Research Paper

THE EFFECT OF CLIMATE CHANGE ON THE SURFACE WATER RESOURCES OF THE LAM DONG PROVINCE

Nguyen Thi Hang[1], Nguyen Ky Phung[2]

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ABSTRACT

Lam Dong is a province located upstream of the Dong Nai river system. Although not as complicated as the downstream provinces affected by natural disasters related to sea level rise, Lam Dong suffers from typical disasters such as droughts and floods. This study focused on assessing the impact of precipitation on flow changes by Mike NAM model. Under the impact of climate change, the results of river basin flow calculations according to climate change scenarios show that the flow of river basins has a marked change in stages, and in particular , under the influence of climate change, the trend tends to increase. Annual flow, in the period 2016- 2035, the Dong Nai river basin increases by 1.75% on average, the Krong No river basin increases by 1.63%, the La Nga river basin increases by 1.79% and the Luy river area Cai Phan Thiet river increased by 2.2%. Research results can serve as a basis for local reference in water resource planning and socio-economic development.

Keywords: *Climate change, water resources, Lam Dong, Mike NAM.*

1. Introduction

Climate change (CC) is one of the biggest challenges in the 21st century. In the fourth report of the Intergovernmental Panel on Climate Change (IPCC-AR4), it was emphasized that global warming and CC are an inevitable phenomenon. Climate change can lead to changes in the hydrological cycle and has a great impact on water resources. In recent years, research on the impacts of climate change on water resources, especially surface water, has attracted the attention of researchers around the world. In these studies, hydrological models are often combined with climate scenarios from global circulation models (GCMs) to examine the possible effects of climate change on water resources and hydrological cycle. The climate change scenarios used in these studies are mainly used from climate change scenarios of the Ministry of Natural Resources and Environment in 2016 (MONRE, 2016).

The objective of this study is to assess the impacts of climate change on changes in the flow of river basins in Lam Dong province. To accomplish this goal, the author used the hydrological

✉ Nguyen Thi Hang
Corresponding author: hangnguyen08@gmail.com
[1]Industrial University of HoChiMinh City
[2]Department of Science and Technology of Ho Chi Minh City

model NAM.

The results of this study provide a clearer view of the change in river flow in Lam Dong at present and in the future and help managers to plan water resources management and planning. for this basin.

2. Materials and methods

2.1. Materials

2.1.1 Introduction of the study area

Lam Dong is one of five provinces in the Central Highlands region of Vietnam, having a geographical location located in the 11°12'30" – 12°26'00" north latitude and 107°15'00" – 108°45'00" east longitude. The total natural land area of Lam Dong is 977,219.6 ha, accounting for 3.1% of the national area and 17.9% of the Central Highlands.

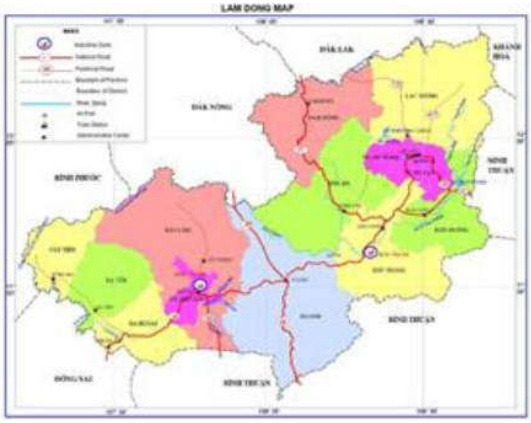

Fig. 1. Administrative map of Lam Dong province

Lam Dong is the watershed of two major river and stream systems: the system consists of the Krong No river - Srepok - Me Cong river with a basin area of 1,248 km^2 and the system of Dong Nai - La Nga river with basin area of 8,524 km^2 includes Da Dang, Da Nhim, Dai Nga, Da Huoai rivers and some tributaries on the left bank of Dong Nai Thuong river, flowing to the Southeast region. The rivers of Lam Dong province play an important role in supplying water to downstream areas of Dong Nai River and Binh Thuan Province.

