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Assessment of climate change impacts on flooding in the downstream of the Dong Nai River

Tran Hong Thai*

Vietnam Institute of Meteorology, Hydrology and Environment, 23/62 Nguyen Chi Thanh, Hanoi, Vietnam

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Abstract. In recent decades, the increasing in greenhouse gas emission has caused global warming leading to many adverse changes of the environment especially the sea level rise and the hydrological regime. The Dong Nai river basin having the downstream part below the sea level is among the most vulnerable basins to climate change. Recents studies showed that the sea level in the downstream of Sai Gon - Dong Nai river basin is rising. Many cities downstream of the basin especially Ho Chi Minh city are being flooded in flow tides which seriously affect the socio-economic development. Thus, research on the future impacts of climate change on flooding in this area is of vital importance. This paper applied the HydroGIS modeling package to predict the flooding levels in the Dong Nai river basin for the period from 2020 – 2100 taking into account the impact of climate change. Inundation maps were developed based on three climate change scenarios namely B1, B2 and A1FI and different sea level rise values (e.g. 15, 25, 50, 75 and 100cm). These maps together with comprehensive analysis on the trend and extent of flooding will assist decision makers in developing mitigation measures coping with flooding in the river basin.

Keywords: Climate change, flooding, Dong Nai river, HydroGIS.

1. Introduction

Climate change has become a globally significant concern in the 21st century because of its potential impacts on society. Vietnam is not an exception. According to recent studies by World Bank and IPCC, Vietnam is among the countries most heavily affected by the consequences of climate change. Mekong and Red rivers' delta are projected to be the most seriously inundated. With sea level rise of 1 meter, about 10% of the population would be directly affected and lost of GDP would be about 10%. Climate change impacts to Vietnam are considered to be serious and demand intermediate planning for adaptation. Therefore, adequate and appropriate research and quantitative assessment about impacts of climate change are of very high importance [1].

Sai Gon - Dong Nai river basin and its surroundings cover an area of about 49643.53 km^2 including 11 provinces: Dac Nong, Lam Dong, Binh Phuoc, Binh Duong, Dong Nai, Tay Ninh, Ho Chi Minh City, Long An, Ninh Thuan, Binh Thuan, and Ba Ria Vung Tau (Firgure 1). The downstream area of the river

* Tel.: 84-4-38359491
E-mail: tranthai.vkttv@gmail.com

basin, including subbasins of Go Dau Ha, Ben Luc, Nha Be, Dong Nai, Sai Gon, Ha Dau Tieng and Tay Ninh, are highly vulnerable to the impacts of climate change. Recently, many cities downstream of the basin especially Ho Chi Minh city are being flooded in flow tides which seriously affect the socio-economic development.

