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Facing multiple challenges: the future of flooding in Can Tho city

Huynh Thi Lan Huong[1,*], Assela Pathirana[2], Tran Thuc[1]

[1] *Vietnam Institute of Meteorology, Hydrology and Environment, 25/32 Nguyen Chi Thanh, Hanoi, Vietnam*

[2] *UNESCO-IHE, Institute for Water Education, Westvest 7, Delft, The Netherlands*

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Abstract. In this paper, we present the case study of Can Tho city (the biggest city in Mekong River Delta, Vietnam), faced with multiple future challenges, namely, (i) climate change driven sea-level rise and tidal effect, (ii) increased river runoff due to climate change, (iii) increased urban runoff driven by imperviousness and (iv) enhancement of extreme rainfall due to urban growth driven micro-climatic change (urban heat islands). A set of models were used to project the future impact of the combination of these influences. Urban growth of the city was projected using the landuse simulation model (Dinamica-EGO) to predict the future landuse up to 2100. The dynamic limited-area atmospheric model (WRF) coupled with a detailed land-surface model with vegetation parameterization (Noah LSM) were used to estimate the anticipated changes in extreme rainfall patterns due to urban heat island effects. Finally a 1-D/2-D coupled urban drainage/flooding models (SWMM-Brezo) were used to simulate storm-sewer surcharge and surface inundation to establish the increase in the flood risk resulting from the changes. The results show that, if the city is developed as prediction, the maximum of inundation depth and area in Can Tho city may increase about 20%. The impacts of climate change on inundation are more serious than that of urbanization.

Key words: urbanization, urban heat island, flooding.

1. Introduction

Many cities in the developing world are growing rapidly due to population growth and migration from rural areas to cities and the transformation of rural settlements into cities. The results are uncontrolled urban sprawl with increasing human settlements, industrial growth and infrastructure development.

Urbanization invariably increase the flood risk, as a result of greater vulnerability to floods due to concentration of population, socio-economic activities and infrastructure in smaller areas and increased flood hazard caused by hydrological and hydroclimatological changes brought-about by the land use and

[*] Corresponding author. Tel: 84-4-37731513.
E-mail: huynhlanhuong@gmail.com

microclimatic changes of urbanization. A great deal of studies over the last twenty years have shown a strong relationship between urban areas and local micro-climate. The "urban heat island" (UHI) effects are now well established, whereby urban areas have higher temperatures than surrounding regions. In many cases UHI can increase the rainfall in vicinity of the cities. A number of studies have found an increase in rainfall in regions downwind of urban areas, with the increase as high as 25% in some areas [1].

In this paper, we discuss the case of Can Tho city which facing all these future challenges, namely, (1) the effect of climate change driven sea-level rise and tide, (2) greater river run-off due to climate change, (3) increased urban runoff driven by imperviousness and (4) enhancement of extreme rainfall due to urban growth driven micro-climatic change (urban heat islands).

In this study, the mathematical models were used to estimate the changes in flood hazard due to climate change and urban growth. The climate change drivers are studied widely and the available research output to establish the magnitude of these were used. An urban growth model was used to predict the urbanization in the future, and then an atmospheric model was used to estimate the impacts of urbanization on local extreme precipitation by `what-if' type simulations of historical extreme rainfall events. Finally a 1-D/2-D coupled urban drainage/flooding model (SWMM-Brezo) was used to simulate storm-sewer surcharge and surface inundation to establish the increase in the flood risk resulting from the changes of rainfall and climate change drivers.

2. Study area

Can Tho city is the largest city of the Mekong River Delta (Vietnam) and considered as the capital of the region. In 2009, the city was recognized as the first level city in Vietnam and hence in the future, Can Tho is envisaged to develop considerably [2]. Over the next 20 years, Can Tho is projected to be a dynamic city not only in the Mekong River Deltabut also in the southern part of Vietnam and the adjacent international regions.

The area of the city is 1,390 km^2 with the population of 1.2 million (in April 2009). The city's population is projected to grow at a moderate rate; however; the migration to the urban areas and industrial zones possibly increases the total population to 1.8 million in 2020 [2].

Just like other cities in Vietnam, Can Tho is faced many typical problems of urbanization (e.g. pollution, social issues), but one of the most serious problems is flooding. On 5 Oct 2009, heavy rains lasted over one hour and caused serious inundation for the city. Several roads such as Mau Than, Tran Hung Dao, Xo Viet NgheTinh, Hoa Binh, and Ly Tu Trong were inundated under one-meter-height of water level. The local people said that this was the largest flooding event over recent decades. Many houses in the city were inundated.