2.1.2 The expression of climate change in Lam Dong

a. The expression of climate change

The expression of climate change is most evident in the characteristics of temperature and precipitation. Calculating and analyzing the series of data from 1980 - 2017 stations shows,

Assessing the trend of temperature factors from 1980 - 2017 shows that the average temperature of many years of Da Lat station is about 17.9°C, Lien Khuong is 21.3°C, Bao Loc is 21.9°C. The temperature trend of the area increased, in Da Lat the annual average temperature increased by 0.0184°C/year, Lien Khuong increased by 0.0223°C/year, Bao Loc increased by 0.0199°C/year.

Regarding precipitation factors, analyzing the data series from 1980 to 2017 showed that the average annual precipitation at Da Lat meteorological station is 1806.1mm, Lien Khuong station is 1602.4mm, Bao Loc station is 3834.9 mm. The annual precipitation trend increased, at 4.9575 mm/year at Da Lat station, at 2.3037 mm/year at Lien Khuong station, at Bao Loc station increased by 7,1698 mm/year.

Lam Dong also occurs many extreme climatic phenomena such as being strongly affected by ENSO phenomena causing droughts and floods.

b. Climate change scenario in Lam Dong province

Temperature

According to the climate change scenario of the Ministry of Natural Resources and Environment in 2016, the scenario RCP4.5, the annual average temperature in Lam Dong in the period of 2016 - 2035 increased about 0.7°C; in the period of 2046 - 2065, the temperature increases about 1.5°C; the period of 2080 - 2090 tempera-

ture increased about 1.9°C.

Thermal distribution in the year, the temperature increase in each month, different seasons, from October to December, the average temperature increases by 0.8°C in the period of 2016 - 2035, increases by 1.5°C in the period of 2046 - 2065 and an increase of 1.8°C in the period 2080 - 2090. In January to March, the average temperature increased by 0.7°C in the period of 2016 - 2035, increased by 1.5°C in the period of 2046-2065, increased by 2°C in the period 2080 - 2090. From July to September, the average temperature increases 0.7°C in the period of 2016 - 2035, increases by 1.5°C in the period of 2046-2065, increases by 1.9°C in the period of 2080-2090 [6].

Precipitation

According to the CC scenario, the average scenario of RCP4.5, precipitation in Lam Dong in the period of 2016 - 2035 increased 3.9%, the period 2046 - 2065 increased by 6.5% and the period 2080 - 2099 increased by 7, 8%.

Seasonally, from October to December, the average precipitation increases by 32.5% in the period of 2016 - 2035, an increase of 35.1% in the period of 2046 - 2065, an increase of 54.4% in the period of 2080 - 2090. From January to March, the average precipitation increased by 3.1% in the period of 2016 - 2035, down by 1.1% in the period of 2046 - 2065, increasing by 6.1% in the period of 2080 - 2090. From January IV to VI average increase of 3.8% in the period 2016 - 2035, up 4.6% in the period 2046 - 2065, increasing 4.1% in the period 2080 - 2090. And from July to October IX average precipitation increased by 10.4% in the period of 2046 - 2065, an increase of 3% in the period 2080 - 2090.

