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Impacts of climate change on the flow in Hong-Thai Binh and Dong Nai river basins

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Abstract. Climate change (CC) is one of the most significant challenges facing human beings in the 21st century. CC will seriously affect lives, production and environment worldwide. It also leads to the increasing temperature and one of its consequences is sea level rise, resulting in unpredicted changes of the river flow. This may cause more severe floods, serious drought and water shortage, further to continent of the salinity intrusions and negatively effect on the human's lives, socio-economic development. In order to assess the changes in flow in Hong - Thai Binh and Dong Nai river basins under influences of CC, in the article flow from two mentioned basins is analyzed under condition of CC. This is important basis to evaluate the effect of CC on other fields relating to water resources. In the article, rainfall-runoff model (MIKE 11 - NAM model) was used to determine the flow in essential locations in Hong – Thai Binh and Dong Nai river basins in the three CC scenarios: A2, B2 and B1 [1].

Keywords: Climate change, flow, Hong-Thai Binh, Dong Nai.

1. Introduction

Hong-Thai Binh and Dong Nai river basins are two of the three biggest river basins in Vietnam. Impacts of CC on these river basins can be very serious. One of the most effected factors is the flow on the rivers. To estimate the changes of flow on two river basins, MIKE 11-NAM was used.

MIKE 11-NAM can simulate flow of basin based on rainfall and evaporation as input data. The result of the routing process is the discharge in the river. Rainfall and evaporation data from 1980 to 2000 of meteorological stations in the basins were used for calibration and verification. NASH and RMSE indexes were used for evaluating calculation results. The flow at key stations was simulated according to three scenarios (A2, B1, and B2) [1].

The results of flow simulation show that the trend of annual flows in Hong-Thai Binh river basin is upwards and in Dong Nai river basin is downwards. For seasonal flows, in Hong-Thai Binh basin, the trend of flood season flows is upwards, of dry season flow is downwards; but in Dong Nai basin, it has decreasing trend in both seasons.

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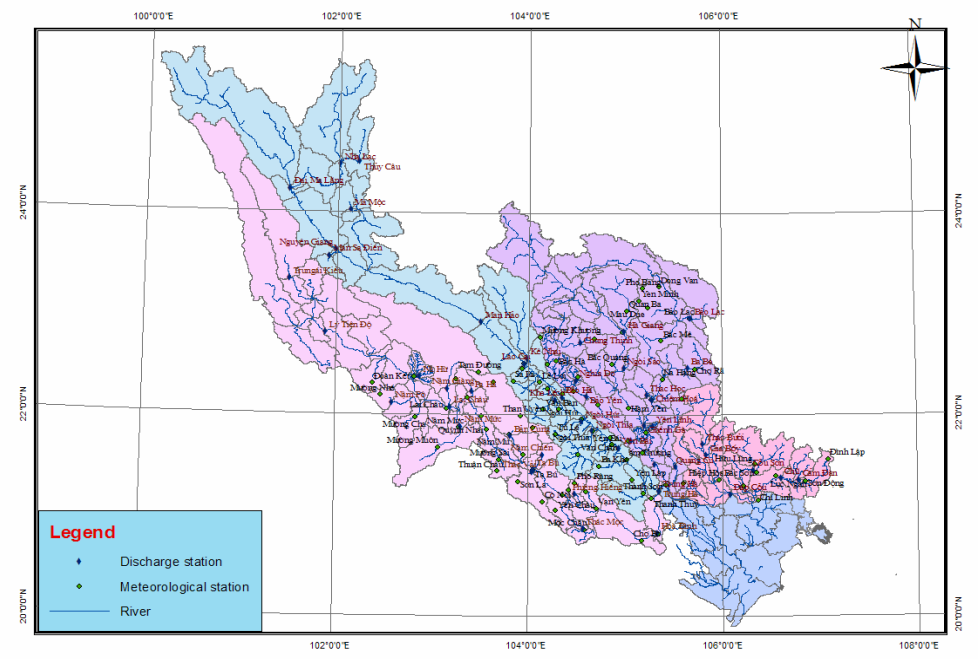

Figure 1. Hong-Thai Binh river basin.

