Impacts of indundation on land use under climate change context in Cuu Long Delta

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Abstract: *Cuu Long Delta is a fertile delta with comprehensive river and canal system having great potential for the development in agriculture, industry, fisheries and ecotourism. The delta plays an extremely important role in the national economy of Vietnam, contributing more than 50% of food productivity and 65% of fish productivity. Its territory covers 13 provinces with the total natural area of 3.96 million hectares and a population of about 18 million people. Under irrigation development planning of Cuu Long Delta in 2012-2020 period and orientations to 2050 in terms of climate change and sea level rise approved by Prime Minister in 2012 has set a target of 2050 to ensure the safety of people's life, production and infrastructure for 32 million people and to respond to climate change, sea level rise and salinity intrusion. Therefore, assessment of impact of climate change on water resources in Cuu Long Delta has been becoming imperative. This paper presents results of study on impact of climate change on population distribution and land use in Cuu Long Delta. The results are part of state-level research project "Assessing impact of climate change on Water resources in Cuu Long Delta" under Science and Technology Program for the National Target Program to respond to climate change.*

Key Words: Cuu Long Delta, Mekong River Delta, inundation, climate change, landuse.

1. Introduction

Nowadays Climate change has been being a hot issue concerned by whole of the world. CC has been causing negative impacts on human living both environment and social-economics. The world has been facing with disasters caused by CC such as tropical eddies in Pacific ocean, high frequency of storms, droughts, salinity intrusions; diseases grow in many countries; biodiversity reduces significantly; food and water security is threaten in many regions of the world.

Vietnam is one of the most vulnerable countries under CC context and Cuu Long Delta is assessed as the area that will suffer most severely by climate change because of flatness of the low-lying terrain. Cuu Long Delta covers about 5% area of Mekong River basin and bordered by the East Sea. The delta is formed roughly as a triangle stretching from My Tho in the east to Chau Doc and Ha Tien in the northwest, down to Ca Mau and the East Sea at the southernmost tip of Vietnam.

Figure 1. Cuu Long Delta

2. Impact of climate change on inundation in Cuu Long Delta

2.1. Background

Flow into Cuu Long Delta comes from two major sources: external inflow from Cambodia and internal flow from rainfall in floodplains. External flow is influenced by flow from upper Mekong (considered by Kratie station) and flow from Tonle Sap lake (considered by Prek Dam station). Mekong River is joined on the right bank by the river and lake system the Tonle Sap. Immediately after that, the Bassac River branches off the right (west) bank and flows into Vietnam territory as Hau River at Chau Doc. The main distributary, Mekong River is named Tien River when flows into Vietnam at Tan Chau. Thus, study on flooding in Cuu Long Delta is a comprehensive task considering both inflow from upstream and sea level.

In baseline period (before 2011), on Mekong River there are many big floods occurred such as in 1961, 1966, 1978, 1984, 1991, 1994, 1996, 2000, 2001, 2002 and 2011. Whereas, floods in 2000, 2002 and 2011 have impacted strongly on inundation in Mekong Delta. Table 1 illustrates some flow patterns of flood events at major hydrological station on low Mekong River.

Table 1. Flow patterns of flood events at stations

Year	Kratie		Tan Chau		Chau Doc	
	H (m)	Q (m3/s)	H (m)	Q (m3/s)	H (m)	Q (m3/s)
1996	23.02	59035	4.86	23600	4.54	8150
2000	22.60	56273	5.04	26000	4.89	7680
2001	22.89	58180	4.77	23800	4.47	7120
2002	22.49	55554	4.81	24400	4.42	6860
2011	22.88	53252	4.78	25100	4.24	8210

Flood in 2000 was a two-peak flood and it occurs hardly in Cuu Long Delta. The first flood peak occurred on 2rd of August, water level at Tan Chau was approximately 4.19 m, 1.0-1.45m higher than water level in the same period in 1961, 1966 and 1996 and flood peak happened ealier about 1 month. The second peak occurred in main flood season in late Semtemper with extreme water level at Chau Doc (4.89 m) and high water level at Chau Doc (5.04 m).

As can be seen in table 1, water level at Tan Chau and Chau Doc was highest in 2000 flood event. Therefore, the authors considered flood event in 2000 as typical simulation for baseline period. The inundation results in baseline period would be basis for comparing and assessing impact of climate change and sea level rise on flooding in the future periods upto 2050. Flow scenarios in future at Kratie referenced the Technical Report of Mekong River Commission(MRC) are estimated for 10-year periods (2011-2020, 2021-2030, 2031-2040, 2041-2050) and in each period of A2 and B2 scenario, the MRC selects a flood event every year which has the maximum volume and highest flood peak and those flood events are in 2020, 2028, 2035 and 2047 for A2 and in 2016, 2028, 2032 and 2047 for B2.

