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FLOOD MAPPING USING SENTINEL - 1&2 DATA WITH GOOGLE EARTH ENGINE CLOUD PLATFORM OF NGHE AN PROVINCE, VIETNAM

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Abstract

Flooding is one of the regular natural disasters in Nghe An province and thus monitoring and assessing flood damages have been addressed by the local government and disaster experts. However, the traditional approach to adoption is expensive and time - consuming. In recent years, with the advances in remote sensing techniques and the availability of free satellite data and platforms, flood damage analysis has become easier. This study was mainly focused on flood mapping in Google Earth Engine - a cloud - based analysis platform. Flood inundated map was generated using pre and post flood images of SAR (i.e., Sentinel - 1) which provides data by continuous observation during the flood. A land use/ land cover map was created using pre - flood cloud - free Sentinel - 2 datasets. Flood damage was assessed by overlaying flood inundated maps on land use/ land cover maps. Results showed that a total area of 172.43 km^2 was flooded (8.71 % of lowland and coastal plain) in Nghe An province, of which 14.39 km^2 was cropland. The findings of this study concluded that combining microwave and optical data for flood mapping and damage assessment in the Google Earth Engine platform is more advantageous and cost - efficient.

Keywords: Flood mapping; Sentinel - 1; Sentinel - 2; Google Earth Engine; Nghe An.

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1. Introduction

In central Vietnam, flooding is a widespread natural disaster and recurring event. Floods occur regularly in the rainy season, from May to the end of October, with high accumulated rainfall (may reach up to 540 mm per month). The lowlands near the river and sea in the east of Nghe An province face the risk of flooding. Rapid unplanned urbanization, climate change, land use/land cover change (LULC), irregular rainfall are the main causes of recurring floods which affects millions of people's lives, infrastructures, economics and local ecosystem. However, there is a lack of effective flood monitoring and model development to monitor the impact of floods.

Nowadays, researchers and agencies are enabled to utilize satellite images with the development of space technology, which can also provide flooding periods and extent approximately (Lamovec et al., 2013). Mapping flooded areas is a key

practice for understanding the affected land use/ cover (D'Addabbo et al., 2018). The use of optical data is difficult due to cloud cover and accessibility of free Synthetic Aperture Radar (SAR) data by the European Space Agency (ESA), in a contrast, Sentinel - 1 created an advantage for monitoring the flood extent because the radar sensor does not depend on solar illumination and has the capacity to penetrate through clouds (Uddin et al., 2019). This information can be beneficial for mitigation measures in times of disaster. One of the most effective platforms for cloud - based geospatial processing is Google Earth Engine (GEE). The Google Earth Engine, introduced by Google, Inc., as a new computing platform for large - scale data processing such as the time series data analysis of Landsat archive (Gorelick et al., 2017) GEE platform hosted a complete, up - to - date and ready SAR data archive of Sentinel - 1A/B Ground Range Detected (GRD) data. In our study, we used Sentinel - 1A/B SAR and Sentinel - 2A/B MSI datasets. Sentinel - 2A/B MSI was used for LULC mapping and Sentinel - 1A/B for flood and flood-affected croplands mapping and monitoring. The capability of SAR sensors to identify flood extent and affected croplands depends on various scattering mechanisms.

The objective of this study is to process and analyze flooded areas during the 2019 flood event in Nghe An Province. Satellite imageries during August - September 2019 were used for investigating pre - flood and flood areas and then subtracting the flooded layer from the pre - flood layer in the GEE platform.

2. Study area

Figure 1: Location of study area - Nghe An province

Nghe An province lies between 18°33' and 20°01' North latitude and from 103°52' to 105°48' East longitude, which is in the center of the northern part of Central Vietnam. It is located between Thanh Hoa and Ha Tinh, bordered to the West by Laos and to the East by the East Sea. It is Vietnam's largest province with complex and diversified topography including seas, plains, midlands and mountains. Nghe An has 7 river basins (with separate estuaries) with the total length of the river being 9,828 km, the average density is 0,7 km/km^2 and the largest river is the Ca (the Lam River). The agricultural land accounts for 1,238,315.48 hectares, of which farming land is 256,834.9 hectares, forest land 972,910.52 hectares, land for aquaculture 7,457.5 hectares, land for salt production 837.98 hectares, land for other agricultural purposes 265.58 hectares, non-agricultural land 124,653.12 hectares, not - yet - used land 286,056.4 hectares.

