Assessment of the impact of urbanization-land subsidence, climate change and implementation of the Irrigation Plan 1547 on flooding in Ho Chi Minh City by the year of 2030

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Abstract: *Flooding in Ho Chi Minh (HCM) City is caused by heavy rain, high tide, flood discharge from upstream, urbanization-land subsidence and climate change. Simulation programs used for flood control of downstream of the Dong Nai river system basin, including model of rainfall flow and hydraulic model (MIKE 11). Simulation scenarios include tidal flooding in consideration of urbanization-land subsidence and climate change in the area. The urbanization data by the year of 2030 is used in accordance with urban space development planning. The impacts of the urbanization-land subsidence, climate change and implementation of the Irrigation Plan 1547 by the year of 2030 is considered according to the scenario of 2030RCP4.5 as the baseline for comparison and the scenario of 2030RCP4.5_P1547. Predicted results show that water levels in the main river as well as in the urban area have increased significantly, resulting in increased flooded areas.*

Keywords**:** *Flooded area, climate change, urbanization-land subsidence, simulation scenarios.*

JEL Classification: Q54; R00; R28.

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1. INTRODUCTION

HCM City is a coastal city, with an intricate network of rivers and canals (about 2,953 routes with total length of about 4,371km), low terrain (about 75% of the area has an elevation of less than 2 m), and rapid land subsidence over 1.0 cm/year over a large area of about 240 km^2, therefore, flooding often occurs, causing serious damage to property, disrupting production processes, limiting public transportation, increasing disease and negatively impacting environmental quality.

Flooding in HCM is caused by heavy rain, high tides, flood discharge from upstream, urbanization-land subsidence and climate change. According to statistics from the authorities, by the end of 2016, the City had 105 flooded points, including 47 points flooded due to rain, 7 points flooded due to tide and 51 points flooded due to rain combined with high tide.

Implementation of the Irrigation Plan to prevent flooding in HCM City area approved by the Prime Minister according to Decision No. 1547 (the Plan 1547) [2] will improve the flood situation in the city.

This paper will present an assessment of the impact of urbanization-land subsidence, climate change and implementation of the Irrigation Plan 1547 on flooding in HCM City by the year of 2030.

2. RESEACRH AND METHODOLOGY

2.1. Simulation inputs

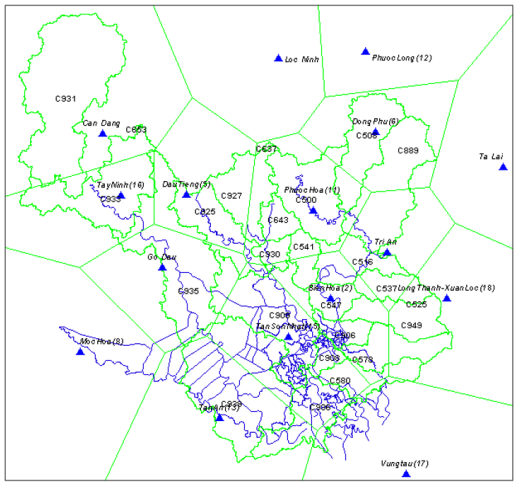
Simulation: Simulation programs used for flood control of downstream of the Dong Nai river system basin including model of rainfall flow (Figure 1) and hydraulic model (MIKE 11) (Figure 2).

Input Data

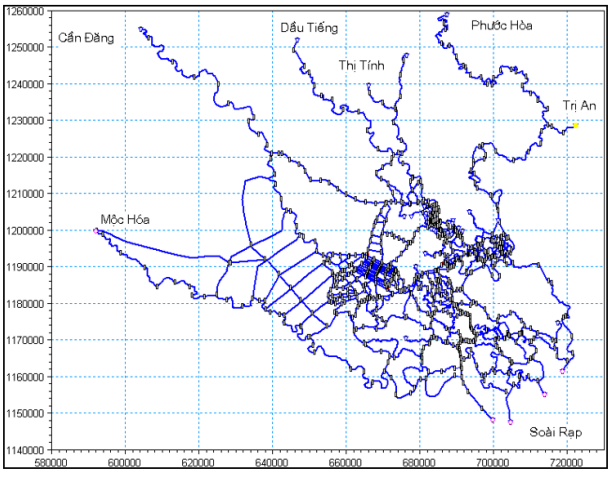
Rainfall data: Rain stations are monitored for the downstream areas of the Dong Nai river system basin using daily rainfall data. Tan Son Hoa station however is calculated using rainfall data for every 15 minutes. The frequency of rainfall is calculated according to the Gumble distribution. Under climate change conditions, rainfall during autumn is calculated corresponding to climate change scenarios (Table 1).

