Future Surface Water Resources Sensitivity to Climate Changes Impacts

Asadolah Akbarian Aghdam, Alimohammad Ahmadvand, Saeed Alimohammadi

Abstract— Due to water resources limitation in most parts of Iran, it is essential to give especial attention on evaluating and managing water resources. Climate changes would significantly affect water resources in future. In this study clime change impacts on water resources has been evaluated. "Karun" as the most watery river in Iran with an annual discharge of 4927.4 MCM at the site of Karun4 dam, is selected as case study. For this purpose 28 scenarios for precipitation and temperature, by using 11 models of AOGCM (Atmosphere-Ocean Global Circulation Model) models from CCCSN (Canadian Climate Change Scenario Network) are established and downloaded for next 90 years. Scenarios are downscaled for being usable for the study region. Evapotranspiration scenarios are generated by models which are provided for the case study region. The precipitation and temperature scenarios are used as input data by the mentioned models to generate future evapotranspiration scenarios. Multivariable empirical regression models based on 30 years monthly historical recorded data are generated to predict future monthly discharge scenarios. All of the models are tested with historical data. The precipitation, temperature, evapotranspiration and discharge scenarios are taken into account to estimate future surface water resources. The study shows that there would be a reduction of 17.20% (38.63 mm/year) in precipitation and 31.51% (58 m^3/s) reduction in annual discharge by the end of 2100. Also annual temperature would have a raise about 22.65% (3.82° C). River runoff would have 27.8% reduction and would cause more than 25% reduction in water surface resources.

Keywords:- MCM, AOGCM, CCCSN, reduction, precipitation, Evapotranspiration.

I. INTRODUCTION

Global warming is expected to occur due to increased carbon dioxide concentration in the atmosphere. Global surface temperature will increase by at least 2.0°C by the next century (IPCC 1996a). A significant change in the earth's climatic system, particularly an alteration of rainfall and temperature in both time and space, is expected [1]. Karun 4 dam's catchment area is categorized between cold and semi-dried to humid and mild climate type. The mentioned catchment area is approximately mountainous, its average elevation is 2354 m and its highest point is about 4200 m. The area at the dam boundary is about 12813.4 km2. Zagros high chain mountains have caused suitable conditions for proper rainfall in this catchment area [2]. High mountain water resources are particularly sensitive to climate change [3].

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The present study aims at quantifying the climate changes impacts on a water resource system and assessing the sensitivity of water resources to climate change. The used methodology has been developed to answer these two major challenges in the field of climate change impacts in the region: to obtain needed scenarios of climate factors and to suggest possible impacts of climate change on suggesting water resources in the future. An Empirical Multivariable Regression Method (EMR) is developed to estimate input discharge to the reservoir of dam. Despite recent papers on problems associated with full-model and stepwise regression, their use is still common throughout ecological and environmental disciplines [4]. The EMR methods have some advantages so that it is still common throughout ecological and environmental disciplines. While they can't include or show all physical conditions of discharge of the river, but they can be provided almost easily and have high accuracy equations for estimating the dependent variable. By using this method 4 models are generated. Some climate factors as precipitation, evaporation, temperature and pre-discharge are used as independent variables. Historical records (which are available for more than 40 years) were used as basic data for the models and all of them are calibrated with the historical data. The future climate factors values are provided from CCCSN using emission assessment AR4 (2007), 11 different models and SR-A1B, SR-A2 and SR-B1 Experiments. Among 65 scenarios there were 28 which could provide required data for this study. Each scenario presents different value for climate factors and also has a large grid size (2.5 to 3.5 degree). So as the downloaded data was large-scale data and couldn't be used for a local catchment and small area, downscaling data was necessary. For this purpose we have used statistical downscaling method. Evapotranspiration scenarios are not available directly from CCCSN network, so we have to establish those and generate data for evapotranspiration. This is done by using a monthly linear regression model for each month. These models are generated by using historical real data of temperature and evapotranspiration. These models are used to calculate evapotranspiration future scenarios from temperature scenarios. All of the 30 years monthly historical recorded data for precipitation, temperature, evapotranspiration and discharge are evaluated and controlled by hydrological methods to be complete and homogenous. The results for climate parameters scenarios obtained from CCCSN network for the region are compared with the outputs of MAGICC-SCENGEN software.

