RISK ASSESSMENT OF URBANIZATION PLAN IN MA RIVER BASIN, THANH HOA PROVINCE

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ABSTRACT

Thanh Hoa province is one of the regions suffering severely from flood in Vietnam. In addition, Thanh Hoa is well-known for being populous, ranking 3rd in Vietnam in terms of population. An urbanization master plan based on Decision No. 3023 dated 10/24/2006[1] has been implemented by 2020 in Thanh Hoa. In this context, this study assesses how flood risk increases according to urbanization, by analyzing the change of inundated areas and affected population according to land use change. Districts and urban centers in Thanh Hoa province with high flood risk were prioritized for conducting necessary countermeasures. The results indicates that downstream areas will suffer more from flood risk as urbanization expands, and also reveals that flood risk may differ due to different years of return period. Finally, how to control urban development in the future was proposed, in order to develop a new and comprehensive approach for planning and policy making in the future.

Keywords: Urbanization, Land use, Inundation Analysis, Affected Population, Flood Risk.

INTRODUCTION

Urbanization is an integral part of economic development. Urbanization contributes to accelerating economic growth, economic restructure and labor structure, and change of population distribution. Urban centers are not only places for new jobs, but also places for consumption of large and diverse goods. As a developing country, Vietnam is witnessing a rapid economic development, and urbanization plays a key role in this growth. However, Vietnam is also well-known for being prone to disasters, especially flood disaster, and urbanization is infamous for increasing disaster risk without a rational plan.

Similar to some other regions in Vietnam, Thanh Hoa province (TH province) has been suffering from severe flood every year. In 2007, inhabitants in TH province experienced a historical flood, with maximum discharge within 45 years recorded in Ma river. With approximately 7,000m3/s of discharge and 2,215cm of water lever, 2007 flood event was recorded as the highest peak since 1980. This study assesses how flood risk increases according to urbanization, by discussing the case of Thanh Hoa province (TH province). TH province is usually mentioned along with Ma river basin, since one third of Ma river basin area lies in TH province. Thus, inhabitants living in TH province are both benefiting and being negatively affected by Ma river.

STUDY AREA

Ma river basin

Ma river is a transboundary river, ranking 4th in Vietnam in terms of length (512km in total, with 410km running through Vietnam and 102km lying in Laos' territory), after Red river, Mekong river and Dong Nai river. The total area of Ma river basin is 28,490km^2, located in Laos and Vietnam. The total area of Ma basin in Vietnam is 17.690km^2 accounting for 62%, and 10.800km^2 in Laos accounting for 38%. The basin covers 5 provinces of Nghe An, Thanh Hoa, Hoa Binh, Son La and Dien Bien[2]. As shown in Figure 1, one third of Ma river basin, which are midland and downstream areas, lies in TH province, causing major damages for people in TH province.

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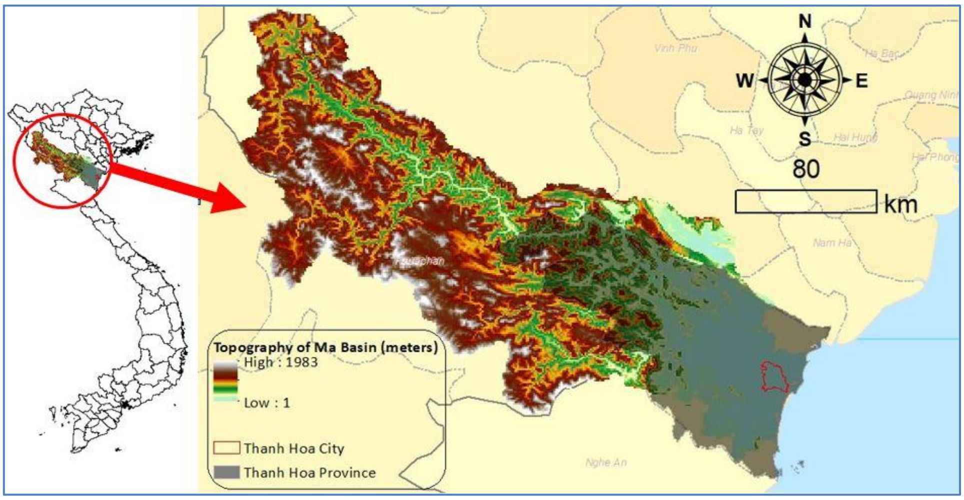


