Application of Open Building Footprints Data in Flood Impact Assessment, a Case Study of Can Tho Province

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Abstract

Floods, the most common disaster in Vietnam, occur due to climatic events (such as storms and rains), discharges from multinational basins, and tidal activities. The Mekong Delta is particularly known for the convergence of these three water sources. In recent years, a significant amount of research has been dedicated to flood modeling and risk assessment, utilizing data from satellites and hydraulic modeling. Residential data plays a crucial role in flood risk assessment, but its sources are limited. Recently, Google and Microsoft have released two sources of residential building data that are freely available to the public. This paper employs Google's Open Building Footprint data and Building data extracted from the Landuse map to assess the impact of floods on the built-up area in Can Tho city. The flood data, provided by MIKE hydraulic modeling, includes return periods of 100, 50, 20, and 5 years (1%, 2%, 5%, and 20% respectively). The current flood data is classified using the Australian Flood Hazard system, which consists of five levels of hazard ranging from Caution to Danger for all. The two building datasets have been overlaid with the flood data in a GIS environment using GIS operations. A geostatistical function has been applied to determine the impact of the flood on the buildings. The results indicate that the area impacted by the flood is smaller for the Google Open Building than for the Landuse data. The primary difference is that the Google Open Building Footprint was created using satellite imagery and focuses on building footprints, while the Landuse data represents the type of land use assigned to the land parcel, which may be significantly larger than the building footprint. In conclusion, the Open Building Footprint demonstrates high potential for use in flood impact assessment.

Keywords: *open building, building footprint, flood assessment, flood impact, Mekong delta*

1. Introduction

Floods are the most common disaster in Vietnam. Flooding occurred in many places from the North to the South, and it had different characteristics. In any area, floods substantially impact the human and socio-economic systems of the locals (UNISDR, 2015, 2016). In recent years, Vietnam has suffered from floods due to abnormal climatic conditions. The floods in Vietnam are of many types, from the pluvial flood in the mountainous and hilly areas to the Fluvial flood in the deltas. The Mekong Delta area is impacted by both types of flood (Apel et al., 2015). In this delta, floods are the primary water source for agriculture and aquaculture. On the other hand, floods are causing trouble for cities and towns (Takagi et al., 2014). The cities are impacted heavily by floods, and the number of losses can be assessed by several methods (Chinh, Bubeck, et al., 2016; Chinh et al., 2017; H. L. T. Huynh & Pathirana, 2011; Ling et al., 2015; Ngo et al., 2018; Nguyen et al., 2017; Takagi et al., 2016; Van Long & Cheng, 2018). They can be GIS-based or statistical models, but the building flood risk assessment is inaccessible due to a lack of data. In the last few research, the lack of building data was solved using statistics or land use data. However, neither is very accurate due to the nature of the data.

Nowadays, Microsoft (Microsoft Bingmap, n.d.) and Google (Google research, n.d.) are publishing free Building footprints that can fill the gap. The Google building footprint data is available in Vietnam. This paper describes some experiences with data from Can Tho province. The building footprint data was downloaded from(Google research, n.d.) with about 781000 entries. The flood data was derived from hydraulic modeling with flood condition scenarios including 100, 50, 20, and 5-year return periods. Those return periods are present for hydrological conditions, a combination of rainfall, upstream floods, and tide levels. The article does not focus on hydraulic modeling; the result of the modeling has been extracted and used to prove the usability of the building footprint in flood impact calculations.

The building footprint is overlayed with the flood data in GIS. The process will show the number of buildings at each level of flood hazard. A similar process was performed with the build-up area extracted from land use data. The comparison between 2 sets of results will give an overview of the usage of building footprint data in flood assessment.

2. Flood hazard and impacts on buildings

2.1 Flood hazard

Flood hazards are one of the most common disasters in the world (IPCC, 2015); in Vietnam, they have caused damage of up to 1 billion US Dollars/year (UNISDR, 2015). In recent years, climate change has pushed floods to higher lev-

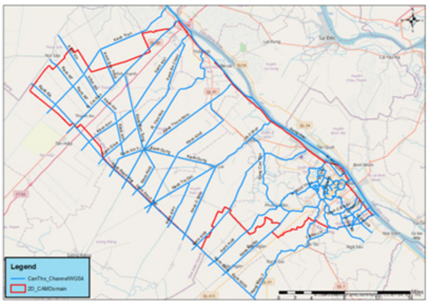


Fig. 1. Can Tho city and hydrological network
Rys. 1. Miasto Can Tho i sieć hydrologiczna