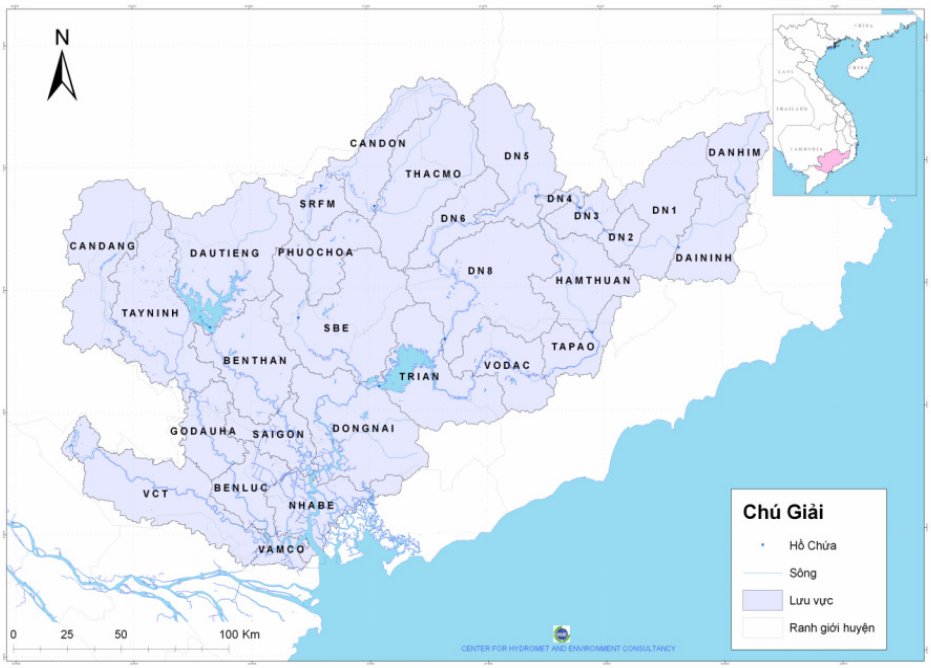

Figure 2. Dong Nai river basin.

2. Application of MIKE NAM model for simulating runoff in Hong-Thai Binh and Dong Nai basin

2.1. Input data

Meteorological data include potential evaporation and rainfall data.

Hydrological data: Average daily discharge data to 2010 at the 10 main hydrological stations in Hong-Thai Binh river system and the two ones in Dong Nai basin were collected for model calibration and verification.

Observation data at 49 rainfall stations and 38 evaporation stations in Hong-Thai Binh river basin and 27 rainfall stations, 11 evaporation stations in Dong Nai basin from 1980 to 2000 were collected.

2.2. Outputs

Outputs are daily discharge at the key hydro-stations in the rivers. These results can be used for water balance and hydraulic calculation.

2.3. Calibration and verification

Meteorological and hydrological data from 1980 to 2000 were used for calibration and verification: Data in the period 1980-1990 were used for calibration, and remaining data for verification.

Parameters were estimated by trial-error method (Table 1&2).

Based on hydrological station network as well as water use and DEM, Hong-Thai Binh and Dong Nai basin were divided into 16 and 29 sub-basins.

Table 1. NAM model parameters of some main sub-basins in Hong-Thai Binh basin.

