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Impact of climate change on water resources in Ca River basin

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Abstract. Base on Climate Change Scenarios (A2, B2, B1), simulation outputs of river flow show the changes of water resources in Ca River. These results are arguments for water resources planning in Ca River under the climate change situations.

Keywords: climate change, water resources, Ca River.

1. Introduction

Climate change (CC) is a major concern of society in general and Vietnam in particular. Due to impacts of climate change, water resources in river is changed in quantity, quality, regime ... Within the framework of the paper, the impact of climate change on flow characteristics on Ca river basin is reviewed.

Ca river, which is largest river system in North Central, is the most important source of surface water for Nghe An and Ha Tinh provinces. Total area of Ca river basin is about 27.200 km^2, in which there are 9470 km^2 in the upper (34%) Laos, 17 730 km^2 (65.2%) in the middle and lower in most of the territory of two provinces of Nghe An - Ha Tinh and a part of the Nhu Xuan district of Thanh Hoa province. Total annual flow of the river system is about 23.1 km^3 Both of which flows into Laos from 4.45 km^3 and was formed in Vietnam km^3 18.6 (up 80.5%) [1].

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2. Climate change scenarios in Ca River basin

Greenhouse gas emissions scenarios which were selected to develop climate change scenarios are low emission scenario (B1 scenario), average emission scenario (scenario B2) and high emission scenarios (scenario A2). Base period (baseline) is 20 years from 1980-1999 [2].

2.1. Temperature

In Ca river basin, by the end of the 21st century, annual mean temperature would increase about 1.4^0C to $2,2^0$C in B1 scenario, about 2.0^0C to 3.1^0C in B2 scenario and about 2.7^0C to 3.4^0C in A2 scenarios, relative to the baseline period (1980 - 1999); After 2050, the difference in the extent of temperature change between the scenarios is more evident.

In Ngan Sau River and Ngan Pho river basins, temperatures rise at the highest rate. In the period 2080-2099, annual mean temperature

would increase to 3.7^{0}C at Ha Tinh station, 3.3^{0}C at Huong Khe station (table 1, figure 1).

2.2. Rainfall

The change of rainfall in seasons can be seen throughout the 21st century. Rainfall may increase in the rainy season and decrease in the dry season at all stations. Rainfall increases between July and December and decreases in January and May more than in the other months. At meteorology stations in mainstream of Ca River, by the end of the 21st century, the monthly rainfall can increase approximately 12.9% to 29.2 % according to A2 scenario, 24.5% (scenario B2) and 17.4% (scenario B1). At stations in Ngan Sau, Ngan Pho river basins, in the rainy season, rainfall increases is less, only 7% to 9%, while rainfall decreases significantly by -28% according to scenario A2 in dry season (figure 2).

Table 1. Changes in annual mean temperature (^{0}C) relative to period 1980-1999 at some stations in Ca River Basin

Scenarios	Periods	Stations								
		Con Cuong	Do Luong	Ha Tinh	Huong Khe	Quy Chau	Quynh Luu	Tay Hieu	Tuong Duong	Vinh
A2	2030 -2039	0.9	0.8	1.0	0.9	0.7	0.7	0.8	0.7	0.8
	2040 -2059	1.5	1.3	1.7	1.5	1.2	1.1	1.4	1.2	1.3
	2060 -2079	2.3	2.0	2.6	2.3	1.8	1.7	2.1	1.9	2.1
	2080 -2100	3.3	2.9	3.7	3.3	2.5	2.4	3.1	2.7	2.9
B2	2030 -2039	0.9	0.8	1.0	0.9	0.7	0.6	0.8	0.7	0.8
	2040 -2059	1.6	1.4	1.8	1.5	1.2	1.1	1.4	1.3	1.4
	2060 -2079	2.2	1.9	2.5	2.2	1.7	1.6	2.0	1.8	1.9
	2080 -2100	2.8	2.4	3.1	2.7	2.1	2.0	2.6	2.2	2.5
B1	2030 -2039	1.0	0.8	1.1	1.0	0.8	0.7	0.9	0.8	0.9
	2040 -2059	1.5	1.3	1.7	1.5	1.1	1.1	1.4	1.2	1.3
	2060 -2079	1.8	1.6	2.1	1.8	1.4	1.3	1.7	1.5	1.6
	2080 -2100	2.0	1.7	2.2	1.9	1.5	1.4	1.8	1.6	1.7

