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Assessment of Flood Hazard in Hanoi City

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Abstract: This paper presents the results of studying flood hazard and vulnerability caused by flood and flood hazard in Hanoi City. By analyzing satellite images, using GIS and geomorphological features, the authors had assessed the actual state of historical flood happening at the end of 2008. The results show that most of Hanoi's flat areas are 0-4m submersible in water. Effective level of inundation increases gradually from two sides into the centre and from the north to the south, consistent with obliquity and terrain characteristics of Hanoi City. Some areas in the west, southwest and south of the city (in districts: Chương Mỹ, Mỹ Đức, Ứng Hòa, Thường Tín, Phú Xuyên) are severely affected by flood with deeply inundated areas; inundation level is at danger level of about 2-4m. The districts in the south of Hanoi have the most vulnerable areas, such as the low lands: Mỹ Đức, Ứng Hòa, Thường Tín, Chương Mỹ, Thanh Oai districts. Chương Mỹ District has 117ha at very high-risk level; Ứng Hòa District has 87 ha. In the inner city, Hà Đông, Hai Bà Trưng and Tây Hồ districts have the highest hazard level. The suburban districts in the south of Hanoi haven the largest agricultural and rural residential land, which are often in deep and prolonged inundation, so the flood risk here is also at high level.

Keywords: Flood, inundation, flood risk hazard, Hanoi City.

1. Introduction

Flood is one of dangerous natural hazard types, causing many damages and severe consequences for society, especially for developing areas. To Hanoi - the biggest centre of economic-culture-society in the whole country - flood and accompanied inundation had already become a serious problem in every rainy season, but it has had too few thorough researches on flood in Hanoi so far, especially in the new (expanded) Hanoi. Meanwhile, the complicated changes of weather and the massive, over control expansion of urban areas are contributing in making Hanoi suffer more severe consequences of this kind of hazard. The giving solutions for preventing and mitigating damages have been very passive, ineffective, and even deadlocking.

Facing that fact, we focused on analysing, assessing and building a general picture of the areas which bear flood hazard risk at different levels in the plain of Hanoi City, then establish all the locations of deep flooding which can arise hazards to destroy and alter the terrain. Based on the warning of the occurrence of extreme

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weather patterns flooding hazard combined with researches on the status of land use planning, we conduct to analyse flood hazard risk in Hanoi City that is used for proposing solutions to minimize damage caused by floods.

2. Data and methodology

2.1. Data

The data used for assessing flood hazard risk in Hanoi City include: series of 7-band-Landsat images, 30m resolution, taken in 1989, 1994, 1996, 1999, 2000, 2005, 2007, and 2009 years, georeferenced in WGS-84 spatial reference system, are used for establishing the lowlands of Hanoi and former rivers; data of elevation of Hanoi terrain extracted from 1:10.000 scale map, adding detailed data of elevation points in Hanoi urban area from 1:5.000 scale map, Aster image data (10m resolution, taken on 16/11/2001 and 13/01/2003); SPOT image taken on 7/11/2008 of flooding actual state in 2008 in Hanoi City; Land use planning map established in 2010 year at scale 1:10.000 is used for analysing and assessing flood hazard risk; Besides, we also used associated map, including administrative maps established in 1980, 1991, and 2008, geological map, geomorphological map, dyke system, population distribution of new Hanoi City.

2.2. Methodology

Process for modelling Hanoi flooding map is carried out systematically as shown in Fig. 1.

Determining inundated areas

In this study, SPOT image taken on 7/11/2008 in Hanoi area is used for establishing actual state of flooded space in Hanoi City when historical flooding phenomenon occurred in the end of 2008.

By analysing and comparing satellite images of various periods, we extracted information layers of frequent flooded areas (from image taken in non-flooding time) and flooded area in floods (from image taken in 2008). To classify water regions, we establish some water samples (combined visual interpretation with conservation in field survey) and use digital image classification method, which is carried out by ILWIS software.

Determining depth of inundation

Flooding level in Hanoi City is determined by flooding trace investigation, inundation space map that is extracted from satellite image taken in 2008 and digital elevation model (DEM) of Hanoi terrain.

Using topographic map (scale 1:10.000, VN 2000 national coordinate system), we created a DEM of the study area terrain with spatial resolution of 30x30m, and accuracy of elevation spots of 0.1 m.

Aiming to warn flooding in the case of extreme weather events, we choose the time when the floods on 11/2008 occurred to calculate. Flooding of Hanoi in 2008 was caused by intense rainfall. It prolonged over the capacity of drainage network. With such characteristics, the flood water levels had insignificant difference, especially the time when the image was taken almost coincided with the highest-level rise. Land was no longer osmotic; the speed of drainage was much smaller than the one of water supply. Because it is typical urban area with many artificial terrains such as residential buildings, roads,... so there is not totally connected between inundated spaces, some of them are just partial flooded. However, water levels in each inundated location are relatively equal.