Water level data: The water level stations for the downstream area of the Dong Nai river system basin are monitored with the hourly data. The sea level rise scenarios only consider the change in average sea level (See Table 2) according to Vietnam's climate change scenario published in 2016.

Headwater flood data: According to the flood discharge process of the Southern Institute of Water Resources Planning during the flood control irrigation planning phase for the HCM City, future scenarios will also partially reduce flood peaks.



▲ *Figure 1. Distribution of downstream rainfall stations*



▲ *Figure 2. Schematic diagram of downstream of the Dong Nai river system basin*

Table 1. Changes in autumn rainfall (%) compared to the base period [1]

Scenario RCP4.5			Scenario RCP8.5		
2016 - 2035	2046 - 2065	2080 -2099	**2016 - 2035**	**2046 - 2065**	**2080 -2099**
11.4 (1.5 ÷ 21.6)	22.6 (8.7 ÷ 38.1)	19.7 (5.1 ÷ 34.4)	14.0 (4.5 ÷ 23.5)	18.4 (8.1 ÷ 29.2)	22.0 (6.6 ÷ 37.3)

Table 2. Raising sea level (cm) based on scenario RCP4.5 from Ke Ga Cape to Ca Mau Cape [1]

Timelines							
2030	2040	2050	2060	2070	2080	2090	2100
12 (7 ÷ 18)	17 (10 ÷ 25)	22 (13 ÷ 32)	28 (17 ÷ 40)	33 (20 ÷ 49)	40 (24 ÷ 58)	46 (28 ÷ 67)	53 (32 ÷ 77)

2.2. Model calibration

Model calibration: The model was calibrated with actual water level in 2013 at the main hydrological stations of the Dong Nai river system, then rechecked with data from 2007. Overall, the model is very good, the error of peak and bottom flood is negligible. The difference in water level between simulation and measurement is low (See Table 3).

Table 3. Parameters of October 2013 water level simulation calibration [3]

Station	River	Correlation coefficients	Max error (%)
Phu An	Saigon	0.987	0.050
Thu Dau Mot	Saigon	0.971	0.076
Nha Be	Dong Nai	0.987	-0.024
Bien Hoa	Dong Nai	0.980	0.243
Ben Luc	Vam Co Dong	0.987	-0.063

Model validation: Based on the set of parameters, the model correction for 2007 at the national hydrological station, including Nha Be, Phu An, Thu Dau Mot, Ben Luc was conducted. Hydraulic model validation was performed on the main river at the national hydrological stations, so the test results were relatively good. Correlation coefficients were also high from 0.971 to 0.987.

2.3. Simulation scenarios

Simulation scenarios include tidal flooding in consideration of urbanization - land subsidence and climate change in the area. The impacts of the climate change by the year of 2030 is considered according to the scenario of contribution of 10% high flood 10% tide, 10% rain under climate change and urbanization-land subsidence (2030RPC4.5) as the baseline for comparison and the scenario of contribution of 10% high flood, 10% tide, 10% rain under climate change and urbanization-land subsidence, built according to Irrigation Plan to prevent flooding in HCM City area [2] has been approved by the Prime Minister according to Decision No. 1547 (Plan 1547) (Phase 1) (2030RCP4.5_P1547). Specific scenarios are presented in Table 4.

Table 4. Simulated scenarios of the Plan 1547 [4]

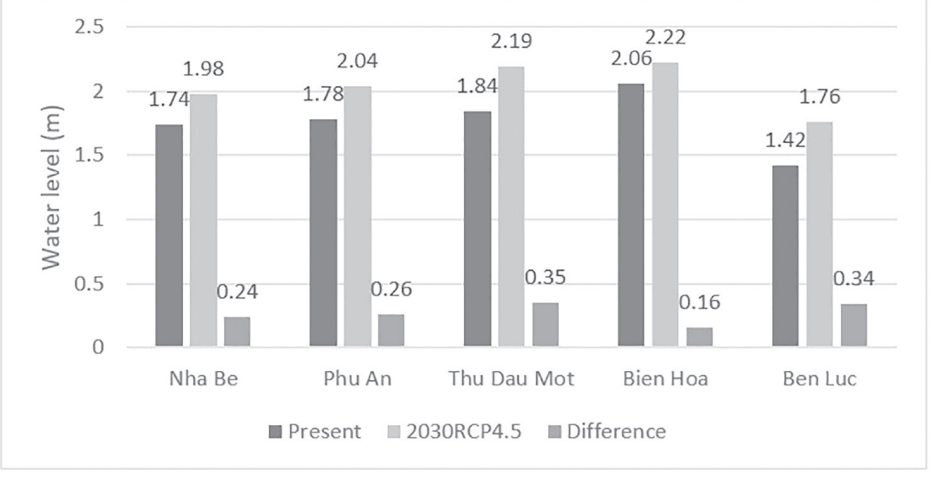
No	Scenario	Rainfall (%)	Tide (%)	Flood (%)	Topography	Climate Change	Land subsidence
1	Present	10	10	10	Not considered	Not consi-dered	Not consi-dered
2	2030RCP4.5	10	10	10	Plan 2030	2030RPC4.5	Subsidence 2030
3	2030RCP4.5_P1547	10	10	10	Plan 2030 + Plan 1547	2030RPC4.5	Subsidence 2030