Simulation scenarios are developed by combining extreme flood events (observed or estimated at Kratie station) and sea level rise scenarios. Those are described as below :

1. Baseline scenario : flood event in 2000; the results from baseline simulation will be used as the base for future scenarios.

2. F1 scenario, 2011-2020 period: flood in 2020, A2 climate change scenario and sea level rise 9 cm;

3. F2 scenario, 2021-2030 period: flood in 2028, climage change scenarios A2, sea level rise 15 cm;

4. F3 scenario, 2031-2040 period: flood event in 2035, climage change scenarios A2, sea level rise 20 cm;

5. F4 scenario, 2041-2050 period: flood event in 2047, climage change scenarios A2, sea level rise 30 cm;

6. F5 scenario, 2011-2020 period : flood event in 2016, B2 climate change scenario and sea level rise 9 cm;

7. F6 scenario, 2021-2030 period: flood event in 2028, B2 climate change scenario and, sea level rise 15 cm;

8. F7 scenario, 2031-2040 period: flood event in 2032, B2 climate change scenario and, sea level rise 20 cm

9. F8 scenario, 2041-2050 period: flood event in 2047, B2 climate change scenario and sea level rise 26 cm.

Some flow patterns of simulating scenarios at Kratie station are shown as Table 2, Table 3, Figure 2 and Figure 3.

Table 2. Flow patterns in periods of A2 scenario

Pattern / Period	Baseline	A2_2020	A2_2030	A2_2040	A2_2050
Daily max. flow (m^3/s)	56273	75305	66975	91795	95292
1 month max. volume (10^6 m^3)	132.2	131.4	114.6	123.9	166.8
3 months max. volume (10^6 m^3)	343.4	342.2	300.4	334.3	407.5
6 months max. volume (10^6 m^3)	498.8	487.0	438.6	524.7	602.6

Table 3. Flow patterns in periods of B2 scenario

Pattern / Period	Baseline	A2_2020	A2_2030	A2_2040	A2_2050
Daily max. flow (m^3/s)	56273	58822	49023	59077	90117
1 month max. volume (10^6 m^3)	132.2	128.6	111.0	127.2	118.3
3 months max. volume (10^6 m^3)	343.4	342.6	283.6	347.5	302.9
6 months max. volume (10^6 m^3)	498.8	498.3	432.4	493.9	500.8

Flood season in Cuu Long Delta starts from June to November. According to statistical data, maximum daily discharge at Kratie in future scenarios is higher than in baseline. In comparing to baseline scenario, for F3 (A2, 2031-2040), F4 (A2, 2041-2050), F7 (B2, 2031-2040) and F8 (B2, 2041-2050) scenarios, both flood peak and volume are higher. For F1 (A2, 2011-2020), F2 (A2, 2021-2030), F5 (B2, 2011-2020) and F6 (B2, 2021-2030) scenarios, flood peak is greater while total vome fluctuate (Tables and Figures as above). Specially, maximum flood peak could reach 95,292 m^3/s in 2050 for A2 (69% greater than baseline).

Downstream boundaries at esturaries corresponding to climate change scenarios are estimated from climate change and sea level rise scenarios proposed by Ministry of Natural Resources and Environment (MONRE) in 2012. Sea level rise changes characteristics of tide and coastline as well, that leads to change in sea level fluctuations. Based on sea level rise scenarios for Vietnam coastal line, the study estimated sea level fluctuations for estuaries of Cuu Long Delta by using ADCIRC model. Rainfall process in 2000 is assumed as rainfall scenario for simulation in Mekong Delta. This precipitation and flood scenarios are input into Isis model to simulate hydraulic regime in Cuu Long Delta. Isis model is inherited from MRC and IHMEN.