Nghe An has a city, 3 towns and 17 districts, of which Vinh city is the economic and cultural center of the province and of the North Central region. The average temperature ranges around 23 °C and 24,2 °C. The annual rainfall is 1,200 - 2,000 mm. The average humidity fluctuates between 80 % and 90 %. The province receives an annual average of 1,460 sunshine hours. With more than 3,1 million people, Nghe An is Vietnam's fourth largest province in the population (Nghe An Portal, n.d.)

3. Data and methodology

3.1. Data

In this study, we used Sentinel - 1, Sentinel - 2 and SRTM satellite datasets. Freely available Sentinel - 1A/B SAR C - band (5.4 GHz) data provided by the European Space Agency (ESA) (SciHub; https://scihub.copernicus.eu) was used. The Sentinel - 1 data has a frequency of 12 days with one satellite and 06 days with two satellites. It is available in four modes, which are Stripmap (SM), Interferometric Wide swath (IW), Extra - Wide swath (EW) and Wave (WV) while more descriptions are available (Torres et al., 2012). The IW mode has been used in our study which is the main acquisition mode for the land surface that meets contemporary service requirements with long - term archives (Torres et al., 2012). Its conflict - free modes with VV + VH (vertical transmit, vertical receive (VV) and vertical transmit, horizontal receive (VH) polarization.

The Sentinel - 1 dataset is hosted on the GEE platform and the available tool of the SNAP software package was used for pre - processing. The GEE platform has been used to perform all the tasks required for SAR satellite data processing. The GEE platform was also used to execute orbit correction, noise removal, radiometric calibration and terrain corrections using SRTM data and converted backscatter intensity to decibels (dB) according to

$$\sigma^{\circ} = 10 \times \sigma^{\circ} \qquad (1)$$

We used all the available Sentinel - 1 SAR imageries for flood mapping, monitoring and flood - affected cropland, the pre - flood period (15th to 22nd August 2019) and the peak flood period (02nd to 03rd September 2019).

ESA's Sentinel - 2A/B MSI satellite data are capable of monitoring land surface conditions. Its revisit time is 10 days with one satellite and 5 days with two satellites. Its spatial resolution is 10 m (bands: 2, 3, 4 and 8), 20 m (bands: 5, 6, 7, 8a 11 and 12) and 60 m (bands: 1, 9

and 10). In this study, we used bands 2, 3, 4 and 8 of Sentinel - 2A/B MSI satellite data for LU/LC mapping. We selected images from March 2020 for the least cloud cover (10 % cloud cover) using the "CLOUDY_PIXEL_PERCENTAGE" tool of GEE. Further, the QA band of Sentinel - 2 was used to remove cloud cover (Kumar et al., 2022).

Finally, all the available images were used for LU/LC mapping of Nghe An province in 2019. Sentinel - 2 MSI based Land Use/Land Cover was used to assume the impact of flood inundation on LU/LC, especially on cropland.

3.2. Methodology

Sentinel - 1 SAR data was used to identify the flood extent and flood - affected rice fields. LU/LC map has been generated using Sentinel - 2A/B MSI data to extract flood - affected cropland, pre - flood waterbodies and other classes. We used the thresholding method to extract inundated pixels. The intensity within the threshold range was classified as flood, while the pixels with intensity above the threshold were classified as non - flooding. Then, the obtained flood extent has been subtracted by the pre - flood layer of water bodies derived from the LU/LC layer for the elimination of water bodies (Figure 2).