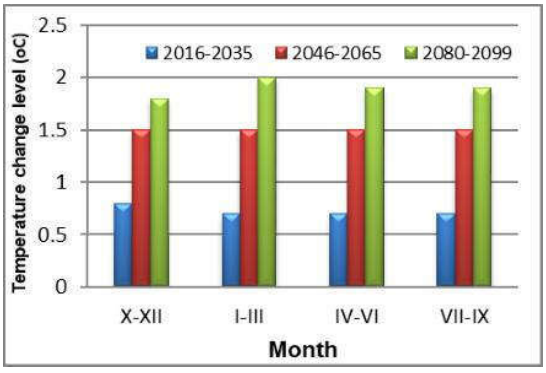

Fig. 2. Temperature changes for months of the year according to RCP4.5 scenario

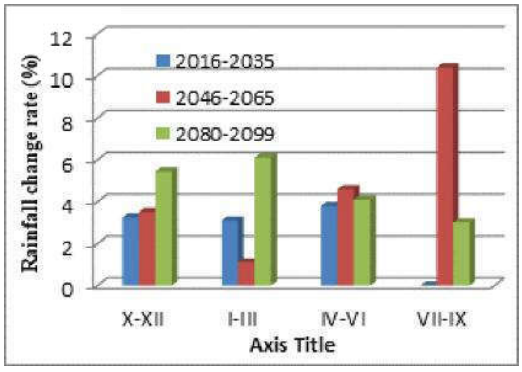

Fig. 3. The change in precipitation in months of the year according to RCP4.5 scenario

2.2. Methods

NAM model structure is built on the principle of vertical reservoirs and linear reservoirs, including 5 vertical tanks as shown in Fig. 4.

- Melted snow storage tanks are controlled by temperature conditions. For tropical climatic conditions in our country, this tank is not considered.

- Surface tank: the amount of water in this tank includes the amount of rain water blocked by the vegetation cover, the amount of water remaining in the depressions and the amount of water in the floor close to the face. The upper limit of this tank is denoted by Umax.

- Lower storage tank: is a land with roots, so plants can absorb water for evaporation and evaporation. The upper limit of the amount of water in this tank is denoted by Lmax, the

current amount of water is denoted by L and the ratio L / Lmax represents the moisture state of the reservoir.

- Upper water storage tank.
- Underground water tank.

Input data of the model

The required input data of the model is represented in two forms: spatial data and non-spatial data.

- Spatial data in the form of maps includes:

River basin topographic map: using elevation digitization model with ARCVIEW software to convert topographic map into DEM form;

Map of networks of rivers and streams, reservoirs in the river basin;

Map of land use;

- Non-spatial data in the form of Database include:

Data on meteorology: rain, evaporation, temperature, ...

Hydrological data: water flow, reservoir parameters;

Data on land include: soil type, soil characteristics, ...

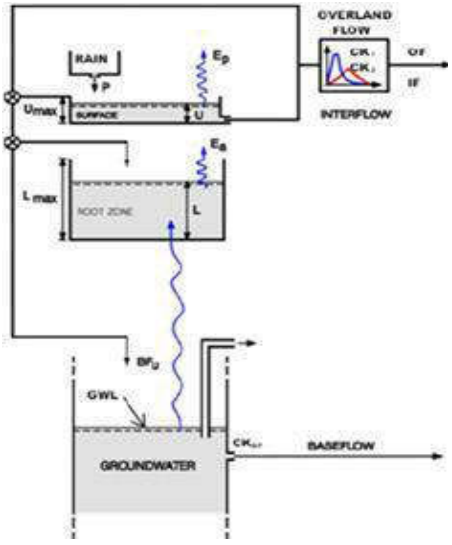

Fig. 4. NAM model structure

Output data of the model

- Calculate and evaluate the water flow, the total amount of incoming water in each sub-region by time (month, season, year);

- Restoring missing monitoring data at monitoring stations.

Edit model parameters to determine the model parameters so that the calculation process line is best suited to the actual process line. Correction of model parameters can be carried out by two methods: wrong test method or optimal method.

In summary, the NAM model is used to determine the process flow path at the watershed section of the basin from rain data by finding a set of parameters that are suitable for the characteristics of the study basin. In order to determine the required parameters, we need to have real flow metrics to measure a few years for model calibration and verification.

3.Results and discussion

3.1. Calculation of river basin flow in Lam Dong province

To assess the impact of climate change on river flows in Lam Dong province. Within the scope of this study, Mike Nam model will be used to calculate the current flow as well as the climate change scenarios.

