IMPACT OF URBANIZATION ON FLOODING IN KHANH HOA PROVINCE

Luong Huu Dung, Doan Huy Phuong, Ngo Thi Thuy, Chu Nguyen Ngoc Son
Viet Nam Institute of Meteorology Hydrology and Climate Change

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Abstract: *Currently, natural disasters such as floods and inundation are increasing both in the quantity and degree of impact. The areas most heavily affected by flooding are low-lying areas such as coastal cities and countries. The characteristics of natural disasters such as floods and inundation are not only affected by changes in climate factors but also by urbanization and human activities. This paper uses the MIKE FLOOD (DHI) model to analyze the impact of urbanization on flood and inundation characteristics in the downstream areas of Cai river in Khanh Hoa province. The results show that the change of urban topography during the urbanization period has significant effects on the floodplain areas in terms of location and intensity, thereby changing the characteristics of flood and inundation distribution spatially.*

Keywords: *Urbanization, flooding, coastal areas, Khanh Hoa province, Viet Nam.*

1. Introduction

Flooding is one of the most dangerous natural disasters with about 70 million people impacted by flood every year [13]. Under climate change context, flooding is more severe especially in urban cities [1, 16]. Flooding is not only a global concern, but also one of the main hazards in Viet Nam that frequently causes severe economic losses and casualties [7]. It was estimated that as of 2010 about 930,000 people in the country are exposed to flood risk, with total annual losses to flooding of approximately 2.6 billion USD [17].

Flood risk is not only a popular threat to riverine areas but also to many densely populated cities and coastal regions. Furthermore, urbanization is rising in Viet Nam that has one of the highest growth rates in the urban population in East Asia. Based on the historical records, in 2013, there were 770 officially designated urban areas in Viet Nam [14]. It was estimated that by the end of 2015, 20 new urban areas had been formed [12]. With the acceleration of urbanization since Doi Moi (social, economic, and political renovation starting in 1986), flood risk has increased in urban areas [4]. This trend is aggravated by population growth, economic development and the associated expansion of buildings and infrastructure into flood-prone areas [4, 10, 11]. During the period 2012 - 2015, several major floods occurred in Viet Namese cities, notably in Ha Noi, Quang Ninh, Da Nang, Can Tho, and Ho Chi Minh City [5]. The number of flood and inundation events has been rising in recent years and therefore flood risk is anticipated to increase due to population and economic development. The major impact of urbanization on the hydrological characteristics of a catchment is to decrease the amount of infiltration into the ground and to increase the speed of surface runoff. Because of the urbanization and road construction, overland flow and drainage were impeded, leading to deeper flooding and longer inundation.

ISET (2016) indicated that the urbanization an infrastructure construction within the floodplain areas of the Vu Gia - Thu Bon river system caused more flood risk in the upstream areas of the floodplain. The natural capacity of floodplains for absorbing and slowing floodwater flow is decreased due to the rising land

Corresponding author: Luong Huu Dung
E-mail: dungluonghuu@gmail.com

surface elevation and urban activities. As a consequence of this, the behavior of extreme flood events is different from what occurred in the past. The flood risks will be transferred from the new planned urban areas to other lower areas. In these lower areas, the risk levels are higher, the flood events may occur faster, the water depth is deeper and finally, flood inundation drains more slowly [5].

Urbanization increases regional impervious surface area, which generally reduces hydrologic response time and therefore increases flood risk [2]. In order to assess urbanization impact on flood risk, two common types of data sources used to analyze and estimate are historical records and flood modeling results. Early studies implemented urbanization impact evaluation on the magnitude and frequency of urban inundation through historical data from the gauging stations [3, 8]. The studies of Villarini, et al (2009) and Prosdocimi, et al (2015) have employed advanced model systems to indicate that the urbanization has a statistically considerable impact on the magnitude and frequency of flood events.

Briefly, the information about river flow, flood and inundation and how they are affected by topography changes associated with urbanization development can help communities reduce their current and future vulnerability to floods. In this study, the impacts of urbanization on flooding are retrieved by assessing the change of topography characteristics in Khanh Hoa province located in Viet Nam over time and flooding exposure consequently.