II. METHODOLOGY

The analysis of potential climate change impacts on the management of water resources requires not only climate factors values but also some models to generate values of dependent required factors which are affected by climate changes. Climate change is expected to alter the hydrological cycle resulting in large-scale impacts on water availability. However, future climate change impact assessments are highly uncertain [5]. Various climate scenarios have been used to suggest possible impacts, but the results indicate a range of outcomes, good and bad, depending not only on the climate but also on the operation of the utility itself [6]. For some cases the average value of scenarios is more reliable and reasonable, so we have used the mean value of climate factors instead working with one of them. Fig. (1) shows flowchart of the methodology.

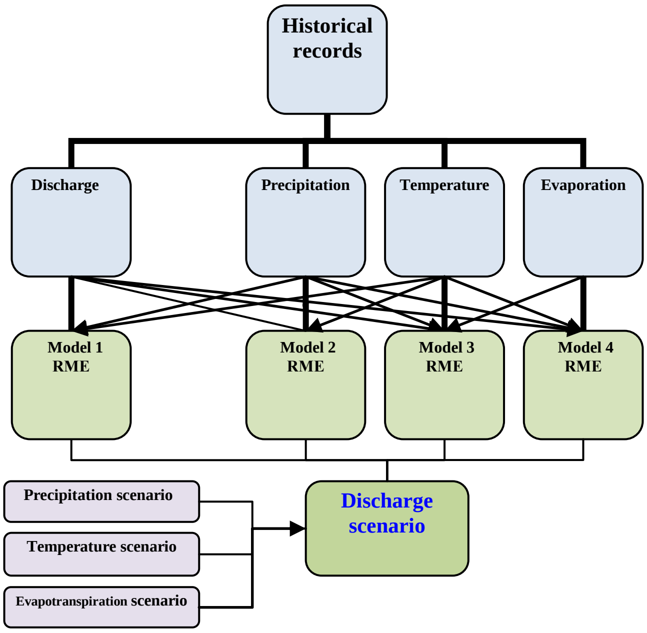

Fig. (1) – Flowchart of obtaining discharge long period scenarios (2010-2100)

If P, T, EVP, Qpre and Q stand for monthly precipitation, mean temperature, evaporation, previous and current month mean discharge, one dependent or response variable (Q) and multiple independent or predictor variables (P, T, EVP and Qpre), giving a dataset that is multivariate and multidimensional. The general empirical multivariable regression equations are as equations (1) and (2):

$$Q = a + b\, f_P(P) + c\, f_T(T) + d\, f_{Qpre}(Q_{pre}) \qquad (1)$$

$$Q = a + b\, f_P(P) + c\, f_T(T) + d\, f_{EVP}(EVP) + e\, f_{Qpre}(Q_{pre}) \qquad (2)$$

In wich a, b, c, d and e are coefficients of the variables of fP , fT , fEVP and fQpre (functions of P, T, EVP, and Qpre respectively). To obtain the best form of the functions, the results of the models should be tested with the real historical data. These functions can have any mathematical form but they are usually linear or logarithmic functions. All of the models should be based on real historical recorded data and should be calibrated with them. In this research we have used both linear and logarithmic form of the functions. Scenarios of monthly precipitation and temperature are downloaded from CCCSN for next 90 years and are downscaled by a new RGAM (Relative Grid Area Method) method. In this method if we consider the catchment area and the network grids of data as schematic Fig. (2) and it is assumed that 4 network grids ABEF, EHGF, EDIH and BCDE cover the catchment area (JKLM), since each grid will cover a part of the catchment and the catchment will be covered by several grids, it is possible to calculate a climate factor (K) value by an equation like equation 3.

$$K = \frac{K_{ABEF} A_1 + K_{FEHG} A_2 + K_{EDIH} A_3 + K_{BCDE} A_4}{Area} \qquad (3)$$