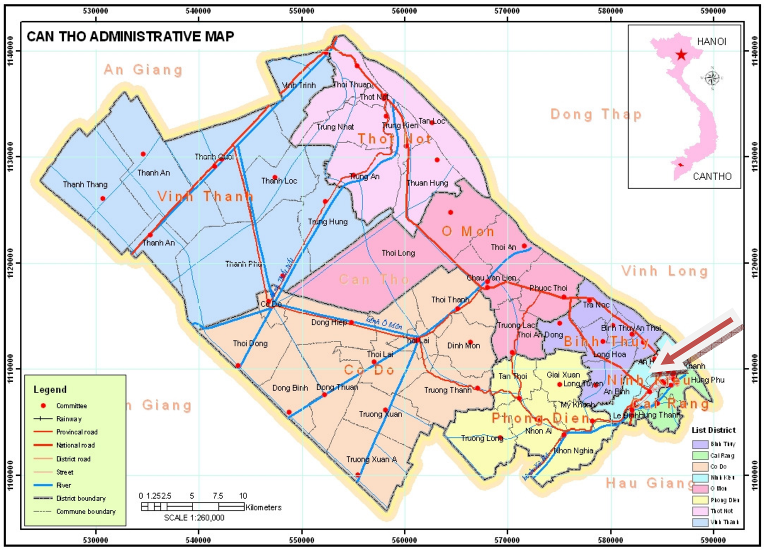


Figure 1. A map of Can Tho city administrative area (includes the surrounding agricultural land). Ninh Kieu district used for 1D/2D urban flood model is marked by the arrow.

Comment [S1]: Nên để hình to hơn cho dễ nhìn.

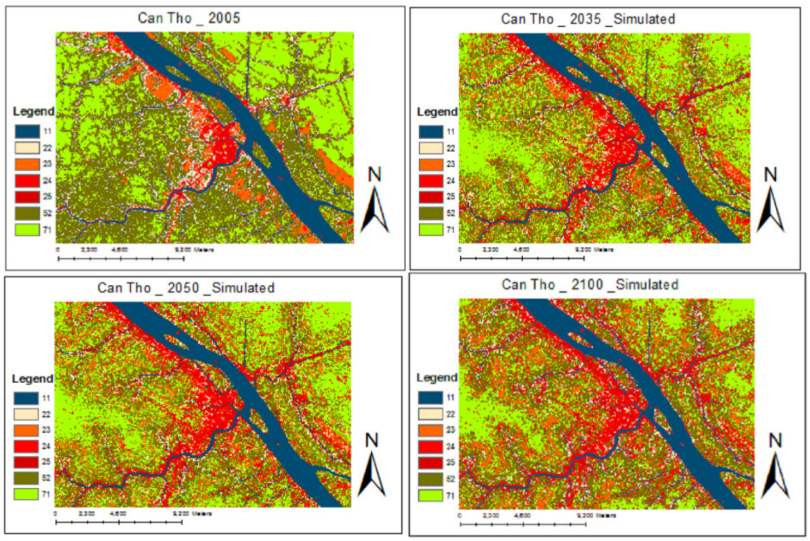
3. Methodology

The main emphasis of the research is the impacts of global and local climate change on urban flooding. Whenever suitable external resources for impacts are available, they were directly adopted (e.g. global climate change impacts on the extreme rainfall) with necessary caveats (e.g. scale issues).

However, for local changes (e.g. UHI) external resources are hardly available. The availability of good urban growth scenarios is essential to the success of the project. In order to predict the urban growth scenarios in future, the celluar-automata based land-use simulation model Dinamica-EGO was used to predict the urbanization. Output from Dinamica-EGO was used as input in a specially modified meso-scale atmospheric model [3] to ascertain the changes that it will induce in the urban microclimate for the city of Can Tho resulting in changes in the precipitation patterns. To achieve this, a meso-scale atmospheric model (WRF) coupled with a land-use model with vegetation parameterization (Noah LSM) was applied. The necessary modeling framework was already developed for this purpose [3, 4] and this framework was applied for Can Tho city with the realistic urban growth scenarios. For urban flood modeling, an integrated model (SWMM-Brezo) [5], developed during the period 2007-2010, was used.

4. Result and discussion

4.1. Future Urbanization



Source: [4]

Figure 2. Future land use change in Can-Tho predicted by Dinamica-EGO model.

Dinamica-EGO needs several historical land-use maps in order to calculate the land-use transition patterns. For Can Tho, the land cover maps of the year 1989 and 2005 were used as the initial and final land-cover maps and the following categories are identified from the training of RS images. Dinamica-EGO simulation was done from 1989 to 2100 at time steps of 5 years.

The resulting urban extent and land-cover distribution predictions of the Can Tho city are used as input for the atmospheric model for further analysis of increasing in precipitation and increment imperviousness to investigate the associated flood risk. The process is explained in sections below.