- Input data of the rain flow model

For the NAM rainfall - flow model, the input of the model, including, spatial data and attribute data. As follows:

Spatial data include: DEM river basin map (90x90); Map of river and stream network in Lam Dong province; Map of grid system of meteorological and hydrological stations in Lam Dong and neighboring provinces.

Attribute data include: Control area of hydrological station; Meteorological data include rainfall, average evapotranspiration daily; Hydrological data include daily average flow.

Meteorological and hydrological data are used with time-of-day steps to allow the study of the flow in detail over time in the basin. Document of daily rainfall including meteorological

stations: Lien Khuong, Bao Loc, Da Lat from 1980 - 2015, in which, data for calculation of baseline scenario are compared with simulation results under the impact of Climate change is 1986 - 2005. In addition, rainfall data at the stations measured rain: Lac Duong, Di Linh, Da Chay, Dam Rong ...

Document on rainfall flow at Dai Ninh, Thanh Binh, Ta Lai, Duc Xuyen and Dai Nga stations.

Document on evaporation is taken from Lien Khuong, Bao Loc and Da Lat stations.

The DEM digitized elevation map combined with the river network map, the hydro-meteorological station network was included in ArcGis 9.3 to determine the topographical characteristics and determine the hydrological parameters of the basin as basin slope, flow direction for the purpose of dividing the basins for the analysis and calculation of flow in the river basin of Lam Dong province.

Fig. 5. DEM map of the study area

Based on a map of sub-basins, administrative maps, a network of rivers and streams, reservoirs, all of Lam Dong province is divided into 53 small sub-regions and the main river basins are Krong No river basin (Srepok) and La Nga. Thuong Dong Nai 1, Thuong Dong Nai 2, Da Nhim, Da Dang, and LVS Cai Phan Thiet - Luy river.

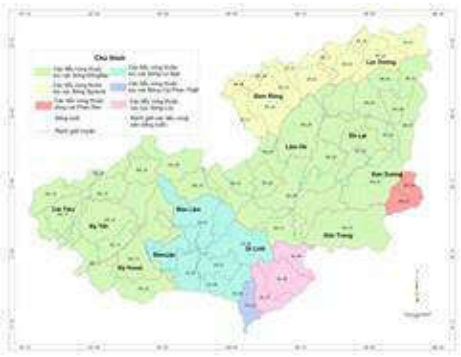

Fig. 6. Hydrological calculation section of Lam Dong province

At the same time, area data controlled by the hydrological measuring station are used to re-examine the divided basin area with ArcGis tool. The base basin map is exported as shape or txt as input to the NAM model.

Results of calculation of flow for river basins in Lam Dong province are as follows:

Results of flow simulation from 1980 - 2017, averaged over many years, the results are as follows:

The Krong No river basin,at Duc Xuyen station, has an average annual flow of 102 m^3/s, the average annual volume is 3216 million m^3. The average flow module for many years in the basin is calculated at 31.5 $l/s.km^2$, the maximum flow module is 222.7 $l/s.km^2$ appears in October/ 2010, the minimum flow module is 4, 2 $l/s.km^2$ appeared in March 2005. Flow regime in the Krong No river basin is divided into 2 seasons: flood season and dry season. The flood season lasts from August to November, the dry season lasts from December to July next year. The total surface flow generated in the entire Krong No and adjacent basin in the period of 1980 - 2017 is 1266.1 million m^3, accounting for 11.6% of the total surface flow in Lam Dong province.

The Dong Nai 1 upstream river basinis calculated from the retention section between Da

Dang River and Da Nhim River, the outlet of the basin up to the section running through Loc Bao Commune - Bao Loc City adjacent to Village 7 - Dak Commune Nia - Gia Nghia town - Dak Nong province, the main river in the basin is Dong Nai river, the length of the main river is 110 km. The average flow module for many years in the basin is calculated at 29.9 l/s.km^2. Flow regime in Thuong Dong Nai 1 basin is divided into 2 seasons: flood season and dry season. The flood season lasts from July to October, the dry season lasts from November to June next year. The total annual average flow of surface water generated over the entire basin of the Upper Dong Nai 1 is 1,174.6 million m^3. The total amount of water in the flood season is 824.6 million m^3, accounting for 70.2% of the average annual water volume, the dry season is 350.0, accounting for 29.8% of the average annual water volume.