Fig. 2. Download data from Google research
Rys. 2. Pobrane dane z Google reaserach

els of damage to Vietnam. In 2020, the flood in the Central Highlands caused a loss of 229 people and affected more than 300,000 houses in Central Vietnam (Nhan dan, 2020). In the South of Vietnam, the main flood was a different story. In the Mekong Delta, the flood is more welcome than denied. The Mekong Delta flood is the primary water source for agriculture and aquaculture (DLR, 2008; Sor et al., 2021; Tuan & Wyseure, 2003). The flood brings water and sedimentation for agricultural development. According to the research of (Tran et al., 2021), the Vietnam Mekong Delta contributes half of Vietnamese agriculture production, mainly rice, annual crops, and aquaculture. The sediment and upstream water have declined in the last decade due to hydro dams and agricultural development in upstream countries.

The flood is welcomed by farmers, who benefit from it, but it is a central problem in surrounding urban (T.T.N. Huynh et al., 2019; Van et al., 2012). The flood caused the loss of properties; the research from (Chinh, Gain, et al., 2016) shows that the buildings were damaged during the flood in Can Tho City.

In the past ten years, researchers have focused on flood assessment, using several methods, from the qualitative to the quantitative. For the impacted building assessment, research using GIS assessment with the primary source of the building is from land use or derived from remote sensing interpretation (Giupponi et al., 2015; Messner Frank & Meyer, 2006; Meyer et al., 2009; Peduzzi et al., 2009; Wright et al., n.d.).

2.2. The flood impact on buildings

Land use data is the primary source of building data for flood risk assessment. In Vietnam, this type of data is the best source for this task, and it provides the type of build-up areas with location and area. The research from (Duong et al., 2019) uses land use data as the main source for estimating damage for objects in flood-prone areas, including some types of buildings such as residential, industrial, and offices.

Land use data is provided by the land administration office or by satellite image classification. The earlier has good building attribute information, but it is challenging to get the precise shape and area of the building. The land use may have been assigned to residents, but the structures may not cover the parcel (Javadian et al., 2011; Joerin et al., 1998; Xuan et al., 2008).

The latter is that until last year, the resolution was the main problem; the shape of the building was not easy to get from the images with traditional classification methods. The manual of semi-manual interpretation/building extraction may not be efficient, especially in complex cases (Mason et al., 2021; Tavus et al., 2018).

In the last few months, Google and Microsoft released free building footprint data (Google research, n.d.; Microsoft Bingmap, n.d.). The data is extracted using a deep learning process with enormous satellite images. In this research, the Google Open Building footprint is used.

3. Methodology

3.1. Study area

According to the General Statistics Office, Can Tho is the heart of the Vietnamese Mekong Delta, the largest city in the region, with an average population of about 1.28 million (Vietnam General Statistics Office, 2018). Can Tho City, located on the right side of the Hau River, has a large urban area in the Ninh Kieu and Binh Thuy districts. The elevation height of Can Tho ranges from 0.5 to 2.4 m. The hydrological network is high-density, with Hau River in the North, Can Tho River, and canals surrounding and crossing the city area.

Fig. 3. Example of building footprint data of Can Tho city

Rys. 3. Przykład śladów zabudowy miasta Can Tho

Tab. 1. Build-up land use

Tab. 1. Zagospodarowanie terenu

Landuse code	Land use name
CAN	Security
CQP	National defence
DBV	Post and telecomunication
DCH	Market
DGD	Education and training
DKH	Science and technology
DSH	Community use
DSK	Other production and business
DTT	Sport
DVH	Culture land
DXH	Social service
DYT	Health care
ODT	Urban residential
ONT	Rural Residential
SKC	Production and business
SKK	Industrial zone
TIN	Believes
TMD	Trade and services
TON	Religions
TSC	Government offices
TSK	Other government lands

Tab. 2. Flood level

Tab. 2. Poziom powodzi

Level	Water depth	Impact
Ankle (<0.1m)	Very low	Uncomfortable
Ankle to Knee(0.1-0.45m)	Low	Harmful to vehicles and low-floor-height buildings
Knee to Waist (0.45- 1m)	Moderate	It is harmful to children, vehicles, and most of buildings
Waist to Neck (1-1.5m)	High	The danger for children and elders and damage to buildings, infrastructure, agriculture,
Over the neck(> 1.5m)	Very high	Danger for all people, heavy damage to buildings, infrastructures, agriculture

3.2. Data

3.2.1. Buiding footprint data

The Building footprint data is in polygon format(ASCII) at https://sites.research.google/open-buildings/#download.