After satisfactory results were obtained from the simulation and validation of the model setup, the same model parameters were used to project future land cover maps in five years interval up to the year 2100. The configuration and internal parameters of the 1989 - 2005 simulation model were used along with other input parameters like restricted areas. Projections of land cover maps for the year 2035, 2050 and 2100 are shown together with observed land cover in 2005 in Figure 2.

The total built up area will increase by 27.6 km^2 by the year 2035, about 41% of increase in 30 years time. By 2050 with a total increment in built up area of $38km^2$ (55%) with respect to the year 2005. Grasslands and shrubs are subjected to a combined decrease of about 12% by 2035 and 17% by 2050.

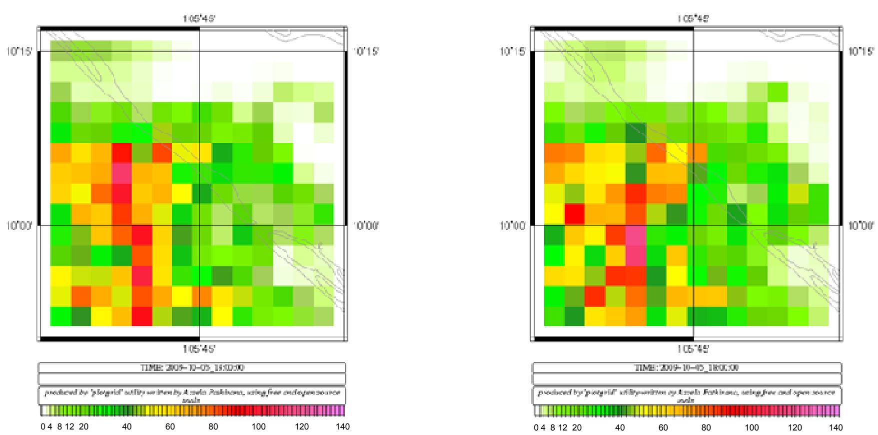
4.2. Impacts of urbanization on local precipitation

The domain configuration was set up to cover study area with a resolution of 1 km. Three two-way nesting domains was set in order to achieve 1km resolution over Can Tho city with computational economy. The time for integration step was 15s.

The land-use distribution from the urban growth model were used as inputs for the atmospheric model runs to establish the impacts of urbanization on local precipitation. Two different maps of land-use in the year of 2005 and 2050 (from Dinamica-EGO) were used to perform controlled numerical experiments to establish what will be changed in rainfall if the city will be developed as projected scenarios.

The process of obtaining these results are as following: Several historical storms in Can Tho city were selected. The WRF/Noah model were developed by using NCEP-FNL global datas as initial/boundary conditions and land-use datas from Dinamica EGO model (2005 as `Past' case and 2050 as `Future' case). The models were validated to closely reproduce the historical results with the `Past' scenario. Then the same model parameters were used with `Future' scenario in order to estimate the impact of urbanization on local precipitation. Figure 3 shows the total simulated rainfall amounts for an extreme event recorded in Oct 2010.

The results show that, there is a clear impacts of urban growth to increase the extreme rainfall quantities. In most of the case study, with the projected land-use map of 2050, the rainfall may increase respectively, especially for the heavy rainfall of which the total rainfall of 30 – 40 mm in 15 minutes. In case of historical rainfall event of 5 Oct 2009, the results show that if the precipitation is more than 40mm, the rainfall in 'future' case is greater than in 'past' case in about 10%. These values will be use for the urban flood simulation below.



Past Future

Figure 3. Total rainfall simulated during the 2009/Oct/05-06 rainfall event.

4.3. Impacts of urbanization and climate change on flooding

The study area is Ninh Kieu district which is the central district of Can Tho city, located nearby Hau Giang and Can Tho rivers. The total area of the district is 2900 ha. However, the sewer system only covers one part of the district, of 660 ha to which we applied the urban model. SWMM-BreZo model has been

Comment [S2]: Not very clear, why the study area is Ninh Kieu only?

calibrated and verificated for the inundation events in 2000 and 2009.

In order to estimate the impacts of urbanization on flooding situation for Can Tho city, the results of rainfall even of Oct 2009 (in past and future land-use map) were used as input for all considered scenarios.

There are 8 different scenarios considered in this study, including: (i) Estimate the impact of urbanization: the results of WRF-Noah; (ii) Estimate the impact of urbanization and sea level rise (SLR): consider the impact of sea level rise (SLR) in 50 and 100 cm. (iii) [6] Estimate the impact of urbanization and SLR and Climate change (CC): consider the impact of sea level rise in 100 cm combined to the flow increasing from upstream in case of high emission scenario (A1FI) [7].

