RAPID ASSESSMENT OF FLOOD EXTENT AND DAMAGES IN QUANG NAM PROVINCE BY USING SENTINEL-1 DATA

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Abstract: *Assessing flood extent and damages is paid great concern from both authorities and researchers because of flood frequency and consequences. Quang Nam, a Central Coast province of Vietnam, experiences enormous tropical storms. The year 2020 is considered the historic storm year, destroying many properties and public constructions and causing many injuries and fatalities. Therefore, rapid assessment of flood extent and damages can provide a timely response to heavy flood events. In this study, the authors adopted the Google Earth Engine (GEE) platform to quickly extract flood extent from Sentinel-1 images and rapid assessment of flood damages. Sentinel-1 images covering Quang Nam province were acquired to assess the flood events on 17 and 23 October 2020. The results show that on October 17th, 2020, 14036.07 ha of Quang Nam province has suffered from the flood, affecting 80667 people, 2242 ha of cropland, and 648 ha of urban area. After six days, on October 23rd, 2020, flooded areas and exposed people reduces to about 66.5% and 72.5%, respectively, while affected cropland and urban area were not recorded. Decision-makers can base on the excellent results of this research to give efficient and timely solutions to respond to floods and their consequences.*

Keywords: Flood mapping, flood damage assessment, Quang Nam province, Sentinel-1, Google Earth Engine

1. INTRODUCTION

Flood is one of the most severe phenomena due to climate change, causing enormous negative impacts on human livings, properties, and nature (Anusha and Bharathi, 2020), (Klemas, 2015). With a long coastal line of 3260 km, Vietnam witnessed many annual floods and suffered their devastations. According to Central Steering Committee for Natural Disaster Prevention and Control, until November 30th, 2020, more than eight storms hit the North and Central of Vietnam in 2020, where Molave storm, striking Vietnam on October 27th, 2020, was the most powerful storm in the last 20 years. Because of widespread intensity and destruction, this storm made multiple landfalls, damaged $430 million,

and led to the death and missing of many people (VnExpress, n.d.). Particularly, Quang Nam is one of the most vulnerable provinces as located in the Central part of Vietnam.

As flood events are more frequent, and sufficient assessment of flood extent and damages play crucial roles in reducing and recovering their consequences (Uddin et al., 2019). Thus, satellite remote sensing is well-known as an efficient method in monitoring natural disasters. With the weather-independent radar system, Sentinel-1 Synthetic Aperture Radar (SAR) data offers the optimal data resource for flood mapping and damage assessment (Huang and Jin, 2020). Moreover, effectively processing data in minimal duration is also a crucial decision in flood hazard management. The approaches using desktop-based tools have a limitation in operating duration because they require a considerable time interval for data downloading and processing (Tiwari et al., 2020). Therefore, Google Earth Engine (GEE),

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a cloud-based image processing platform, appears as a high-performance tool to access numerous satellite images and process a large scale of geospatial data, which people can use without being expert information technology (Gorelick et al., 2017).

This study proposed a method for automatically and rapidly producing flood extent maps and assessing its damages in Quang Nam province by utilizing Sentinel-1 SAR data on GEE platform.

2. CASE STUDY AND DATA COLLECTION

2.1. Case study

Quang Nam is located in the central coast region of Vietnam, with a 125km stretch of coastline (Quang Nam Provincial People's Committee, 2013). The province comprises flat land along the coast and increasingly high elevation towards the West, in which 72% of its surface is covered by mountains and hills (Figure 1). Quang Nam province has about 900km of the natural river system and consists of two main river systems, namely Vu Gia-Thu Bon and Tam Ky, which enter the East Sea through Cua Dai and Cua Lo estuaries. As a result, the province is vulnerable to storms because of landslide risk in the West and heavy floods in the East.
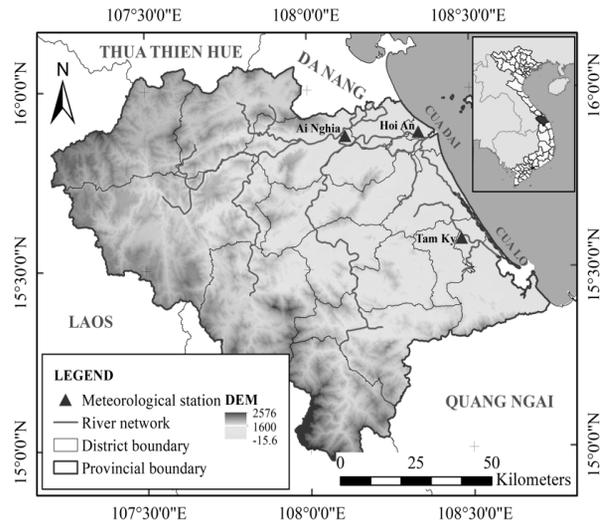