Figure 1: Ma river basin, TH province and TH city

27 districts in TH province

TH is a province in the North Central Coast region of Vietnam. With the population of 3,514,173 in 2015, ranking 3rd in Vietnam (after only Ho Chi Minh city and Hanoi city. Total area of TH province is 11,133.4 km² (5th in Vietnam). TH province is subdivided into 27 district-level sub-divisions, with 24 districts, 2 district-level towns, and one provincial city, named Thanh Hoa city (TH city). These 27 districts are further subdivided into 28 commune-level towns (or townlets), 579 communes, and 30 wards.

Urbanization master plan with 76 urban centers

In order to meet the need of economic development, Thanh Hoa Provincial People's Committee has approved Decision No. 3023 dated 10/24/2006 regarding to a master plan for urbanization in TH province by 2020.

According to data from 2006, there were 33 urban centers in TH province, including: one provincial city, 2 communes and 30 municipalities. According to urbanization master plan, the number of urban centers is expected to reach 76 by 2020, increasing about 35-40 centers compared to 2005. These 76 centers are classified into 5 different administrative ranks based on their importance for the economy of TH province.

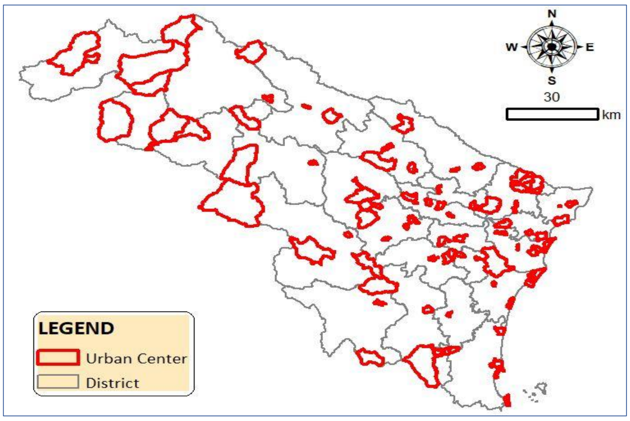


Figure 2: Distribution of 76 urban centers and 27 districts

METHODOLOGY

Figure 3 illustrates three main parts in this study's methodology: analysis of land use change, inundation analysis with different land use and analysis of affected population by inundation with different land use. Land use data for 2007 and 2015 is processed using GIS tool, in order to analyze change of land use in different years. Secondly, same ground rainfall and ground discharge are used with different land use (2007 and 2015) to run Rainfall – Runoff – Inundation (RRI) model[3]. Combined with frequency analysis, map of inundation depth for rainfall with return period are developed. Then, with analysis of land use change which was just obtained in the previous step, inundation change between 2007 and 2015 is analyzed. Thirdly, by using population census data, affected population by inundation with different land use was analyzed. Noted that all population are assumed to live in urban areas. Finally, potential risk of existing urbanization was assessed by combining existing urbanization plan with the previous analysis in order to control urban development in the future was proposed.