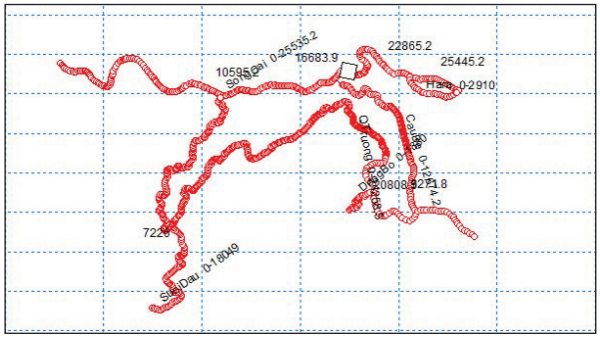


Figure 1. Schetch of river network in MIKE 11 model

2. Study area and methodology

2.1. Study area

Cai River is the largest river in Khanh Hoa province, located in the range of 120°03' - 120°37' North latitude, 108°41' - 109°12' East longitude. The Cai River basin area is 2,000 km^2 and covers the whole of Nha Trang City, Dien Khanh and Khanh Vinh districts and part of the area of Cam Lam district of Khanh Hoa province and MaDrak of Dak Lak province.

Khanh Hoa Province is located in the South Central Coastal Region of Viet Nam. The total population of the province in 2019 was around 1,336,143. The province has core developed areas such as Nha Trang city and Cam Ranh Bay port. Khanh Hoa Province has set a goal to become a centrally-governed type 1 city by 2025. The province has approved many planning projects at a total cost of VND61 billion. These projects mainly invest in urban residential and housing areas and traffic roads.

2.2. Input data

Using the hydrological stations and observed flow data, the simulated river network for hydraulic estimation of the Cai River was established with the total main river length of 31 km as shown in Figure 1.

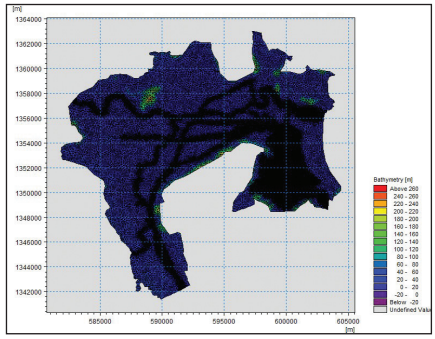


Figure 2. Grid calculation on Mike 21 FM model

• Boundary conditions:

- Upper boundary: Observed flow discharge data at Dong Trang station

- Midstream boundary: The flow discharge process of tributaries entering the Cai River, simulated from the Mike NAM model based on the observed meteorological data (rainfall and evaporation) in Nha Trang, Dong Trang and

Khanh Vinh station.

- Lower boundary: The observed water level process at the estuary of Cai river.

• Topographic data: Topographic data which covers the whole Cai basin is collected with the scale 1:10,000 then analyzed and used for the flexible mesh generation(calculation grid setting up) by the ArcGIS software.

• Setting up the calculation grid for the study area: Depending on the different areas in simulation, the resolution of calculation grid would be different. For riverside areas, the possibility of flooding is higher then need more detailed simulation, so the calculation grid is divided into thicker, while for the areas far from the river and the possibility of flooding is lower, grid is set up into sparser net. The calculation grid for the study area is presented in Figure 2.

2.3. Numerical techniques

In order to present the change of flooding status in Khanh Hoa province in the different topographic situations, the hydraulic software MIKE package i.e. MIKE FLOOD coupling MIKE-11HD and MIKE 21FM is used. The change of topography under urbanization is illustrated in the digital elevation model (DEM) that integrated in MIKE 21FM in the form of the flexible mesh system to visually present the change of flooding characteristic in 2D space.

In order to combine the advantages of both 1-D and 2-D models and overcome their disadvantages, MIKE FLOOD allows coupling the MIKE 11 and MIKE 21 models in the simulation process, reducing the computation time but still being able to simulate both the flow in the channel and on the field sites or flood plains as well as simulating the hydro-hydraulic process within the whole system. This is the final stage in setting up the hydraulic model system. In this study, based on the MIKE-11HD and MIKE 21FM models set up above, the two are connected in the MIKE FLOOD model through the linkage type called “Lateral”. The simulated results of the MIKE FLOOD model then are converted into GIS file format to estimate and calculate the flooding area corresponding to the flooding depth range.

3. Results and discussion

In this study, to evaluate the effects of urbanization on flood characteristics, the research team conducted inundation simulation process using MIKE FLOOD model with the hydrological data input corresponding to the flood event occurred in 2009 with the frequency of 1% and 2 topographic data in 2010 and 2018 respectively.

The topographic data in 2010 is selected to represent the topographic feature of the study area before the urbanization period and the topographic data (with some planned areas) in 2018 is selected to represent the topography characteristic after the urbanization period. The main difference between the two topographic inputs is that, for the topographic data in 2018, the terrain elevation of the areas including Dien Toan, Dien An, and Dien Thanh communes of Dien Khanh District, Vinh Chung, Vinh Hiep, Vinh Thanh communes and other the southern wards of Nha Trang city located in the lower part of the Cai river are planned to be raised by 2 - 3 m for the building constructions compared to the terrain elevation in 2010 of the same areas.