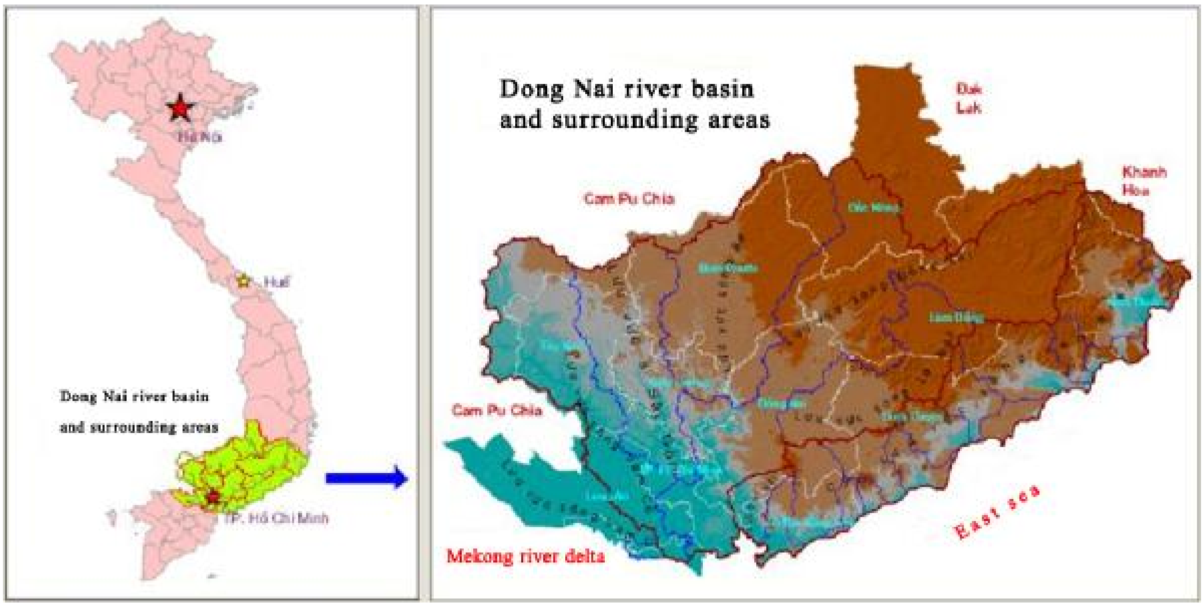

Figure 1. Location of the Dong Nai river basin and the surrounding areas.

2. Literature review

In this study, the HydroGIS modeling package was used to investigate the impacts of climate change on flooding in Sai Gon – Dong Nai river basin. The software is integrated from the hydraulic mathematical models, material conservation and database management models in GIS formats. The data used in the model included the GIS background data (terrain, administrative, land use, vegetation, soil, traffic, irrigation...); basic data, also known as solid boundary data, simulating geometry structure of rivers and canals, embankments, works…); hydro-meteorologica data (rain, wind, evaporation, seepage, water level, salinity, wind, material load in the estuary, flow, salinity…) [2].

The model was calibrated and validated based on the data series from June to December in 2000. A 10-year return period flood, having the discharge of 4500 m^3/s at Tri An station and of 600 m^3/s at Dau Tieng station, in October 2000 was used to calibrate the model. Another flood in August 2008 was used to verify the model. Results of calibration and verification were fit to measured data [3]. The simulation is good, and. The simulation is good, and the model was then used to calculate inundation depth for a 10-year return period flood occurred in October 2000.

Using runoff at upstream boundaries and sea water level at downstream boundaries with considering sea level rise data (Table 1), the level and extent of flooding subjected to different climate change scenarios can be calculated by the HydroGIS modeling package.

Table 1. Sea level rise (cm) compared to the period 1980-1999 [4].

Scenarios	**The timeline of the 21st century**								
	2020	2030	2040	2050	2060	2070	2080	2090	2100
Low (B1)	11	17	23	**28**	35	42	50	57	**65**
Medium (B2)	12	17	23	**30**	37	46	54	64	**75**
High (A1FI)	12	17	24	**33**	44	57	71	86	**100**

Flood modelling for the period 2020-2100 was divided into four phases including 2020-2039, 2040-2059, 2060-2079, and 2080-2100. In each phase, the HydroGIS model was used to predict inundation depth and area with input hydrological data for medium and large floods.

3. Flooding situation in scenario B1

Total inundated area in Dong Nai river basin will increase in B1. However, the differences in total inundated area between the four phases for the period from 2020 to 2100 would not be dramatic and the rate of increasing in the extent of the inundated area would less than that of B2 scenario.

Table 2. Inundation depth and largest inundated area in scenario B1 with flood control by Dau Tieng reservoir.

Unit: Area (km^2)

	Inundated area with H < 1m	**Inundated area with 1m < H < 2m**	**Inundated area with H > 2m**	**Total inundated area**
		2020 – 2039		
High flood	1963.25	699.19	27.12	2689.55
Medium flood	2347.14	303.58	24.80	2675.52
		2040 – 2059		
High flood	1977.90	769.51	27.56	2774.96
Medium flood	1970.50	765.81	24.84	2761.14
		2060 – 2079		
High flood	1787.03	1015.00	27.57	2829.60
Medium flood	1804.28	969.50	24.38	2798.16
		2080 – 2100		
High flood	1631.84	1248.60	27.62	2908.06
Medium flood	1594.70	1242.93	26.33	2863.96

Ratio of areas inundated below the depth of 1 m decreases, wheras ratio of areas inundated from 1 to 2 m increases with the increase in sea level.