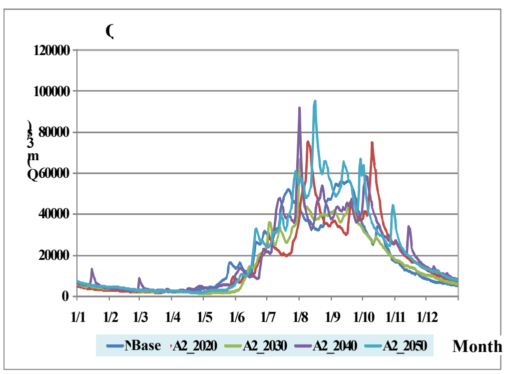

Figure 2. Hydrograph at Kratie in periods, A2 scenario

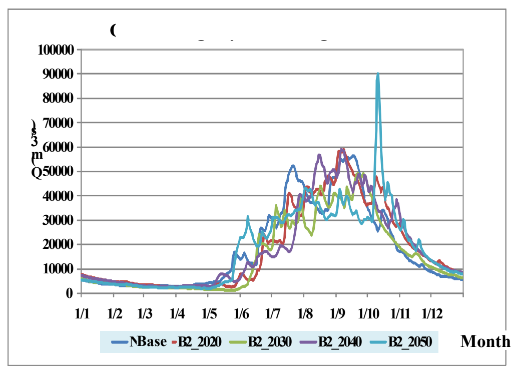

Figure 3. Hydrograph at Kratie in periods, B2 scenario

2.2 Impact of climate change on induation in Cuu Long Delta

In Cuu Long Delta, flooded area is about 1.9 million ha in flood season lasting 3-5 months and damages dramatically living and scio-economy. On other hand, flood transports huge amount of alluvias for Cuu Long Delta which help fertilizing soil, diversifying aquatic ecosysterm, deadcidifying and desalting for rice fields. The simulation results shows that in sea level rise 30 cm scenario, extreme floods in mid 21st century inundates about 2.7 million ha (greater 25-37% than baseline) occupying 60-67% total area of Cuu Long Delta. In which, area with flooded depth higher than 0.5 m is 1.6 million ha (40% area of Cuu Long Delta) and higher than 1.0 m is 1.9 million ha (26% area of Cuu Long Delta) (Figure 4 and 5).

Most of Cuu Long Delta area is agricultural and residential land. Thus, inundation affects seriously production and human living in Cuu Long Delta. This study assesses impact of climate change on agricultural land (2 crops and 3 crops) and residential land. The results are shown in tables and figures as follows:

Table 4. Flooded area corresponding to depths, baseline scenario

Land type	Flooded area corresponding to depths (ha)						
	Total	≥ 0,25m	≥ 0,5m	≥ 0.75	≥ 1m	≥1.25	≥ 1.5m
3 crops land	501628	354862	266607	208757	155677	123970	104024
2 crops land	858616	755293	691580	632300	581959	526593	448534
Residential land	288877	214189	172466	144619	121614	104913	89006

Table 5. Flooded area corresponding to depths, F1 scenario

Land type	Flooded area corresponding to depths (ha)						
	< 0.25m	≥ 0.25m	≥ 0.5m	≥ 0.75	≥ 1m	≥1.25	≥ 1.5m
3 crops land	581086	421660	303002	231072	176033	134370	111938
2 crops land	952564	795716	730126	668485	611420	559043	488582
Residential land	338705	245438	191365	157400	132590	112366	96670

Table 6. Flooded area corresponding to depths, F2 scenario

Land type	Flooded area corresponding to depths (ha)						
	< 0.25m	≥ 0.25m	≥ 0.5m	≥ 0.75	≥ 1m	≥1.25	≥ 1.5m
3 crops land	572869	398121	266382	189621	135950	107734	88529
2 crops land	966920	772757	668007	586413	515688	434329	354832
Residential land	338433	231428	167393	130985	106753	88198	70670

Table 7. Flooded area corresponding to depths, F3 scenario

Land type	Flooded area corresponding to depths (ha)						
	< 0.25m	≥ 0.25m	≥ 0.5m	≥ 0.75	≥ 1m	≥1.25	≥ 1.5m
3 crops land	610613	448576	304251	226350	167603	127719	105478
2 crops land	1025501	816503	716202	644813	591333	528486	442150
Residential land	369088	259750	190507	153593	128421	107523	88359

Table 8. Flooded area corresponding to depths, F4 scenario

Land type	Flooded area corresponding to depths (ha)						
	< 0.25m	≥ 0.25m	≥ 0.5m	≥ 0.75	≥ 1m	≥1.25	≥ 1.5m
3 crops land	661245	530182	355597	247873	176583	129254	103308
2 crops land	1132830	895084	750301	659285	587235	519622	433172
Residential land	415308	303444	212108	160913	128048	105787	86322

Table 9. Flooded area corresponding to depths, F5 scenario

Land type	Flooded area corresponding to depths (ha)						
	< 0.25m	≥ 0.25m	≥ 0.5m	≥ 0.75	≥ 1m	≥1.25	≥ 1.5m
3 crops land	578907	418609	298693	227427	172774	132253	109084
2 crops land	949746	792852	726215	661430	604521	556298	484545
Residential land	336859	243243	188938	154949	130241	110710	94840