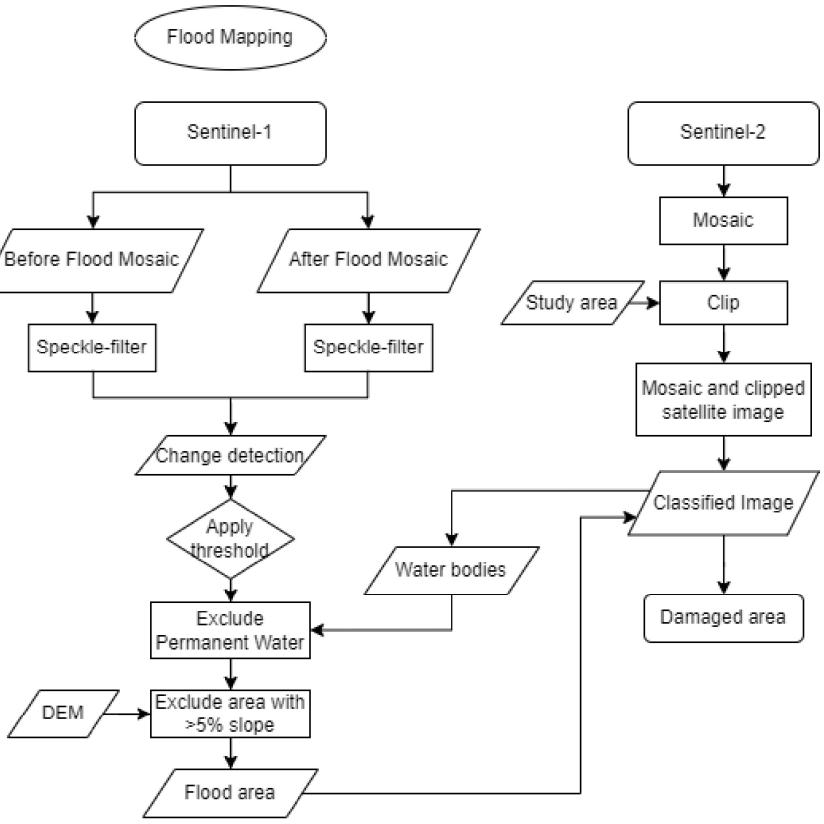

Figure 2: Flow diagram indicating the methodology of the study

The entire analysis has been performed in the GEE cloud platform, then a web - based IDE code has been developed by JavaScript code (https://code.earthengine.google.com/646b8312fea683781c28ee923fd4d00f) to estimate flooded areas and flood - affected cropland (Figure 3). Finally, the inundation layer obtained was refined using open - source GIS tools.

