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APPLICATION OF OPTICAL REMOTE SENSING IMAGERY AND DECISION TREE (DT) ALGORITHM IN FLOOD MONITORING AND STATISTICS: A CASE STUDY IN QUANG NAM PROVINCE, VIETNAM

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Abstract

Flooding on a large scale causes severe damage to natural and socio - economic conditions. Traditional flood statistics methods require surveyors to go directly to the site, which is time - consuming and costly. The development of satellite technology makes it possible for people to observe the earth from a distance on a large scale. Artificial intelligence (AI) algorithms provide powerful means of processing satellite image data. The study used satellite images MODIS (Moderate Resolution Imaging Spectroradiometer) with two sensors, Terra and Aqua, to observe the area of Quang Nam province, Vietnam, with an 8 - day temporal resolution. The Decision Tree (DT) artificial intelligence algorithm is applied to identify flooded pixels. The study has provided statistical results and spatial distribution of flooded areas in Quang Nam province in 2020. The flooded area of Quang Nam province tends to increase in the last months of the year and until January next year. Some districts, such as Nam Giang, Tam Ky and Phuoc Son, have large flooded areas. There is a trend similarity when comparing the flooded area with the rainfall value of the study area.

Keywords: Remote sensing; MODIS; Flood; Decision Tree.

1. Introduction

Flood is one of the most damaging natural disasters in Vietnam and many other regions worldwide [1 - 3]. In recent years, the natural hazard and flood situation in the Central region and Quang Nam province of Vietnam has become more complicated [2, 4 - 6]. Traditional flood statistics methods require surveyors to go directly to the site, which is time-consuming and costly [7].

The development of satellite technology makes it possible for people to observe the earth from a distance on a large scale [8]. Active and passive satellites with multi-spectrum can detect flood locations as events occur [9, 10]. Remote sensing technology is now widely known as a powerful tool in natural resource management and monitoring of natural phenomena with the ability to provide data on a large spatial scale and high temporal resolution [7 - 9]. Remote sensing images have become a valuable source of data in monitoring floods. Some kinds of satellite image data are commonly used in flood monitoring, such as Landsat-8, Sentinel-2, MODIS (MODerate resolution Imaging Spectroradiometer) or synthetic aperture radar (SAR) [11 - 13].

Some simple models have been applied in monitoring and statistics of the flooded areas from remote sensing images, such as weight of evidence (WOE) and frequency ratio [14, 15]. In addition, many multivariate methods have been used in flood risk studies, such as logistic regression, analytic hierarchy process (AHP), and analytic network process (ANP) [16]. Flooding is a complex phenomenon, and expert opinion - based models introduce a large source of error that makes it challenging to achieve high performance. Artificial intelligence (AI) algorithms provide powerful means of processing satellite image data and are able to overcome the weaknesses of previous models. Some models are used in hydrology, such as Artificial neural networks (ANN), fuzzy logic (FL) and, adaptive neuro-fuzzy interface, Decision Tree [17, 18].

This study uses satellite image MOD09A1 product from MODIS satellite with a spatial resolution of 500m and time resolution of 8 days to monitor and statistics the flood situation in Quang Nam province in 2020. The Decision Tree model is used to identify water - related pixels with 550 sample points selected based on the hydrological system and Digital Elevation Model (DEM). Then, flood maps are identified using a map of water locations after excluding points that overlap with the hydrological system. Finally, the results are evaluated by the AUC area and compared with the total rainfall at some stations in Quang Nam province.