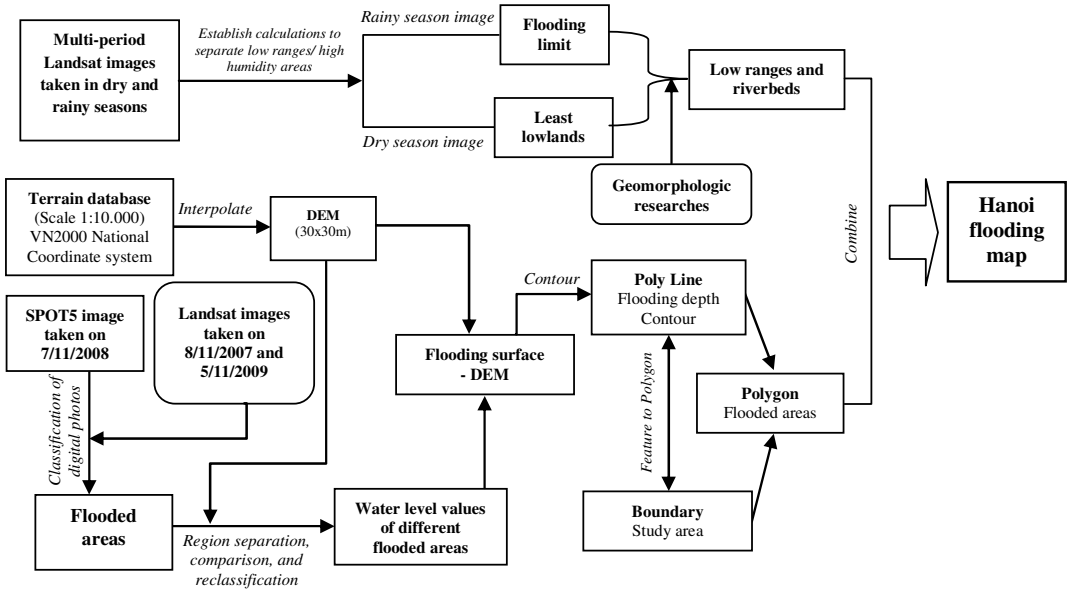

Fig. 1. Diagram of Hanoi flooding map-modelling process.

To calculate height of inundation level in each location exactly, we compared the boundary of flooded areas with DEM. Inundation level of a whole area is the value of height of inundation level in the boundary.

Inundation depth is calculated by subtraction of two raster layers: topography (DEM) and elevation of flooding level. The result is a raster in which positive pixel values mean flooded areas and negative pixel values mean un-flooded areas. Flooded areas are then classified in value ranges of inundation level and displayed by colour scale from dark to light tones corresponding to each value range from high to low on the flooding map.

Determining low ranges and former rivers

To separate low ranges and ancient riverbeds, we use remote sensing image processing combined with geomorphologic studies [1]. Besides, we also use multi-period remote sensing images taken in rainy and dry seasons to determine low ranges and former rivers automatically (they can be missed if only analysing at specific time). Based on the variation of sunken terrains' critical flooding in many different rainy seasons, we can establish the boundaries of low ranges / former rivers, where inundation depths are greater than contiguous areas (it cannot be determined if only using DEM).

The low ranges and riverbeds may be at risk of deep flooding and capable to become axial forces of flooding flows in dyke broken situation. It is necessary to use this layer and the one containing flooding information to build flooding map of Hanoi.

Assessing flood hazard risk

Method of risk assessment is based on three basic concepts including: *1)* Vulnerable possibility caused by flood is potential loss of responsive ability of residential community and environment when they are placed before threat of flood hazard. Vulnerable possibility is often considered correlatively to factors suffered risk. They are understood to be all the objects in the

study area, including the direct objects of flooding such as people, houses, transport and communication systems,... or the indirect such as loss of economy and society; *2)* Flood danger level is appearance probability of one flood that can cause bad damage to an area in a period of time. In quantitative calculations, flood danger risk is usually showed by values of inundation depth, flood velocity, inundation duration,... In this study, the specific hazard type given to assess is inundation using the scenario of historical flood happening in the end of 2008; and *3)* Flood risk level, flood danger level, and vulnerable possibility caused by flood are related to each other by the following expression [2]:

$$\mathbf{R} = \sum_{i}^{n} H_i \mathbf{V}_i$$

In the expression above: H is flood risk level, V is vulnerable possibility, indicating measure of component factor loss, the index i indicates factor suffered risk.

The process of flood risk assessment contains three main contents as shown in Fig. 2.