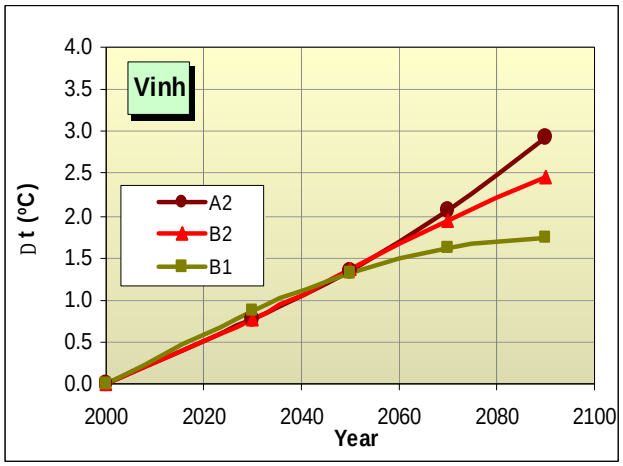

Figure 1a. Changes in annual mean temperature (^{0}C) relative to period 1980-1999 at selected stations.

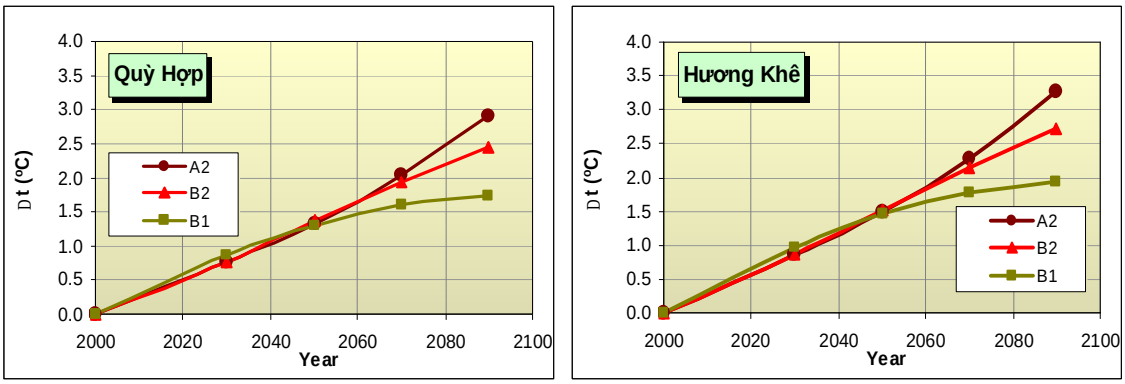

Figure 1b. Changes in annual mean temperature (^{0}C) relative to period 1980-1999 at selected stations.

