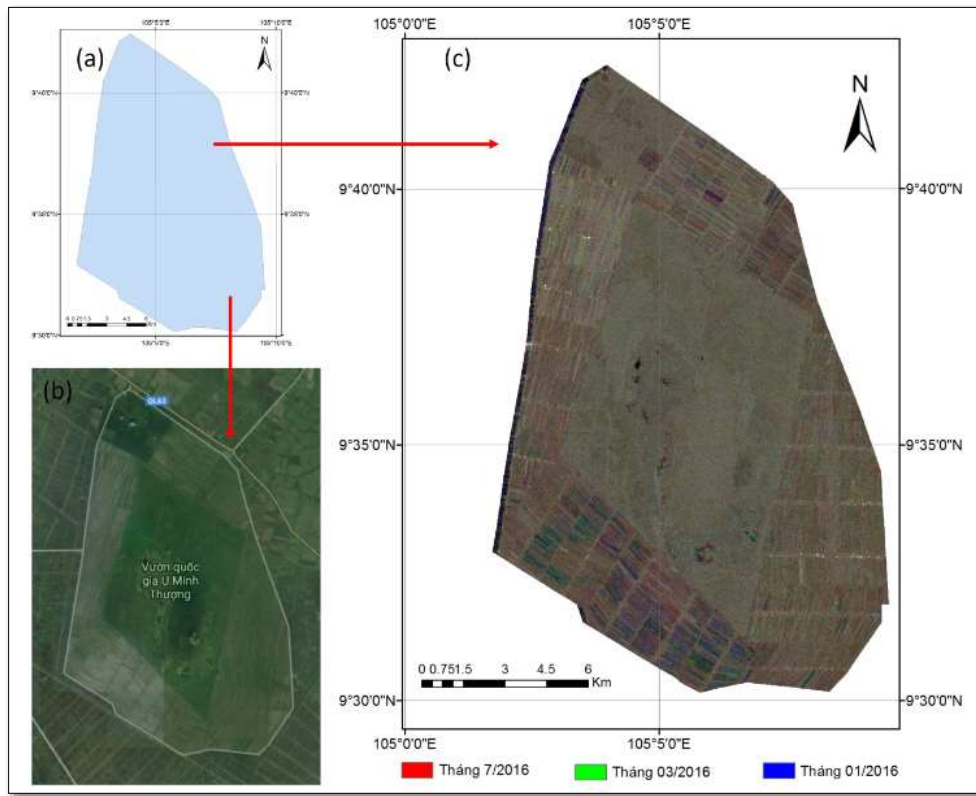

Figure 1. Location of the study area. (a) The study area; (b) U Minh Thuong Nation Park on high resolution satellite image (Google Earth). (c) The composite RGB of multi-temporal Sentinel-1 images in 2016 (R:G:B=7/2016:03/2016:01/2016)

U Minh Thuong has many types of primitive forest with unique value of peat swamp forest in Vietnam and in the world. U Minh Thuong Nation Park has two distinct area such as the core zone and the buffer zone. The core zone of U Minh Thuong National Park should be preserved and the outer buffer zone is the residential area of local residents. Acorrding to Decision No. 11/2000/QĐ-TTg dated 14/01/2002 by the Prime Minister, area of the U Minh Thuong National Forest included 21,107 ha in which the core zone is 8,038 ha and the buffer zone is 13,069 ha. The core zone is unchanged and the buffer zone of the forest is changed because of households living, farming, cultivating and contracting forests. U Minh Thuong National Park is recently being invested to research and conserve the rare and valuable biological and biological sources. At the same time, it has been implemented a project to develop ecotourism and culture travel.

2.2. Materials and pre-processing

The data used were Sentinel-1 images with repeat cycle of 12 days. According to that Sentinel-1 suitable for monitoring the changes of land cover objects. The experience SAR images is C-band, Level-1 with GRD level, 10m spatial resolution and VV polarization. In this article, the authors used 12 Sentinel-1 scences and the characteristic of the experience materials are shown on Table 1.