Dau Tieng reservoir, to some extent, would not perform efficiently in flood defence and prevention for downstreams.

4. Flood situation in scenario B2

The flood trend in Dong Nai river basin is complex in 2020-2100 period due to climate change and sea level rise, combining with increasing trend in flow at upstreams. Areas inundated below the depth of 1 m decreases, wheras ratio of areas inundated from 1 to 2 m increases (Table 3).

Table 3. Inundation depth and largest inundated area in scenario B2 with flood control by Dau Tieng reservoir.

Unit: Area (km^2)

	Inundated area with H < 1m	**Inundated area with 1m < H < 2m**	**Inundated area with H > 2m**	**Total inundated area**
		2020 – 2039		
High flood	1967.05	701.99	28.17	2697.20
Medium flood	2347.04	305.18	25.25	2677.47
		2040 – 2059		
High flood	2037.20	769.20	29.36	2835.76
Medium flood	1883.45	904.96	28.14	2816.55
		2060 – 2079		
High flood	1717.50	1120.00	37.77	2875.27
Medium flood	1720.00	1101.00	35.77	2856.77
		2080 – 2100		
High flood	1663.70	1238.20	48.87	2950.77
Medium flood	1653.20	1227.20	46.87	2927.27

Generally, in the future, if there would be only Dau Tieng reservoir used in flood control, the ability to reduce flood in the downstream would be very limited. The difference in inundated areas between two schemes: with and without flood control reservoir with high and medium flood are less than 30 km^2. When sea level rises as high as 75 cm, despite the present of Dau Tieng reservoir, the downstream of the Dong Nai river will still be flooded up to 2950.8 km^2 of which 58% of areas is inundated under 1m, 40% of areas is inundated between 1 and 2m and 2% of area is inundated over 2m.

In the period from 2020 to 2100, the Dong Nai river basin is affected by sea level rising up to 100cm causing flooding in a very large areas. The provinces which are seriously affected include Long An, Tien Giang provinces and Ho Chi Minh city.

5. Flooding situation in scenario A1FI

According to scenario A1FI, flooding extent will increase due to sea level rise. The largest inundated area in the region occurs in 2080-2100 period with sea level rising up to 100cm.

Ratio of inundated area with different inundation depth also varies with the increase of sea level. The higher the sea level is, the more the highly inundated areas (1-2m and more) and the less the moderately inundated areas (less than 1metre). In 2080-2100 period, if sea level rises up to 100 cm, 51% of the area is highly flooded and 47% of the area is moderately flooded.

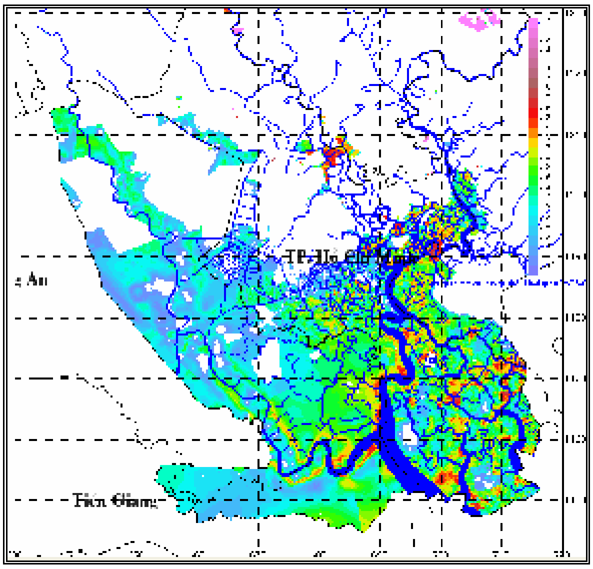

Figure 2. Inundation map caused by High flood in the 2020 - 2039 period.