2. Methodology

2.1. Study area

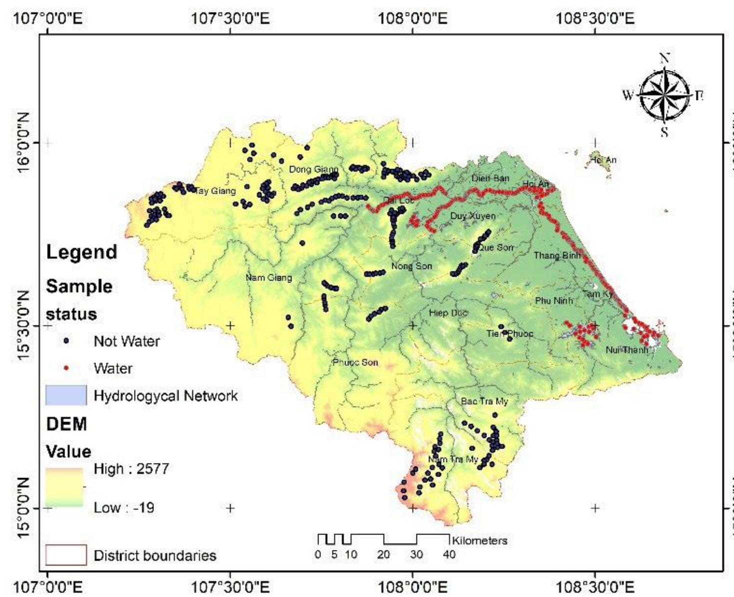


Figure 1: Location map of the study region in Quang Nam province

Quang Nam is a coastal province in Central Vietnam, geographically located from 14°57'10" to 16°03'50" North latitude and 107°12'50" to 108°44'20" East longitude. The topography of Quang Nam is gradually tilted from West to East, forming three distinct ecological landscape types: high mountains in the West, midland in the middle, and a coastal plain with a 125 km long coastline. The mountainous area occupies 72 % of the natural area, with many mountains over 2,000 m high such as Lum Heo, Tion, Gole - Lang, and Ngoc Linh mountain. In addition, the topographical surface is divided by a fairly dense system of rivers, including the Vu Gia, Thu Bon, Tam Ky and Truong Giang rivers [19].

The natural disaster situation in Quang Nam province is very complicated and tends to increase in the number of natural disasters, quantity, and severity. Some natural disasters that often occur in Quang Nam are tropical depressions, storms, floods, droughts, saltwater intrusion, and landslides [20].

2.2. Material and methods

The selected remote sensing image data is the MODIS MOD09A1 image product with the full name MODIS/TERRA surface reflectance 8 - day l3 global 500 m SIN GRID V005. This product provides surface reflection with a spatial resolution of 500 m × 500 m for seven optical spectral channels and an 8 - day temporal resolution [21]. Therefore, this is considered a satellite image product with a good spatial resolution with wide coverage, providing high-quality observations on a large scale.

The satellite image products are carried out to remove the effects of clouds by the condition of Surface reflectance of Band 3 < 0.2 [22, 23]. Based on Bands 1, Band 2, Band 3 and Band 6 of satellite images, EVI and LSWI indexes are calculated according to formulas (1) and (2) [22 - 25]. The study is based on Hydrological network data and DEM to select points for the model with 80 % training (440 points) and 20 % testing (110 points). The Decision Tree model is used to identify pixels related to water. Flood maps is established from water pixels after removing locations that overlap with the hydrological system.

$$EVI = 2.5\frac{NIR - RED}{(NIR + 6 \times RED - 7.5 \times BLUE + 1)} \quad (1)$$

where NIR: surface reflectance of the near - infrared band.

RED: surface reflectance of the red band.

BLUE: surface reflectance of the blue band.

$$LSWI = \frac{(NIR - SWIR)}{(NIR + SWIR)} \quad (2)$$

where NIR: surface reflectance of the near - infrared band.

SWIR: surface reflectance of the short - wave infrared band.