The results of inundation simulation in the downstream area of Cai river using the MIKE FLOOD model corresponding to the two scenarios of topography in 2010 and 2018 show that the flooded area occurs in Dien Khanh districts and the Nha Trang city, the specific results are as follows:

The topography scenario in 2010:

In Dien Khanh district, there are 18 affected communes with a total flooded area of 75.4 km², of which 4 communes are most affected with over 80% of the flooded area, including: Dien Thanh, Dien Lac, Dien Phu and Dien Khanh town. The flooding depth in the communes of Dien Khanh district is mainly at a depth of less than 1.5 m, only Dien An, Dien Thanh and Dien Toan communes have the largest inundation depth from 2.5 - 3 m. The agricultural land area affected by flooding is mainly in Dien Khanh district with a total area of 24.80 km², the flood depth ranges from 1 - 1.5 m. The flooded residential area in Dien Khanh district is 1.54 km^{2,} most of the flooded depth is less than 1.5 m.

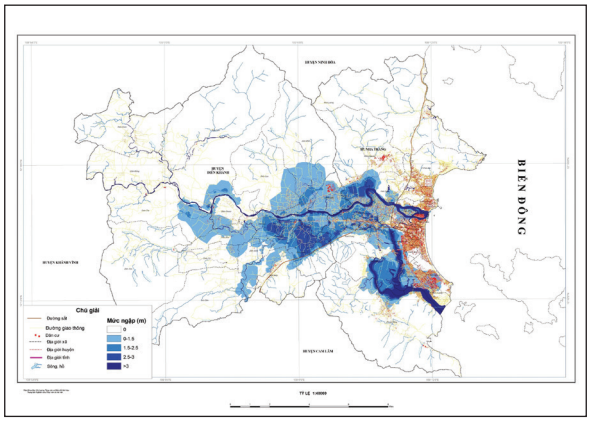


Figure 3. Inundation map corresponding to the topography scenario in 2010

In Nha Trang city, there are 17 affected communes/wards with a total flooded area of 30.57 km², in which the most affected places include Vinh Ngoc, Vinh Thanh, Vinh Hiep, Vinh Trung communes and Ngoc Hiep, Phuoc Hai, Phuoc Long wards. Flooding depth in Nha Trang city is mostly below 1.5 m. The communes/ wards with the greatest flooding depth include: Ngoc Hiep Phuoc Hai and Xuong Huan wards with over 10% of the ward areas being flooded up to 3 m. The flooded residential area in Nha Trang city is 3.14 km^2, most of the flooded depth is less than 1.5 m.

The topography scenario in 2018:

In Dien Khanh district, there are 15 affected communes with a total flooded area of 47.64 km² in which there are 4 communes most affected including: Dien Khanh, Dien Binh, Dien Lac, Dien Phu and Dien Khanh town. The degree of flooding in the communes of Dien Khanh district is mainly common at the depth of less than 1.5 m, the communes of Dien Lac, Dien Thanh, Dien Phu and Dien Khanh town are the places with the largest inundation depth (over 2 m). The agricultural land area affected by flooding is mainly in Dien Khanh district with a total area of 18.40 km², the common flood depth is from 1 - 1.5 m. The flooded residential area in Dien Khanh district is 1.14 km², most of the flooded depth is less than 1.5 m.

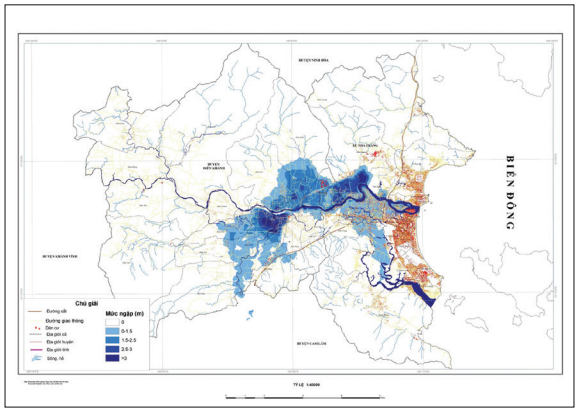
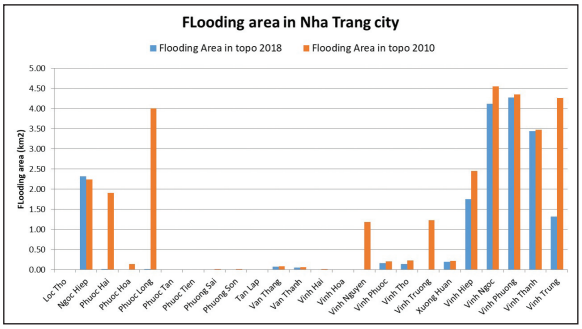


Figure 4. Inundation map corresponding to the topography scenario in 2018

In Nha Trang City, there are 12 affected communes/wards with a total flooded area of 17.82 km², in which, the most affected places including Vinh Hiep, Vinh Thanh and Ngoc Hiep wards with a proportion of flooded area above 50% of the area of communes. The flooding depth in the Nha Trang is mostly below 1.5 m. The communes/wards with the greatest inundation depth include: Xuong Huan and Ngoc Hiep wards with inundation depth from 2.5 - 3 m. The flooded residential area in Nha Trang city is 1.39 km², most of the flooded depth is less

than 1.5 m.

