APPLICATION OF GOOGLE EARTH ENGINE PLATFORM TO IDENTIFY FLOODED AREAS AND ASSESS FLOOD DEPTH IN QUANG TRI PROVINCE

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Received: 11 August 2023; Accepted: 5 September 2023

Abstract: *In recent years, the Application of the Google Earth Engine Platform has gained substantial recognition as a powerful tool for remote sensing and geospatial analysis. This paper delves into its utility within the context of flood monitoring and assessment, focusing on Quang Tri Province for the historic flood in 2020. The study leverages the platform's capabilities to identify and delineate flooded areas, offering a timely and accurate overview of the extent of inundation during flood events. Moreover, the paper demonstrates how the Google Earth Engine Platform enables the assessment of flood depths, providing critical insights for disaster management and response planning. By amalgamating satellite imagery, terrain data, and hydrological information, the study showcases the platform's potential to enhance flood-related decision-making in vulnerable regions like Quang Tri Province. The findings underscore the significance of innovative geospatial technologies in addressing the challenges posed by flooding, ultimately contributing to more effective disaster mitigation strategies and informed policymaking.*

Keywords: *Google Earth Engine, inundation, Central Viet Nam, Remote sensing, Sentinel-1, automatic.*

1. Introduction

In recent times, flood research has evolved towards larger spatial and temporal scales, higher image resolution, shorter revisit intervals, automation, and closer proximity to real-time data. However, this developmental trend is accompanied by increasing demand for image storage capacity, computational power, and novel image processing algorithms. As a response to these challenges, the Google Earth Engine (GEE) platform was introduced in 2012 to eliminate the aforementioned barriers in remote sensing studies. GEE incorporates numerous powerful image-processing algorithms that enable users to swiftly process and extract information from Google's satellite image repository [1].

Furthermore, GEE's Publish functionality empowers researchers to construct comprehensive web applications, enhancing the accessibility of their research to laypersons without basic programming knowledge. In the domain of resource and environmental monitoring, several notable products have emerged. CoastSat [2] tracks and analyzes coastal shoreline dynamics globally, HazMapper [3] maps natural disaster risks, AgKit4EE [4] simulates agricultural land use processes in the United States, CCDC [5] monitors land use changes, and O-LCMapping [6] classifies land cover types. Multiple studies have recognized GEE's substantial potential in flood research.

Annually, the Central region of Viet Nam experiences consecutive waves of overlapping floods and storms with complex, intense, and abnormal characteristics. The historic flood events in 2020 inflicted severe damage to properties, the environment, human lives, and livestock in the Central provinces. In Quang Tri, the peak water levels on the Hieu River in Dong Ha on October 8th and October 19th surpassed the historic flood levels of 1983 by 0.11 m and 5.36 m respectively. The peak water level on the Thach Han River on October 18th was 7.40 m, exceeding the historic flood level of 1999 by

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0.11 m [7]. Therefore, the objective of this study is to apply the Google Earth Engine cloud computing platform to develop a web application for estimating post-flood damages using indicators such as inundated area, affected crop area, and impacted population. This will be demonstrated through a case study of the 2020 flood event in Quang Tri Province.

2. Data and Methodology

2.1. Data

The data of this study includes collections of remote sensing data (Table 1), a library of functions available on the GEE platform, and statistics on damage after the 2020 flood in Quang Tri Province.

Satellite data used in research:

Table 1. Image data used

TT	Date received data	Type of data	Resolution	Image ID
1	10/10/2020	Sentinel 1	10 m	S1A_IW_GRDH_1SDV_20201010T224410_20201010T224435_034740_040C29_6DBD
2	10/10/2020	Sentinel 1	10 m	S1A_IW_GRDH_1SDV_20201010T224341_20201010T224410_034740_040C29_D8BD

DEM data used:

MERIT DEM was developed by removing many error components (absolute bias, stripe noise, speckle noise, and tree height bias) from existing spatial DEMs (SRTM3 v2.1 and AW3D-30 m v1). It represents terrain elevation at 3s resolution (~90 m at the equator) and covers land areas between 90 N - 60 S, referenced to Geoid EGM96 [17].