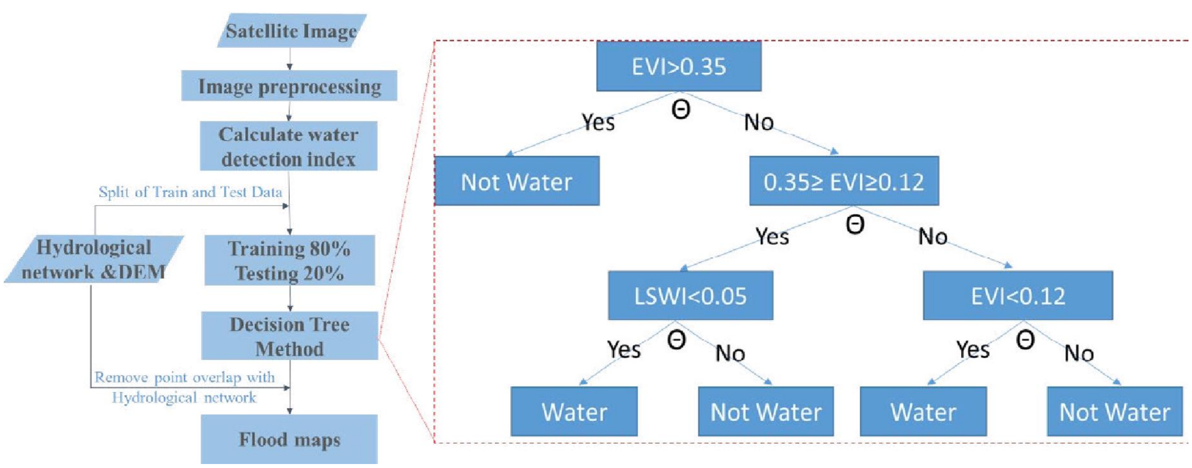


Figure 2: Flow chart of study

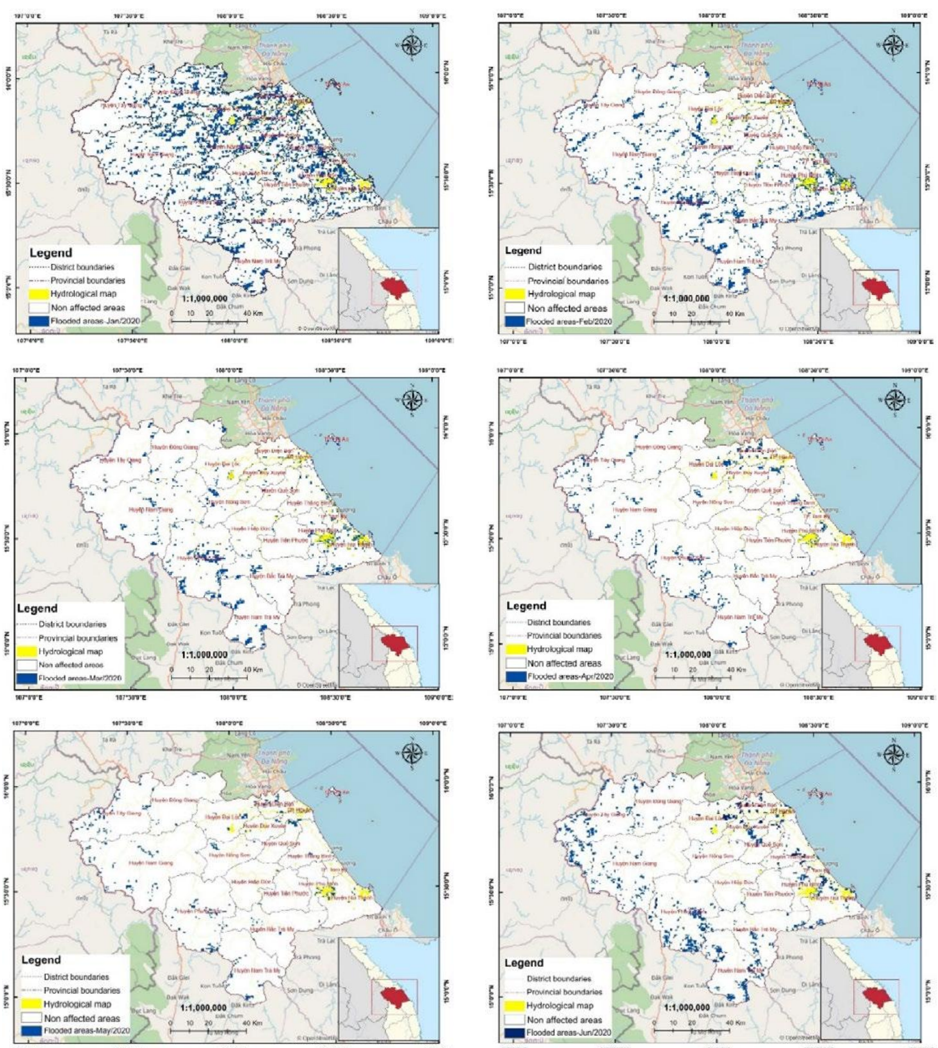
Monthly rainfall data measured at meteorology stations in Quang Nam province is used to evaluate the correlation between the monthly flooded areas in Quang Nam province in 2020.