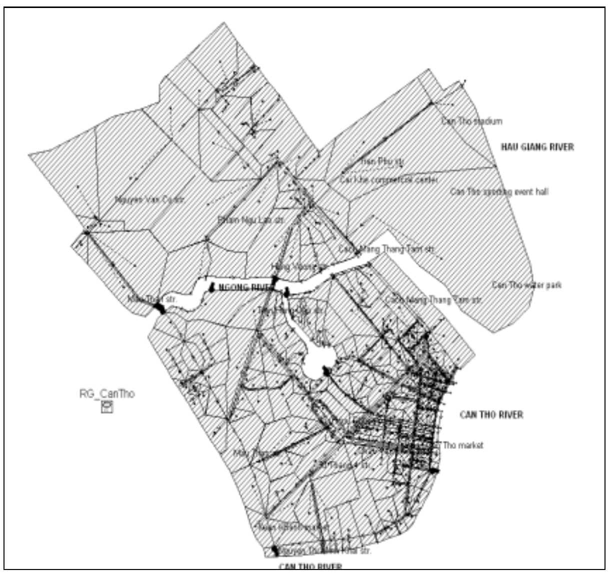


Figure 4. SWMM model for Can Tho.

Table 1. Summary of results of flooding simulation

Factors	Maximum Inundation depth (m)		Maximum Inundation area (ha)	
	Rainfall (Land-use map of 2005)	Rainfall changing by urbanization (Land-use map of 2050)	Rainfall (2005)	Rainfall (2050)
Without CC consideration	0.84	1.02	177	208
SLR – 50cm	0.87	1.08	177	208
SLR – 100 cm	1.26	1.33	183	213
A1F1 + SLR 100cm	1.38	1.51	186	216

Figure 14 shows an example set of inundation results for the four scenarios. The results of these simulations are summarized in Table 1.

Comment [S3]: Where?

5. Discussion and conclusions

The results show that if the city develops as prediction, the maximum of inundation depth and area in Can Tho may increase by about 18 cm (18%) by 2050 due to the land-use change driven hydrological and hydro-meteorological effects only. It seems that the impact of climate change, in its worst combination (A1F1 flow with SLR 100cm) on inundation is more serious than that of urbanization-driven land-use change. The maximum inundation depth in Can Tho may increase by more than 50cm (around 60%). The inundation area is not likely to change significantly comparing among scenarios.

Figure 5. Highly inundated areas.

In the scenario that combines CC with local rainfall change, the maximum of inundation depth may rise up to 1.51 m - an 80% increase. The most serious inundation area is surrounding Nguyen Van Cu and Mau Than Streets (Figure 5) which are located near the Ngong Channel - the main collecting water channel of the district. When heavy rain occurs, the water from other roads, channels and sewers will concentrate in this channel. As the drainage capacity of the channel is not sufficient for the large amount of water, the low surrounding areas are routinely inundated. The possibility of the increase of inundation depth in this area up to 1.51 m, is alarming indeed as this level may pose a danger to human life.

Beside the above critical areas, the maximum inundation depth of the rest of the areas do not change significantly, this value only 0.73m in the scenario of A1F1 + SLR 100cm compare to 0.66m in the baseline scenario, it is located near Nguyen Thi Minh Khai, Phan Dinh Phung street. It seems that, these areas have been affected only by rainfall changing and have not had clearly impacts by the water level from river.

Both in the present and the future the area with high inundation depth (> 0.5m) is not excessively large. The maximum area of inundation depth > 0.5 m largest only 26.33 ha (accounting for 12% of the total inundation area). The area increased by 20% due to urbanization driven rainfall change and 34% due to climate change (A1F1+SLR100cm). The combination of these two facts increases it by 50%.

Investigations of the flooded areas show two distinct categories of flooding, namely the areas dominated by largely local rainfall-driven flooding (name the streets, areas) and those influence mainly by river water level.

The present study is an attempt to integrate the impacts of several drivers of future change and therefore involves a complex chain of analysis. As stated at the beginning, such analyses invariably generate significant degree of uncertainty in the final outcome. We urge the reader to exercise caution when interpreting the results presented here in a quantitative sense. Each stage of simulations has its own sources of significant uncertainties: Urbanization modeling was largely based on rules derived from past behavior of the city. While this would capture the essential behavior of the urbanization as conditioned by geographical, cultural and societal factors - there are host of other parameters that will not remain unchanged in the future. For example a major trunk road is being constructed between Can Tho and the Ho Chi Minh city which would make the travel between the two cities much faster. This will definitely have a hitherto unseen influence on growth. On the other hand, the government of Vietnam is very much active in planning for the future taking climate change and other future changes into account. Future regulatory action can restrict urban growth.

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