In this study, vulnerable possibility is determined through actual state of land use, which is classified into groups of land use types with different vulnerable possibility when they are suffered impacts of inundation hazard. These results are used as input data for calculating risk level. The flood risk level (H) is established through inundation map of Hanoi City, classified by depth-area.

3. Results and discussion

3.1. Types of flood in Hanoi delta

The cause of flood and inundation contains two conditions, the necessary condition is intense rainfall, and the sufficient one is elevation and slope of terrain. The Red River delta in general or Hanoi in particular has low terrain. Its average elevation from mean sea level is about 3-5m. There are some places that are much lower, about 1.5-2m, such as in several hamlets, villages belonging to My Duc, Chuong My, Ung Hoa, Phu Xuyen or Thanh Tri districts. Therefore, flood and inundation is a natural phenomenon frequently happening here and it has repeatedly caused severe damages to both human and property. Based on the main causes of flood and inundation, the National Centre for Hydro - Meteorological Forecasting divides them into 4 types: 1) Flooding is due to heavy rainfall inland; 2) Flooding is due to heavy rainfall inland associated with river flood; 3) Large river flood overflows, causes broken local dykes combined with heavy rainfall inland and storm surge; 4) Large flood causes broken dykes and flooding widespread.

Through the actual state of some large floods and inundations [3], we can notice that all the past floods and inundations caused many serious losses of lives and property. However, since 1986, when Hoa Binh hydroelectric dam was built on Da River, this phenomenon has been mitigated and it might no longer happen after Son La hydroelectric dam going into operation. The most concern to Hanoi nowadays is the first cause of flood types (due to heavy rainfall inland), such as recent typical flooding on November 2008. This flooding was caused by unusually heavy and prolonged rainfall event. By the time of the afternoon on November 1st, 2008, the total rainfall in Hanoi area ranged from 350 to 550mm. In other locations, the value of rainfall is much higher, for examples in Ung Hoa District (603mm), Ha Dong District (707mm), Thanh Oai District (914mm).

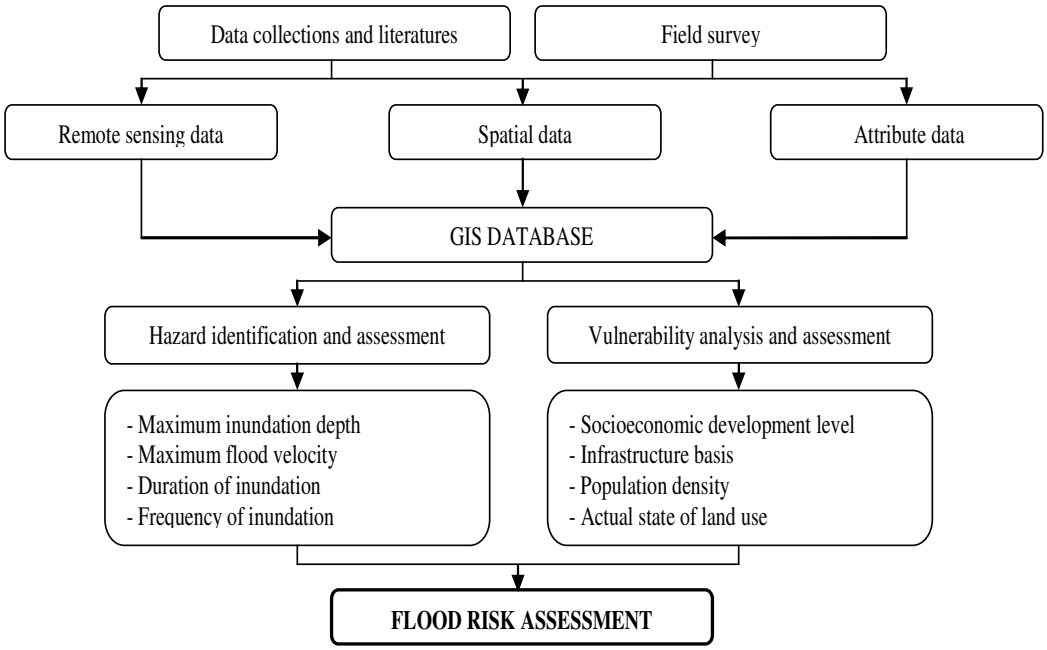

Fig. 2. Process of flood risk assessment [2].

According to observed data series during the rain, the rainfall in the first two days was considered as a record. In former Hanoi area, it has been the biggest rainfall since the historical rain on November 1984. In former Ha Tay Province, this is the heavy rainfall, which has never occurred since meteorological observation started its operation (for approximately 100 years).

About the cause of this flooding, besides heavy rainfall, it was because of the trespass to natural drainage lines that becomes more and more serious under the effects of urban network and residential construction development due to rapid urbanization. This is a big and serious reason for inundation to Hanoi. In the context of global climate change with the trend of increasing extreme weather phenomena, the heavy rainfalls as in 2008 year may occur at any time. This is the reason why we use this flood's actual state in our study to assess flood hazard and flood hazard risk for Hanoi City.