Flood trace data:

In order to assess the accuracy of the results of flood depth interpretation, the study used the October 2020 flood trace survey data set in Quang Tri Province by the Quang Tri Sub-Department of Water Resources. [18]. The survey data is presented in Table 2.

Table 2. Flood trace data in 2020

	X	Y	Elevation of flood mark (m)
1	586746.4	1561395	3.81
2	586889.6	1558939	3.63
3	589288.7	1562172	2.86
4	589685.5	1561929	2.82
5	594723.3	1560573	2.21
6	595053.6	1560970	2.28
7	595381.7	1561036	1.38
8	596037.7	1561235	4.19
9	596875.8	1561507	4.90
10	596811.8	1562393	4.26

2.2. Methodology

2.2.1. Primary data collection method

This method is utilized in the following tasks: Collecting satellite image data from the Google Earth Engine (GEE) platform required for flood damage estimation, including:

Sentinel-1A Image Data: The study selects image data from the period between September and November 2020 to calculate the flooded area after the 2020 storm event in Quang Tri. Besides, the selection of radar images for this study will help reduce the impact of the environment on the accuracy of the images as in optical satellite images.

Additional Data: Other datasets are employed for computation and result calibration, including global surface water data and digital elevation model data.

These datasets are gathered and processed using the Google Earth Engine to perform comprehensive flood damage estimation, involving the calculation of inundated areas, affected agricultural land areas, and impacted population figures.

2.2.2. Secondary data collection method

Methods used in the work: (1) Collecting domestic and foreign studies related to the application of GIS and remote sensing technology, Google Earth Engine cloud computing technology to assess damage after rain floods and monitoring environmental changes and (2) Collecting reports on flood situation and damage after floods in Quang Tri in 2020.

2.2.3. Remote sensing image processing method

Remote sensing images will be collected in two periods (Figure 1): The period before the flood and the period after the flood. After performing the steps of combining image scenes and satellite image data preprocessing, the final image result will be determined by the pixel value quotient between the images of the pre- and post-flood period. The final image result determines the flooded area based on the thresholding method to classify pixels that are water and not water.