3. RESULTS AND DISCUSSION

3.1. Present and forecasted flood situation at HCM City

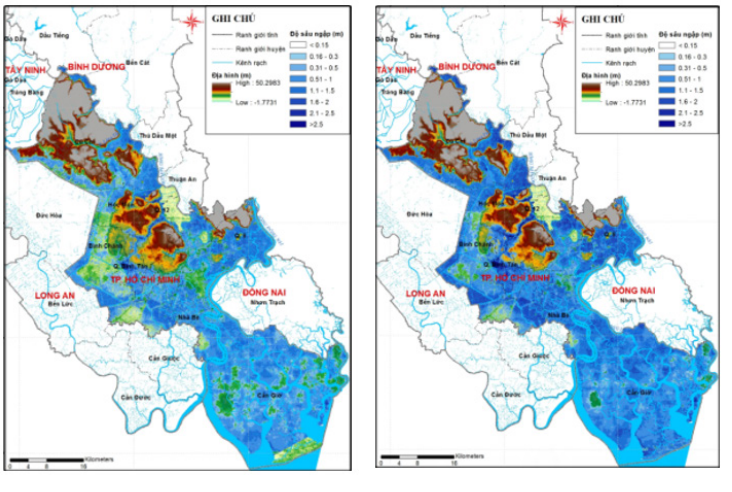
Present scenario

Water levels: Water levels in the major rivers and in urban areas are rising. Those at Nha Be, Phu An, Thu Dau Mot, Bien Hoa, Ben Luc stations are 1.74, 1.78, 1.84, 2.06, 1.42m, respectively (Figure 3).



▲ *Figure 3. Water levels of the present scenario versus the scenario of 2030RCP4.5*

Flooded area: Total flooded area in the whole HCM City is 120,118 hectares, accounting for 60.5% of the total natural area. Flood depth is of 0.2 to 1.5m depending on the area. The total flooded area in the protected area currently is 26,028 ha, accounting for 46.8% of the total calculation area (Figure 4).



Scenario of Urbanization-land Subsidence and Climate Change Impact (2030RCP4.5)

Water level: For the scenario of 2030RCP4.5, almost all water levels in the main rivers and in the region will be rised significantly. Those at Nha Be, Phu An, Thu Dau Mot, Bien Hoa, Ben Luc stations are 1.98, 2.04, 2.19, 2.22, 1.76m, respectively. The differences comparing to the present scenario at Nha Be, Phu An, Thu Dau Mot, Bien Hoa, Ben Luc stations are 0.24, 0.26, 0.35, 0.16, 0.34m, respectively (See Figure 3).

Flooded area: The total flooded area of HCM City for the scenario of 2030RCP4.5 is about 141,758 ha, accounting for 71.5% of the natural land area and 21.641 ha higher than that of the present scenario (Figure 4).

The total flooded area in the protected area for the scenario of 2030RCP4.5 is about 36,726 ha, accounting for about 55% of natural land area, and increase by 10,698 ha comparing with that of the present scenario. The flooded area with a depth of less than 1m, 1-2m, more than 2m are 20,264 ha, 14,737 ha, 1,725 ha, respectively (Figure 6).

Scenario of Urbanization-land Subsidence, Climate change impact and implementation of the Plan 1547 (2030RCP4.5_P1547)

Water levels: For the Scenario of 2030RCP4.5_P1547, almost all water levels in the main rivers will increase. Those at Nha Be, Phu An, Thu Dau Mot, Bien Hoa, Ben Luc are 1.98, 2.07,

▲ *Figure 4. Flooded maps of the present scenario and the scenario of 2030RCP4.5*

2.25, 2.23, 1.77m, respectively. The differences comparing to the scenario of 2030RCP4.5 at Nha Be, Phu An, Thu Dau Mot, Bien Hoa, Ben Luc are 0.00, 0.03, 0.06, 0.01, 0.01m, respectively. In the protected area by the flood control system in accordance with the scenario of 2030RCP4.5_P1547, the water level will be reduced by 0.87m comparing with the scenario of 2030RCP4.5 and reach the level of +1.22m (Figure 5).