Upstream of Thuong Dong Nai 2 river basinis calculated from the retention section between Dong Nai river and Dak Buk So river to the confluence between Dong Nai river and Da Huoai river (village 6 area - Da Kho commune - Da Teh district). - Lam Dong, the length of Dong Nai main river in the basin is estimated about 125 km Based on the calculation results of the above table, the average flow module for many years in the basin is calculated at 43.0 l/s.km^2. The largest monthly flow module is 161.4 l/s.km^2 appearing in August, 2006, the minimum monthly flow module is 2.7 l/s.km^2 appearing in March 2005. The flood season lasts from July to October, and the dry season lasts from November to June of the following year, the total annual average flow of many years arising over the entire Upper Dong Nai 2 basin is 2,726.0 million m^3, accounting for 25.0% of the total surface flow in Lam Dong province The total amount of water in the flood season is 1,913.7 million m^3, accounting for 70.2% of the average annual water volume, the dry season is 812.3 million m^3, accounting for 29.8 % of total average water for many years. In the period 1986 - 2005, the total flow of flood season was 1914 million m^3, the dry season was 812 million m^3 and the year was 2773 million m^3.

Da Dang river basin has 2 main rivers: Da Dang river and Cam Ly river, Da Dang river originating from Xa Lat area, Lac Duong town - Lac Duong district, then entering with Cam Ly river in Tan Van commune - Lam Ha district, the length of Da Dang river, taking into account the outlet of the basin about 70 km, Cam Ly river is about 64.1 km long. Calculating the flow of Da Dang river basin, the basin with average flow module in many years in the basin is calculated at 32.2 l/s.km^2. Flow in Da Dang basin is divided into 2 seasons, flood season and dry season. The flood season lasts from December to November, and the dry season lasts from December to July next year. The total annual surface flow generated in the entire Da Dang and adjacent basin is 1,272.2 million m^3, accounting for 11.7% of the total surface flow in Lam Dong province. The total amount of water in the flood season is 714.0 million m^3, accounting for 56.1%, the dry season is 558.2 million m^3, accounting for 43.9%.

The Da Nhim river basinhas the main stream of Da Nhim river, the river originates from the north of Gia Rich mountain (1,923m), Lac Duong district, Lam Dong province, near the border with Khanh Hoa and Ninh Thuan provinces, the river flows through Don Duong and Duc Trong districts and pouring into Da Dang river near Pongour waterfall, the length of the main river to the entry point with Da Dang river is about 130km. Based on the calculation results from the model, the average flow module

for many years in the basin is calculated at 29.2 l/s.km^2. According to the calculation results of the experience frequency of the calculation year, the flow regime in the basin of Da Nhim and adjacent rivers is divided into 2 seasons: flood season and dry season. The flood season lasts from August to November, the dry season lasts from December to July next year. The total average flow of surface water for many years in the entire Da Nhim and adjacent basin is 1,992.5 million m^3, accounting for 18.3% of the total surface flow in Lam Dong province. The total amount of water in the flood season is 1,118.2 million m^3, accounting for 56.1% of the average water volume in many years, the dry season is 874.3million m^3, accounting for 43.9% of the total average water volume for many years. In the period 1986 - 2005, the total annual flow generated in the basin was 1889 million m^3, the flood season was 1118 million m^3, the dry season was 874 million m^3. In terms of flow, the average water flow in the flood season is 106.1 m^3/s, the largest average water flow in the flood season is 187.9 m^3/s (in 2007), the smallest average water flow in the flood season is 57.7 m^3/s (2010). The dry season has an average water flow of 41.6 m^3/s, the largest water flow in the dry season is 87.2 m^3/s, the minimum flow in the dry season is 24.4 m^3/s.