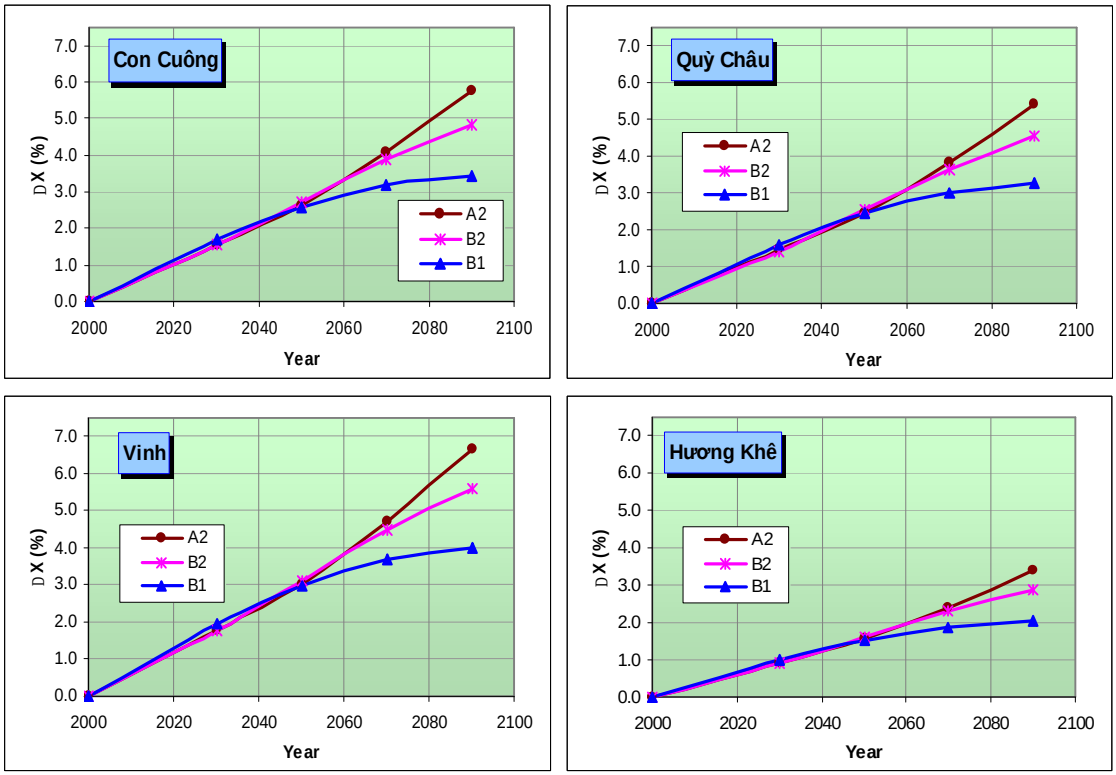

Figure 2. Change in rainfall relative to period 1980-1999 (%) at selected stations in Ca River basin.

2.3. Potential evapotranspiration (ETo)

Evapotranspiration is an important factor involved in direct hydrological cycle that causes changes in flow in the basin. The consequence of climate change is the change of air temperature causing change in evapotranspiration. As the temperature, annual evapotranspiration will be able to have an increasing trend. The annual mean potential evapotranspiration in three climate change scenarios would increase similarly relative to baseline scenario. After 2050, the increasing trend among the scenarios is different; the most in scenario A2 through B2 to B1. During period 2080-2099, the highest increases is 24.1% relative to period 1980-1999 in scenario A2, follow is 20.8% (scenario B2) and 15.2% (scenario B1) (figure 3).

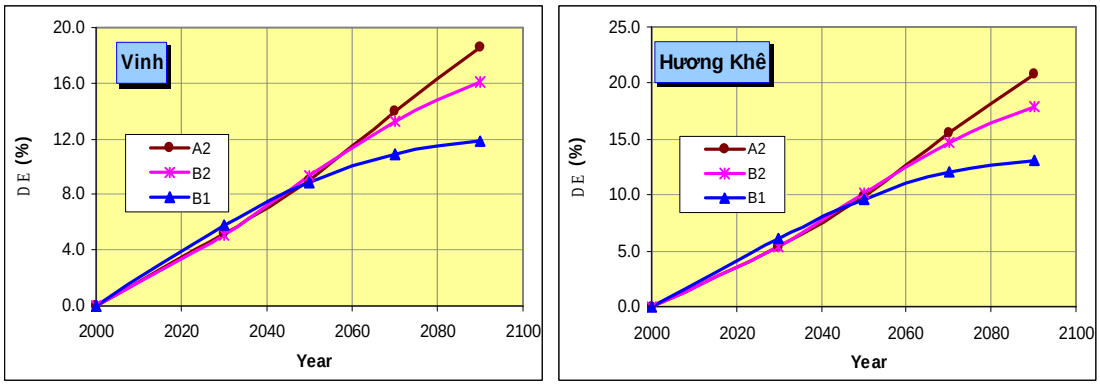

Figure 3. Change in evapotranspiration (%) relative to the period 1980-1999 at selected stations.