No	Sub-basin	Area (km^2)	Parameters								
			Umax	Lmax	CQOF	CKIF	CK1,2	TOF	TIF	TG	CKBF
1	Lai Chau	33,882	13	102	0.228	200	35.8	0.631	3.54e-005	0.9	2,000
2	Ta Bu KG	10,607	10	221	0.628	200	50	0.533	3.92e-005	4.46e-005	1,243
3	Yen Bai	48,000	10	100	0.261	200	30.1	0.467	0.00978	9.97e-006	1,000
4	Bao Yen	4,960	23.6	165	0.307	498.4	29.4	0.459	0.453	0.7	2,000
5	Dao Duc	8,260	15.4	136	0.246	200	29.2	0.571	0.027	0.08	1,000
6	Chiem Hoa	16,500	6.75	139	0.489	471.6	42.7	0.344	0.528	0.2	1,800
7	Ghenh Ga KG	1,200	10	100	0.436	200	50	0.000429	0.000246	3e-005	1,000
8	Vu Quang KG	1,230	10.2	104	0.459	260.2	45.3	0.107	0.463	0.0282	3,019
9	Thac Buoi	2,220	10	100	0.476	200	26.9	2.77e-005	8.23e-005	0.176	3,219
10	Chu	2,090	10	100	0.697	200	33.2	0.0591	1.4e-005	0.864	1,263

Table 2. NAM model parameters of some main sub-basins in Dong Nai basin.

No	**Sub-basin**	**Area (km^2)**	**Parameters**								
			Umax	**Lmax**	**CQOF**	**CKIF**	**CK1,2**	**TOF**	**TIF**	**TG**	**CKBF**
1	Ta Pao	2,004.17	10	119	0.486	948.8	42.9	0.78	0.8	0.1	1,000
2	Phuoc Long	2,370	20	206	0.384	200	60	0.973	0.99	0.15	1,000

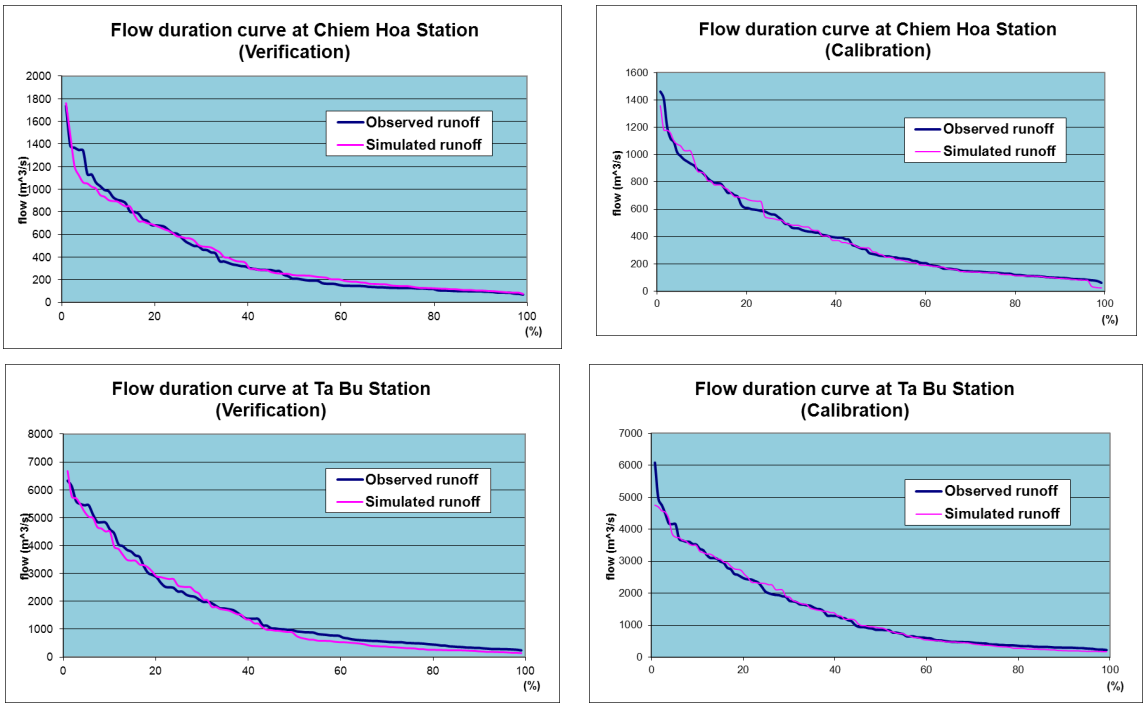

Figure 3. Observation discharge and Calculation discharge at some hydrostations in Hong-Thai Binh river basin.