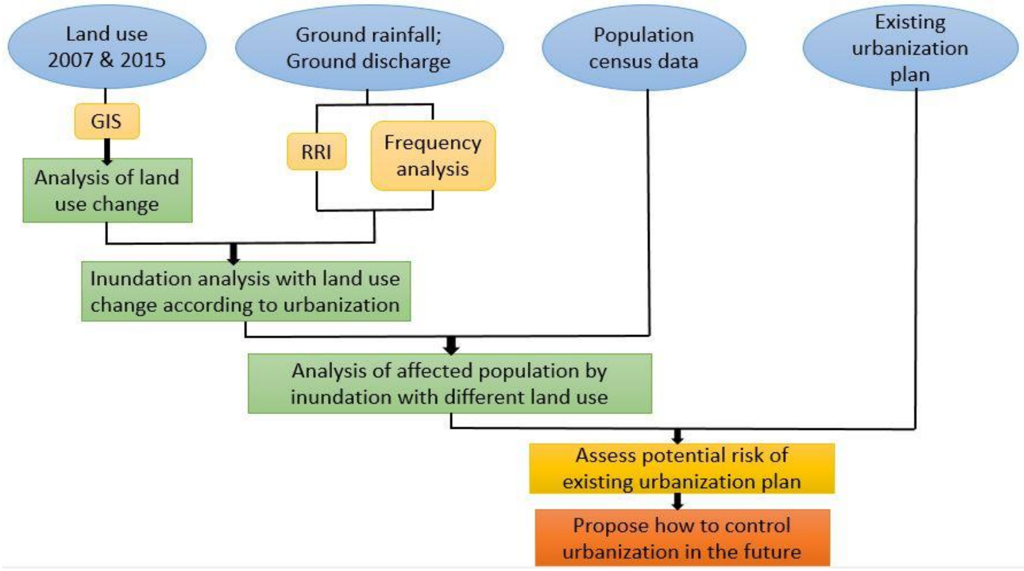


Figure 3: Methodology flow

DATA

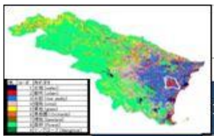
For analysis of land use change, JAXA land use maps for Northern region of Vietnam[4] (2007 and 2015) were used. For RRI simulation, HydroSHEDS DEM data (resolution: 30s) was used, along with daily ground rainfall for 2007, 2012 and 2000. For frequency analysis, ground rainfall for 21 years (1995-2015) was used. For analysis of affected population, population census data from TH province's Statistical Yearbook[5] was used, along with expected population data of 76 urban centers in TH province from official urbanization master plan was used.

RESULTS AND DISCUSSION

Analysis of land use change

Area of a type of land use was calculated by using the maps in 2007 and 2015 published by JAXA Table 1 illustrates how much area (km^2) of each land use type had changed into another type between 2007 and 2015. For example, the first cell 1-1 (186.04) means there was 186.04 km^2 of water body area remained unchanged from 2007 to 2015. Besides, the second one 1-2 (7.83) means there was 7.86 km^2 of water body area in 2007, which changed into urban area in 2015. The second part of the table explains to total area of each type in 2007 and 2015. It is easy to see total area for urban area had increased 22.04 km^2, from 593.21 km^2 in 2007 to 571.17 km^2 in 2015, making up 3.86% of difference**.**

Table 1: Analysis of land use change from 2007 to 2015 in TH province (Unit: km^2)



		2015									
		1 (Water)	2 (Urban)	3 (Rice Paddy)	4 (Crop)	5 (Grass)	6 (Orchards)	7 (Bareland)	8 (Forest)	9 (Mangrove)	Total(2007)
2007	1	186.04	7.83	20.41	5.07	0.49	0.61	12.89	0.52	0.66	234.53
	2	6.52	363.16	61.22	105.70	1.03	4.42	24.94	1.29	2.90	571.17
	3	46.26	101.72	1203.98	106.98	1.70	10.10	27.33	1.52	2.29	1501.89
	4	9.33	90.88	81.45	793.97	30.69	51.12	59.75	57.65	4.33	1179.18
	5	7.56	3.03	17.65	239.02	863.74	99.79	121.77	603.43	1.16	1957.14
	6	1.08	18.04	9.13	134.93	8.28	137.71	17.02	30.86	0.14	357.18
	7	6.63	4.72	18.65	48.63	90.38	25.04	93.29	57.04	1.86	346.24
	8	10.87	1.48	2.86	56.14	366.03	46.65	75.11	4362.66	0.52	4922.32
	9	1.54	2.35	6.29	4.46	0.21	1.47	0.74	0.27	3.68	21.00
	Total (2015)	275.83	593.21	1421.64	1494.91	1362.54	376.92	432.83	5115.24	17.53	11090.65

Total (2015)	275.83	593.21	1421.64	1494.91	1362.54	376.92	432.83	5115.24	17.53
Total(2007)	234.53	571.17	1501.89	1179.18	1957.14	357.18	346.24	4922.32	21.00
Changes	41.29	22.04	-80.24	315.73	-594.60	19.74	86.60	192.92	-3.48
	17.61%	3.86%	-5.34%	26.78%	-30.38%	0.00%	25.01%	3.92%	-16.55%

RRI calibration and validation

For RRI simulation, 2007 land use map and 2007 actual rainfall was used to calibrate, with the duration of 35 days, from September 20th to October 24th, in order to focus only on flood period. With the Nash-Sutcliffe coefficient of 90.1%, this calibration was considered a pretty good simulation.