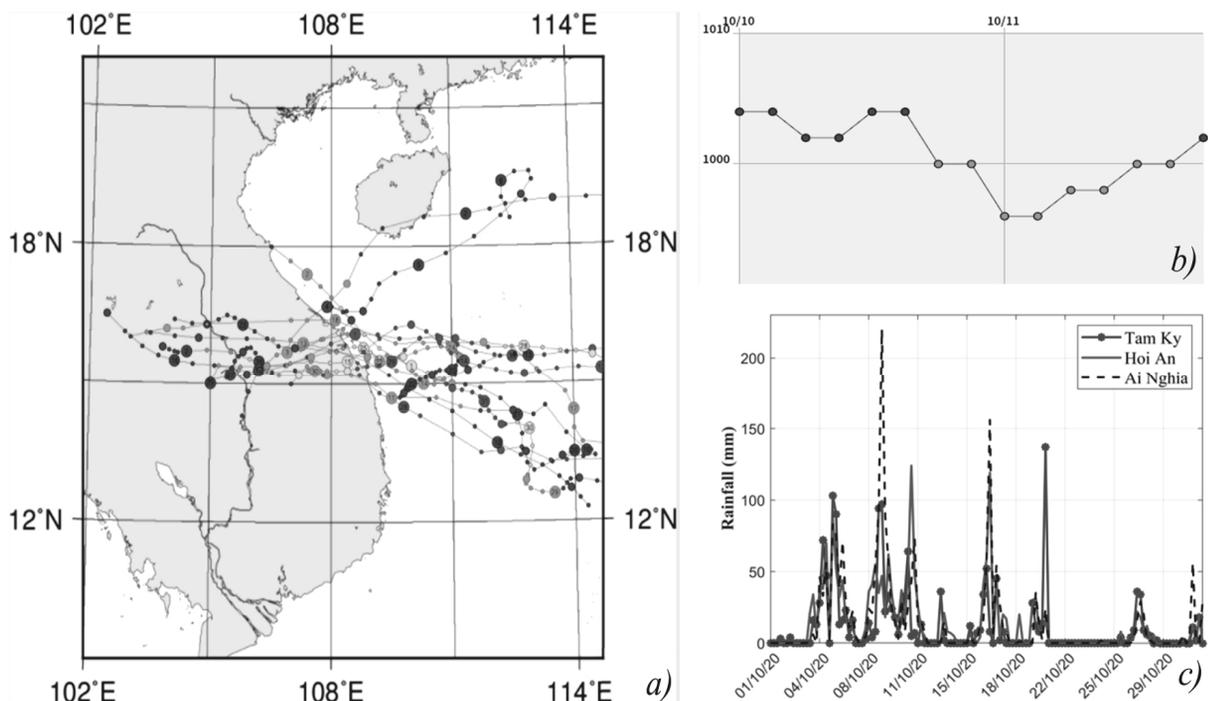
Figure 1. Case study of Quang Nam province

Figure 2. a) Tracking chart of storms crossing Quang Nam province (1990-2020);
b) Central Pressure Chart of storm Linfa;
c) Rainfall at some stations in Quang Nam in October 2020

Quang Nam province, home of 1,495,812 people (General Statistics Office, 2020), becomes an attractive destination for domestic and foreign tourists because of its ancient and beautiful sites. In addition to its natural beauty, the province is also reconsigned as a potential investment area with about 110 projects invested as of 2017 (VOV.VN, n.d.). However, these potentials in nature and economy are being threatened by tropical storms, which often appear from September to November and are accompanied by heavy rains. In the last three decades, Quang Nam has directly suffered at least 20 storm events (Figure 2a), in which if only considering the year of 2020, at least 4 tropical storms have hit Quang Nam. Notably, the deadly and destructive tropical storm Linfa (Figure 2b) struck Quang Nam province, the area that was already flooded by previous seasonal monsoon events, on October 11th, 2020 and caused catastrophic flood and landslides, forcing thousands of people to excavate their home (Floodlist, 2020). Moreover, the historic amounts of rainfall during the storm and the continuous rainfall battering in the next ten days led to the more severe inundation in Quang Nam (Figure 2c).