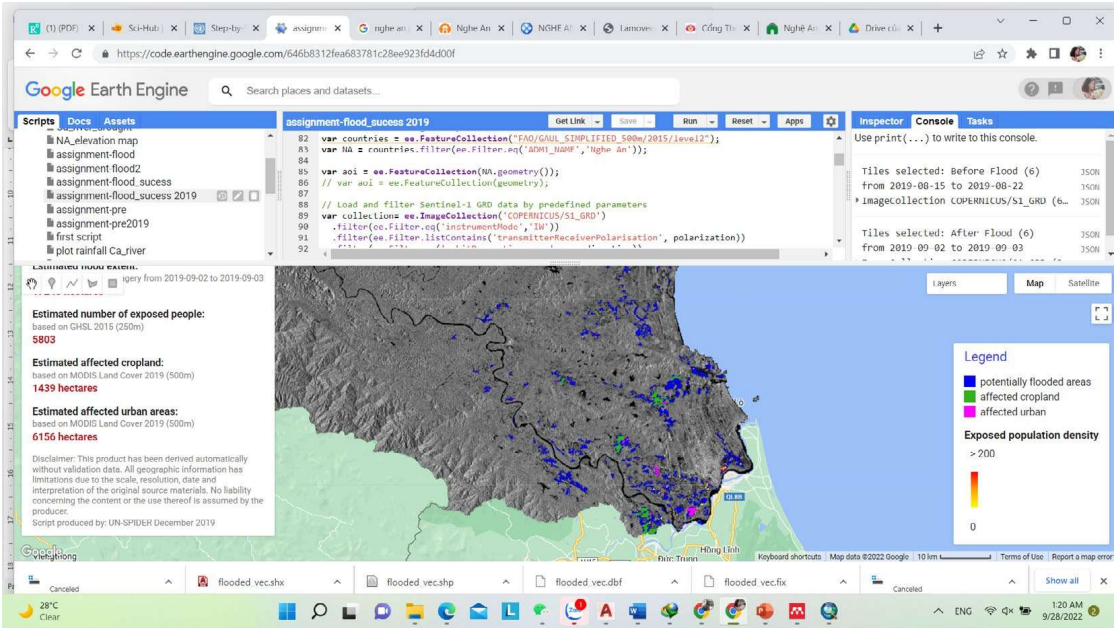

Figure 3: Google Earth Engine Interface

4. Result and discussion

4.1. Flood inundation map

The cause of the flood was due to excessive and continuous rainfall from 29th August 2019 to 5th September 2019 which was obtained from Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data (Figure 4). Based on the rainfall data, pre and post flood datasets were selected from Sentinel - 1. Therefore, a flood inundated map was built and a total area of 172.43 km^2 (i.e., 8.71 % of lowland and coastal plain) was flooded (Figure 5).

