APPLYING GOOGLE EARTH ENGINE TO ASSESS THE IMPACT OF URBAN FLOODING IN NINH KIEU DISTRICT IN THE PERIOD FROM 2018 TO 2021

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ABSTRACT: Ninh Kieu District is an important socio-economic center of Can Tho City. According to statistics in 2019, this region has an average population of 280,792 people, with an area of 29.23 km^2. Ninh Kieu district is a region with relatively low terrain, so urban flooding often occurs due to the impact of rainstorms, high tides and floods upstream of the Mekong River. This paper presents the results of using Google Earth Engine to interpret Sentinel-1 satellite images to identify flooded areas in Ninh Kieu District from 2018 to 2021. Sentinel-1 satellite image is selected in this research because of its ability to receive cloud-penetrating data by using radar waves, which Ninh Kieu District during the research periods had high cloud coverage. The 2019 population data of Ninh Kieu District is used to determine the number of exposed people in the study area. Research results have shown the location and flooded area and the number of exposed people, create the basis for building appropriate solutions for managers in this region.

1. INTRODUCTION

Ninh Kieu District is one of the administrative units of Can Tho City, which is considered as the driving force for the city's development. Ninh Kieu District has a favorable geographical position and with many arterial roads passing through, surrounded by Vinh Long Province, Binh Thuy District, Cai Rang District and Phong Dien District. This region has a flat topography, the difference in elevation is not large, with the common average altitude from 0.8 m to 1.2 m (People's Committee of Ninh Kieu District, 2015). Due to the special properties, geological formation process and the interlaced river and canal system, the ground is weak and the load-bearing strength is low, only from 0.2 kg/cm^2 to 0.5 kg/cm^2 (People's Committee of Ninh Kieu District, 2015). Based on data from the Can Tho City Statistics Office, in 2019 Ninh Kieu District has an average population of 280,792 inhabitants (with 133,911 men and 146,881 women) on an area of 29.23 km^2 (Can Tho City Statistics Office, 2020).