3.2. Space affected by the flooding in 2008 and flooding surface elevation

Based on digital image classification method combined with multi-period satellite images, flooding space and elevation of different areas in Hanoi in the flooding on November 2008 are extracted and calculated. In this case, we used SPOT5 image capturing Hanoi area (taken on 7/11/2008) and detail DEM (Fig. 3). Although on the day when the image was taken, the highest water level was no longer existed, it still reflects the severity of the flooding in Hanoi at that time.

The calculated results show that most of Hanoi delta's area is inundated and the flooding surface elevations in different areas are not the same because of being divided by artificial terrains. The elevation of flooding surface ranges from 5.5-7m, the highest elevation is in the sunken areas of Chuong My and My Duc districts.

3.3. Assessing inundation in Hanoi City

The information layer about inundation depth in Hanoi (Fig. 4), which is shown in the previous section about methodology, is the result of combination between flooding level layer and detail DEM.

This map shows the inside and outside areas affected by inundation at different levels with interval of 0.5m; low ranges and former rivers in deep inundation that potentially appear axial forces of flooding flows if dykes are broken or flood overflows dykes.

The system of former rivers in Hanoi delta is flows that are linked together to drain off the water of Red River system in the past. Due to lack of understanding and immediate interest, the former rivers have been filled recently for many purposes, even for building residential buildings crossing them, leading to deep inundation and locally high in these regions.

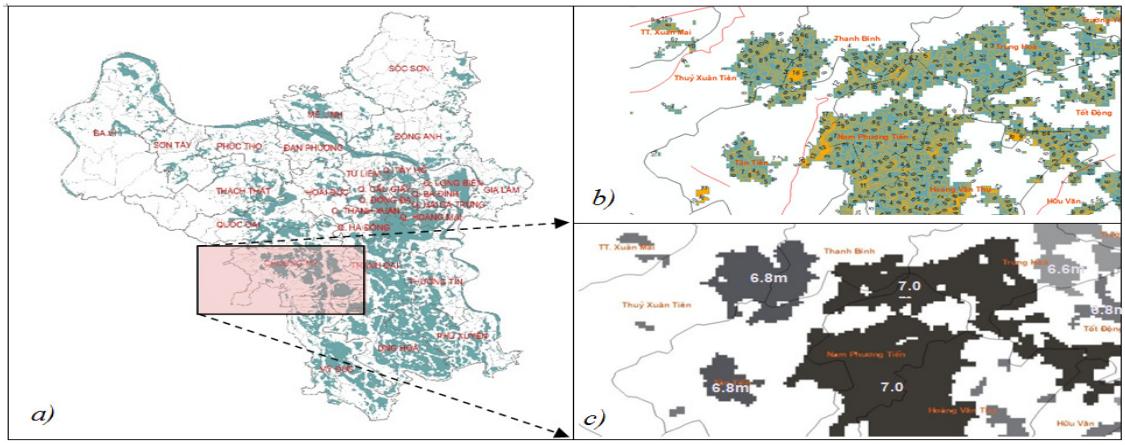

Fig. 3. a) Diagram of the flooding in 2008 interpreted from SPOT image (taken on 7/11/2008); b) Flooding area integrated with DEM to establish flooding surface elevation in different area; c) Diagram of calculated flooding surface elevation.