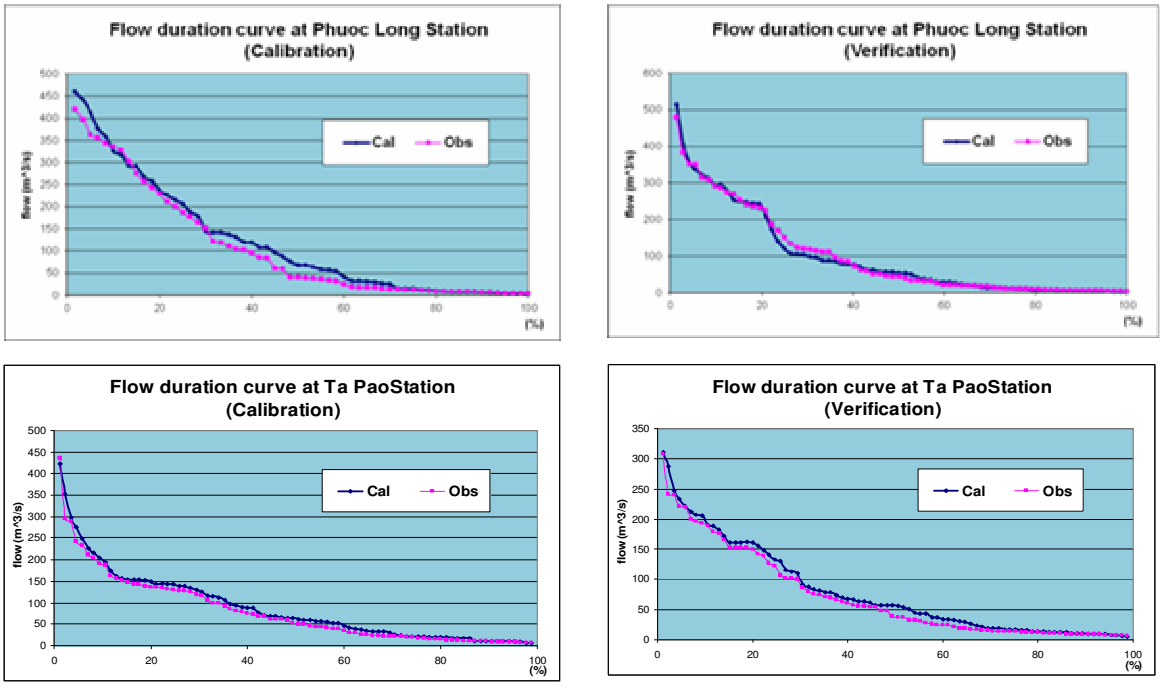

Figure 4. Observed and calculated discharges at some hydro-stations in Dong Nai river basin.

3. Assessing impacts of climate change on flow in Hong-Thai Binh and Dong Nai river basin

The flow at hydro-stations and sub-basins was simulated according to three climate change scenarios (A1, B1, B2). The period from 1980 to 2000 is baseline one; the flow was simulated in five periods: 2020 - 2039, 2040 - 2059, 2060 - 2079 and 2080 – 2099 for climate change scenarios.

3.1. Annual flow

The total annual flow in the Hong-Thai Bình river basin has an increasing tendency in all three scenarios. While flow of the Dong Nai river basin has a decreasing in the period from 2020 to 2100.

In Hong-Thai Binh river basin: There are many large tributaries in the system. Variation of simulated flow in the sub-basins is different in each climate change scenario. However, it can be seen that the trend of average annual flow is upwards in comparison with baseline period, and period by period. In accordance to the changes of precipitation and potential evaporation. In particular, the difference is evident in the period 2080-2099.