Due to the above natural features, Ninh Kieu District is one of the regions of the Mekong Delta that is often heavily affected by urban flooding (Can Tho City Department of Construction, 2016). The three main causes of urban flooding in this region include: heavy rainfall, high tides and floods upstream of the Mekong River (Can Tho City Department of Construction, 2016). In recent years, along with the socio-economic development, the urbanization process in Ninh Kieu District has taken place rapidly and complicatedly, many new residential areas have sprung up, creating a great pressure on the drainage system of this region. This phenomenon has aggravated urban flooding in Ninh Kieu District, causing great damage to communities living in this region (Can Tho City Department of Construction, 2016). To solve this problem, managers need to assess the area affected by urban flooding in Ninh Kieu District, creating a basis for the development of appropriate solutions and policies to prevent and mitigate damage caused by this phenomenon. One of the effective technological solutions to accomplish this task is the application of remote sensing (RS) to identify flooded surfaces in urban areas from satellite image data. This solution has been used in many parts of the world with different approaches, bringing positive and reliable results for flood prevention (Sowmya et al., 2015; Beaton et al., 2019; Yang and Cervone, 2019; DeVries et al., 2020; Vanama et al., 2020). This paper presents the results of Sentinel-1 satellite image interpretation using Google Earth Engine (GEE) platform to identify flooded areas in Ninh Kieu District from 2018 to 2021 (UN-SPIDER, 2019). Sentinel-1 satellite image is selected for interpretation and identification of flooded areas because of its ability to receive cloud-penetrating data by using radar waves, which Ninh Kieu District in the research periods fell in the rainy season, so it had high cloud coverage. Besides using Sentinel-1 satellite image data, this research also uses 2019 population data to estimate the number of exposed people in the study area. Figure 1 depicts the administrative scope of Ninh Kieu District in the VN2000 coordinate system.
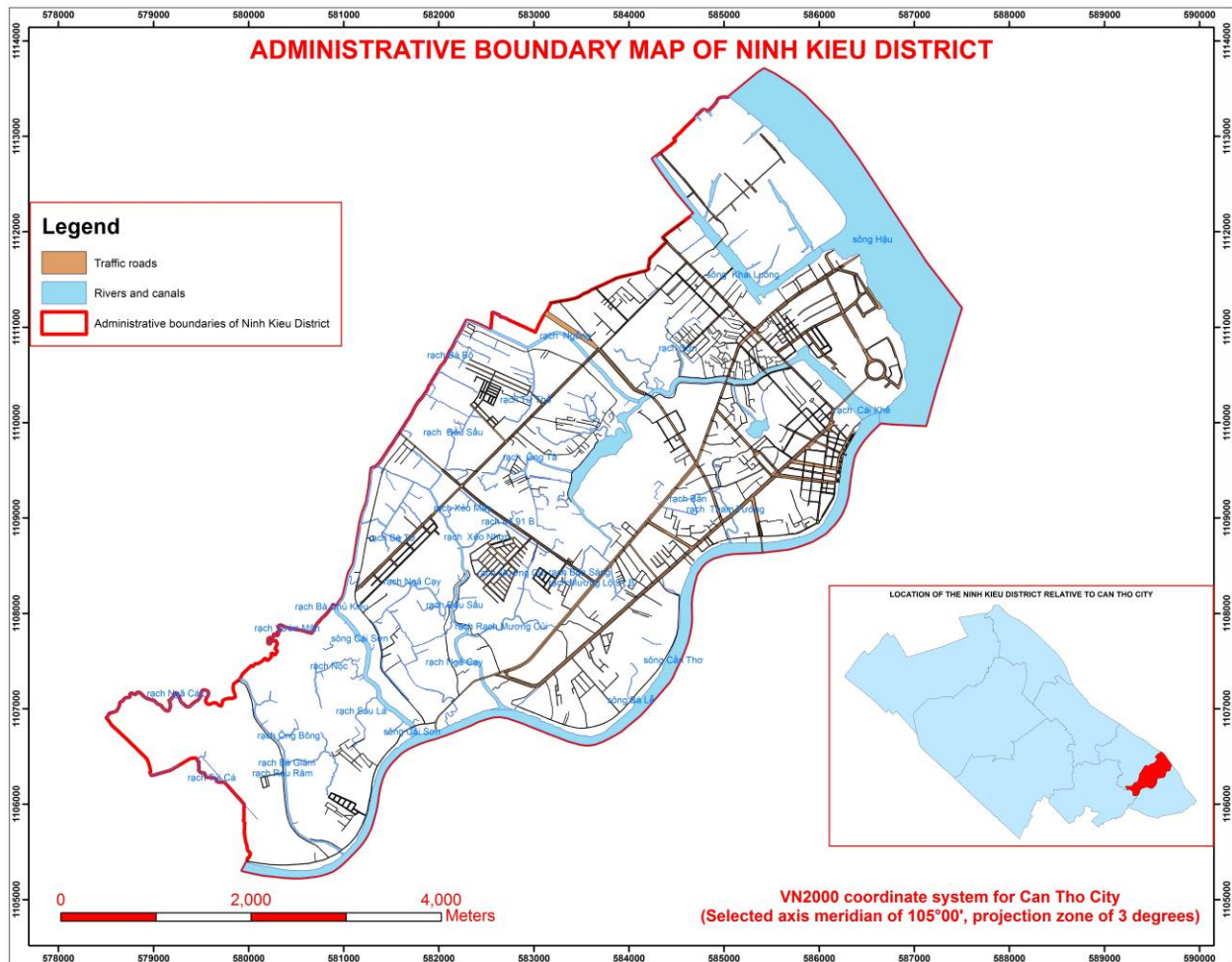
Figure 1. The geographic location and administrative boundaries of the study area - Ninh Kieu District.

2. METHODS AND DATA

2.1 Research methods

To achieve the set objectives, this research was deployed based on four main methods: (1) field survey and data collection method, (2) RS and GIS method, (3) experts consulting method, (4) data processing method. The process of assessing the impact of urban flooding on Ninh Kieu District is carried out according to the approach of identifying water-covered areas using Sentinel-1 satellite image data (UN-SPIDER, 2019). The results of identifying water-covered areas from the GEE platform are also used to estimate the number of exposed people based on 2019 population data by wards in the study area.