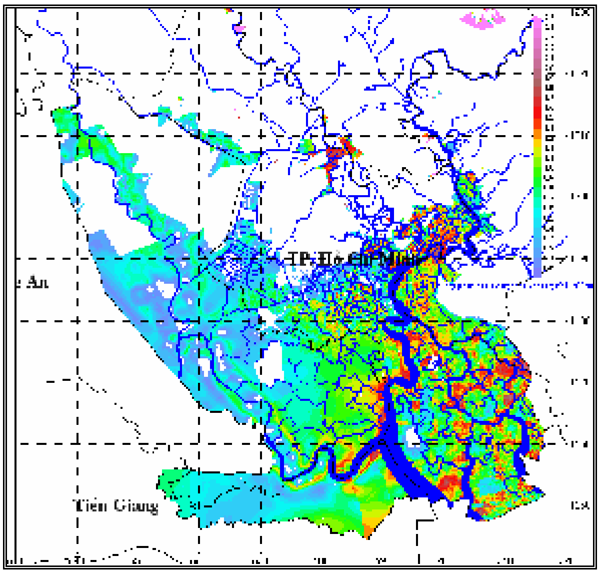

Figure 3. Inundation map caused by High flood in the 2040 - 2059 period.

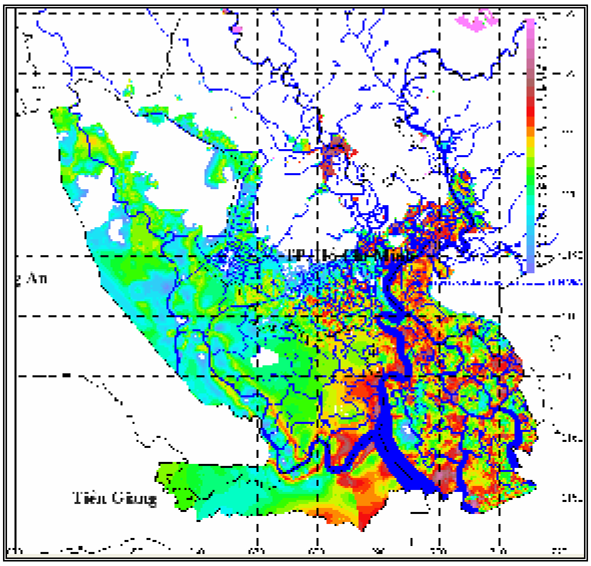

Figure 4. Inundation map caused by High flood in the 2060 - 2079 period.

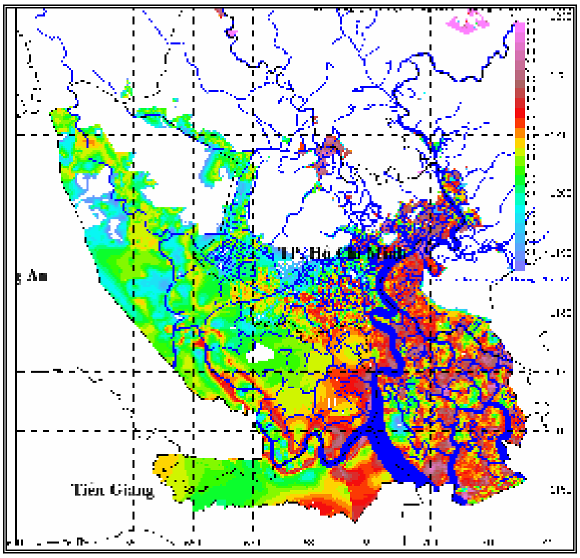

Figure 5. Inundation map caused by High flood in the 2080 - 2100 period with sea level rise 75cm.