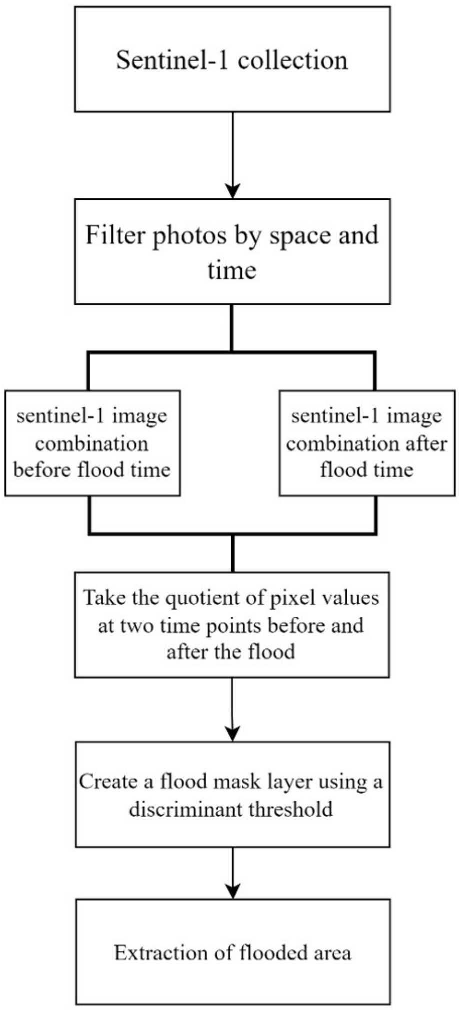

Figure 1. Inundation value extraction diagram

2.2.4. Floodwater depth calculating method

The calculation procedure for predicting the submerged depth is based on the DEM elevation numerical model data [8]. The topographic elevation values in the boundary area are determined as the initial datum, from which the inner floodplain depth values will be determined by subtracting the initial elevation numerical value from the DEM value in a flooded area. In Figure 1, for instance, the highest level reached by the floodwater is 100 meters above sea level (asl). At the location marked as "A" on the cross-sectional diagram, the elevation of the land is measured at 95 meters asl, n of the river water surface (depicted as the blue line in Figure 2), which will lead to an underestimation of water depth. Most DEMs typically capture the water surface elevation over the active channel at a specific time, and this bias will persist and potentially be substantial, particularly for large rivers.

The process of calculating flood depth prediction consists of the following 5 main steps: (1) Identifying Boundary Cells; (2) Extracting the Elevation of the Boundary Cells ; (3) Assigning the Boundary Cells Elevation to the Domain cells; (4) Floodwater Depth Calculation; (5) Smoothing [8].

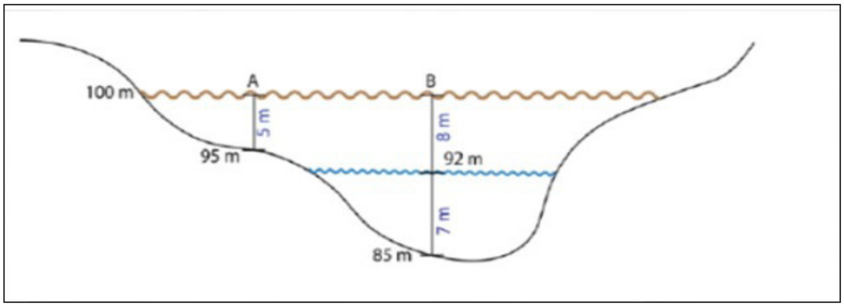

Figure 2. Theoretical Floodplain Cross Section Illustrating the floodwater Depth Estimation

2.2.5. Program development techniques

Developing a web application using the JavaScript programming language on the code editor - EE Code Editor. The entire process of handling input data and interpreting satellite images is coded using functional functions within the integrated library of the GEE platform. When the user presses the start button, the processing process will take place, starting from retrieving user-entered data from the keyboard, preprocessing images, noise filtering, applying thresholding to distinguish in and extracting flood-affected area data, refining results, overlaying flood layer data to extract layers of data regarding the affected population and the damaged crop area, and finally displaying the results on the screen.

3. Research result

3.1. Flood situation

From October 6 - 21, 2020, the Quang Tri Province experienced heavy rainfall with high intensity over a wide area within a short period (Figure 3), ranging from 1,600 to 2,600 mm. In mountainous districts, there was a sudden increase in rainfall, notably in Huong Hoa district, where the total measured rainfall for the entire event reached 3,117 mm, with 849 mm recorded on October 17 alone. From October 27 - 29, 2020, influenced by Typhoon 9 and the residual effects of the storm, the province continued to experience heavy to very heavy rainfall. The common range of rainfall was between 100 - 210 mm, with some areas receiving even more, such as Vinh O with 323.2 mm, Ta Rut with 322 mm, and Khe Sanh with 250 mm. The occurrence of heavy rainfall and soil erosion led to widespread flooding across Quang Tri Province. In this study, the authors focus on the first flood (October 6 - 12). This is the period with very heavy rainfall up to 5911 mm which peaks on October 8.