The impact assessment of urban flooding in Ninh Kieu District in this research includes the following six main stages: (1) collecting relevant data, (2) converting the coordinate system of administrative boundary data, (3) interpreting Sentinel-1 satellite images on the GEE platform, (4) extracting and overlaying data using QGIS software, (5) estimating total flooded area and number of exposed people, (6) evaluating results and making recommendations. The implementation process of the urban flooding impact assessment is shown in Figure 2.
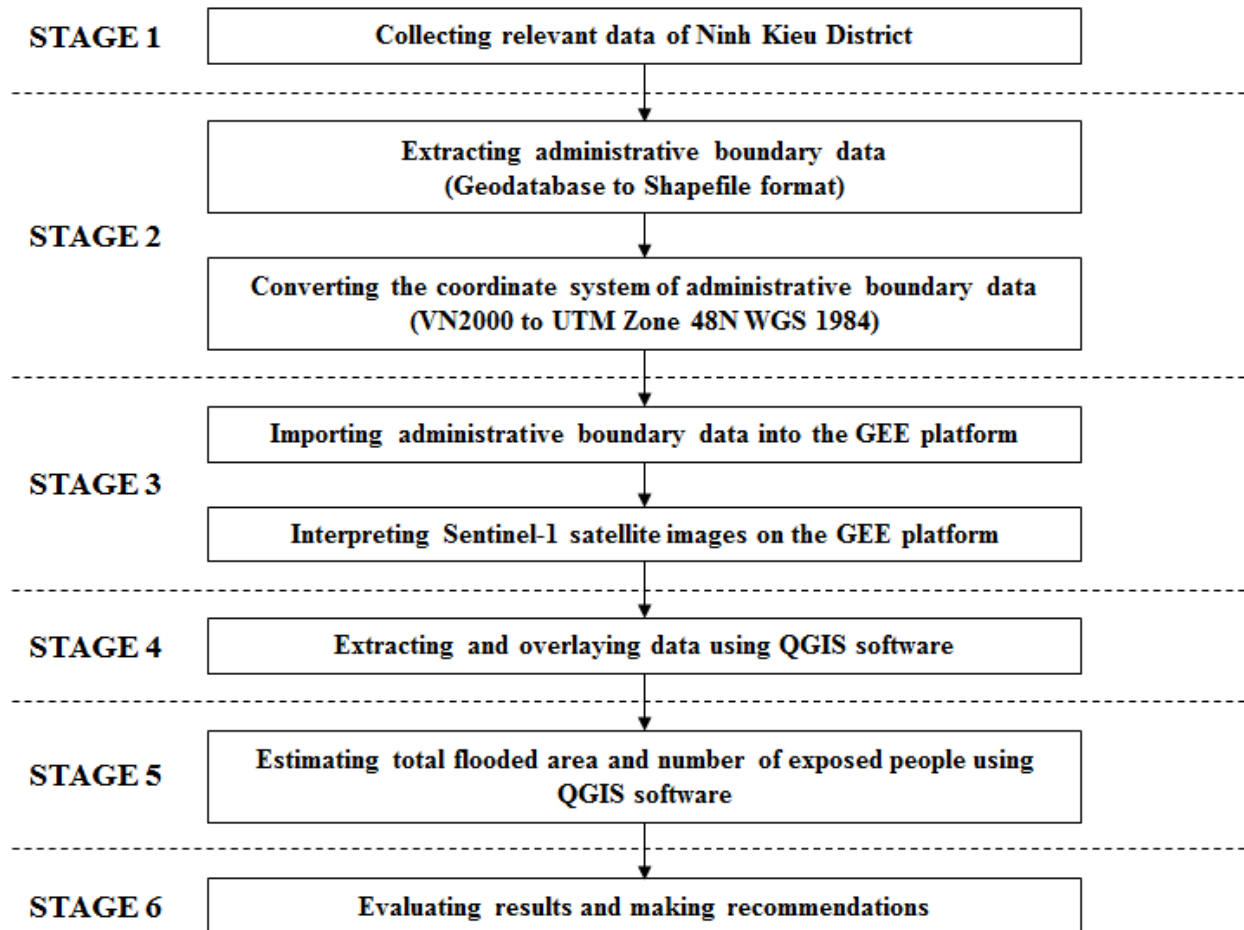
STAGE 1	Collecting relevant data of Ninh Kieu District

STAGE 2	Extracting administrative boundary data (Geodatabase to Shapefile format)
	Converting the coordinate system of administrative boundary data (VN2000 to UTM Zone 48N WGS 1984)

STAGE 3	Importing administrative boundary data into the GEE platform
	Interpreting Sentinel-1 satellite images on the GEE platform

STAGE 4	Extracting and overlaying data using QGIS software

STAGE 5	Estimating total flooded area and number of exposed people using QGIS software

STAGE 6	Evaluating results and making recommendations

Figure 2. The implementation process of the research.

2.2 Research data

In order to assess the impact of urban flooding in Ninh Kieu District, the following three types of data were used in the research process: (1) Shapefile administrative boundary data, (2) Sentinel-1 satellite image data, (3) 2019 population data of Ninh Kieu District. Administrative boundary data was collected from the Mekong Delta Geographic Information Systems Project (MGIS) in Personal Geodatabase format. This data was extracted as a Shapefile layer and converted the coordinate system from VN2000 to UTM Zone 48N WGS 1984. The administrative boundary data is used to determine the calculated extent of the area where the impact of urban flooding is to be assessed. The Sentinel-1 satellite image data is integrated on the GEE platform, it only needs to be declared and can be used in the image interpretation process. The Sentinel-1 satellite image data is used to identify water-covered surfaces based on the principle of Synthetic Aperture Radar (UN-SPIDER, 2019). The 2019 population data of Ninh Kieu District is used to determine the number of exposed people in the study area.

3. RESULTS AND DISCUSSION

The time periods selected for evaluation are six periods of heavy urban flooding and Sentinel-1 satellite image data is available for interpretation from 2018 to 2021 in the study area. The six specific periods are: (1) 09/10/2018 to 20/10/2018, (2) 29/09/2019 to 10/10/2019, (3) 17/10/2020 to 28/10/2020, (4) 31/10/2020 to 11/11/2020, (5) 13/11/2020 to 24/11/2020, (6) 01/09/2021 to 29/09/2021.