3. Results and discussion

3.1. Flooding in Quang Nam province in 2020

Table 1. Statistics of the flooded area in Quang Nam province in 2020

District/ Month	Flooded area in district level (km^2)															
	Tay Giang	Dong Giang	Nam Giang	Dai Loc	Dien Ban	Hoi An	Duy Xuyen	Nong Son	Que Son	Thang Binh	Phuoc Son	Tien Phuoc	Phu Ninh	Tam Ky	Bac Tra My	Nui Thanh
1	68.0	211.0	1805.5	228.8	103.0	46.8	115.8	137.0	54.5	143.3	222.8	53.0	106.0	275.5	138.5	257.8
2	54.8	72.3	837.5	36.8	25.5	27.3	39.0	68.0	9.3	52.3	221.3	23.3	49.3	269.5	153.5	244.8
3	32.5	44.5	373.5	21.0	13.5	17.5	10.0	32.3	0.0	14.5	208.0	2.8	28.5	107.3	70.8	103.8
4	82.0	47.0	430.5	13.0	1.8	16.0	5.8	13.3	1.8	5.5	156.5	5.0	31.3	70.3	66.3	69.5
5	37.8	17.3	262.3	18.8	15.8	14.5	8.5	15.8	8.0	7.0	57.3	0.5	19.3	58.5	30.0	59.0
6	83.3	44.5	587.3	39.8	24.8	28.8	34.3	9.8	16.0	31.8	164.8	3.0	27.8	145.0	67.3	149.8
7	131.8	55.8	388.5	9.0	7.3	23.3	5.5	5.5	0.0	1.5	163.8	1.5	8.5	76.5	25.3	76.0
8	15.8	19.0	470.0	15.5	41.3	26.3	28.5	3.5	11.0	116.0	26.0	1.5	8.8	168.3	13.5	161.8
9	171.8	125.0	837.3	48.3	21.5	28.5	23.5	20.0	4.0	10.3	227.3	6.8	14.5	98.5	56.8	98.0
10	86.3	91.5	1237.0	225.0	74.3	51.8	62.5	35.3	19.5	137.8	76.8	16.3	28.8	259.8	79.5	264.5
11	66.3	160.8	1673.5	346.8	93.8	33.3	128.3	139.8	44.5	68.8	224.0	87.0	41.3	203.0	159.0	192.5
12	32.0	28.3	671.8	62.0	76.0	35.5	79.5	32.8	21.0	99.0	159.5	7.8	32.0	127.8	99.0	117.3