2.2. Data collection

Sentinel-1 is a satellite constellation designed by the European Space Agency (ESA) to monitor natural disasters with high-resolution data. Sentinel-1 data provides Level-1 Ground Range Detected (GRD) products, which consists of focused SAR data with the advantage of operating at wavelengths without being affected by cloud cover or lack of illumination. Sentinel-1 data provides multiple polarizations, including Vertical-Horizontal polarization (VH) and Vertical-Vertical polarization (VV), which supply more information on inundated areas than single-polarized and be widely used in flood extent mapping. In this study, two Sentinel-1 GRD images with a resolution of 10m were acquired, focusing on the flood event in mid-October 2020 triggered by storm Linfa (Table 1).

Table 1. List of Sentinel-1 images used in the study

Product	Date	Polarization
S1A_IW_GRDH_1SDV_20201017T223604_20201017T223633_034842_040FCF_A410	October 17th, 2020	VH + VV
S1B_IW_GRDH_1SDV_20201023T223520_20201023T223549_023946_02D83D_772B	October 23rd, 2020	VH + VV

In addition to Sentinel-1 SAR data, some required data extracted from web applications were also used as a part of flood extent mapping and damage assessment. The study area's reference permanent water was obtained from a reliable online source providing statistics on water surface information, namely the Global Surface Water Explorer dataset, developed by the European Commission's Joint Research Centre. The terrain slope was derived from ALOS Global Digital Surface Model (https://www.eorc.jaxa.jp/ALOS/en/aw3d30/) to be responsible for a supportive parameter for flood water classification. For the assessment of flood damages, population statistics in Quang Nam province in 2020 were taken from WorldPop (https://www.worldpop.org/), the 100m resolution dataset for spatial demographic (Figure 3). Furthermore, the 500m resolution dataset of cropland and urban area in Quang Nam were also utilized from the Moderate Resolution Imaging Spectroradiometer (MODIS) image (https://modis.gsfc.nasa.gov/).
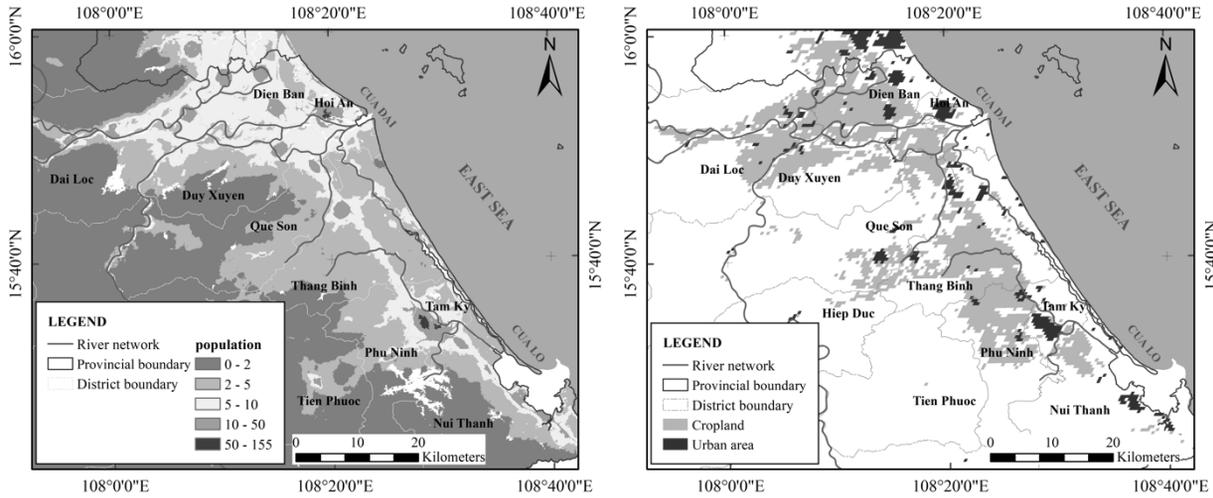
Figure 3. Population (left) and Cropland - Urban area (right) in Quang Nam province