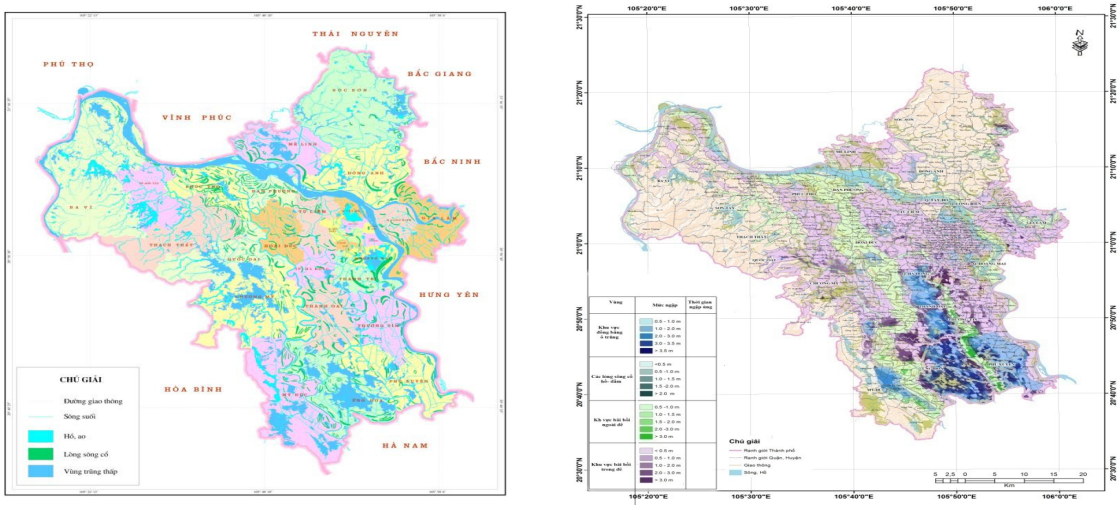

Fig. 4. Diagram of low ranges and former rivers (in the left) and inundation map in Hanoi City on date 7/11/2008 (in the right).

To verify the calculated results, the inundation depths on map are compared with actual measured data of flooding levels [4]. The results show that there are four non-inundation locations on the map based on calculation but their actual inundation levels based on field survey range from 0.2 to 0.3m. This is consistent with the reality, because at the time when the image was taken, flooding level drained off and lower. Based on real measured data, we notice that if the inundation level in fact is about 0.2-0.3m, it cannot be seen as a flooding area on the map. Thus, we can temporarily conclude that the inundation level by the time 7/11/2008 is much lower than its peak, around 0.2-0.3m. However, when the real inundation level subtracts this figure, the corresponding values on inundation map with intervals of 0.5m are completely accurate *(Table 1)*.

Statistics of inundated area in accordance with boundary of districts/towns show that inundated area increases from districts/towns in the north to districts/towns in the south, and from districts/towns in the east to districts/towns in the west (Fig. 5). This is completely consistent with obliquity of Hanoi delta's terrain - gradually lower from the north to the south and from the east to the west.

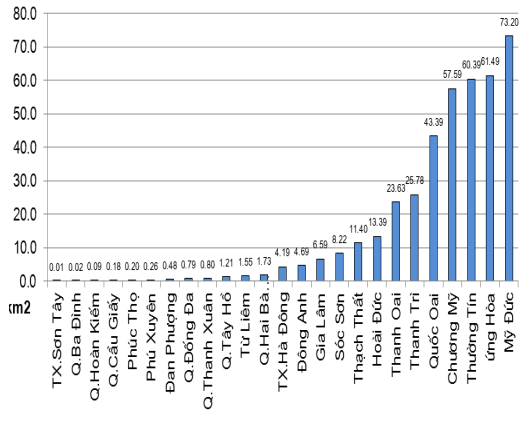

Fig. 5. Inundated area in Hanoi city (calculated in accordance with administrative boundary of districts/towns).

Inundated area increases in the central area of Hanoi (Fig. 6). This place has high popularity density. Inhabitant lives on the high ridge along riverbed, which is 6-7m in height and central alluvia 4-4.5m high. However, it is because of the concretizing process for many purposes, such as building houses, condominiums, ways,... many areas of ponds, lakes, canals, drainage ditches are significantly narrowed. This reduces permeability and drainage possibility here, so this area easily gets inundation.

On the other hand, many systems of infrastructural basis cross flow direction, such as system of roads, residential areas,... It reduces drainage possibility; besides, water cannot totally recede in heavy rainfall conditions because of the lack of drainage system in the central area that causes temporary inundation on streets with common inundation depth at 0.5m. Inundation area and depth is especially high in the southwest of Hanoi, such as in My Duc, Chuong My districts,... with 4300-7300ha inundated, 2-4m deep. Low terrain is also the main cause that makes the south of Hanoi to become "a sea" in heavy and prolonged rainfalls.

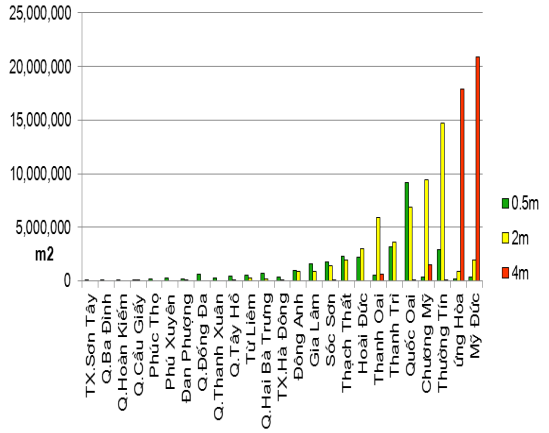

Fig. 6. Inundated area in Hanoi City (calculated in accordance with inundation levels 0.5m, 2m, and 4m).