3. Impacts of climate change on river flow

In order to assess impacts of climate change on water resources, the rainfall-runoff model is used with projected rainfall, potential evapotranspiration in the future according to climate change scenarios. Analysing simulation results from model shows the picture of river flow in the future.

3.1. Annual flow

Generally, annual flow throughout the basin tends to increase in all three scenarios. However, the change in annual in each tributary has a certain difference.

In period 2030 – 2039: Change in annual flow between three scenarios A2, B2 and B1 compared to the baseline period is not so much different. At Yen Thuong on mainstream of Ca river, annual flow increase by 4.85 to 5.39 (m^3/s) (about 0.9 ÷ 1.07 %) depending on the scenarios. At Hoa Duyet stations on Ngan Sau River, annual flow decreases slightly (table 2).

Table 2. Change in rainfall, potential evapotranspiration (ETo) and runoff at selected hydrology stations in Ca River basin, scenario B2 [3].

Period	Station	Rainfall (%)	ETo (%)	Runoff (%)	Station	Rainfall (%)	ETo (%)	Runoff (%)
1980-1999	Nghia Khanh	0.00	0.00	0.00	Yen Thuong	0.00	0.00	0.00
2020-2039		2.00	4.56	1.18		1.93	4.78	0.73
2040-2059		3.29	8.20	1.91		3.36	8.77	1.60
2060-2079		4.54	11.62	2.73		4.73	12.49	2.47
2080-2099		5.59	14.04	3.64		5.91	15.15	3.63
1980-1999	Dua	0.00	0.00	0.00	Son Diem	0.00	0.00	0.00
2020-2039		2.02	4.62	1.09		0.86	5.56	-0.93
2040-2059		3.46	8.54	1.87		1.53	10.38	-1.57
2060-2079		4.83	12.21	2.81		2.17	14.95	-2.09
2080-2099		6.01	14.82	3.90		2.71	18.22	-2.26
1980-1999	Thac Muoi	0.00	0.00	0.00	Hoa Duyet	0.00	0.00	0.00
2020-2039		1.78	5.75	0.43		0.89	5.43	-0.36
2040-2059		3.17	10.45	0.93		1.61	10.32	-0.63
2060-2079		4.50	14.84	1.51		2.29	14.89	-0.86
2080-2099		5.62	17.94	2.22		2.87	18.09	-0.91

In period 2080 – 2089, on mainstream of Ca river, the flow increase quite high relative to period 1980 - 1999. According to scenario A2, annual flow at Yen Thuong increases over 5% relative to baseline. In accordance with scenarios B2 and B1, annual flow at Yen Thuong increases from 2.1% to 3.75%. In Ngan Sau River basin, in period 2080 – 2099, annual flow is lower the period 1980-1999 and 2020-2039. At Hoa Duyet station, annual flow according to scenario A2 reduced 0.98% relative baseline period. The results corresponding to B2 and B1 reduced by approximately 1.06% and 0.96%.

The change of flow in different branches is the results of the different changes of rainfall and evapotranspiration according to scenarios in each sub-catchment. In mainstream, annual flow tends to increase markedly over the period, while the tributaries such as La; Ngan Sau tends to decrease slightly. Flow across the system tends to increase in accordance with the trend of rainfall, evapotranspiration and temperature in different climate change scenarios.

3.2. Flow in flood season

In period 2020 – 2039: In scenario A2, average flood flow at Yen Thuong station raises approximately 2.19%; at Hoa Duyet increases about 0.96% relative to the period 1980 - 1999. The increasing of average flood flow for

scenario B2 at two stations Yen Thuong and Hoa Duyet are 2.19% and 0.95%, for scenario B1 will be 2.45% and 1.05%. In this period, there is no significant difference between 3 scenarios.