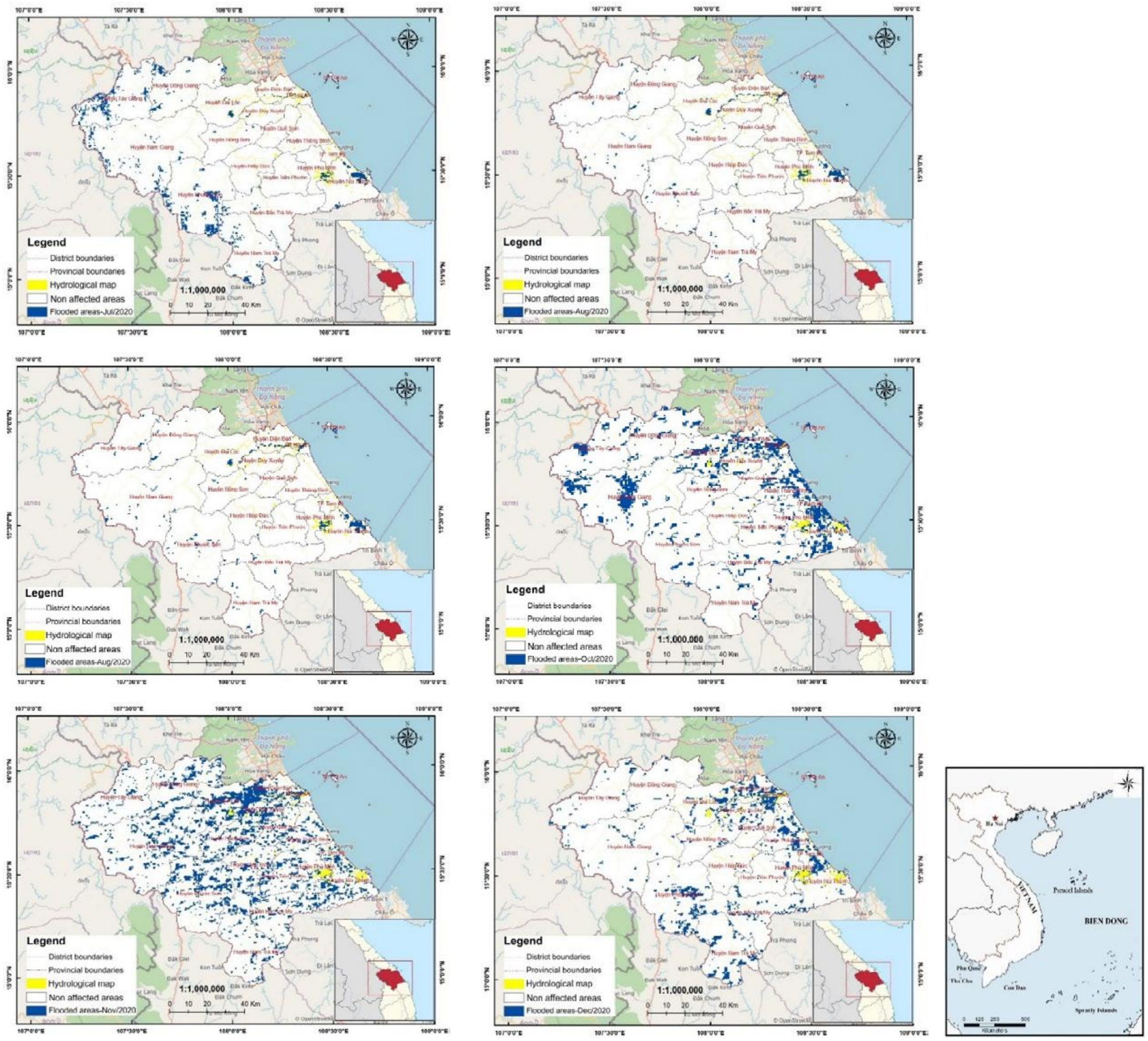


Figure 3: Flooding in Quang Nam province in 2020

The study has established the spatial distribution of monthly floods in Quang Nam province in 2020. Figure 3 shows the flooded area in some districts in a time period. However, the general trend is that the flooded areas increase in early October and highest in November, then gradually decreases until December and January next year. Some districts have high flood areas, such as Tam Ky, Dien Ban, Dai Loc, Hoi An, Thang Binh, and Phu Ninh (Table 1).

Besides, from the above monthly flood maps, it can be seen that floods in Quang Nam province in October is concentrated in some location along the Ban Thach river, such as Tam Ky, Phu Ninh, and Thang Binh. On the other hand, the flooded area is relatively uniform over Quang Nam province, concentrated in Dien Ban and Dai Loc in November.