Sentinel-1 satellite image interpretation on GEE platform helps to identify flooded areas in selected periods (UN-SPIDER, 2019). The results of image interpretation are extracted in vector format and combined with administrative boundary data (using QGIS software) to determine the flooded area for each ward of Ninh Kieu District. This is an important factor to assess the impact of urban flooding in the study area. The results obtained by this process are presented in Figure 3. The flooded area data in the chart shows that the three periods with the largest total flooded area are: (1) 17/10/2020 to 28/10/2020, (2) 09/10/2018 to 20/10/2018, (3) 31/10/2020 to 11/11/2020. The obtained results also show that An Binh, An Khanh, Cai Khe and Hung Loi are four wards that have larger

flooded areas than the rest in Ninh Kieu District during research periods. The value of flooded area obtained from image interpretation is also used to estimate the percentage of flooded area by wards in Ninh Kieu District. These results are shown in Figure 4. The data in this chart indicate that An Cu, An Hoa, An Lac, An Nghiep, Tan An and Thoi Binh are six wards with a larger percentage of flooded area than the rest in Ninh Kieu District during research periods. During the period from 17/10/2020 to 28/10/2020, the study area was most heavily flooded, expressed by the percentage of flooded area in each ward is the largest in six selected periods.
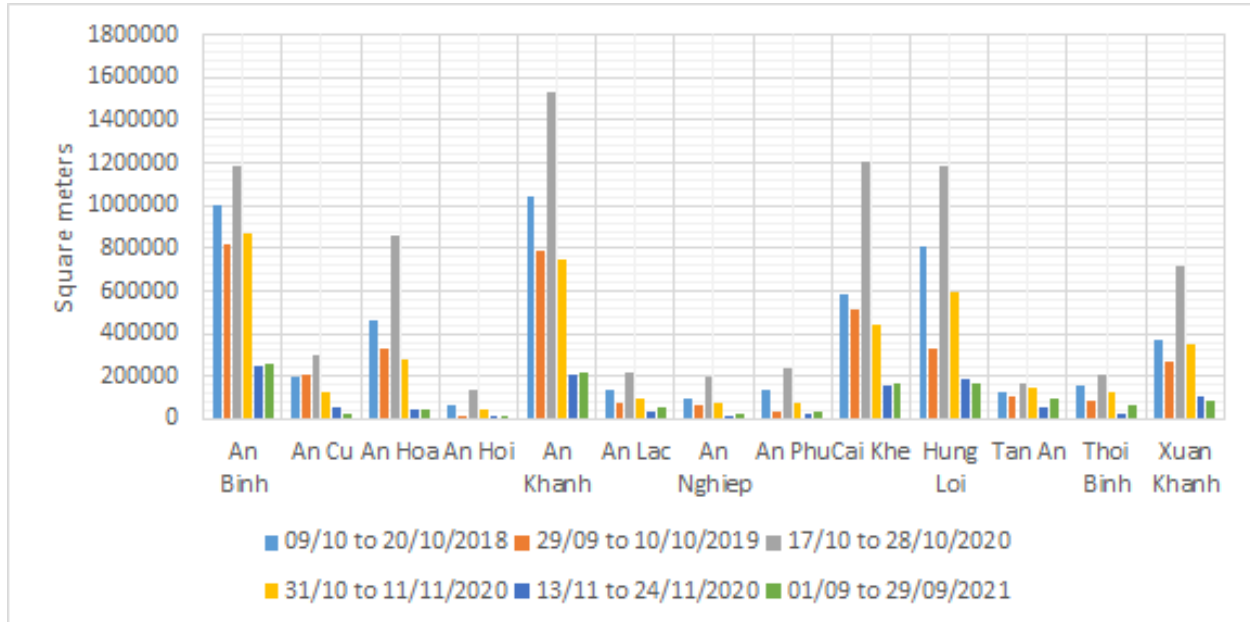
Figure 3. The chart shows the total flooded area by wards in six selected periods.
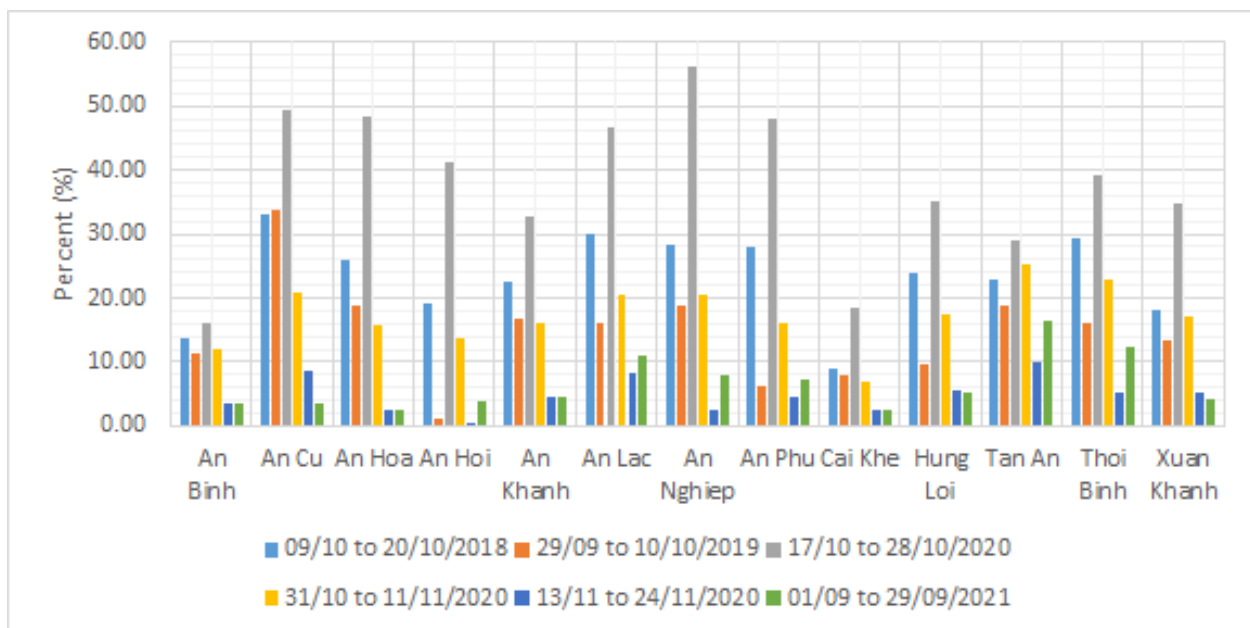