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Table 1. The characteristic of multi-temporal Sentinel-1

Specifications	Sentinel-1 data
Acquisition time	17/01/2016; 22/02/2016; 29/03/2016;22/04/2016; 28/05/2016;09/06/2016;27/07/2016; 20/08/2016; 25/09/2016; 19/10/2016; 12/11/2016;18/12/2016
Ascending/Descending	Ascending
Mode	IW (Interferometry Wide Mode)
Band	C-band (5.46 Hz)
Polarization	VV+VH
Level processing	Level-1 GRD (Ground Range Detected)
Resolution	10x10m
Bit depth	16 bit

The data pre-processing was performed by the SNAP toolbox with four main steps such as (*i*) Calibration to sigma nought; (*ii*) Terrain correction by DEM of STRM; (*iii*) Convert to dB value; (*iv*) Multi-temporal filter. The study area was clipped by polygon boundary on the time-series Sentinel-1 data (Figure 1c).

In addition, the experience material in this study included a Current land use map of U Minh Thuong district in 2015. The interpretation land cover objects in multi-temporal Sentinel-1 and assessment the classification result were based on the current land use map in 2015.

3. METHODOLOGY AND RESULTS

3.1. Analysis of feature land cover patterns by multi-temporal SAR images

Land cover patterns in U Minh Thuong from January to December in 2016 are divided into two main groups: (*i*) The changes patterns and (*ii*) The unchanges patterns (Figure 2). The changes patterns include in cultivated land such as paddy rice, crop land… and wetlands for transfer of land use purposes. The unchages patterns are built-up land, perennial, water and indigo forest in core zone areas. Figure 2 shows the composite RGB images of three days of Sentinel-1 data. The different colors in the composite image correspond to the different of land cover patterns. White or back in RGB images are unchanged objects because of the stability backscatter value of time series SAR images (Figure 2a and Figure 2d). On the other hand, the colorful patterns in the RGB image are changed objects because backscatter value of each pixel in each month are great differents (Figure 2b and Figure 2c).

To determine the variability backscatter value of each patterns, the authors proposed using texture value such as mean and standard deviation value of time-series Sentinel-1 images during a year. Standard deviation is given by Eq (1):

$$std_i = \left(\frac{1}{n-1} \sum_{i=1}^{n} \left(x_i - \bar{x} \right)^2 \right)^{\frac{1}{2}} \tag{1}$$

Where: std_i - the standard deviation value of each pixel which is calculated by 12 scences; x_i - backscatter value of each pixel; $\bar{x}$ - average value of time-series images of each pixel.

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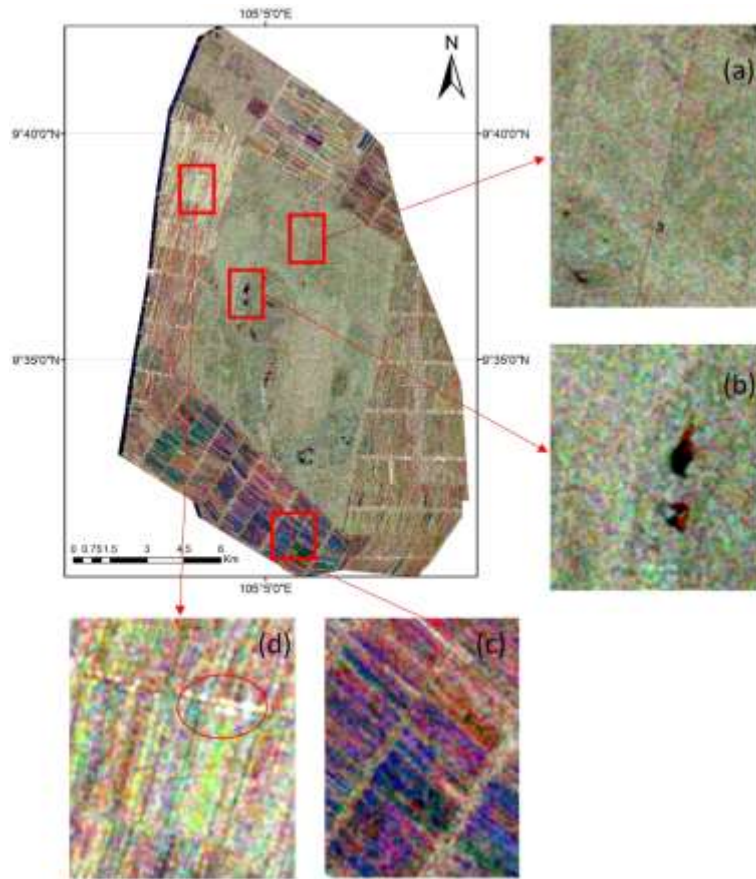Hanoi, Vietnam, April 22–26, 2019