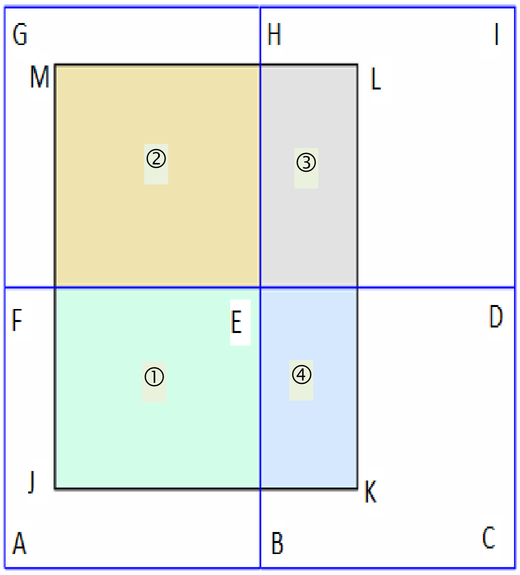

Fig. (2)- Sample network grids and catchment area position.

In equation (3) KABEF , KFEHG , KEDIH and KBCDE are the values of K factor in grids ABEF, FEHG, EDIH, and BCDE respectively and Area is the area of the catchment. Ai is the relative area of grid number i (i=1,2,3,4). The Ai , KABEF , KFEHG , KEDIH , and KBCDE can be computed by using equations like equations (4) and (5) respectively:

$$\begin{aligned} A_1 &= |(\lambda_B - \lambda_J)||(\varphi_E - \varphi_J)| \\ A_2 &= |(\lambda_E - \lambda_J)||(\varphi_L - \varphi_E)| \\ A_3 &= |(\lambda_K - \lambda_E)||(\varphi_L - \varphi_E)| \\ A_4 &= |(\lambda_K - \lambda_B)||(\varphi_D - \varphi_K)| \end{aligned} \qquad (4)$$

$$\begin{aligned} K_{ABEF} &= \frac{T_A + T_B + T_E + T_F}{4} \\ K_{FEHG} &= \frac{T_F + T_E + T_H + T_G}{4} \\ K_{EDIH} &= \frac{T_E + T_D + T_I + T_H}{4} \end{aligned} \qquad (5)$$

$$K_{BCDE} = \frac{T_B + T_C + T_D + T_E}{4}$$

The geographical coordinates (latitude φ and longitude λ) of the catchment area are as following:

$\lambda_J = 31.33$ *North Latitude* $\varphi_J = 49.55$ *East Longitude*

$\lambda_K = 32.67$ *North Latitude* $\varphi_K = 49.55$ *East Longitude*

$\lambda_L = 32.67$ *North Latitude* $\varphi_L = 51.75$ *East Longitude*

$\lambda_M = 31.33$ *North Latitude* $\varphi_M = 51.75$ *East Longitude*

Fig. 3 shows the definition of latitude φ and longitude λ on a perspective view of the Earth.

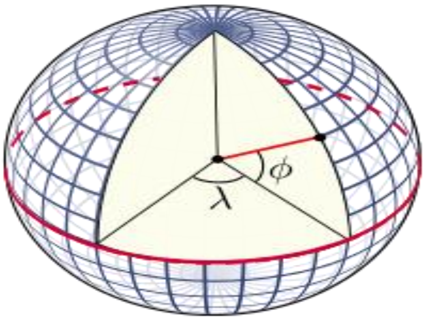

Fig. (3)- A perspective view of latitude (φ) and longitude (λ) (http://en.wikipedia.org/wiki/Latitude)

The RGAM downscaling method results is compared with historical real data. Fig. 4 shows the comparison with the monthly temperature of historical data for the same period (1979-2008).