In Dong Nai river: although both rainfall and potential evaporation are increased, but the increase in rainfall is not considered, while there is a rapid increase in evaporation, thus it lead to a strong decrease in flow in some sub-basins. Among the three scenarios, the rates of change are different; the decreasing rate of annual flow in B1 scenarios is the highest and in A2 scenario is the slowest.

3.2. Flood season flow

According to three climate change scenarios, there are increasing trends of flood season flow in Hong-Thai Binh basin. In general, the increase in flood flow in the A2 scenario is the highest in comparison with the baseline period and in the B1 scenario the lowest. Meanwhile, the flow in the months of flood season in Dong Nai basin has decreasing tendency. The trend of change in monthly flow changing during the flood season is similar to that in flood season flow.

3.2.1. For Hong – Thai Binh river basin

In the period 2020-2039: Compared with the baseline period, calculated flood flow at the stations increase from 1 to approximately 2%. Flood season discharge at Yen Bai station in scenario A2is 1327m^3/s increasing by 1.7% compared with the baseline period; at Ta Bu station is 2881m3/s increasing by 1.57%; at Vu Quang station is 1769m3/s increasing by 1.13%. The increasing in flood flow corresponding to scenarios at the three stations Yen Bai, Ta Bu and Vu Quang are 1.72%, 1.56% and 1.29% (B2 scenario), 1.97%, 1.79% and 1.46% (B1 scenario). Respectively, this period shows that there are unconsidered differences of the increase in flow in the scenarios. The increase in flood flow in scenario B1 is the highest.

In the period 2080 - 2099: Flood flow discharge increases quite markedly compared with the baseline period as well as significant differences in calculated results in the scenarios, among them increase in the flood flow in the A2 scenario is the highest, at the stations Yen Bai, Ta Bu and Vu Quang are 1418m^3/s (increasing by 8.71%), 3041m^3/s (increasing by 7.22%) and 1855m^3/s (increasing by 6.08%). The calculation flood flow in B2 scenario is smaller. And the increases in comparison with baseline are respectively 6.96% at Yen Bai station, at 5.86% at Ta Bu station and 5.24% at Vu Quang station. Those in B1 scenario are 4.55%, 3.87 and 3.34%, respectively.

3.2.2. For Dong Nai River Basin

In the period 2020-2039: Flood season discharge at the Phuoc Hoa station in A2 scenario is 467m^3/s decreasing by 4.5% markedly compared with the baseline period; at Ta Lai station is 544m^3/s decreasing by 3.1%; at station Ta Pao is 154m^3/s decreasing by 1.9%; at Tri An station is 863m^3/s decreasing by 2.8% and at Phuoc Long station is 154m3/s decreasing by 2.6%. The decrease of flood flows under different scenarios at stations Phuoc Hoa, Ta Lai, Ta Pao, Tri An and Phuoc Long are 4.5%, 3.1%, 1.9%, 2.8 % and 2.5% (B2 scenario); 4.7%, 3.0%, 1.8%, 2.7%, 2.7% and 2.4% (B1 scenario). Respectively, this period shows that there is not significant difference the reduction level of flow among the scenarios. The decrease in the B1 scenario is the highest.

In the period 2080-2099: Flood season discharge decreases quite markedly compared with the baseline period as well as significant differences in results calculated by the scenarios. Accordingly, the calculation results shows that B1 scenario results in the strongest decreasing flood flow, at Phuoc Hoa, Ta Lai, Ta Pao, Tri An and Phuoc Long stations are 456m^3/s (decreasing by 6.7%), 520m^3/s (decreasing by 7.5%), 151m^3/s (decreasing by 3.7%), 839m^3/s (decreasing by 5.6%) and 152m^3/s (decreasing by 4.5%). Respectively, the flood season flow in B2 scenario is smaller and decreases in comparison with the baseline period are 7.4% at Phuoc Hoa, 8.0% at Ta Lai, 4.7% at Ta Pao, 7.1% at Tri An and 5.7% at Phuoc Long. In B1 scenario the decrease are 9.0%, 8.8%, 5.3%, 7.7% and 6.3% respectively.