Figure 4. The chart shows the percentage of flooded area by wards in six selected periods.

The results of image interpretation of flooded areas by wards are combined with administrative boundary data to build urban flood maps using QGIS software. These maps are shown in Figure 5 respectively in the order of the six selected periods. The distribution of flooded areas on the maps shows that the period from 17/10/2020 to 28/10/2020 has the largest flood extent, while the period from 13/11/2020 to 24/11/2020 has the smallest flood extent. These maps also indicate areas located near riverbanks or with low topographical elevations that are frequently flooded during the selected periods.
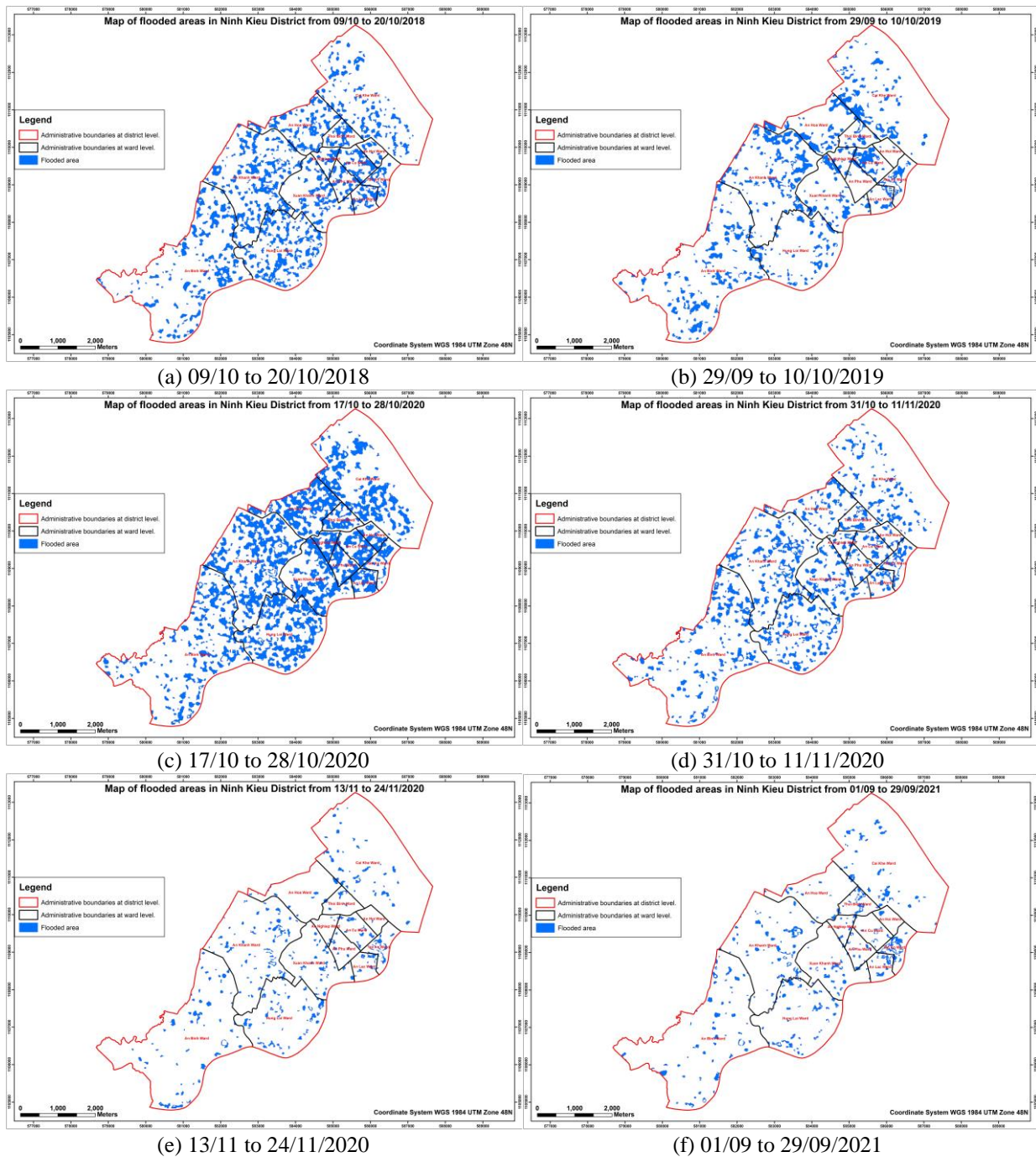
(a) 09/10 to 20/10/2018