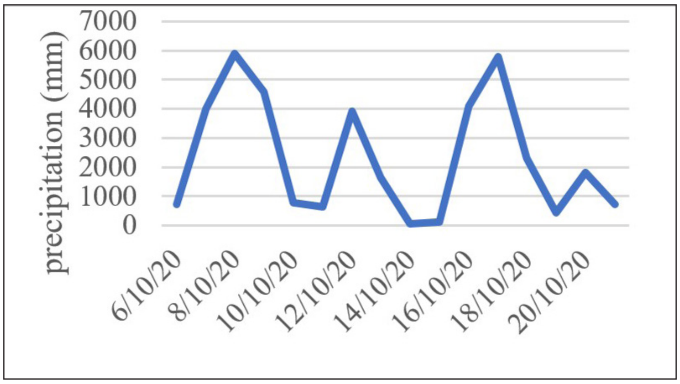

Figure 3. Precipitation in Quang Tri Province from October 6 to October 21, 2020

3.2. Building a Web application to assess the impact of flooding in Quang Tri Province

The Web application consists of two main components (Figure 4): (1) The input parameter setup window for the application, including the time before and after the flood occurrence, the polarization mode of the satellite image, and the threshold value for flood area extraction; (2) A map displaying the computed results of the application.

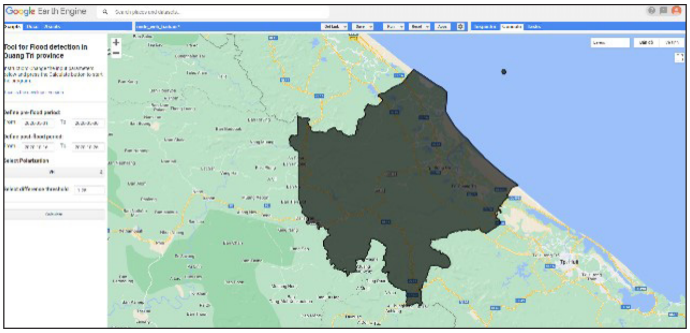

Figure 4. Initial Web Application Interface

The input data about the geographical boundary of Quang Tri Province, and the satellite data sets required for the calculation and assessment of inundation are all pre-programmed in the program. For the 2020 flood in Quang Tri Province, the user-entered data set includes the time before and after the flood; polarization mode (polarization): VH; Threshold for discriminating between pixels that are water and pixels that are not water.

After setting parameters and running the evaluation program, the Web interface will appear with the following additional components (Figure 5): (3) Window to download the resulting data classes after running (Tasks) including Layer shapefile flood data, raster flood data layer (Flood_extent_raster), flood depth data layer (Flood_Depth); (4) Flooded area statistics results table; (5) Annotation of data layers on the map thing; (6) Optional tool to display data layers.

According to the calculation results for the period from October 6, 2020, to November 6, 2020 (Figure 6), the flooded area of Quang Tri Province is estimated at 22.584 (ha) which is equivalent to about 5% of the natural area of Quang Tri Province. The flooded areas are primarily concentrated in the eastern lowland districts of Quang Tri Province. These are regions with dense populations and serve as the main agricultural production areas of the province. Therefore, during periods of heavy rainfall and flooding, these are the most severely affected areas in Quang Tri Province.