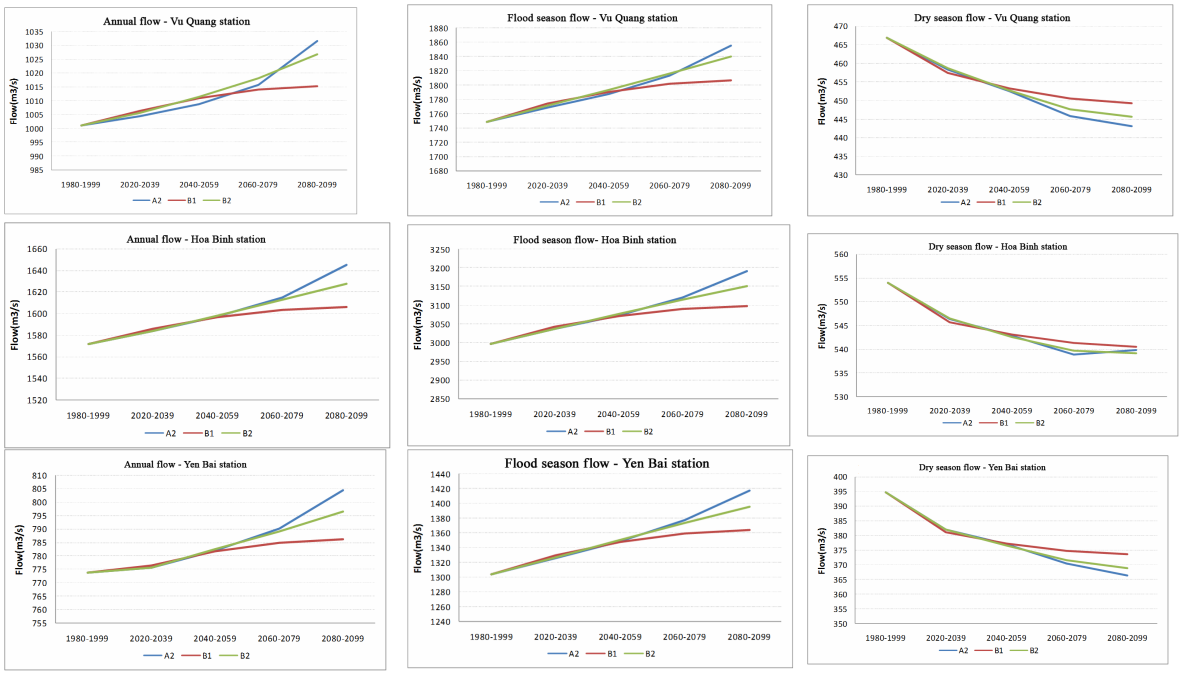

Figure 5. Annual flow, flood season flow, dry season flow at some sub-basins in Hong-Thai Binh river basin under climate change scenarios.