La Nga River originates from Di Linh plateau, Bao Loc, the confluence of three small streams named: Roha, Dak Toren and Dak No at an average height of over 1,000m, the highest place to 1,460m. The basin of the river includes most of Bao Loc district (Lam Dong), Tanh Linh (Binh Thuan), Tan Phu and Dinh Quan (Dong Nai). The length of the river from source to destination is about 210km. The section running through Dong Nai province is 70km long. The length of the main river in the basin is estimated at 70 km, taking into account the outlet of the basin (Da Mi lake area - Loc Nam commune - Bao Lam district bordering Binh Thuan province). Based on the calculation results of the above table, the average flow module for many years in the basin is calculated at 51.4l/s.km^2. Moderate flow module in flood season is 101.6 l/s.km^2. Moderate flow module in dry season is 26.3l/s.km^2. The total average flow of surface water for many years in the whole La Nga and adjacent basin is 2,100.2 million m^3, accounting for 19.3% of the total surface flow in Lam Dong province. The total amount of water in the flood season is 1,391.7 million m^3, the dry season is 708.5 million m^3.

3.2. Impact of climate change on river basin flows in Lam Dong province

Within the scope of this study, only focus on assessing the impact of climate change on river flows according to RCP scenario 4.5.

Calculation of river basin flow according to climate change scenario RCP 4.5 shows that the flow of river basins has changed markedly in stages, and especially with the effects of climate change shows that the flow tends to increase.

a.The average annual flow

In the period of 2016-2035, the annual flow of Dong Nai river basin (Thuong Dong Nai 1, Thuong Dong Nai 2, Da Dang river basin and Da Nhim river basin) increases by 1.75% on average, the flow of Krong No river basin increases 1 , 63%, La Nga river basin increased by 1.79% and Luy river area of Cai Phan Thiet river increased by 2.2%. By the end of the century, the flow of Dong Nai river basin (Thuong Dong Nai 1, Thuong Dong Nai 2, Da Dang river basin and Da Nhim river basin) increased by 3.39% on average, the flow of Krong No river basin increased by 3.12 %, La Nga river basin increased by 3.39% and Luy river area of Cai Phan Thiet

river increased by 2.17%.

Period of 2046 - 2065: total annual flow of Thuong Dong Nai 1 river basin is 1195 million m^3, Thuong Dong Nai 2 river basin is 2771 million m^3, Krong No river basin is 1287 million m3, Da Dang river basin is 1295 million m^3, Da Nhim river basin 2022 million m^3, Luy river basin - Cai Phan Thiet about 378 million m^3.

Period 2080 - 2099: By the end of the century, the total flow in Thuong Dong Nai 1 river basin is 1212 million m^3, Thuong Dong Nai 2 river basin is 2808 million m^3, Krong No river basin is 1304 million m^3, Da Dang river basin is 1315 million m^3, Da Nhim river basin 2043 million m^3, the total flow in La Nga river basin is about 2168 million m^3, Luy river basin - Cai Phan Thiet about 382 million m^3.