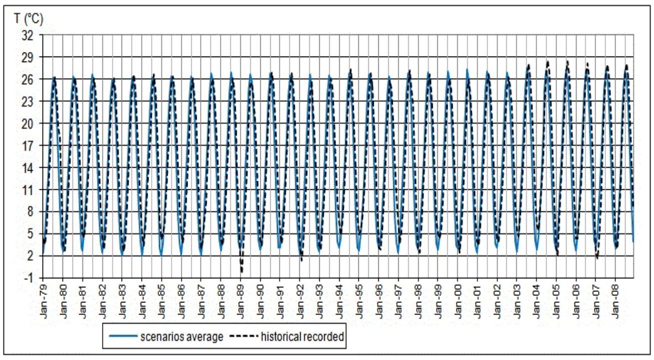

Fig. (4) The RGAM downscaling method results in compare to historical recorded monthly temperature

III. STUDY SITE AND SPECIFICATIONS OF RESERVOIR AND HYDROELECTRIC POWER PLANT

For this study, a large area located in south-west of Iran, a sub basin of Karun river basin was considered. Karun river is the most watery and the longest river of Iran which originates from Zagros Chain Mountains. In downstream of Gatvand diversion dyke this river enters into Khuzestan Plain and finally joins Persian Gulf. In recent decades electricity generation potential of this river is highly taken into consideration and expanded efforts are carried out for actualization of this potential. One of these efforts is construction the Karun Dams Series for controlling floods of this river and generating hydroelectric energy. Karun river's catchment area is located in Karun 4 dam's boundary in south-west of Iran between northern latitude of 31◦ 20' to 32◦ 40' and eastern longitude of 33◦ 49' to 45◦ 51' in Zagros Chain Mountain area and belongs to the Esfahan and Charmahal & Bakhtiary Provinces. The catchment area is approximately mountainous, its average height is 2354 m and its highest point is about 4200m. The area of Karun River catchment at the dam boundary (Fig. 5) is about 12813.4 km2. Zagros high chain mountains have caused suitable conditions for proper rainfall in this catchment area in a way that amount of average annual rainfall in last 30 years is estimated about 680 mm. Also average yearly evaporation from reservoir of dam is estimated about 1811.2 mm. River average annual discharge is 4.9274*109 m3 and minimum temperature at the site of dam is equal to 8°C. The maximum temperature is estimated about 4.32°C. Monthly historical recorded data for precipitation, temperature, evapotranspiration are available for more than 30 years from 1974 to 2008 in the catchment area. This data are collected and evaluated, completed and tested for statistical homogeneity.

Fig. (5) - Karun 4 Dam location and catchment area boundary

The preliminary studies of Karun 4 Project were carried out in 1967 in the frameworks of water resources development project and general planning of Karun River catchment area resources by Harza International Consultant. The contract of first and second phases of project studies, which is concluded between Mahab Qods Consulting Engineers and IWPC, is in its final stage.

It should be mentioned that due to complexity of the project during second phase studies, the French Company of Koine Bleiye has also supervised and approved the project studies as the assistant company. The dam's first study was conducted in 1995 and river diversion began in 1997. Concrete pouring began in 2006 and the power plant began producing electricity in November 2010. On December 11, 2010, the second generator for the dam became operational and was connected to the grid. The dam will eventually have an installed capacity of 1,020 MW. The dam was inaugurated on 6 July 2011 by Iranian President. Karun 4 reservoir dam is located in Charmahal & Bakhtyari Province with 180 kilometer distance to south-west of Shahrekord City and 4 kilometer distance to downstream of Armand and Bazoft Rivers conjunction.

Karun 4 reservoir dam is located in Charmahal & Bakhtyari Province with 180 kilometer distance to south-west of Shahrekord City and 4 kilometer distance to downstream of Armand and Bazoft Rivers conjunction, Fig. 5. The main targets of Karun 4 dam construction are:

- Regulation of Karun River water
- Controlling destructive floods and overflows of Karun river
- Generating hydroelectric energy of about 2107 billion Kw/h

Karun 4 dam reservoir have an average width of 500 m. Its normal level will be 1025 m and its minimum level will be 996 m. reservoir volume is about 2190 MCM from which 748.7 MCM is useful and 1097 MCM is dead. Annual regulative water by the Karun 4 Dam reservoir is equal to 3136*1000000m3. Karun 4 Dam lake is formed by two branches of Armand River (with length of 40.5 km) and Bazoft River (with length of 28 km). The area of lake at the ordinary level is 29.23 km2.