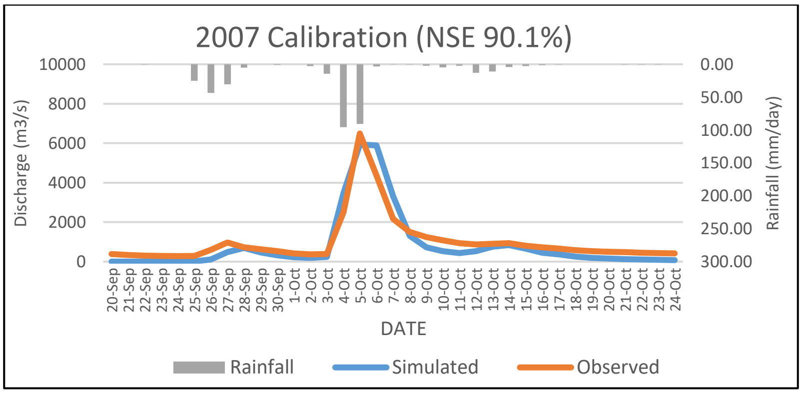


Figure 4: RRI calibration

Inundation analysis with land use change according to urbanization

After finishing RRI simulation and analysis of land use change, inundation change with assumption of 2007 and 2015 land use was analyzed for flood with different return periods. Specifically, the study focused on 3 cases of return period: 30-year (188mm), 50-year (211mm) and 100-year (245mm) return period. The maximum rainfall of 2007 flood event is around 186mm, which is almost the same as 30-year return period (188mm). Next, for each case of return period, there were two sub-cases for land use: 2007 and 2015 land use. Then for each sub-case, percentage of inundated areas was divided into four different categories of inundation depth, based on its potential danger for people. More details are illustrated in Figure 7. It is easy to see, total percentage of areas with inundation above 0.3m (>=0.3m) increases according to return periods and urbanization from 2007 to 2015.

Analysis of affected population

After inundation analysis with different land use, affected population was assessed by assuming all of population live in urban areas. Urban areas and inundated areas were overlaid by using GIS, which are visualized in Figure 5 and Figure 6. Thus, affected population for different inundation depth and return periods was calculated, which are shown in Figure 7 and Figure 8.