3. METHODOLOGY

The overall methodology of this study consists of two main stages, including flood extent mapping and flood damages assessment (see Figure 4). The details are described hereafter.
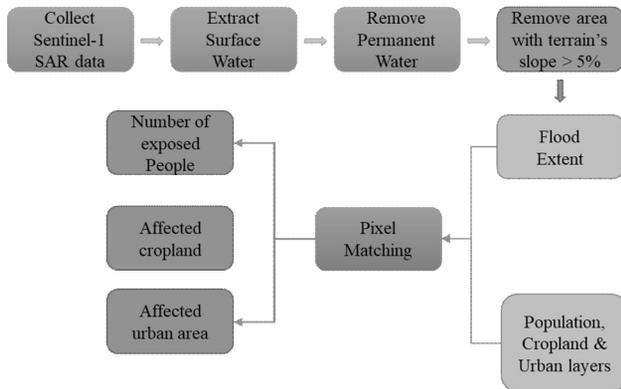

Figure 4. Overall methodology of this study

3.1. Flood extent mapping

Four steps to develop a flood extent map were conducted as shown in Figure 4. By subtracting the surface water extraction results between during and post-flood event images, the temporal water map, including flood water and permanent water (e.g., rivers and reservoirs) was generated. Flood extent is assumed to be the water surface's appearance in a short period; in contrast, permanent water is held for a long time. Therefore, the flood extent map would be

obtained by separating permanent water pixels from the temporal water map. In this paper, Global Surface Water Explorer dataset was employed to delineate permanent water, which is defined as the existence of water in more than 10 months. Water cannot be stored in the terrain's slope is greater than 5%, and it should be found in a milder slope area. Thus, in the last step of this stage, area having a slope greater than 5% would be removed to produce the flood extent map.

The procedure of flood extent mapping was carried out by using GEE, a cloud-based image processing platform. This platform provides enormous useful functions, including creating and storing the program in Script tab; searching available functions in Docs tab; importing and storing raster as well as vector data in Assets tab; writing and running Javacript or Python programming language on the dashboard, and allowing users to see the results as well as export them under lots of formats.

3.2. Flood damage assessment

After defining flood extent, rapid assessment of flood damages was performed to determine the number of exposed people, affected cropland and urban area (see Figure 4). Specifically, the population in Quang Nam province in 2020 was extracted and counted based on the population layer taken from WorldPop. Cropland was retrieved by extracting

Class 12 (Croplands) or Class 14 (Cropland/natural vegetation mosaic) in MODIS image, while the urban area was obtained using Class 13 (Urban and built-up). Finally, pixel matching was performed, by applying Pixel Area Method in GEE, to determine the affected area. More precisely, a pixel was considered affected if it was in both the cropland/urban area and flood extent map.

4. RESULTS

4.1. Flood extent mapping

On October 17th, 2020, the flood remained occurring in Quang Nam province due to the historic amounts of rainfall during Linfa storm and the continuous rainfall in the next ten days. Sentinel-1 images were collected to extract the surface water and generate the temporal water map by GEE platform. The flood extent map was then obtained by separating permanent water pixels from the temporal water map (Figure 5). The results reveal that flood extent covered about 14036.07 ha of Quang Nam province and mostly occurred in the delta and along with the main river systems, i.e. Vu Gia – Thu Bon and Tam Ky. Two districts experienced the most tremendous damage of the flood: Dai Loc and Thang Binh, where more than 3000 ha was affected.
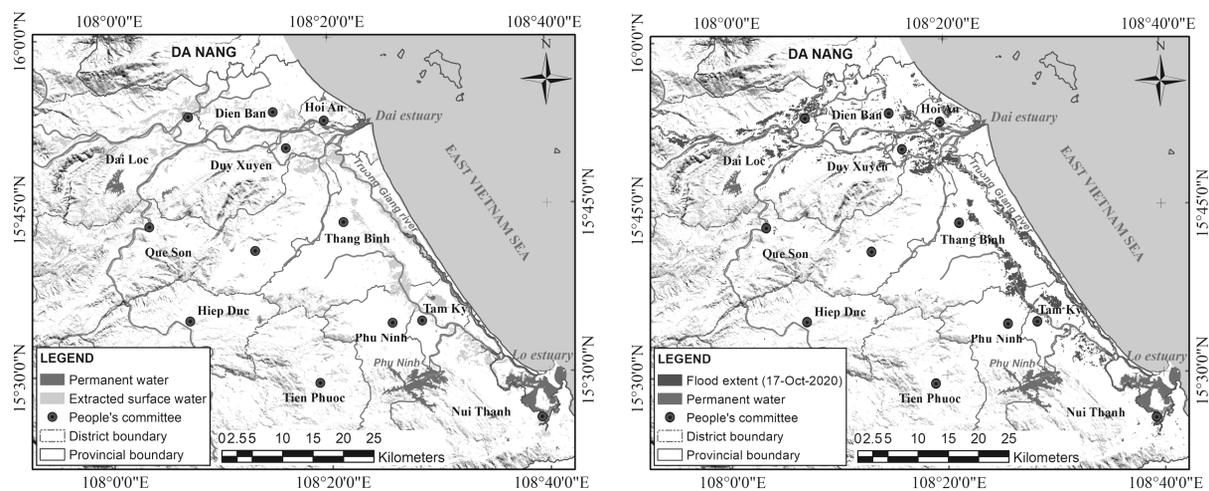
Figure 5. Temporal water map (left) and flood extent map of Quang Nam province on October 17th, 2020