IV. EMPIRICAL MULTIVARIABLE REGRESSION MODELS

Base on the historical monthly recorded data of precipitation, temperature, evapotranspiration and discharge, the empirical multivariable regression models are established. In these models variables precipitation, temperature, evapotranspiration and monthly pre-discharge are as predictive variables and current monthly discharge is as response variable. Tab. 1 presents the structure of the models. Statistically all of the models have high correlation coefficient with historical data. Tab. 2 presents the *p-values* and the *correlation coefficient* of the models. Historical data of monthly discharge for period 1977-2002 is available. By using historical recorded data for monthly precipitation, temperature and evapotranspiration for the same period, the results of the models are compared with the real data. Fig. 6 shows the comparison of each of the models with historical real data.

Tab. 2. Summary of the EMR models specifications

model	predictor variable	*Constant*	*P*	*T*	*EVP*	*Qpre*	Multiple R	R Square	Adjusted R^2
	coefficient	*a*	*b*	*c*	*d*	*e*			
1	Con , Evap , T , P , Qpre	158.627	0.321	-5.694	0.038	0.534	0.8115	0.6585	0.6536
	P-value	0.0000	0.0587	0.0000	0.2537.	0.0000			
2	Con , T , P , Qpre	150.766	0.31	-5.753		0.541	0.8105	0.6570	0.6533
	P-value	0.0000	0.0677	0.0000		0.0000			
3	Con , Ln(Evap) , T , Ln(P) , Ln(Qpre)	2.675	-0.012	-0.043	-0.044	0.634	0.900	0.810	0.807
	P-value	0.0000	0.1749	0.0000	0.0679	0.0000			
4	Con, T , Ln(P) , Ln(Qpre)	2.389	0.00002	-0.0339		0.631	0.8978	0.8061	0.8040
	P-value	0.0000	0.9745	0.02152		0.0000			

Tab. (1) – EMR models for Karun 4 catchment area

Model No.	Empirical Multivariable Regression Model (EMR)
1	$Q = 150.766 + 0.31\ P - 5.753\ T + 0.541\ Q_{pre}$
2	$Ln(Q) = 2.389 + 0.00002\ P - 0.039\ T + 0.631\ Ln(Q_{pre})$
3	$Q = 158.627 + 0.321\ P - 5.694\ T - 0.038\ EVP + 0.534\ Q_{pre}$
4	$Ln(Q) = 2.675 - 0.012\ Ln(P) - 0.043\ T - 0.044\ Ln(EVP) + 0.634\ Ln(Q_{pre})$

There are 14 hydrological data recording station in the region which record data regularly. Monthly precipitation, temperature and evapotranspiration values are calculated for the catchment area using all of the 14 stations data surrounded across the area. Dada already have been evaluated, completed and controlled by hydrological methods from the point of being homogenous. Monthly discharge for 1977-2002 period is calculated at Karun 4 dam position, using the discharge of the two main branches connect to the main river branch before dam position.

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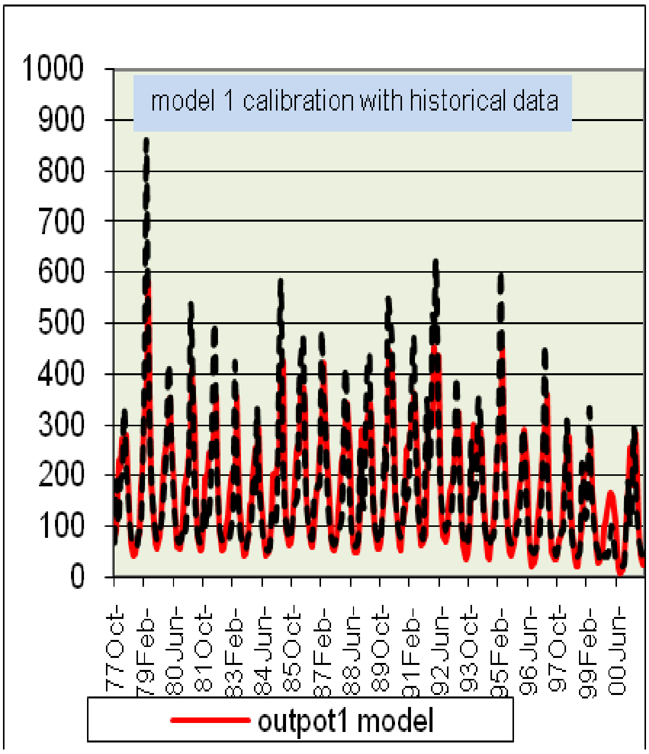
IV. EVAPOTRANSPIRATION REGRESSION MODELS