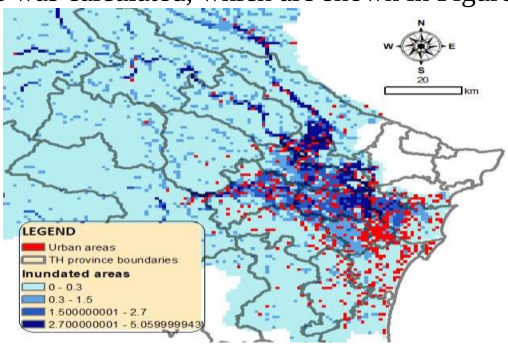


Figure 5: Urban areas and inundated areas with 2007 land use

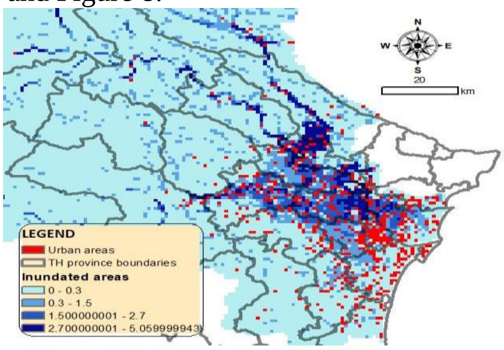


Figure 6: Urban areas and inundated areas with 2015 land use

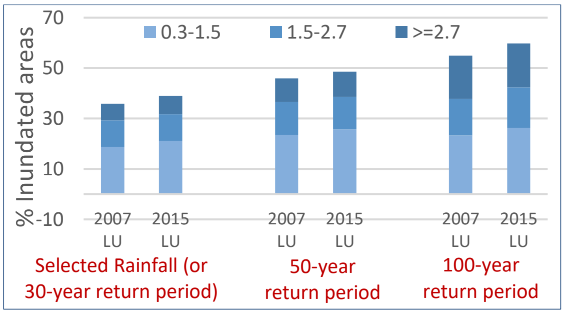


Figure 7: Inundation analysis with different land use in TH province

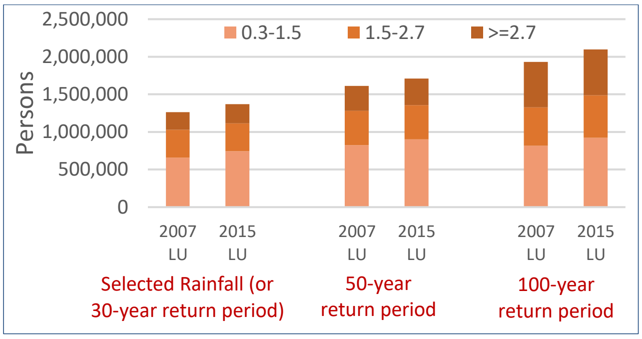


Figure 8: Analysis of affected population in TH province

From Figure 8, affected population living in the area with inundation above 0.3m (>=0.3m) increases according to return periods and urbanization from 2007 to 2015. In other words, land use change, or urban development, has exacerbated flood risk, leading to increasing number of people influenced by inundation.

Discussion of flood risk in 27 districts and 76 urban centers

Affected population increased greatly according to different Land use, especially in case of 30-year and 100-year return period. As a consequence, difference of affected population was obtained based on land use change (2007 and 2015). Only 9 out of 27 districts shows significant change, which are illustrated in the figure 7 in the order of direction, from North to South.

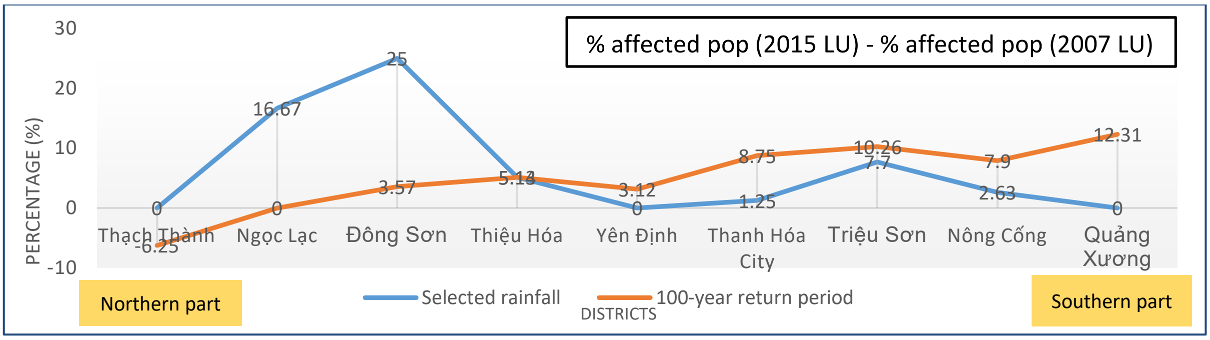


Figure 9: Change in % of affected population according to Land use change

In case of 30-year return period, change in percentage of affected population tends to decrease from Northern to Southern part. Meanwhile, in case of 100-year return period, change in percentage of affected population is low in Northern districts and higher in Southern ones (downstream areas). Figure 8 and Figure 9 have visualized this aforementioned phenomenon:

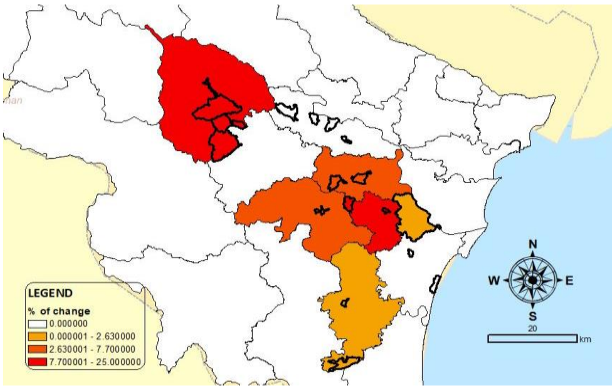


Figure 10: Change in % of affected population according to Land use change and Distribution of urban centers needed to be prioritized (30-year return period)