Figure 2. Analysis of land cover objects on multi-temporal SAR images. (a) The plants in the core zone of U Minh Thuong Nation Park; (b) The changes of water object in the core zone; (c) Paddy rice and cultivated land; (d) Buit-up land.

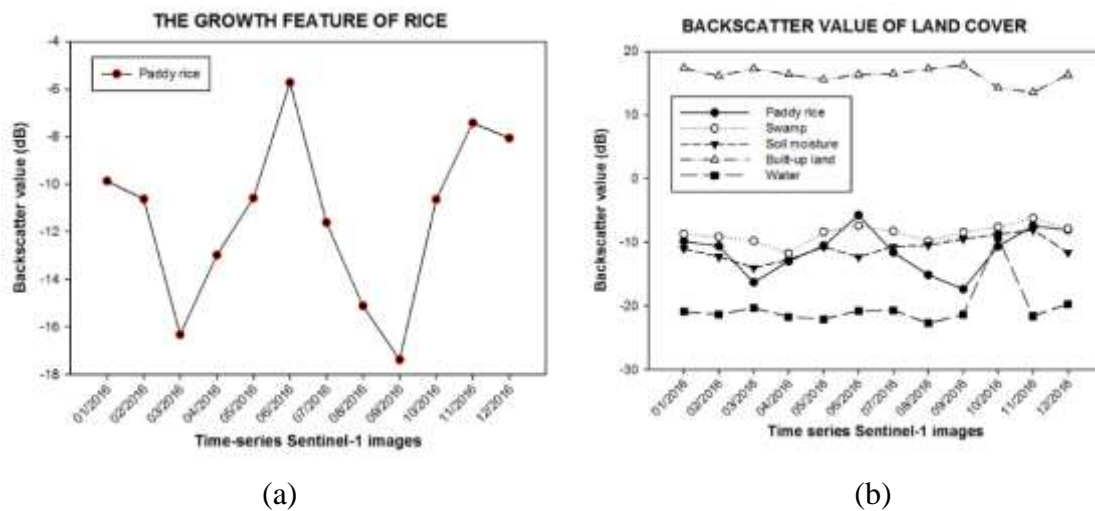(a)   (b)

Figure 3. The correlation between backscatter value of multi-temporal Sentinel-1 images and the feature of land cover objects. (a) The growth feature of rice; (b) Backscatter value of land cover objects.

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The correlation between backscatter value in time-series SAR images and the feature of land cover objects is shown in Figure 3. The higher value of backscatter standard deviation value, the higher the changes. In contrast, the unchanged patterns have lower backscatter standard deviation value than the changed pattern (Figure 3). The object which is the highest standard deviation value in the study area is paddy rice. The paddy rice is discrimated based on the corresponding to phenology of rice and backscatter value of multi-temporal SAR images (Figure 3a). Consequently, land cover objects has changed by phenology of plants species and human impacting.