(b) 29/09 to 10/10/2019

(c) 17/10 to 28/10/2020

(d) 31/10 to 11/11/2020

(e) 13/11 to 24/11/2020

(f) 01/09 to 29/09/2021

Figure 5. Maps of flooded areas in Ninh Kieu District in the six research periods.

The data of flooded area by wards is also used to estimate the number of exposed people in the study area. The number of exposed people in the study area is estimated based on the following formula:

Number of exposed people by wards = Flooded area by wards × Population density by wards

The data of flooded area by wards calculated using the QGIS software is presented in Figure 3. The population density data by wards is estimated by dividing the population by wards by the area of wards in 2019. The values of estimated population density by wards in 2019 are depicted in Figure 6. The calculation results of the number of exposed people by wards in selected periods are presented in Figure 7. The data in the chart indicates that the two periods with the largest number of exposed people are: (1) 17/10/2020 to 28/10/2020, (2) 09/10/2018 to 20/10/2018. Figure 7 also show that An Hoa, An Khanh and Hung Loi are three wards that have larger number of exposed people than the rest in Ninh Kieu District during research periods.
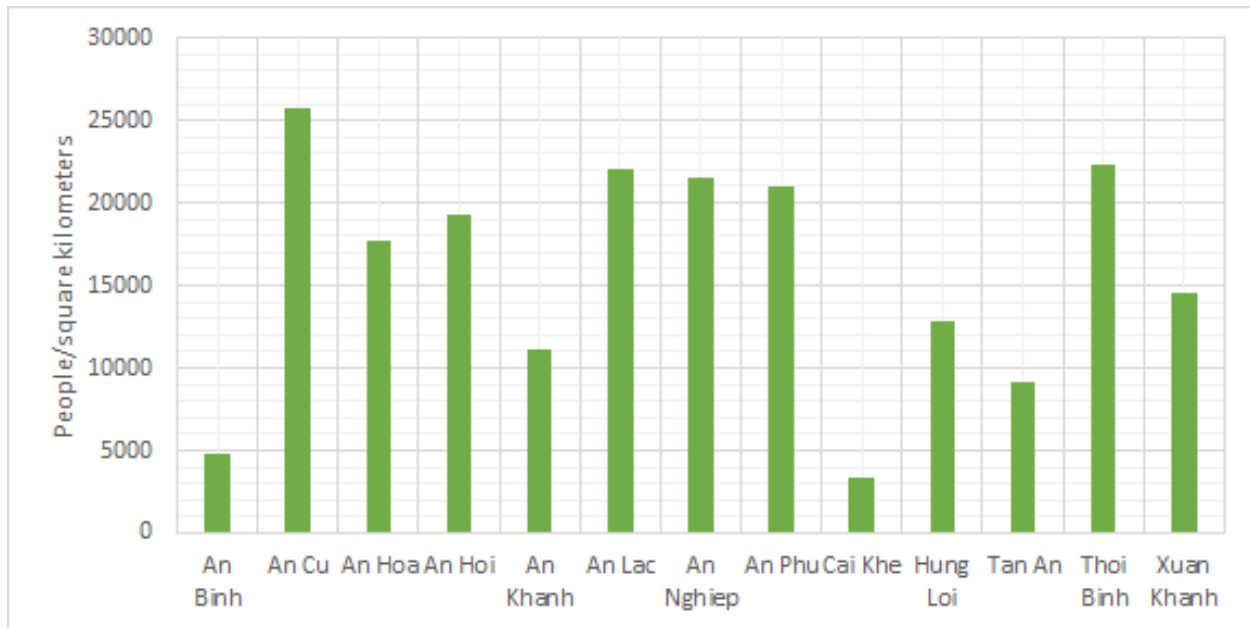
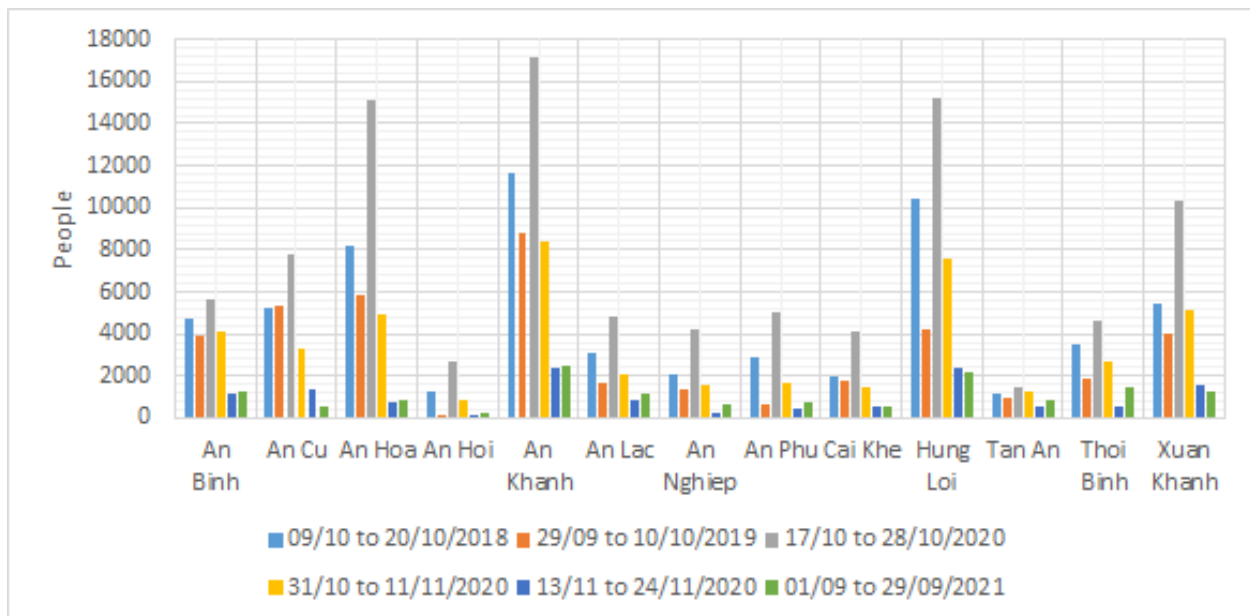**Figure 6. The chart shows population density by wards in Ninh Kieu District in 2019.**