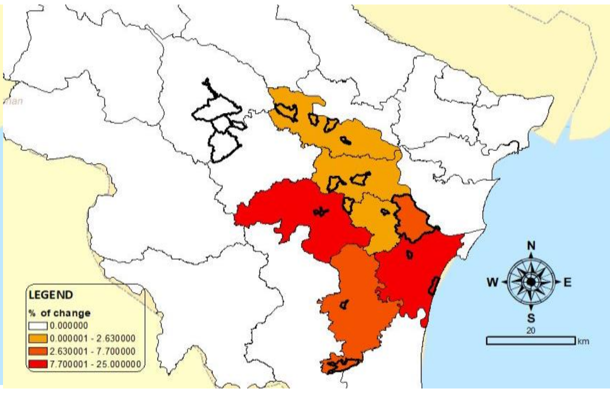


Figure 11: Change in % of affected population according to Land use change and Distribution of urban centers needed to be prioritized (100-year return period)

Figure 10 and Figure 11 suggest that 18 out of 76 urban centers should be prioritized for conducting necessary countermeasures, which are: TH city, Yen My, Nong Cong, Quang Thai, Quang Xuong, Quan Lao, Yen Tam, Yen Thai, Yen Truong, Trieu Son, Thieu Tam, Van Ha, Dong Hoang, Rung Thong, Lam Son, Minh Son, Ngoc Lac, Kien Tho. In additon, each urban center should be prioritized for conducting different countermeasures, based on 30 or 100-year return period.

Discussion: In case of 30-year return period, change in percentage of affected population tends to decrease from Northern to Southern part. Meanwhile, in case of 100-year return period, change in percentage of affected population is low in Northern districts and higher in Southern ones (downstream areas). To explain for this phenomenon, it is important to note that in case of 100-year return period, inundated areas increase greatly. Therefore, Northern districts are already inundated even with 2015 land use. After urbanization, however, since the urban development has been expanding towards downstream direction (Southern part), the inundation become exaggerated, leading to higher flood risk for districts in Southern areas, or downstream areas. According to this research, high flood risk usually occurs in downstream – ideal areas for urban expansion. As a result, for downstream districts and urban centers, the authorities or policy makers should take great care of countermeasures and investments for flood control, considering various characteristics of different places. Some districts or urban centers need infrastructures based on 30-year return period, meanwhile others might require construction according to 100-year return. For example, TH city shows high change of percentage in both cases. However, since in 100-year case, change of percentage is higher, so the authority of TH city should focus on conducting countermeasures and infrastructures based on criteria and standards for 100-year return period.

CONCLUSION AND RECOMMENDATION

Conclusion: In this paper, it has been proved that urbanization creates adverse impacts on flood risk: the number of inundated areas and affected population will increase, as urban development expands. Among the total 27 districts and 76 expected urban centers in TH province, only 9 out of 27 districts and 18 out of 76 urban centers suffering from low to high level flood risk (based on change in percentage of affected population according to land use change). It is also interesting to note that these districts and urban centers mostly gather in downstream – ideal area for urban development. Besides, each district and urban center has its own unique characteristics (topography, population, etc.), so it is important for the authority and policy makers to keep in mind that different countermeasures for different places are strongly recommended. For example, some districts or urban centers need infrastructures based on 30-year return period, meanwhile others might require construction according to 100-year return period. In addition, the analysis of affected population in Thanh Hoa Province, in its 27 districts and 76 urban centers can be served as helpful materials for the authority of Thanh Hoa, as well as for policy makers in order to make timely and necessary decision.

Recommendation: For further study, future projection for population in TH Province should be conducted, so as to see how strongly inundation will affect people in the long term. Secondly, not only urban areas, but also the impact of other types of Land use (water body, crop, grass, etc.) should be considered into analysis. In addition, equal distribution of rainfall stations and sufficient availability of discharge stations are also greatly suggested, in order to stimulate a smooth process for analyzing, assessing, weather forecasting and early warning.

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