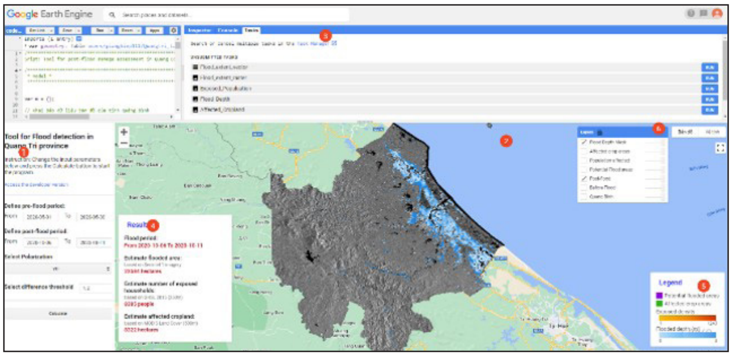

Figure 5. Web interface after running the program

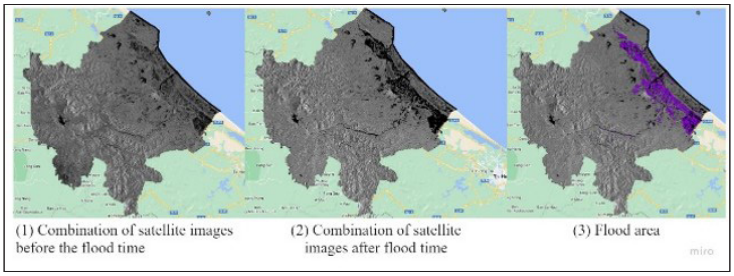

Figure 6. Output data layer

Table 3. Statistical table of the flooded area by district

TT	District	Area (ha)	Percentage
1	Con Co	3.57	169
2	Cam Lo	1,052.77	3.06
3	Dakrong	510.92	0.47
4	Dong Ha	1,076.66	14.79
5	Gio Linh	4,795.69	9.94
6	Hai Lang	6,066.71	14.19
7	Huong Hoa	177.20	0.15
8	Trieu Phong	6,065.70	16.70
9	TX. Quang Tri	355.35	4.79
10	Vinh Linh	3,307.52	5.22

The flood statistics reveal (Table 3) that among the districts, Dong Ha, Hai Lang, and Trieu Phong are the districts with the largest flooded areas. Among them, Trieu Phong district is the most severely affected, with nearly 17% of its total area in the flood-affected region. Districts in the West such as Cam Lo and Dakrong, due to mainly their mountainous terrain and high slopes, have less flooded areas compared to other districts.

The results of flood analysis for the times before and after flooding for the historic October 2020 flood in the Thach Han and Ben Hai river basin are shown in Figure 7. The flood trail data in 2020 coincides with 9/10 points compared to the flood prediction results in 2020, with an accuracy of 90%, which is quite high reliability. However, the extent of flooding is significantly influenced by the initial threshold set by the program, where higher threshold values result in larger flooded areas and vice versa. During the research process, a threshold value of 1.2 was selected, as it proved to be suitable for generating accurate and minimally erroneous flooding results due to its balanced value.

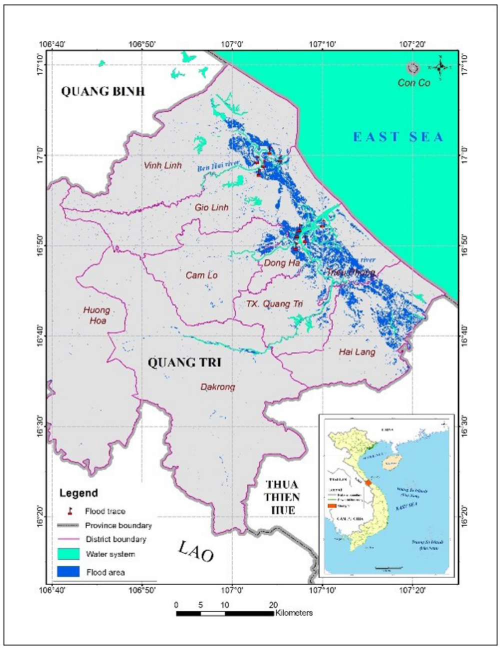

Figure 7. Map of interpretation of flooded areas in 2020 with corresponding flood traces of Quang Tri Province.

3.3. Flood depth

The results of the flood depth calculation program indicate that the flood depth layer varies from 0 to 3 meters (Figure 8), depending on each area, and is constrained within the extent of the flood area layer. Statistical results show that most of the areas are flooded with levels ranging from 0 to 1 m. Areas with large flood depths are concentrated mainly near the Ben Hai and Thach Han River basins.

The results after calculating the flood depth for DEM are compared with the survey data of the historical flood trail survey in 2020 shown in Table 4.