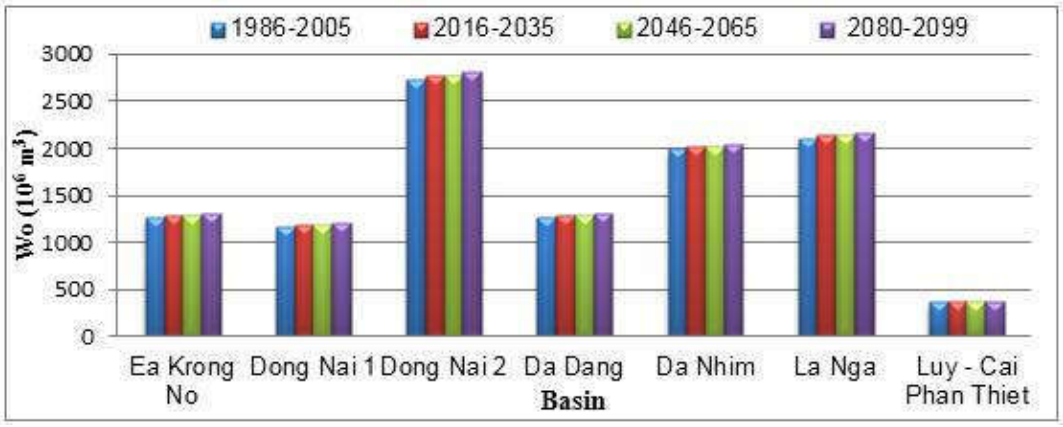

Fig. 7. Total flow of river basins according to RCP4.5 scenario (106 m^3)

b.The average flow in the flood season

The flow of flood season has many changes, in the period of 2016 - 2035, the flood season in Dong Nai river basin (Upper Dong Nai 1, Thuong Dong Nai 2, Da Dang river basin and Da Nhim river basin) increases by 1.13% on average. The basin of the Krong No river in the flood season increases by 1.2%, the La Nga river basin increases by 1.11% and the area of Luy river in Cai Phan Thiet river increases by 2.78%. By the end of the century, the flood season in Dong Nai river basin increased by an average of 2.89%, the river basin of Krong No flow increased 2.62%, La Nga river basin increased 2.94% and Luy river area Cai Phan Thiet river increased by 2.86%.

Period 2046 - 2065: total flow of flood season Thuong Dong Nai 1 river basin is 837million m^3, Thuong Dong Nai 2 river basin is 1941 million m^3, Krong No river basin is 774 million m^3, Da Dang river basin is 724 million m^3, Da river basin Nhim 1129 million m^3, La Nga river basin is 1412 million m^3, Luy river basin - Cai Phan Thiet about 173 million m^3.

Period 2080 - 2099: By the end of the century, the total flow of flood season in Upper Dong Nai 1 river basin is 848 million m^3, Thuong Dong Nai 2 river basin is 1964 million m^3, Krong No river basin is 783 million m^3, Da Dang river basin is 735 million m^3, Da Nhim river basin is 1135 million m^3, the total flow in La Nga river basin is about 1433 million m^3, Luy river basin - Cai Phan Thiet is about 176 million m^3.

c. The average flow in dry season

The dry season flow according to the RCP4.5 scenario tends to increase, especially in the period of 2016 - 2035 and the period of 2080 -

2099. In the dry season, the Dong Nai river basin (Upper Dong Nai 1, Thuong Dong Nai 2, Da Dang river basin and Da Nhim river basin) increases about 2.37%, the basin of Krong No river in dry season flows increases by 2.06% La Nga river basin increased by 2.47% and Luy river area of Cai Phan Thiet river increased by 1.62%

2016 -2035 2046 - 2065 2080 - 2099

Fig. 8. River basin flow module according to RCP scenario 4.5 (l/s.km^2)

4. Conclusion

Climate change scenarios for the Lam Dong river basin developed for the period 2016-2035, 2046-2065, 2080-2099 show an increase in temperature and increase in precipitation in the future. Rainy season has reduced but not significantly.

Under the impact of climate change, river basin flow calculations according to climate change scenarios show that the flow of river basins has markedly changed in stages, and in particular, under impacts of flow climate change tend to increase, especially, the flow in dry season also tends to increase slightly.

In general, the forecasted results of future flow changes may not be completely accurate due to uncertaimty in the forecast of the comprehensive climate models (GCM). However, the results achieved here can be referenced in the management of water resources in the river basin of Lam Dong province. In subsequent studies, the author will continue to consider the effects of climate change in conjunction with the effect of changing vegetation cover on flow changes.

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