Table 10. Flooded area corresponding to depths, F6 scenario

Land type	Flooded area corresponding to depths (ha)						
	< 0.25m	≥ 0.25m	≥ 0.5m	≥ 0.75	≥ 1m	≥1.25	≥ 1.5m
3 crops land	580497	409712	276875	197945	142043	112147	92756
2 crops land	976944	787193	689261	609066	544906	468664	385119
Residential land	343850	238499	174786	137102	112363	94711	77056

Table 11. Flooded area corresponding to depths, F7 scenario

Land type	***Flooded area corresponding to depths* (ha)**						
	< 0.25m	**≥ 0.25m**	**≥ 0.5m**	**≥ 0.75**	**≥ 1m**	**≥1.25**	**≥ 1.5m**
3 crops land	627309	481940	330563	241440	179506	134714	110637
2 crops land	1049132	839209	743233	670190	607118	555369	482502
Residential land	380755	274982	202408	161199	132869	111901	95344

Table 12. Flooded area corresponding to depths, F8 scenario

Land type	***Flooded area corresponding to depths* (ha)**						
	< 0.25m	**≥ 0.25m**	**≥ 0.5m**	**≥ 0.75**	**≥ 1m**	**≥1.25**	**≥ 1.5m**
3 crops land	655971	526102	361724	262247	194103	143863	114757
2 crops land	1112487	882474	762465	689518	621887	556762	480815
Residential land	407983	299775	217110	170627	139349	115767	96848

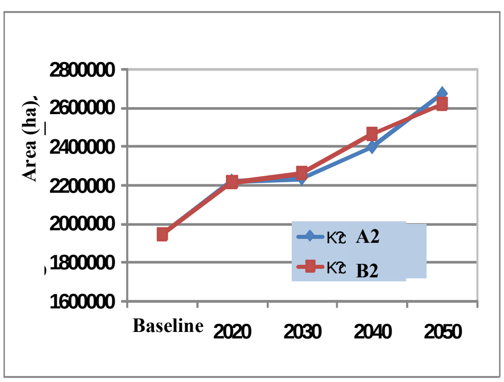

Figure 4. Change in inundation area in periods in Cuu Long Delta

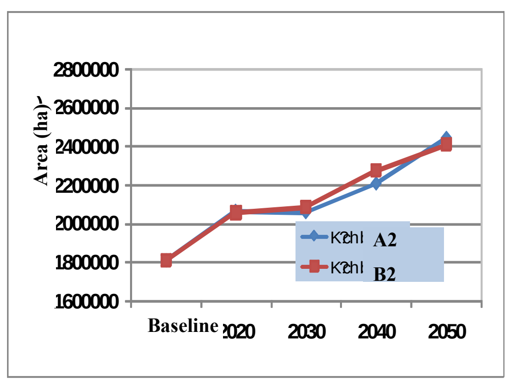

Figure 5. Change in inundation land in periods in Cuu Long Delta (agricultural and residential area)

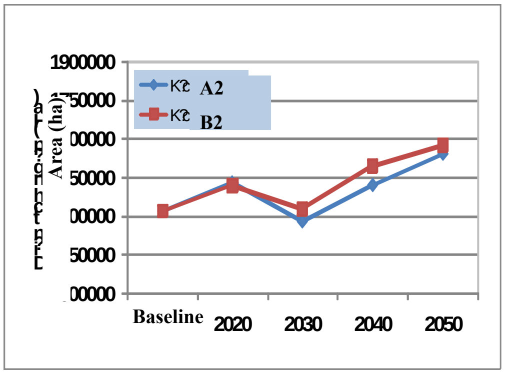

Figure 6. Change in 0.5m depth inundation area in periods in Cuu Long Delta

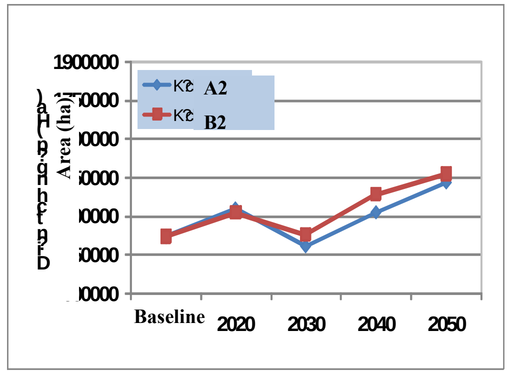

Figure 7. Change in 0.5m depth inundation land in periods in Cuu Long Delta (agricultural and residential area)

By analyzing the results, several key findings are shown:

+ In F1, F2, F5 and F6 scenarios (sea level rise 9-15 cm), total flooded area increase about 0.3 million ha (15%) compared to baseline (approximately 1.8 million ha). Flooded area with the depth higher 0.5 m is 1.2 – 1.3 million ha more 2-9% than baseline. The area for 1.0 m depth is near 1.0 million ha and greater 6-8% than baseline scenario.