After six days, on October 23rd, 2020, the flooded area in Quang Nam province reduced considerably to about 9339 ha, but the flood was still severe in some regions (Figure 6). The results show that three districts along Truong Giang and Tam Ky rivers, i.e. Nui Thanh, Tam Ky and Thang Binh still suffered from a severe flood, in which the latter is the only district with the flooded area higher than 1000 ha. Meanwhile, the flooded area in Dai Loc district, where Vu Gia river flows through, has dramatically reduced about 81% compared to that on October 17th 2020, making it the fastest district in flood reduction.
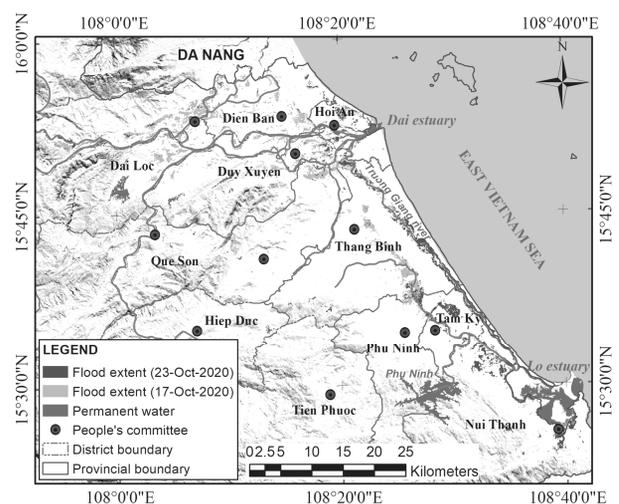
*Figure 6. Flood extent map of Quang Nam province on October 23rd, 2020*

4.2. Flood damage assessment

Flood always impacts on human's life and properties; therefore, flood damage assessment is a necessary and crucial step for decision makers to have timely response solution to mitigate flood consequence. In this study, flood damages were assessed for flood events triggered by storm Linfa in Quang Nam province on 17 and 23 October 2020 based on three elements: number of exposed people, area of affected cropland and affected urban area. The flood damages were determined by overlapping flood extent extraction with layers of three above elements on GEE, and results of damage assessment were shown in Figure 7 and Table 2. After six days, although cropland and urban area were not impacted by flood, more than 20,000 residents still suffered the consequences of the flood, mostly along Truong Giang and Tam Ky rivers.

Table 2. Flood damage assessment in Quang Nam province

	17/10/2020	23/10/2020
Number of exposed people	80667	22188
Affected cropland (ha)	2242	0
Affected urban area (ha)	648	0
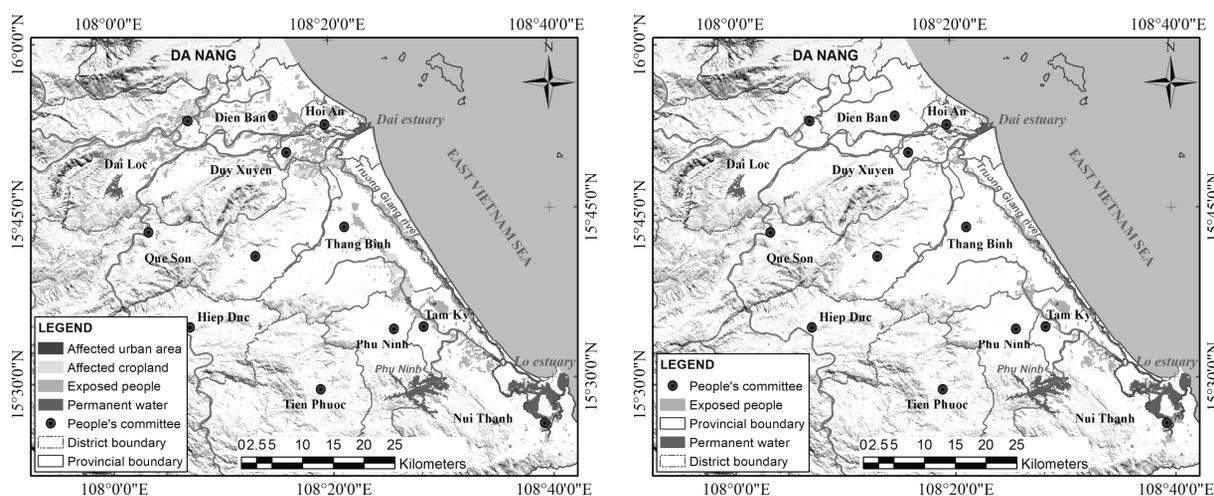
Figure 7. Flood damage assessment on October 17ᵗʰ(left) and October 23ʳᵈ, 2020 (right)