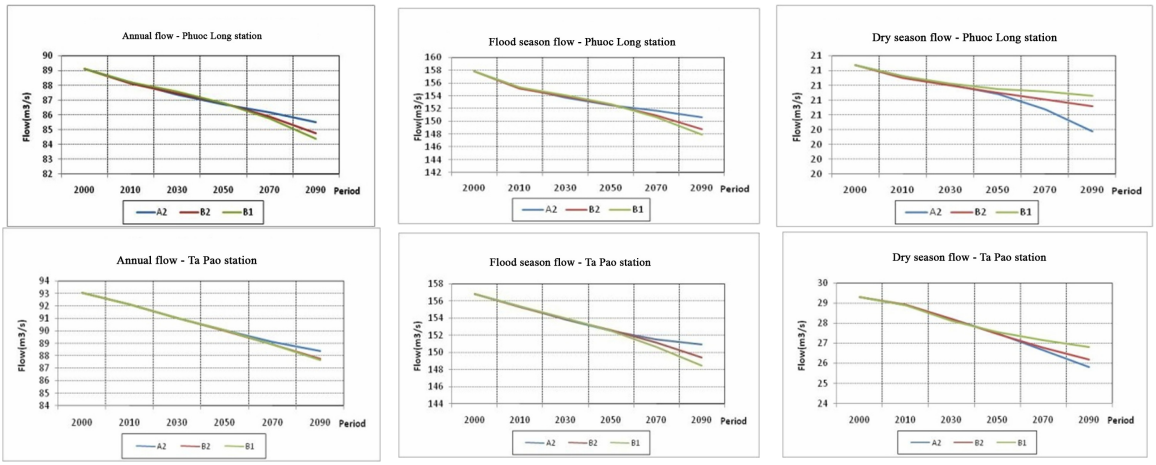

Figure 6. Annual flow, flood season flow, dry season flow in some sub-basins in Dong Nai river basin under climate change scenarios.

3.3. Dry season flow

There is a decreasing trend of average dry season flow in Hong-Thai Binh and Dong Nai basins in all three climate change scenarios.

3.3.1. For Hong-Thai Binh basin

In the period 2020-2039: in scenario A2, the average dry season flow at Yen Bai station is 382 m^3/s, smaller 3.26% in comparison with baseline; at Ta Bu station, it is 382m^3/s, smaller than baseline period 1,12% ; at Vu Quang station in Lo river, average dry season flow is 492 m3/s, decreasing by 9m3/s (1.84%). The decreases in B2 scenario is 1.72% (Yen Bai), 1.56% (Ta Bu), 1.29% (Vu Quang). And the decrease in B1 scenario is 1.97%, 1.79%, 1.46% respectively.

In the period 2080-2099: in scenario A2, average dry season flow at Yen Bai station decreases 28 m^3/s or 7.21% in comparison with baseline; in Da river basin, at Ta Bu station - 1.58%. In Lo river, at Vu Quang station, average dry season flow decreases 5.09%. The decreases in B2 and B1 are 6.58%, 5.38% (Yen Bai), 1.72%, 1.78% (Ta Bu), 4.56%, 3.78% (Vu Quang) respectively.

3.3.2. For Dong Nai basin

In the period 2020 – 2039: In scenario A2, the average flow in dry season at Phuoc Hoa station is 69m^3/s decreasing 3,9%; at Ta Lai station is 113m^3/s decreasing by 2,5%; at Ta Pao station is 28m^3/s decreasing by 4,0%, at Tri An station is 117m^3/s decreased by 3,4% and at Phuoc Long station is 21m^3/s decreased by 1,5% in comparison with baseline period. The correlate decrease in scenario B2 is 3,9% at Phuoc Hoa station, 2,6% at Ta Lai station, 40% at Ta Pao station, 3,5% at Tri An station and 1,6% at Phuoc Long station. The correlate decrease in scenario B1 is 4,1%, 2,7%, 4,3%, 3,7% and 1,7%.

In the period 2080 – 2099: In scenario A2, the dry-season flow at Phuoc Hoa station decreases to 4,2m^3/s or 8,3% in comparison with the baseline period; at Ta Lai station, the dry-season correlate flow decreases by 6,4%. The correlate decrease in scenario B2 and B1 are 6,8% và 6,1% at Phuoc Hoa station and 6,3% and 6,0% at Ta Lai station.

Table 3. Changes in annual flow, flood, dry season flow on Hong-Thai Binh basin in climate change scenarios in comparison with baseline period (%).