+ In F3, F4, F7 and F8 scenarios (sea level rise 20-30 cm), total flooded area increase about 0.4-0.6 million ha (22-35%) compared to baseline. Flooded area with the depth higher 0.5 m is 1.3 – 1.5 million ha more 14-20% than baseline. The area for 1.0 m depth is around 1.0 million ha and greater 8-13% than baseline scenario.

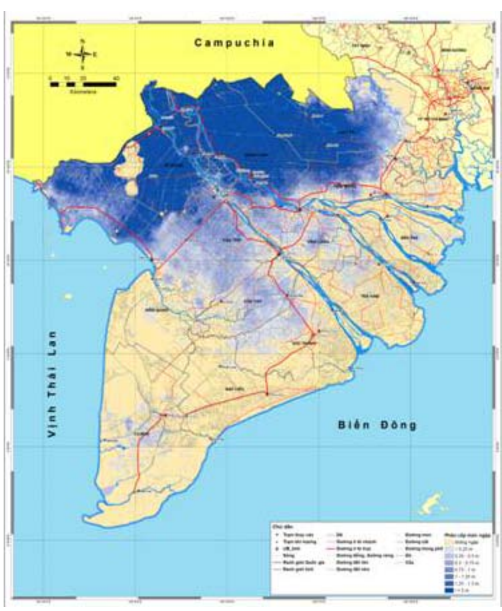

Figure 8. Inundation map of Cuu Long Delta in 2000, baseline cenario

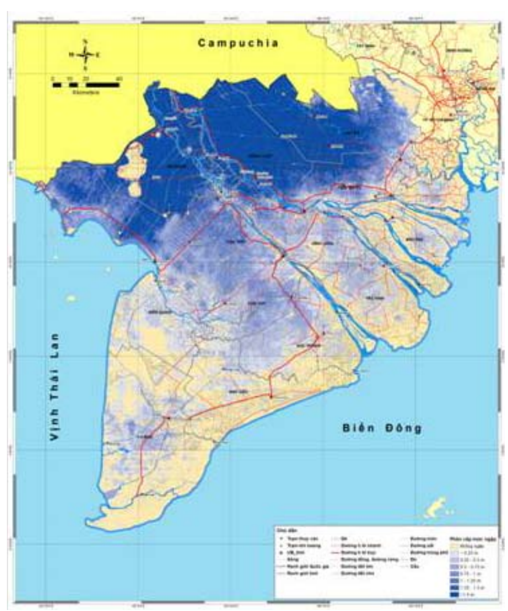

Figure 9. Inundation map of Mekong Delta in 2047, B2 scenario – sea level rise 30 cm

Conclusion

This paper summaried results of state-level research project "Assessing impact of climate change on Water resources in Cuu Long Delta". The study estimates inundated area in scenarios according to different flooded depths. The paper also assesses impacts of inundation on laduse especially agricultural and residential land. This would be a basic for social-economic development planning and resettlement – migration plans in the future.

References

[1.] AusAID. Adaptation Options to Reduce the Vulnerability of Mekong Water Resources, Food Security and the Environment to Impacts of Development and Climate Change. 2010

[2.] IMHEN. Impacts of climate change on water resources and adaptation measures. 2010

[3.] Tran Thuc, Nguyen Van Thang, Hoang Duc Cuong. "Develop climate change scenario for Vietnam". MeteoHydrology magazines. 2009

[4.] MRC. Adaptation to climate change in the countries of the Lower Mekong Basin. Regional synthesis report, MRC Technical Paper No 24, September 2009.

[5.] MRC. Impacts of climate change and development on Mekong flow regimes. First assessment – 2009. MRC Technical Paper No 29, June, 2010.

[6.] Prime Minister's Decision No. 1397/QĐ-TTg dated September 25th 2012 approving the Mekong River Delta Irrigation Plan in 2012-2020 and Orientation to 2050 in terms of climate change and sea level rise.

[7.] Southern Institute for Water resources planning. General Mekong River Delta Water resources plan in terms of climate change and sea level rise. 2010.

[8.] UNFCC. (1992). Retrieved from The United Nations Framework Convention on Climate Change.

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