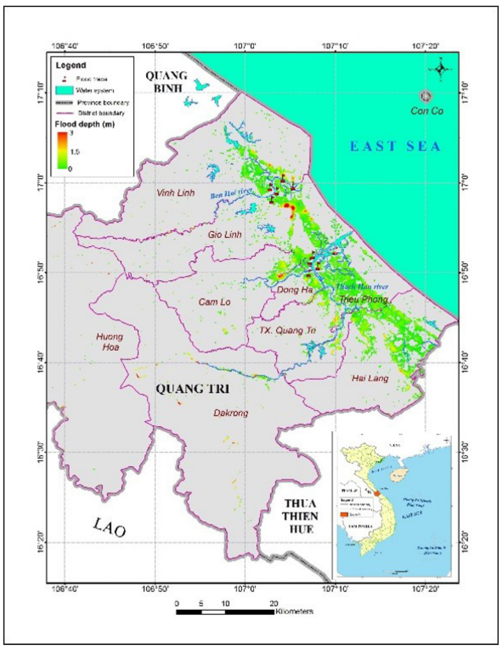

Figure 8. Flood depth map according to flood traces surveyed in 2020

Table 4. Statistics of flood simulation results from DEM data source

Flood traces	Actual flooding depth (m)	Flood depth from DEM Merit (m)
1	2.3	1.9
2	1.24	0.8
3	0.31	0.50
4	0.27	0.6
5	0.63	1.2
6	3.84	3.02
7	0.34	0.8
8	3.23	2.98
9	1.29	1.7
10	2.02	2.4

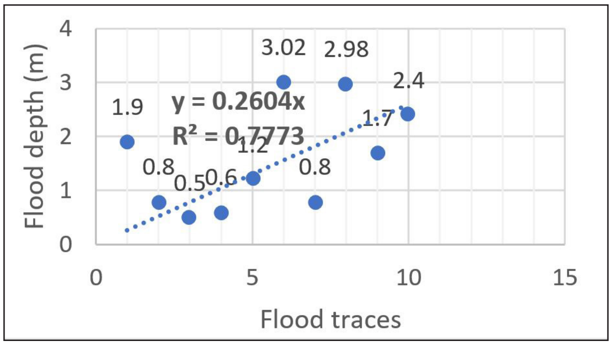

Figure 9. Correlate actual flood depth and simulated flood depth from DEM data source

Simulation results (Figure 9) show that the flood depth estimation tool using the Merit DEM data source achieves quite a high correlation ($R^2 = 0.7773$). This is because the terrain has had many of the error components of the MERIT DEM removed, a result of the noise removal algorithm used to create it.

However, these results are still inaccurate, as many positions deviate significantly from the actual data. The main source of these data is preeminent due to the resolution of the input DEM. Given the relatively large research scope (provincial level), to optimize the program's efficiency, the author is optional for the MERIT DEM source with a resolution of 90 meters. To enhance the accuracy of the flood depth data layer, users should consider utilizing DEM sources with higher resolutions (below 30 meters) and confine their study area to a smaller extent, thus increasing the overall precision of the data.

4. Conclusion

In summary, this study focused on the flood situation and its assessment using a Web application in Quang Tri Province. Intense rainfall occurred from October 6 to 12, 2020, leading to widespread flooding. The Web application had two main parts: A customizable input setup for flood parameters and a map showing computed results. From October 6 to 12, 2020, the flooded area covered about 22,584 hectares, primarily in the eastern districts. Besides, the flood depth calculation showed depths ranging from 0 to 3 meters within the flooded area layer. Yet, precision was affected by input DEM resolution. Choosing a 90-meter MERIT DEM source for the large-scale study area helped optimize efficiency. For better accuracy, users are advised to consider high-resolution DEMs for smaller study scopes. In addition, the depth estimation method employed in the program is suitable for narrow and flat inundation areas with relatively small depth differentials. When dealing with broader inundation areas, as one moves further into the center of the inundated zone, the water level becomes uneven due to significantly different flow patterns compared to the two sides (or the adjacent boundary). Consequently, the depth of inundation varies accordingly. The study offers insights into flood patterns and impact assessment, aiding future flood management endeavors.

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