	Period	Vu Quang			Hoa Binh			Yen Bai			Chu		
		A2	**B1**	**B2**	**A2**	**B1**	**B2**	**A2**	**B1**	**B2**	**A2**	**B1**	**B2**
Annual	2020-2039	0.33	0.52	0.47	0.23	0.35	0.25	0.78	0.91	0.79	0.23	0.35	0.25
	2040-2059	0.77	0.97	1.04	1.05	1.01	1.12	1.61	1.57	1.69	1.05	1.01	1.12
	2060-2079	1.46	1.29	1.70	2.12	1.43	1.98	2.73	2.03	2.60	2.12	1.43	1.98
	2080-2099	3.04	1.41	2.57	3.97	1.59	2.93	4.66	2.18	3.56	3.97	1.59	2.93
Flood season	2020-2039	1.13	1.46	1.29	1.70	1.97	1.72	1.34	1.54	1.35	1.70	1.97	1.72
	2040-2059	2.21	2.43	2.57	3.40	3.32	3.55	2.55	2.49	2.66	3.40	3.32	3.55
	2060-2079	3.69	3.09	3.88	5.63	4.20	5.31	4.15	3.14	3.94	5.63	4.20	5.31
	2080-2099	6.08	3.34	5.24	8.71	4.55	6.96	6.52	3.38	5.17	8.71	4.55	6.96
Dry season	2020-2039	-1.84	-2.01	-1.74	-3.26	-3.49	-3.23	-1.37	-1.50	-1.35	-3.26	-3.49	-3.23
	2040-2059	-3.08	-2.93	-3.05	-4.51	-4.44	-4.62	-2.01	-1.97	-2.07	-4.51	-4.44	-4.62
	2060-2079	-4.51	-3.52	-4.14	-6.16	-5.12	-5.88	-2.72	-2.28	-2.58	-6.16	-5.12	-5.88
	2080-2099	-5.09	-3.78	-4.56	-7.21	-5.38	-6.58	-2.54	-2.43	-2.67	-7.21	-5.38	-6.58

Table 4. Changes in annual flow, flood, dry season flow on Dong Nai basin in climate change scenarios in comparison with baseline period (%).

Station		Ta Pao			Phuoc Long		
Scenario		A2	B2	B1	A2	B2	B1
Annual	2000 - 2019	-0.91	-0.96	-0.91	-1.61	-1.69	-1.61
	2020 - 2039	-1.89	-1.85	-1.79	-2.56	-2.48	-2.36
	2040 - 2059	-2.71	-2.68	-2.73	-3.33	-3.28	-3.28
	2060 - 2079	-3.32	-3.63	-3.90	-3.85	-4.34	-4.58
	2080 - 2099	-3.71	-4.73	-5.29	-4.52	5.73	-6.29
Flood season	2000 - 2019	-0.91	-0.96	-0.91	-1.61	-1.69	-1.61
	2020 - 2039	-1.89	-1.85	-1.79	-2.56	-2.48	-2.36
	2040 - 2059	-2.71	-2.68	-2.73	-3.33	-3.28	-3.28
	2060 - 2079	-3.32	-3.63	-3.90	-3.85	-4.34	-4.58
	2080 - 2099	-3.71	-4.73	-5.29	-4.52	-5.73	-6.29
Dry season	2000 - 2019	-1.59	-1.56	-1.65	-1.09	-1.13	-1.03
	2020 - 2039	-4.03	-4.01	-4.35	-1.48	-1.58	-1.47
	2040 - 2059	-6.41	-6.56	-6.23	-2.11	-2.06	-1.77
	2060 - 2079	-9.30	-8.86	-7.64	-3.12	-2.53	-1.99
	2080 - 2099	-11.91	-10.67	-8.54	-4.53	-2.95	-2.28

4. Conclusion

It can be seen that: in the three scenarios, the average flow has an increasing tendency in Hong-Thai Binh river basin and a decreasing one in Dong Nai river basin. For seasonal flow, in Hong-Thai Binh river basin, the trend of flood flow is upwards, dry season flow downwards. In Dong Nai river basin, the trend of both flood-season flow and dry-season flow is downwards.

Acknowledgements

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