3.4. Assessing flood hazard risk in Hanoi City

a. Assessing vulnerable possibility

A map of Vulnerable possibility areas is built based on thematic information layers about natural, socio-economic actual state on GIS background data. There are two main information groups used to build vulnerable possibility caused by flood in Hanoi: *1)* Information about inundation hazard - the factors cause vulnerability - including inundation depth and flood force, which are taken from Hanoi inundation map; and *2)* Information about factors suffer vulnerability, such as population density, infrastructural basis, types of natural resource, which show damage level about lives and properties caused by hazard. This kind of information is taken from Hanoi land use map in 2010.

In this map, there are 77 different types of land use, which are classified into six groups at different vulnerable possibilities to flood hazard: urban residential land, rural residential land, public land, agricultural land, forest land, and unused land.

Vulnerable possibility caused by flood is different to each of land use groups. Public land use group, such as schools, hospitals, administrative areas, and roads... is the most easily vulnerable group because it has large area and there are many valuable devices and machines. On the other hand, this is the place where it has little standing response if flood occurs. That is why vulnerable possibility of this group is highest. The other land use groups with different response possibilities and damage levels are divided into different vulnerable possibilities. If traffic roads, where inhabitants gather crowded around, are inundated, inhabitants will be isolated, leading to increase flooding vulnerability significantly. Groups of urban residential land and rural residential land are less vulnerable than public land group but their vulnerable possibilities are still high or medium because residential houses are the place containing people's property, such as food, cattle, and other civil accessories. When flood occurs, urban houses are damaged much more than rural houses because they have more property. Endurance of rice and vegetables to flooding are lower than other industrial plants, so vulnerable possibility of rice and vegetable fields are higher than industrial plants'. Unused land or rivers are least vulnerable areas to flooding.

To each group of land use types, we analyse percentage of area affected by flood and divide them into five levels: very low, low, medium, high, and very high *(Table 2).*

In reality, vulnerable possibilities of different land use groups are not identical. Public land group is most easily vulnerable under the impact of inundation, others corresponding to different possibilities are presented in *Table 4*. Differences among these groups are quantified by the weight values, which are calculated by Analytical Hierarchy Process (AHP) *(Table 3).*

The weight values of each land use groups will be multiplied by the weight values established through inundated percentage of each subjects in that land use group (*Table 4*). Vulnerability map is the synthesis of calculated results for six land use groups and it is divided into five levels: "Very high", "High", "Medium", "Low", and "Very low" (Fig. 7).

b. Assessing flood risk in Hanoi City

Hanoi flood risk is assessed based on the results of inundation hazard assessment (Fig. 5) and inundation vulnerable possibility assessment (Fig. 7) in the city using the scenario of the flooding in the end of 2008, which is equivalent to 1% flood frequency. Hanoi flood risk level is assessed based on the inundated depth area of different land use groups. The correlation between inundation hazard and vulnerable possibility is presented in Table 4. The map of Hanoi flood risk assessment is displayed in Fig. 8. The statistics of the area of all Hanoi flood risk levels is shown in Table 5.

Table 1. Comparison between inundation levels based on map and field survey at some locations

Point	Field coordinates	Inundation level (m) based on map	Inundation level (m) based on field survey	Actual inundation level by the time taking image (in case inundation level lower 0.2-0.3m)
1	20°59'27,2''N; 105°47'47,2''E	(0-0.5)	0.5	0.2-0.3
2	20°59'25,4''N; 105°48'03,3''E	(0-0.5)	0.6	0.3-0.4
3	20°59'49,2''N; 105°48'37''E	Non - inundation	Non - inundation	Non - inundation
4	21°01'10,1''N; 105°49'49,3''E	Non - inundation	Non - inundation	Non - inundation
5	21°01'39,7''N; 105°50'03,8''E	(0-0.5)	0.5	0.2-0.3
6	21°01'44,1''N; 105°49'51''E	Non - inundation	Non - inundation	Non - inundation
7	21°01'44,4''N; 105°49'46,4''E	(0-0.5)	0.5	0.2-0.3
8	21°01'41,9''N; 105°49'57,7''E	(0.5-1)	1	0.7-0.8
9	21°02'16.5''N; 105°49'47.5''E	Non - inundation	0.3	Non - inundation
10	21°02'14.3''N; 105°49'45.2''E	(0.5-1)	1	0.7-0.8
11	21°02'33.4''N; 105°49'57.5''E	(0-0.5)	0.6	0.3-0.4
12	21°01'49.3''N; 105°48'43.9''E	(0-0.5)	0.5	0.2-0.3
13	21°01'53.6''N; 105°48'42.3''E	Non - inundation	0.2	Non - inundation
14	21°02'01.4''N; 105°48'49.7''E	0-0.5	0.4	0.1-0.2
15	21°01'46.7''N; 105°49'02.4''E	Non - inundation	0.3	Non - inundation
16	20°57'28.9''N; 105°47'57.8''E	0.5-1	1	0.7-0.8
17	20°57'47.6''N; 105°47'48.2''E	(0-0.5)	0.7	0.4-0.5
18	20°57'35.3''N; 105°47'28.4''E	Non - inundation	Non - inundation	Non - inundation
19	20°59'12.3''N; 105°48'48.2''E	Non - inundation	0.3	Non - inundation
20	20°57'28.9''N; 105°47'53.8''E	(0-0.5)	0.6	0.3-0.4