3.2. Methodology

Based on the changes of land cover objects and backscatter value of multi-temporal Sentinel-1 images, the authors propose a method for monitoring the changes of land cover in U Minh Thuong National Park (Figure 4). Land cover mapping is discriminated by using decision tree method which the input data includes texture images and paddy rice image. The texture images are standard deviation image, mean value image which are created based on 12 Sentinel-1 scences. The threshold value in nodes are chosen by the changes characteristics of land cover objects in multi-temporal Sentinel-1 in 2016 and comparing with the current land use map.
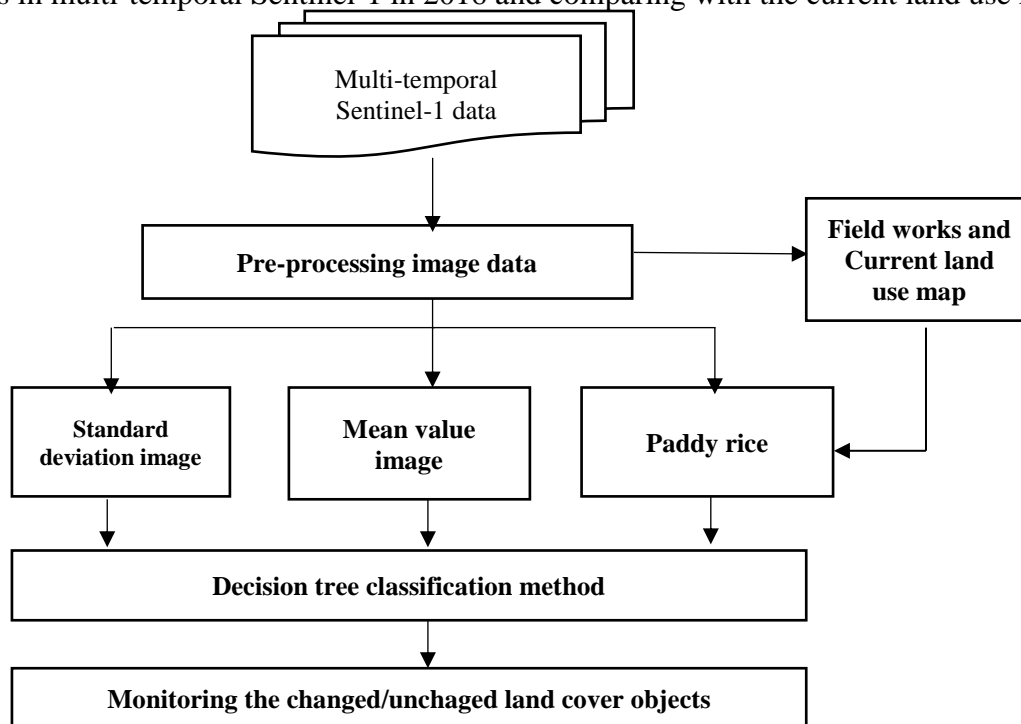

Figure 4. The proposed method for discriminated the changed/unchanged objects using time-series SAR images

According to the current land use map and analysis backscatter value in multi-temporal Sentinel-1, the land-cover patterns in U Minh Thuong content of wetland, unchanged area, paddy rice, built-up land and NTS (aquatic production land). Wetland is defined as the area coverd by water which has significant changes during period a year. The wetlands in U Minh Thuong are mainly aquaculture or swamps. Therefore, the wetland has a changed object. The water is defined as the area covered by water which has a low changes such as lake, river, drainage. The cultivated land is paddy rice area. The core zone and the unchanges area is segmented to unchanged objects.
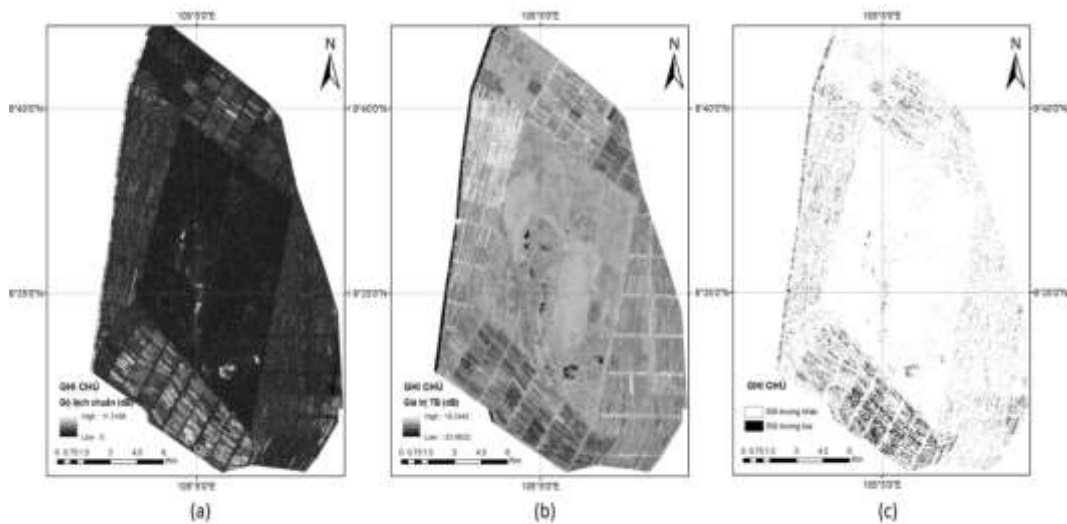
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Figure 5. (a) Standard deviation image; (b) Mean value image; (c) Paddy rice image