In period 2080 – 2099, flood flow increases considerably over the period and is a big difference between three scenarios. At Yen Thuong and Hoa Duyet stations, comparing with baseline period, according to scenario A2, flood flow increases about 9.55% and 3.73%. For scenario B2, results are lower than A2, with increase by 7.58% at Yen Thuong and 3.01% at Hoa Duyet. Scenario B1 augments the lowest rate, only 4.98% and 2.07%.

In general, flow in months of flood season has an increasing trend. At Yen Thuong station, flow in August has the highest increasing trend, from 4.4% in period 2020-2039 to 17.7% in period 2080-2099 compared with baseline period in scenario A2. In accordance with Ngan Sau River where flood season starts later, from September to December, in period 2020 – 2039, flow in November increases the most about 1.26% and in period 2080 – 2099, flow in December has the largest increase is 4.27%.

3.3. Flow in dry season

Normally, flow in dry season has a reducing trend in entire basin.

In period 2020 – 2039, according to scenario A2, average flow in dry season at Yen Thuong would reduce about 2.42% relative to period 1980 - 1999. At Hoa Duyet station on Ngan Sau river, average low flow also decrease 3.87% compared with baseline period. The falling rate of low flow corresponding to scenario B2 is 2.33% at Yen Thuong station and 3.79% at Hoa Duyet station, and to scenario B1 is 2.75% and 3.46%.

In period 2080 – 2099, in scenario A2, average low flow at Yen Thuong station reduces 7.16% compared with baseline period. At Hoa Duyet station on Ngan Sau River, low flow reduces 12.6%. Corresponding reductions in B1 and B2 scenarios are 6.9% and 5.75% at Yen Thuong stations, 11.1% and 8.44% at Hoa Duyet.

Analyzing flow distribution in dry months shows that: in the first and middle months of dry season, although rainfall downs but low flow still rise because the recharge of ground water which is cumulated in rainy season. At the end of dry season, starting transition to flood season, although rainfall increases a little but this mount of rainfall almost fills for soil moisture leading to low flow increases strongly. Flow in May has the biggest reduction. According to A2 scenario, average flow of May in period 2020 – 2039 at Yen Thuong and Hoa Duyet decrease corresponding 8.8% and 6.8% relative to period 1980-1999; in period 2080 – 2099, this rare is 26.7% and 26.4%.

Change of annual flow and flow in flood and dry season at two typical hydrology stations are shown in figure 4.