Table 2. Vulnerable possibility caused by flood of land use groups in Hanoi City

Land use groups		Unused land and river	Forest land and industrial plant	Agri-cultural land	Rural residential land	Urban residen-tial land	Public land	Total
Vulnerable possibility	Inundated area	Inundated area (ha)						
Very low	0-20%	934.264	134.676	16,842.447	1,273.964	416.036	1,894.158	21,495.545
Low	20-40%	324.048	40.059	7,874.868	266.616	42.606	374.607	8,922.804
Medium	40-60%	84.210	0.000	6,150.308	166.548	91.574	49.382	6,542.021
High	60-80%	0.000	52.280	934.513	135.573	0.000	84.429	1,206.795
Very high	80-100%	54.999	77.722	1,831.534	69.832	100.364	116.597	2,251.049
Total vulnerable area (ha)		*1,397.522*	*304.736*	*33,633.670*	*1,912.533*	*650.580*	*2,519.173*	40,418.214
% Total vulnerable area		*3.458*	*0.754*	*83.214*	*4.732*	*1.610*	*6.233*	100
Weight		0.0242	0.0385	0.0805	0.1322	0.2766	0.4479	

Table 3. Matrix determining vulnerable possibility weight of land use groups

Land use groups	Unused land and river	Forest land and industrial plant	Agricultural land	Rural residential land	Urban residential land	Public land	Weight
	(a)	(b)	(c)	(d)	(e)	(f)	
(a)	1	3	5	6	8	9	0.0242
(b)	1/3	1	4	5	7	8	0.0385
(c)	1/5	1/4	1	3	5	6	0.0805
(d)	1/6	1/5	1/3	1	4	5	0.1322
(e)	1/8	1/7	1/5	1/4	1	3	0.2766
(f)	1/9	1/8	1/6	1/5	1/3	1	0.4479

Table 4. Matrix assessing the risk caused by impact of flood

Risk level of hazard	Vulnerable possibility				
	Very low	*Low*	*Medium*	*High*	*Very high*
Very low	Very low	Very low	Low	Low	Low
Low	Very low	Low	Medium	Medium	Medium
Medium	Low	Medium	Medium	High	High
High	Low	Medium	High	High	Very high
Very high	Low	Medium	High	Very high	Very high

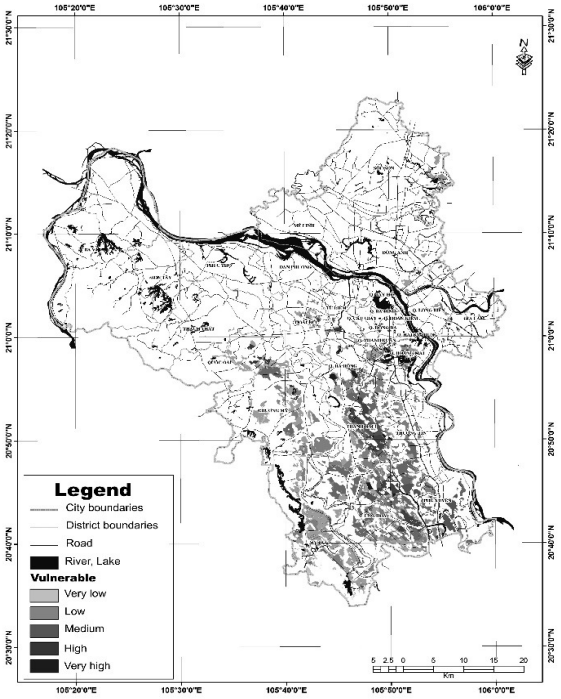

Fig. 7. Hanoi flood vulnerable possibility map.

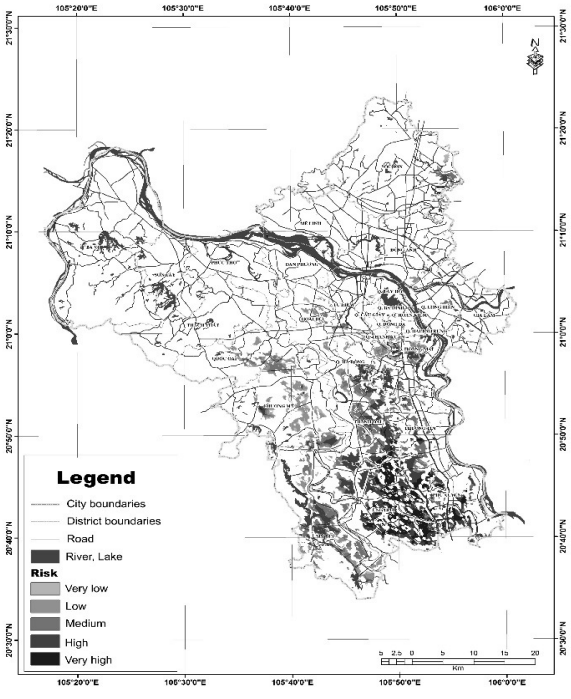

Fig. 8. Hanoi flood risk map.