3.3. Discusion

The classification result which presents the changed/unchanged land cover objects in U Minh Thuong National Park using multi-temporal Sentinel-1 data are shown in Figure 6.
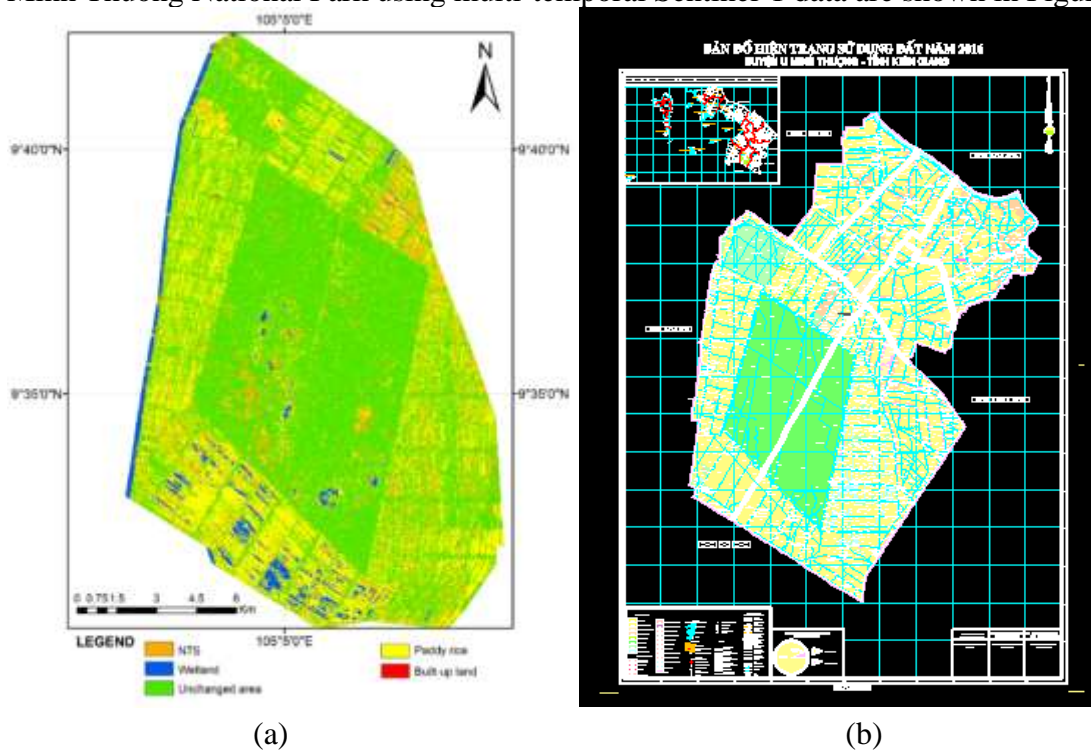

(a)   (b)

Figure 6. (a) The changed/unchanged objects in U Minh Thuong National Park; (b) The current land use map in 2015 in U Minh Thuong district.