The study area is defined by regions in the data viewer. However, downloading this method's data is enormous, about 6.7GB. The extensive data volume causes difficulty in analysis. Google allows downloading by area, which is defined by the WKT polygon. The data downloaded by WKT polygons cover all study areas in this study. The downloaded data was converted and clipped with the study area boundary.

3.2.2. The Build-up area from land use data

The land use data are collected from the Can Tho Department of Environment and Nature Resources. The data are in Microstation.DGN file format as the National standard. The original data has been converted to GIS format with attributes of land use code and name. The built-up area has been extracted from land use data based on the land use type as the following table:

3.3. Flood data modeling

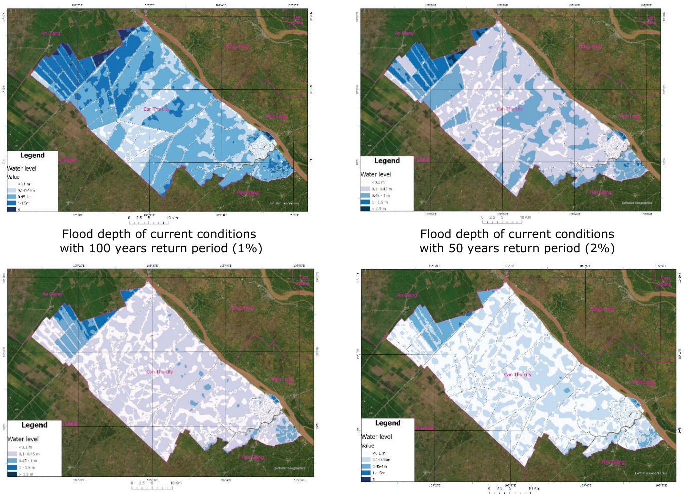
Flood data provided by hydraulic modeling. The flood model was built using DEM (5 m), land use data, a hydrological network, and a pipeline network. The input rain data was interpreted using the Can Tho area's statistical rainfall data. From the 20 years of rainfall of 4 stations surrounding Can Tho, the probability of rain of 10% or a 10-year return period was predicted by Historical Intensity-Duration-Frequency (IDF) curves. Based on input rainfall, the model provides the flood data in ASCII grid format with a resolution of 5m, containing each point's location and water depth in the entire area of Can Tho province.

The output of flood modeling is an ASCII grid with the water depth value. The data was imported and clipped with the study area boundary before the main process.

3.4. Urban flood assessment

The flood data is reclassed into five levels based on how the flood can affect the people and assets:

The reclassed flood data are overlayed with the Building footprints layer and Landuse build-up data, and the results are



Flood depth of current conditions with 100 years return period (1%)

Flood depth of current conditions with 50 years return period (2%)

Flood depth of current conditions with 20 years return period (5%)

Flood depth of current conditions with a five-year return period (20%)

Fig. 4. Flood data from hydraulic modeling
Rys. 4. Dane powodziowe z modelowania hydraulicznego

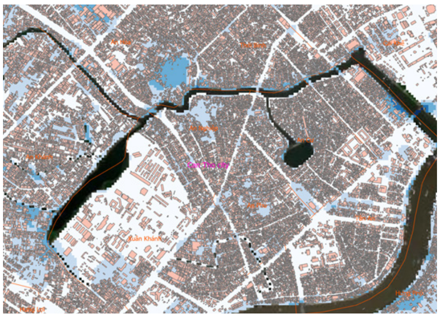


Fig. 5. Overlaying Flood data with Building footprint data
Rys. 5. Nałożenie danych o powodzi z aplikacji Building footprint

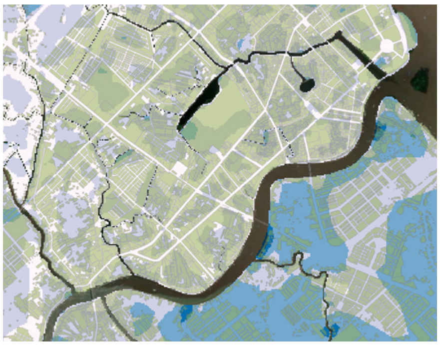


Fig. 6. Overlaying Flood data with Land use build-up data
Rys. 6. Nałożone dane o powodzi na dane o budynkach z Land use map

counted in GIS. Simple overlay operation and zonal statistics in GIS software gave the final result.