With the scale of the first phase, instead of building 12 floodgates with protected area of about 1,800km², only 8 floodgates was built with protected area of about 1/3 comparing to the Plan 1547.

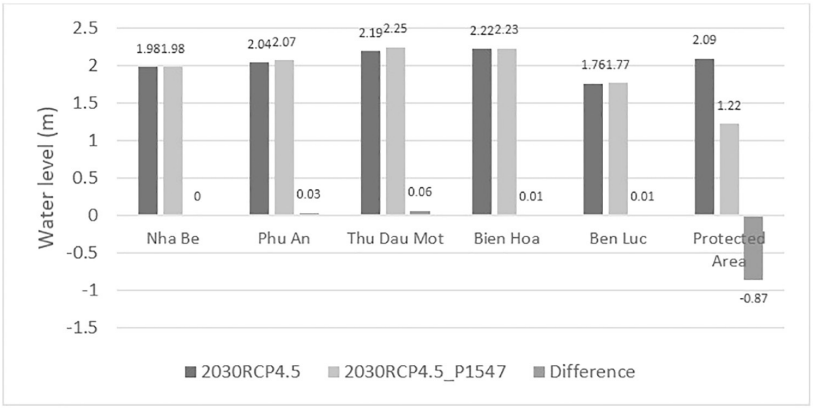
Flooded area: The total flooded area of HCM City, after the construction of flood control works is about 134,847 ha, accounting for about 68% of natural land area and decrease about 6,911 ha comparing to without those.

The total flooded area in the protected area for the Scenario of 2030RCP4.5_P1547 is about 30,584 ha, accounting for about 55% of natural land area, and reduce by 6,142 ha comparing with the scenario of 2030RCP4.5. The flooded area with a depth of less than 1m, 1 - 2m, more than 2 m are 20,4184 ha, 8,685 ha, 1,482 ha, respectively. Corresponding to depths of 1 - 2m, the reduction of about 6,052 ha and the depth of over 2m, the reduction is about 243 ha comparing with the scenario of 2030RCP4.5 (Figure 6).

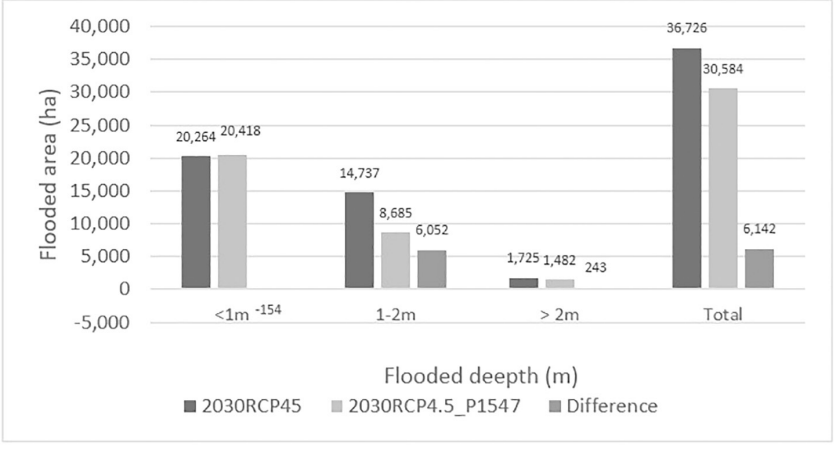
4. CONCLUSION AND RECOMMENDATION

Flooding in HCM City is caused by heavy rain, high tide, flood discharge from upstream, urbanization-land subsidence and climate change. Predicted results show that water levels in the main rivers as well as in the urban area has been increasing significantly, resulting in increased flooded area.

When construction of 8 large floodgates and connecting them with existing dyke system to protect the Central and Southern regions of the City, floods under tidal impacts in the inner City will be significantly reduced. On the other hand, the water level in the main rivers outside the protected area has slightly increased in Phu An, Ben Luc, Bien Hoa stations. The dredging of canals in the Central and Southern regions when the tidal protection barrier was built did not have much impact on lowering urban water levels.



▲ *Figure 5. Projected water level according to the scenario of 2030RCP4.5_P1547 versus the scenario of 2030RCP4.5*



▲ *Figure 6. Simulated Flooded Area for scenarios of 2030RCP4.5 and 2030RCP4.5_P1547*

It is recommended that the People's Committee of HCM City soon develop an integrated strategy to minimize the impact of urbanization-land subsidence climate change on flooding in the City ▪

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