Comparison of inundation characteristics caused by flood event in 2009 between two topographic scenarios in 2010 and 2018:



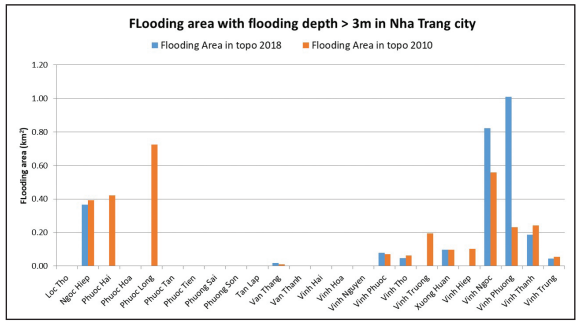
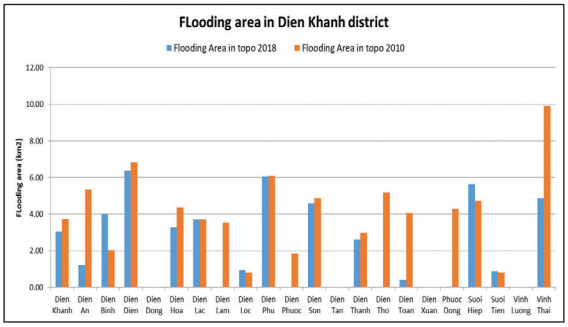


Figure 5. Comparison of flooded areas in Nha Trang city between 2 topographic scenarios in 2010 and 2018



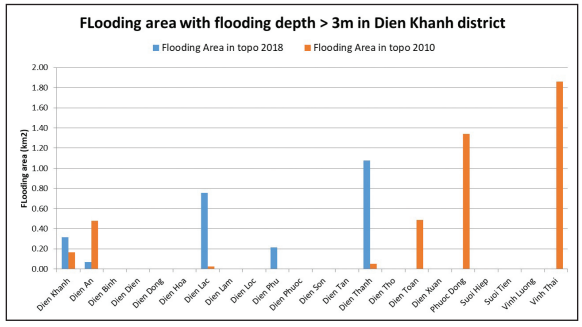


Figure 6. Comparison of flooded areas in Dien Khanh district between 2 topographic scenarios in 2010 and 2018

Based on the data observed from the inundation area graphs and maps, it can be seen that the inundation area in the whole study area caused by the flood event in 2009 on the 2010 terrain is larger than on the 2018 terrain. However, it can be observed that the inundation area corresponding to the flooding depth over 3 m in the 2018 topographic scenario is greater than that in the 2010 topographic scenario occurring at some wards and communes of Nha Trang city and Dien Khanh district. Meanwhile, other wards and communes which have quite large flooded area in the 2010 topographic scenario are not inundated in the 2018 topographic scenario. These no flooding areas coincide with the areas planned to be raised in terms of topography elevation. Therefore, it can be concluded that the difference in flooded area of some areas between the two scenarios may be caused by the change of the base elevation in the floodplains downstream. In summary, it can be concluded that the urbanization development through leveling or raising the ground elevation can indirectly change the location of low floodplain areas. This leads to the inundation area and inundation depth being changed accordingly.

4. Conclusion

The paper presented the main results of the study on the impact of urbanization on flood characteristics. The study implemented an inundation simulation caused by the flood event in 2009 for the downstream areas of Cai river in Khanh Hoa province, corresponding to two topographic scenarios in 2010 and 2018. In the study, the MIKE FLOOD model coupling 1-dimensional models MIKE 11 and 2-dimensional MIKE 21 is used to simulate flooding and inundation for the study area. The results show that the total flooded area in the 2010 topographic scenario is generally larger than that in the 2018 topographic scenario. However, for the case with the flooding depth over 3 m, the results showed that the flooded area of some areas corresponding to the

2018 topographic scenario is larger when compared to the 2010 topographic scenario. In addition, for the 2018 topographic scenario, the areas which have no inundation are the areas planned to rise the topography elevation. Therefore, it can be concluded that urbanization and urban planning have indirectly changed the location of floodplains at the river downstream, thereby changing the spatial distribution of flooding and inundation.

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