Table 5. Total area of risk levels under the impact of inundation

Risk level	Area (ha)	Percentage (%)
Very low	12350.70	30.6
Low	6016.32	14.9
Medium	11384.10	28.2
High	7685.91	19.0
Very high	2981.18	7.4
Total	40418.21	100.0

The evaluated results show that the regions having the most vulnerable area belong to the districts in the south of Hanoi, such as the low lands of Mỹ Đức, Ứng Hòa, Thường Tín, Chương Mỹ, Thanh Oai districts,... The Chương Mỹ District has 117ha at "very high" risk level and Ứng Hòa District has 87ha. In the city downtown, the districts featuring highest hazard risk level are Hà Đông, Hai Bà Trưng, and Tây Hồ. The sub-urban districts in the south of Hanoi contain a large amount of agricultural land and rural residential land area, which are usually in deep and prolonged inundation on the large surface so the flood risk of these areas are also at high level.

4. Conclusions

The result of Hanoi flood studying based on analysing actual state of the flood in the end of 2008 - equivalent with 1% flood frequency - shows that:

- Hanoi is flooded mainly due to heavy rainfall with high intensity, exceeding permeability and drainage possibility;

- The flooding actual state in 2008 shows that: most of Hanoi's plain area is inundated at 0-4m deep. The effective level of inundation increases from both two sides into the centre and from the north to the south, consistent with obliquity and terrain characteristic of the city. Some areas in the west, southwest and south (in Chương Mỹ, Mỹ Đức, Ứng Hòa, Thường Tín, and Phú Xuyên districts) suffer severe effects of floods with deep inundated area; the inundation level is at danger, about 2-4m.

- The low lands and former rivers are established based on applying geomorphology studies and remote sensing materials. All these areas are in deep inundation in the case of flooding and are able to form axial forces of flows, which can destroy terrain when Hanoi begins to stand the impacts of flood from the rivers;

- Although the flood risk assessment result of our project has not reached the high level of details, its semi-quantitative results have practical significance in orientation of Hanoi planning and development.

- The system of former rivers in Hanoi delta is flows that are linked together to drain off the water of Red River system in the past, so they need to be utilized and widened to become the drainage routes for the city. All constructions occupying on the former rivers are prohibited and the major drainage systems of the old buildings crossing through these former rivers need to be built. The functions of Day River and Nhue River are drainage systems for Hanoi in the past, so it is necessary to restore their functions by many solutions, such as restoring the entrances of these rivers at the acute angle positions to Red River, setting the rivers straight at the secondary meanders to increase the drainage speed in the rainy seasons...

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References

[1] Nguyễn Hiệu, Đặng Văn Bào, Đặng Kinh Bắc, Application of Remote sensing - GIS combining geomorphological signs for surveying the former rivers in the West of Hanoi city, Proceedings of National Workshop on Application of GIS in 2011, Agricultural Publishing House, 2011 (in Vietnamese).

[2] Tomoharu Hori, Ji-quan Zhang, Hirokazu Tatano, Norio Okada, and Shuichi Iikebuchi, Micro-zonation-based Flood Risk Assessment in Urbanized Floodplain, Proceedings of The Second Annual IIASA-DPRI Meeting "Integrated Disaster Risk Management: Megacity Vulnerability and Resilience", IIASA, A-2361 Laxenburg, Austria, 2002.

[3] Vũ Văn Phái (editor), Trần Nghi, Ngo Quang Toan, Đặng Văn Bào, Nguyễn Cao Huần, Pham Van Cu, Tran Thanh Lam, Tran Thanh Ha, Hoang Thi Van, Part 1: Geology, geomorphology, physical geography, landscape geography, administrative geography, economic geography, infrastructure, residents, traffic and urban planning. In the "Thang Long Thousand years of Culture Collection", Volume 1, "Culture-Communication and Vietnamese Economic Times" Hanoi Publishing House, 2007 (in Vietnamese).

[4] Nguyễn Tiền Giang and et al., Collecting, analysing existing documents about flood of Hanoi, Report of project "Strengthen the capacity for mitigation and adaptation to geo-hazards related to environment and energy development in Vietnam" (SRV-07/056) (in Vietnamese).