Figure 7. The chart shows the number of exposed people by wards in six selected periods.

The estimated results of total flooded area and number of exposed people area used to create the charts in Figure 8 and Figure 9. The chart in Figure 8 shows that the period with the largest flooded area is from 17/10/2020 to 28/10/2020 $(8,147,171 \text{ m}^2)$, and the period with the smallest flooded area is from 13/11/2020 to 24/11/2020 $(1,155,111 \text{ m}^2)$. The number of exposed people is displayed in the bar chart of Figure 9, with the maximum value falling in period from 17/10/2020 to 28/10/2020 (98,131 people), the smallest value falling in period from 13/11/2020 to 24/11/2020 (12,727 people).
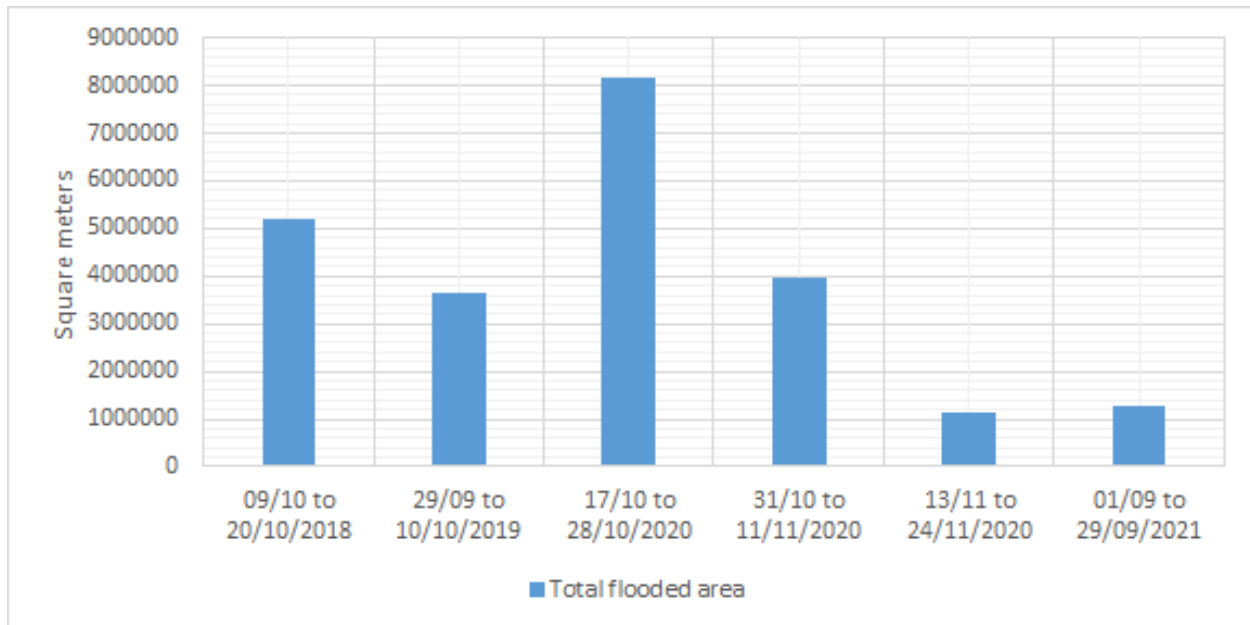
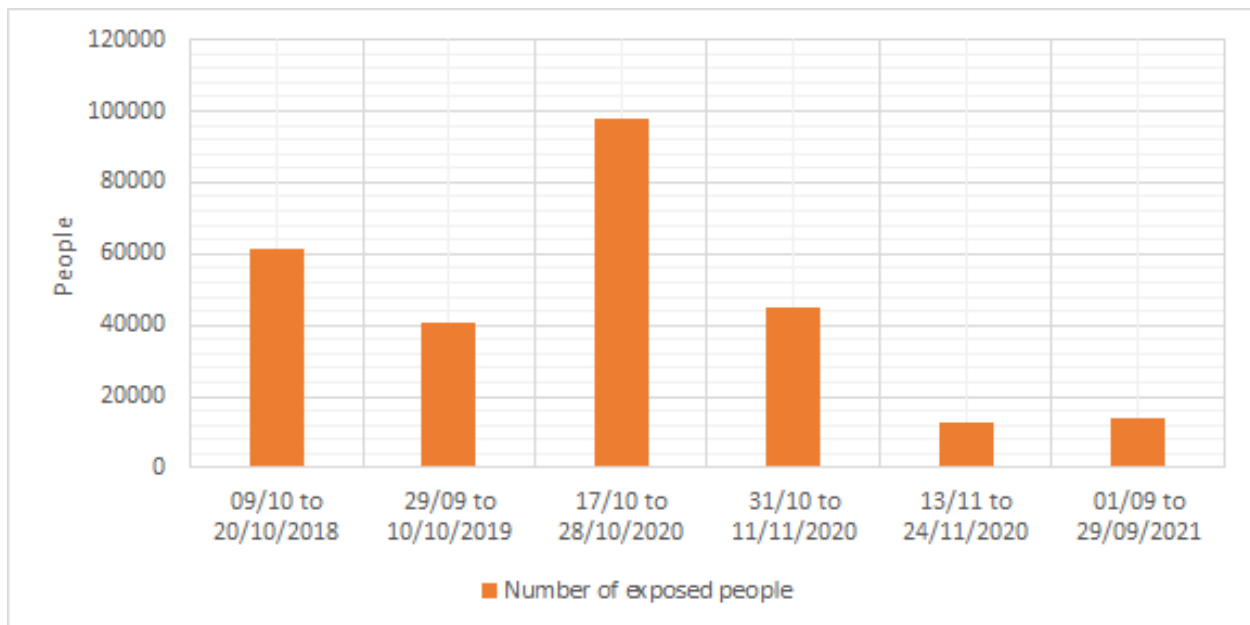**Figure 8. The bar chart shows the total flooded area in selected periods.**

Figure 9. The bar chart shows the number of exposed people in selected periods.

4. CONCLUSIONS AND RECOMMENDATIONS

This research has initially assessed the main impacts of urban flooding on Ninh Kieu District by estimating two factors: total flooded area, number of exposed people. The obtained results indicate that Ninh Kieu District is a region frequently affected by urban flooding, especially during high tide months of the year. These results also show that the period most affected by urban flooding in the study area is from 17/10/2020 to 28/10/2020 with the estimated values being the largest in the six selected periods. This research also indicates that the application of GEE platform to assess the impact of urban flooding in particular and floods in general is a suitable and modern approach with great development potential. During the implementation of this research, a process for assessing the impact of urban flooding using the GEE platform and QGIS software has been developed. This process will be a useful reference for future studies on urban flooding in the Mekong Delta.

5. ACKNOWLEDGMENTS

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