4. Result and discussion

4.1. Flood hazard

The flood has been modeled with the MIKE package. The flood model considers interactions between water sources and the terrain, the hydraulic network, and the city's drainage system. The city has just completed its Flood risk management system (FRMS), which protects the core urban area in the Ninh Kieu and Binh Thuy districts; the system is included in the modeling. In this research, the input water source condition determines the flood scenarios. The flood scenarios are defined by the condition of rainfall combined with the water level in Hau River and the surrounding hydrological network.

Flood data are in current condition with 100, 50, 20, and 5-year return scenarios in Figure 4. The results show that the flood extends and water levels are increased with harder conditions. In the 5-year return period scenario, the flood only occurred in the city's northwest and part of the Cai Rang district. Those places are relatively low elevation and have no protection construction.

The 20-year return period has similar results to the 5-year one. However, the flood area now has a higher water level. The city center of the Binh Thuy and

Tab. 3. The area affected by flood using Building footprint data
Tab. 3. Obszar dotknięty powodzią na podstawie danych dotyczących powierzchni budynku

Scenario	The area affected by the flood of each level (ha) using the Building footprint			
	100 years return period (1%)	50 years return period (2%)	20 years return period (5%)	50 years return period (20%)
Impacted areas (ha)	5071.52	4211.64	2980.47	1964.49
Percentage	78%	64%	46%	30%

Tab. 4. The area affected by flood using Landuse Build-up data
Tab. 4. Obszar dotknięty powodzią na podstawie danych dotyczących użytkowania gruntów (Landuse)

Scenario	The area affected by the flood at each level (ha) was calculated using the Landuse Build-up data			
	100 years return period (1%)	50 years return period (2%)	20 years return period 5%	50 years return period (20%)
Impacted areas (ha)	12826.03	10976.07	7923.09	5355.87
Percentage	80%	68%	49%	33%

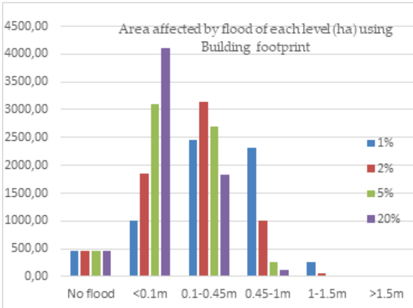


Fig. 7. Compare the flood-impacted area between scenarios using Building footprint data
Rys. 7. Porównanie obszarów dotkniętych powodzią między scenariuszami, w oparciu o dane dotyczących powierzchni budynku (Building footprint)

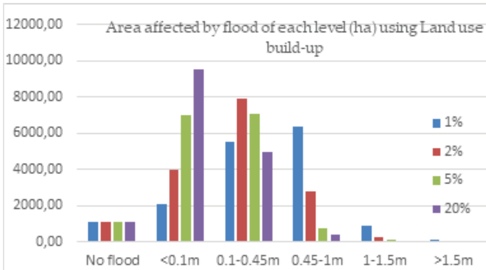


Fig. 8. Compare the flood-impacted area between scenarios using Land use build-up data
Rys. 8. Porównanie obszaru dotkniętego powodzią między scenariuszami, korzystając z danych o zagospodarowaniu terenu (Land use map)

Ninh Kieu districts is in low flood hazard. In the northwest, the flood is high, which can be dangerous for most people.

The 50-year return period brought the flood in most of the Cai Rang district, with some places having high water levels. It spread the flood in a large part of the city. In the core urban area, the FRMS shows its benefit when keeping the flood in urban areas low.

The highest scenario is bringing 100-year rainfall combined with abnormally high water levels in the hydrological network due to upstream flood and high tide together. In this case, most of the areas in Can Tho city are threatened by flood, and some parts of the urban area in Cai Rang district are in the danger zone for all people. In core urban areas, the flood protection system is still capable of avoiding high floods. In this scenario, large parts of the city are under high and very high water levels, especially in the west.

Flood and building footprint data are overlaid on a GIS and statistical environment. A similar process is repeated with Land use build-up data.

4.2. Flood impact

The flood impact on buildings, calculated using Building footprint, is about 6534 ha. Depending on the flood scenario, the area of buildings affected increases from 30% to 78% of the total building area.

The building area affected by each water level changes between scenarios, as shown in Fig. 7. The more challenging conditions give a larger area at high water levels.

A similar result is archived when using Landuse Build-up data. The result is slightly different from the result of Building footprint in relative percentages. The result is shown in Tab. 4 and Fig. 8.

The flood data, overlayed with building footprint data and building data from land use data, are calculated in GIS. The results are shown in the following table:

The results clearly stated that the area affected by floods using Building footprints is far lower than the area calculated from Land use data. The differences are based on the fact that the building footprint is based on actual buildings; meanwhile, the land use data naturally is the area of land utility, which includes all buildings with surrounding objects and facilities such as internal roads, open spaces, or green area within the land use parcels.