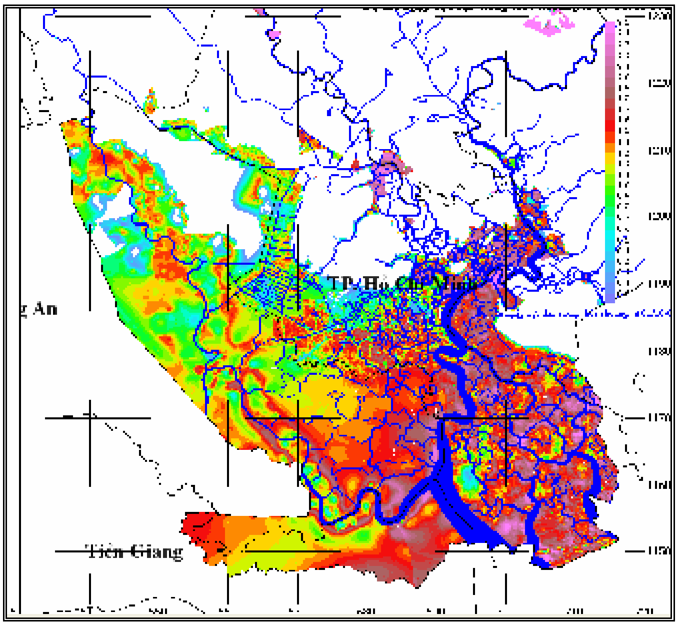

Figure 6. Inundation map caused by High flood in the 2080 - 2100 period with sea level rise 100cm.

6. General assessment of climate change impact on flooding in the downstream of the Dong Nai River

In the 2020-2100 period, according to emission scenarios B1, B2 and A1FI, rainfall in the southern part increases only around 1-2% in the rainy seasons resulting in a negligible changes in discharge in the Dong Nai river basin. With respect to the highest floods in each computation phases, the differences in total discharge of the upstream stations (Tri An, Dau Tieng, Phuoc Hoa, Thi Tinh and Vam Co Dong) are about 300-540 m^3/s. The differences in total inundated areas in the downstream part of the Dong Nai river basin between all scenarios are not dramatic.

The results also showed that as sea level rise together with the increase in rainfall, the difference in inundated areas between scenarios B1, B2 and A1FI are more pronounced.

Low elevation areas such as Ba Ria Vung Tau, downstream areas of HCM city, Long An and Tien Giang province were always inundated in high and medium flood conditions. In addition, parts of Binh Duong and Dong Nai provinces were also flooded.

As sea level rises, the extent of area inundated from 1m to 2m depth is also increased.

In general, the downstream area of the Dong Nai river basin has relatively large inundated area due to effects of climate change. Without impact of sea level rise due to climate change, the main reason of flooding is flow tides in combination with high river discharge. Therefore, the inundated areas under 1m depth are relatively large. Under climate change condition, the combination of flow tides, increasing river discharge due to heavy rainfall and sea level rise will cause greater inundation area and depth (from 1 to 2m depth).

If the sea level rise combines with high river discharge (without taking into account the flood prevention capacity for downstreams of reservoirs Dau Tieng, Tri An, Thac Mo, Phuoc Hoa), the inundation area and depth will be very high. Table 4 presents the inundation areas in Ho Chi Minh city computed for climate change scenarios B1, B2 and A1FI, in the period 2080 – 2100.

Table 4. Inundation area in Ho Chi Minh City in the period 2080-2100

Climate change Scenarios	Sea level rise 50cm		Sea level rise 75cm		Sea level rise 100cm	
	Inundation area (km^2)	Scale (%)	Inundation area (km^2)	Scale (%)	Inundation area (km^2)	Scale (%)
B1	1,805.9	86.2				
B2			1,833.2	87.5		
A1FI			1,862.6	88.9	1,889.4	90.2

7. Conclusion

The present paper analyses the current inundation situation and predicts the projected flooding taking into account the impacts of upstream river discharge, flow tide and sea level rise. The increase in sea level together with high river flow causes large inundation area and depth.

The inundation maps obtained from simulation results for three climate change scenarios together with comprehensive analysis on the trend and extent of flooding will assist decision makers in developing mitigation measures coping with flooding in the river basin.

Acknowledgements

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