5. CONCLUSION

In this study, the authors proposed an efficient method for flood extent mapping and damage assessment from Sentinel-1 image, the high resolution and water-independent data, on a cloud-based platform namely GEE. This is due to the fact that Sentinel-1 data provides high-quality image in flood events even when there are the appearance of cloud cover and rainfall, which will be the excellent issue for weather-dependent satellite systems. Moreover, GEE platform offers the online-based analysis without downloading any data or supported software, which reduces a significant amount of time compared to traditional methods. The results show that on October 17ᵗʰ, 2020, Quang Nam province has suffered from a heavy flood, which covered 14036.07ha of land, and affected 80667 people, 2242ha of cropland, and 648ha of urban area. After six days, the flooded area dramatically reduced by 9339ha, and there was no effect recorded on cropland and urban area. However, 22188 people still suffered flood consequences. From these findings, decision-makers can have the basis to offer suitable and timely solutions to deal with the natural flood event and mitigate its consequence. In the future, when the natural flood disaster becomes

more frequent and severe, GEE will help people to achieve better disaster response and management.

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Tóm tắt:
ĐÁNH GIÁ NHANH PHẠM VI VÀ THIỆT HẠI DO NGẬP LỤT
Ở TỈNH QUẢNG NAM SỬ DỤNG DỮ LIỆU ẢNH SENTINEL-1

Do tần suất xuất hiện và hậu quả nặng nề gây ra bởi lũ lụt ngày càng có xu hướng tăng, việc đánh giá phạm vi và thiệt hại do ngập lụt thu hút nhiều sự quan tâm từ cả chính quyền và các nhà nghiên cứu khoa học. Quảng Nam là một tỉnh vùng biển nằm ở miền Trung Việt Nam, phải hứng chịu rất nhiều cơn bão nhiệt đới. Năm 2020 được coi là năm của cơn bão lịch sử, phá hủy hàng loạt tài sản, công trình công cộng và gây ra nhiều thương vong. Do đó, đánh giá nhanh phạm vi và thiệt hại do ngập lụt có thể giúp ứng phó kịp thời trước những trận lũ lớn. Trong nghiên cứu này, các tác giả đã sử dụng nền tảng Google Earth Engine (GEE) để trích xuất nhanh phạm vi ngập lụt từ dữ liệu ảnh Sen-tinel-1 và phân tích nhanh diễn biến lũ cũng như thiệt hại do lũ lụt gây ra vào ngày 17 và 23 tháng 10 năm 2020. Kết quả cho thấy vào ngày 17 tháng 10 năm 2020, 14036,07 ha của tỉnh Quảng Nam đã bị ảnh hưởng bởi lũ, tác động đến 80667 người, 2242 ha đất trồng trọt và 648 ha khu đô thị. Sau sáu ngày, vào ngày 23 tháng 10 năm 2020, diện tích ngập lụt và số người bị ảnh hưởng giảm xuống lần lượt là 66,5% và 72,5%, trong khi hoa màu và thành thị không còn chịu ảnh hưởng bởi lũ. Những người có thẩm quyền về mặt quyết định và chiến lược có thể dựa trên kết quả của nghiên cứu này để đưa ra các giải pháp hiệu quả và kịp thời để ứng phó với lũ lụt và hậu quả do chúng gây ra.
Từ khóa: *Phạm vi ngập lụt, đánh giá thiệt hại do lũ, tỉnh Quảng Nam, dữ liệu ảnh Sentinel-1, Google Earth Engine*