Tab. 5. The area affected by the flood

Tab. 5. Teren dotknięty powodzią

	The area affected by the flood of each level (ha) using the Building footprint				**The area affected by the flood at each level (ha) was calculated using land use data**			
Flood level	*100 years return period (1%)*	*50 years return period (2%)*	*20 years return period 5%*	*50 years return period (20%)*	*100 years return period (1%)*	*50 years return period (2%)*	*20 years return period 5%*	*50 years return period (20%)*
No flood	462.75	461.39	462.93	464.39	1133.16	1069.95	1133.81	1136.59
<0.1m	1000.19	1861.43	3091.06	4105.58	2081.10	3994.27	6983.40	9547.84
0.1-0.45m	2461.68	3135.92	2688.82	1833.86	5530.01	7869.75	7055.64	4945.59
0.45-1m	2320.62	1001.28	266.89	123.62	6327.45	2792.05	752.33	385.78
1-1.5m	264.07	67.39	24.60	7.01	870.39	286.14	114.84	24.39
>1.5m	25.15	7.05	0.16	0.00	98.18	28.14	0.28	0.11
Total	6534.47	6534.48	6534.51	6534.66	16040.31	16040.32	16040.35	16040.50

5. Conclusion

The building footprint data has a large volume with an accuracy of over 70% for the study area. Compared to the local data of residential and buildings, such as Land use data, the building footprint naturally has better accuracy with precise cover of the buildings.

The results of using building footprint and Landuse build-up data in flood impact assessments show that the area of the building affected by flood is largely different between the two datasets. The building footprint result is that about 6534 ha of the building area is affected by the flood, compared to 16040 ha, according to land use data.

Using the building footprints in flood impact analysis shows the high potential applications. The high-detail data from the building footprint helps the researchers and users calculate the impact of floods with better accuracy than land use data.

Ethical statement

The authors state that the research was conducted according to ethical standards.

Funding body

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Conflicts of interest

The authors declare no conflict of interest.

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Zastosowanie aplikacji Open Building Footprint dla oceny skutków powodzi, studium przypadku prowincji Can Tho

Powodzie, najczęstsza katastrofa w Wietnamie, powstają w wyniku zjawisk klimatycznych (takich jak burze i deszcze), zrzutów z basenów międzynarodowych oraz działań pływowych. Delta Mekongu jest szczególnie znana z połączenia tych trzech źródeł wody. W ostatnich latach znaczną część badań poświęcono modelowaniu powodzi i ocenie ryzyka, wykorzystując dane z satelitów i modelowanie hydrauliczne. Dane mieszkaniowe odgrywają kluczową rolę w ocenie ryzyka powodziowego, ale ich źródła są ograniczone. Niedawno firmy Google i Microsoft udostępniły publicznie dwa źródła danych o budynkach mieszkalnych. W artykule wykorzystano dane Google Open Building Footprint oraz dane budowlane pobrane z mapy Landuse w celu oceny wpływu powodzi na obszar zabudowany miasta Can Tho. Dane dotyczące powodzi, dostarczone za pomocą modelowania hydraulicznego MIKE, obejmują okresy powrotu wynoszące 100, 50, 20 i 5 lat (odpowiednio 1%, 2%, 5% i 20%). Bieżące dane dotyczące powodzi są klasyfikowane przy użyciu australijskiego systemu zagrożeń powodziowych, który składa się z pięciu poziomów zagrożenia, od ostrożności do zagrożenia dla wszystkich. Na dwa zbiory danych budynków nałożono dane dotyczące powodzi w środowisku GIS przy użyciu operacji GIS. Do określenia wpływu powodzi na budynki zastosowano funkcję geostatystyczną. Wyniki wskazują, że obszar dotknięty powodzią jest mniejszy w przypadku danych Google Open Building niż w przypadku danych Landuse. Podstawowa różnica polega na tym, że Google Open Building Footprint utworzono przy użyciu zdjęć satelitarnych i skupiono się na śladach budynków, podczas gdy dane Landuse reprezentują rodzaj zagospodarowania terenu przypisany do działki, który może być znacznie większy niż ślad budynku. Podsumowując, Open Building Footprint wykazuje duży potencjał do wykorzystania w ocenie skutków powodzi.

Słowa kluczowe: *budynek otwarty, powierzchnia budynku, ocena powodzi, skutki powodzi, delta Mekongu*