3.2. Evaluate model performance and compare with rainfall data

The study compared the rainfall at meteorological stations and the flooded area in some districts of Quang Nam province. Figure 4 shows the trend of increasing flooded areas in the last months of the year and until January next year. The results at all three stations show that the flood peak in October, the flooded area will gradually decrease until December and January next year. The result demonstrates that the flooded area is relatively low from March to September. This period corresponds to the dry season in Quang Nam province. The evaluation results show a good performance of the model with AUC = 93.9 % (Figure 5).

In Figure 4, the flooded area value tends to increase as precipitation increases, showing the correlation between these two factors. The rainfall value increase makes the flooded area increase. The results show that rainfall and flooded area tend to change in the same way. The results at Dai Loc stations show that the heaviest rainfall occurs in October, and then the flood peak occurs in November. Rainfall tends to change earlier than the flooded area representing water storage in this area.

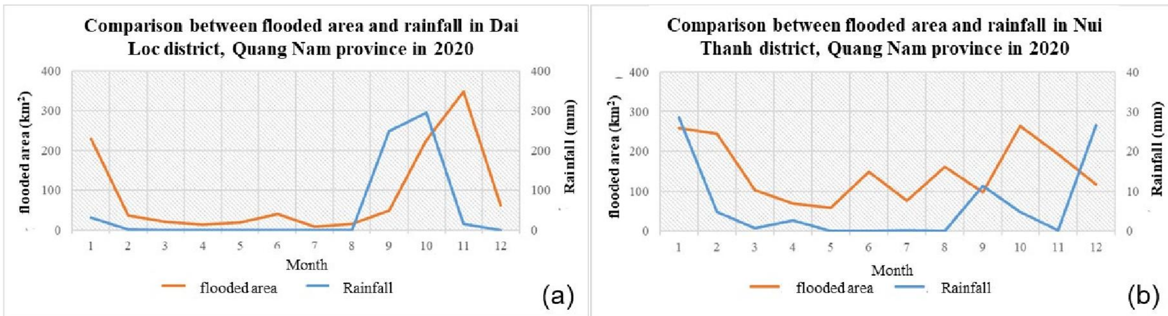


Figure 4: Comparison between flooded area and total rainfall at Dai Loc (a) and Nui Thanh (b) stations in Quang Nam province in 2020

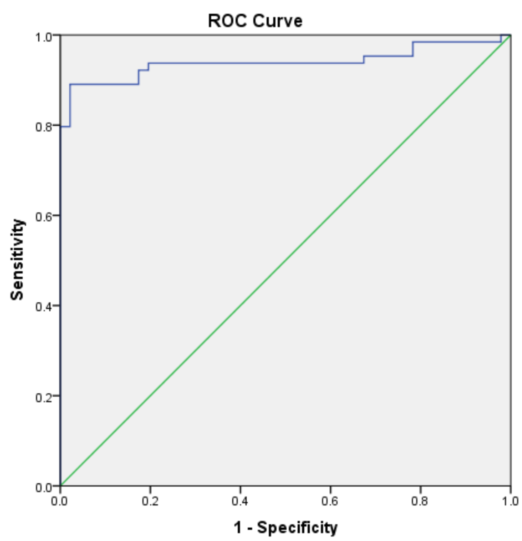


Figure 5: The area under the curve score (ROC - AUC) - 93.9 % of performance

4. Conclusion

The study used the satellite image MODIS MOD09A1 product and the Decision Tree algorithm to detect and monitor the flooded area of Quang Nam province in 2020 by using EVI and LSWI indexes. The model results show good performance with an AUC area of 93.9 %. In addition, the study has statisticized the monthly flooded area and established the spatial distribution map of the flooded areas in Quang Nam province. The flooded area tends to increase in the last three months of the year and lower between March and September. In general, there is a similarity in the increasing (or decreasing) trend of rainfall compared with the flooded areas.

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