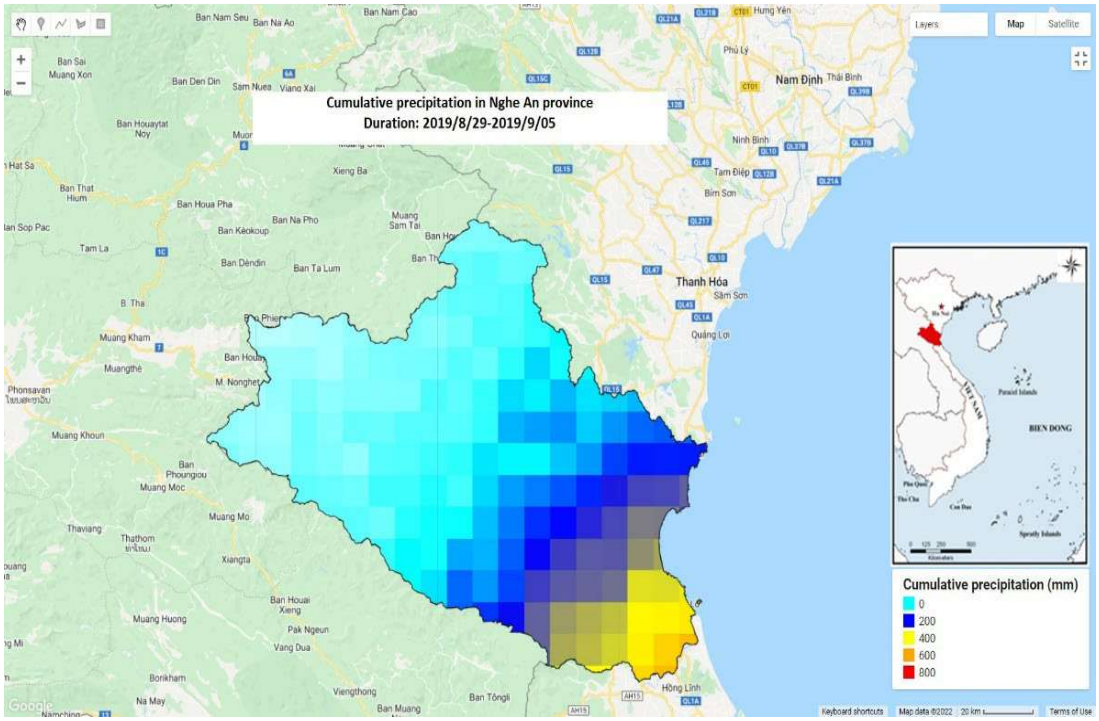

Figure 4: Rainfall data during August 29th - September 5th 2019

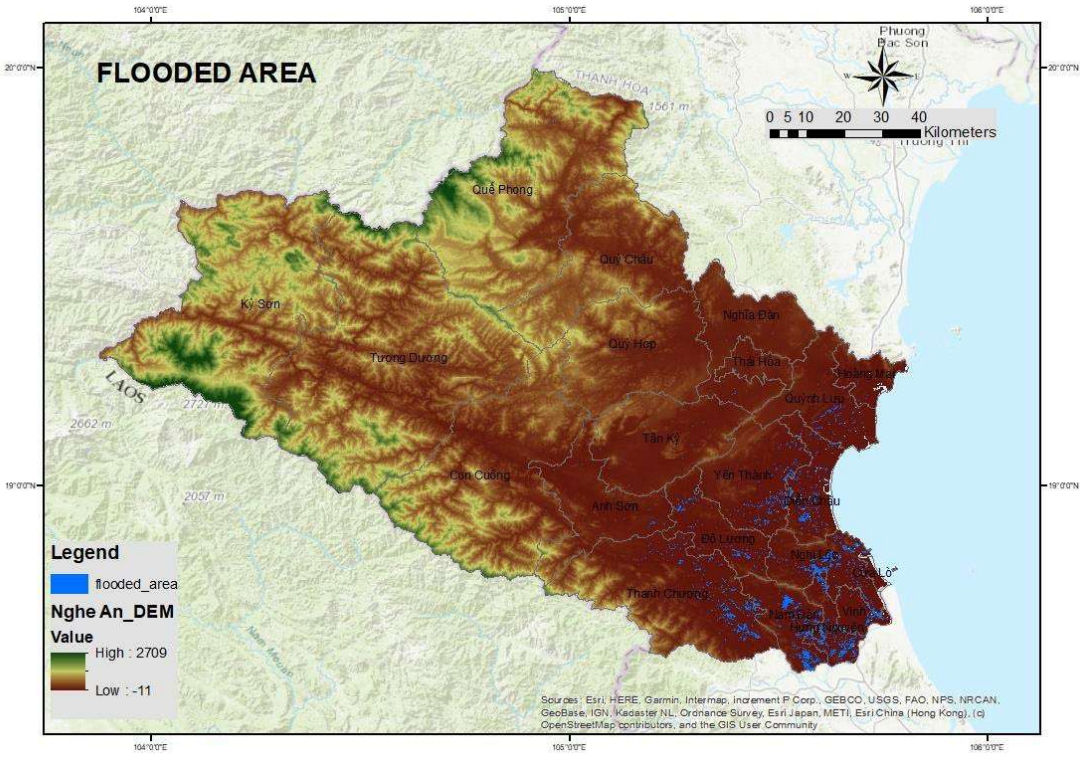

Figure 5: Flooded inundation map in Nghe An province

4.2. Land use/ land cover map and flood damage assessment

LULC map was developed to estimate damage initially using a mosaic of Sentinel - 2 pre - flood datasets (Figure 6).