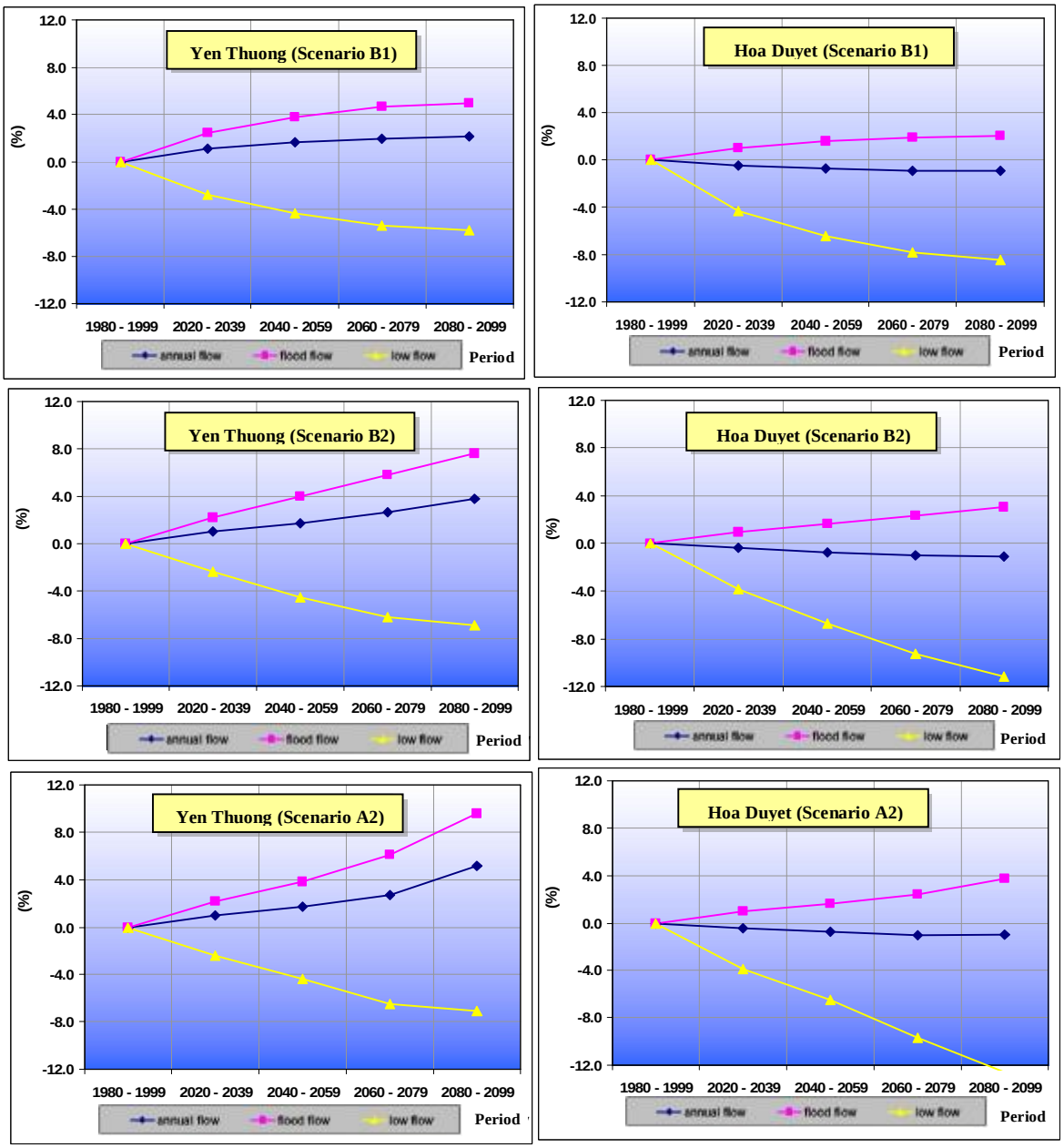

Figure 4. Rate of change in annual flow, flood flow and low flow (%) at Yen Thuong and Hoa Duyet stations according to climate change scenarios [3].

4. Conclusions

Climate change scenarios for Ca River basin in 21st century are developed corresponding to low, medium and high emission scenarios. Base on climate change scenarios, the changes in water resources has assessed.

At the end 21st century, overall Ca basin, annual mean temperature increases about 2.2^0C relative the period 1980 -1999 and would be reach to 3.7^0C in Ngan Pho, Ngan Sau River Basin. Average potential evapotranspiration (ETo) in Ca basin rises from 13% to 24%.

Total annual rainfall in Ca basin by the end of 21st century tends to increases from 3% to 6% compared with period 1980 - 1999. In rainy season, rainfall may increase over 9%, maximum increasing in a month can be reach nearly 30%. In dry season, rainfall decreases from 2% to 9%, and largest reduction rate in a month can be found about 27% at several locations.

Climate change could lead into increasing annual flow volume. In mainstream, by the end of 21st century, average annual flow increases about 3%. In Ngan Sau, Ngan Pho rivers, it reduces about 0.9% relative to period 1980-1999.

In flood season, average flood flow increases about 10% in mainstream of Ca river and 3.5% in Ngan Pho, Ngan Sau rivers. Average monthly flow in flood season could increase 16% in mainstream and 3% to 4% in tributary relative to baseline period.

Average low flow on overall basin has a decreasing trend, with greater reducing on right side of Ca basin. Average flow in last month of dry season and transition month to flood season reduces the most.

Acknowledgements

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