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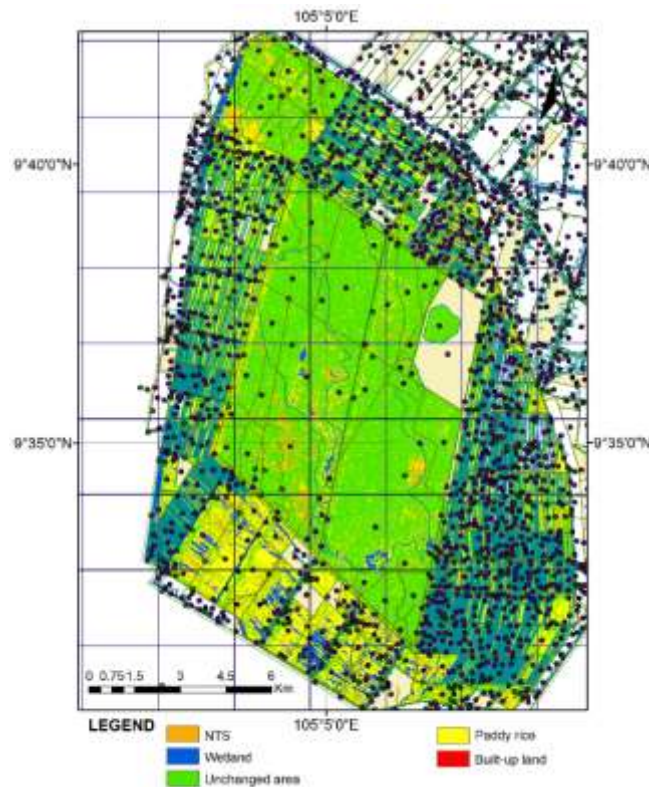Hanoi, Vietnam, April 22–26, 2019

Figure 7. The assessment accuracy of the classification results by using current land use map of U Minh Thuong district in 2015

The accuracy of classification result is assessed by U Minh Thuong current land use map (Figure 7). We choose 100 check points which corresponded to the location on the current land use map. The classification accuracy archived to 85%. The confusion matrix for accuracy assessment is shown on Table 2.

Table 2. Assessment accuracy of the proposed method

		Classification data					
		Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	PA (%)
Reference data	**Layer 1**	18	3	1	0	0	78
	Layer 2	4	20	2	0	0	73
	Layer 3	0	2	22	1	0	75
	Layer 4	0	2	0	15	0	84
	Layer 5	0	0	0	0	10	90
	UA (%)	78	74	75	83	90	

Overall accuracy 85.0%

Kappa 80.8%

Where: Layer 1 - NTS; Layer 2: Wetland; Layer 3 – Unchanged area; Layer 4-Paddy rice; Layer 5 – Built-up land

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The highest changed area are paddy rice, NTS and wetland. The changes of wetland is caused by conversion of land use propose. The code of wetland in current land use map are ONT, LUC and CLN. However, the lake in the core zone has high changes during a year due to the lack of water in dry season. The unchanged water area is the North of U Minh Thuong park. The unchanged area is the core zone of U Minh Thuong Nation Park which has the major of swamp forest and evergreen forest or perennial in the buffer zone. The unchanged area correspond to the code RSX; CLN; RSM; ONT in the current land use map. The built-up land is located residential area in the buffer zone of the U Minh Thuong National Park. The built-up land has the highest backscatter value in multi-temporal SAR images as well as the classification accuracy of these objects is high.

4. CONCLUSION

The proposed method discriminated the changed/unchanged objects in U Minh Thuong National Park by using multi-temporal Sentinel-1 images data with the accuracy 85%. The core zone of U Minh Thuong National Park which is conserved the biodiversity of wetland area can be monitored by multi-temporal SAR images. The changed or unchanged objects effect to human living and the conserved areas in U Minh Thuong. The classification accuracy of the proposed method assessed by the current land use map of U Minh Thuong district in 2015. The built-up land and wetland have the highest accuracy with relatively 90% and 83% because of the constrast of backscatter value in time-series SAR data. The wetland and unchanged area have low accuracy with 74% and 75% because the SAR image have still speckle noise and changes of land use purpose which have not been identified clearly. The proposed method supported one of remote sensing methods for monitoring changed/unchanged land cover objects by using time-series of SAR images, especially cultivated land, paddy rice and aquatic production land.

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