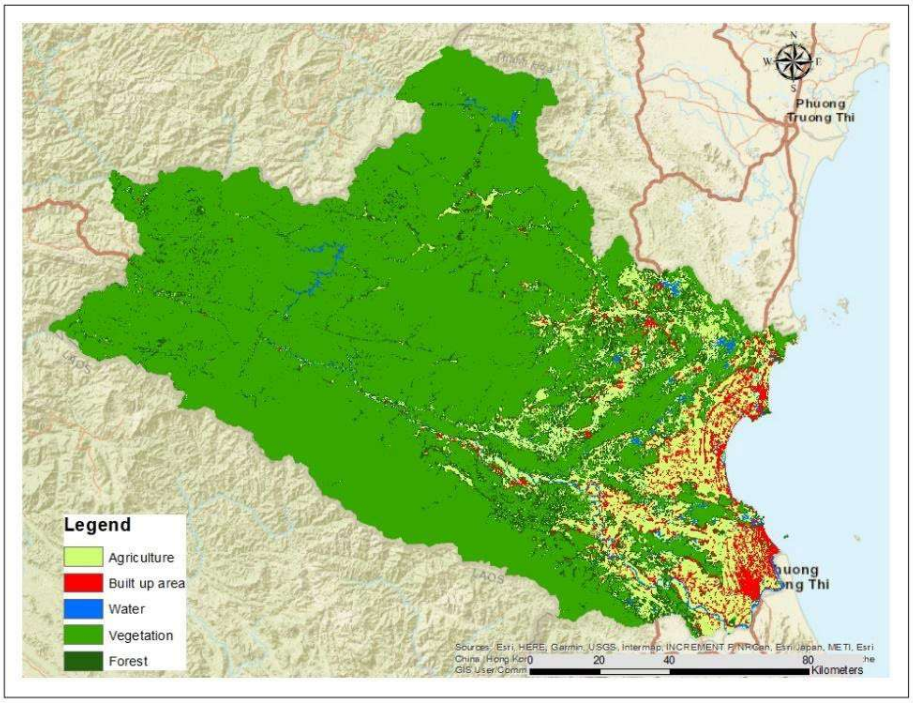

Figure 6: Land use/ land cover map of Nghe An Province in 2019

The affected LULC classes were extracted from the flood map derived from the Sentinel - 1 dataset. The affected areas were urban area (6156 ha), cropland area (1439 ha) and mainly located in the Southern - East of the province (Figure 7).

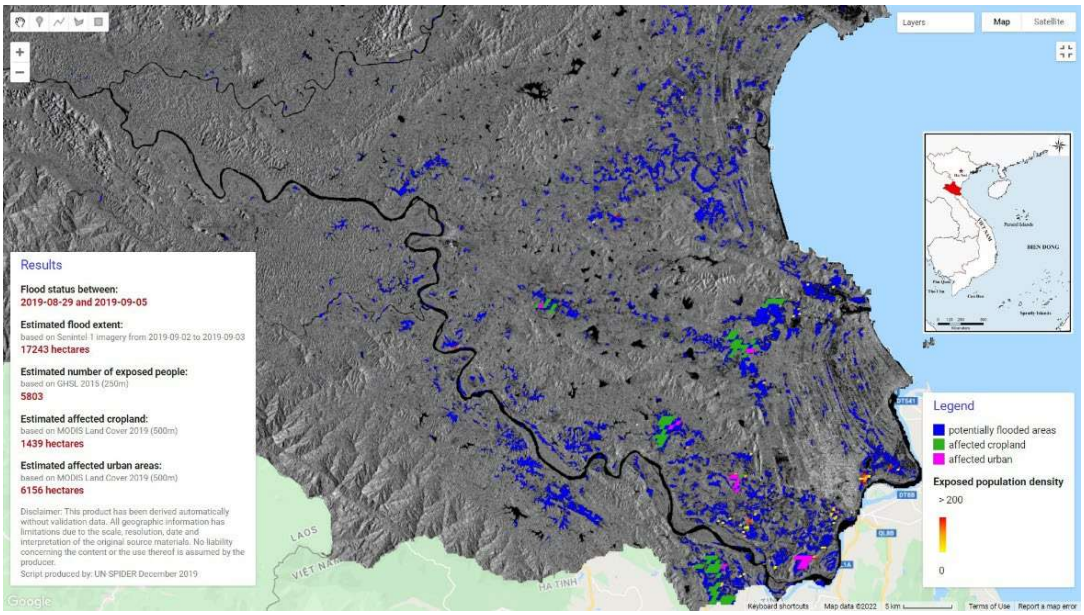

Figure 7: Affected land use the land cover map

5. Conclusion

A web - based JavaScript code was developed to process huge datasets hosted on the GEE platform within a minute for robust flood mapping, monitoring and estimation of flood - affected cropland using SAR imagery at a large scale with all - weather capability. We observed the concurrent floods (August - September 2019) in Nghe An province and found that about 8.71 % of the lowland and coastal plain (172.43 km^2) area were flooded, affecting about 5,803 persons. The severely flood - affected cropland was about 1439 ha. The findings of this study are useful for policymakers and preventive measures for disaster management. Moreover, GEE has been shown to be a very useful tool in preparing an emergency response related to floods and evaluating the damaged area.

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