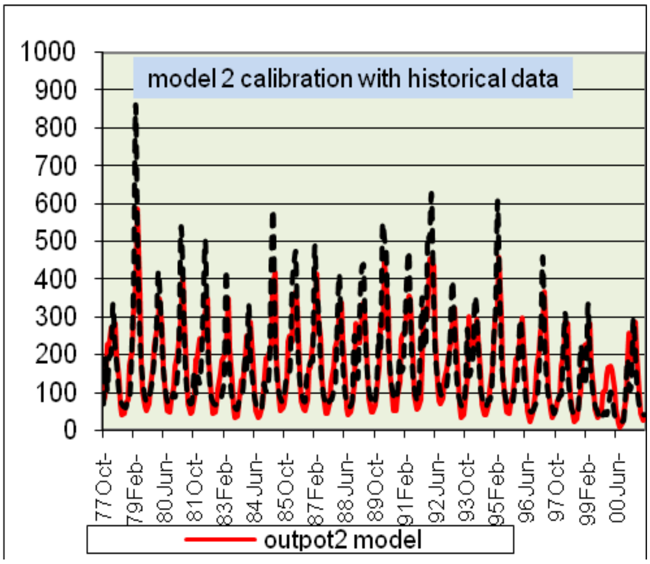
The relationships between monthly temperature and evapotranspiration are presented in Tab. 3. The linear regression equations are obtained based on historical recorded data. The relationship between monthly precipitation and evapotranspiration is tested and is seen that is quite poor and can be escaped. Tab. 3 shows the correlation coefficient of the data. *PET* stands for potential evapotranspiration, T is temperature and *a* and *b* are the coefficient which are computed by statistical formulas.

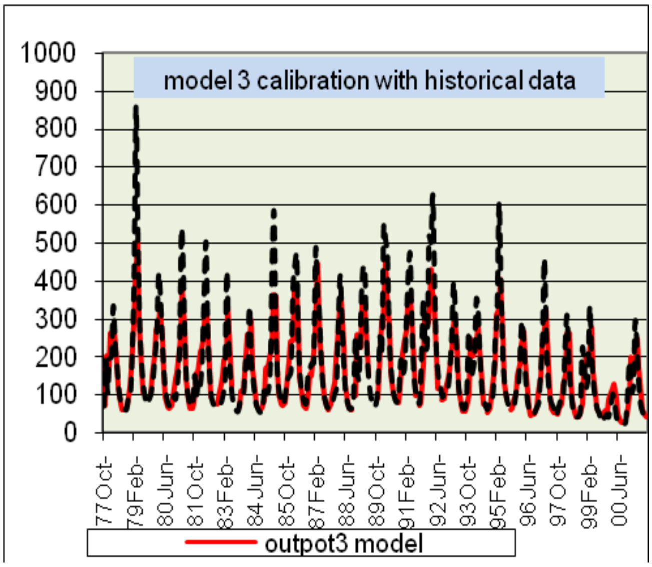
Tab. 3. Evapotranspiration estimation equations

(PET = a + b T)

month	*b*	*a*	R^2
Jan	15.47996	-37.9462	0.9271
Feb	15.59055	-40.4333	0.9274
Mar	15.70409	-42.8474	0.9290
Apr	15.76852	-44.187	0.9290
May	15.87557	-47.3342	0.9331
Jun	15.87553	-47.0611	0.9330
Jul	16.01773	-47.5271	0.9291
Aug	16.30997	-50.3009	0.9289
Sep	16.17408	-48.8888	0.9280
Oct	16.0499	-47.6987	0.9269
Nov	16.19859	-47.7939	0.9425
Dec	16.24468	-46.6445	0.9575







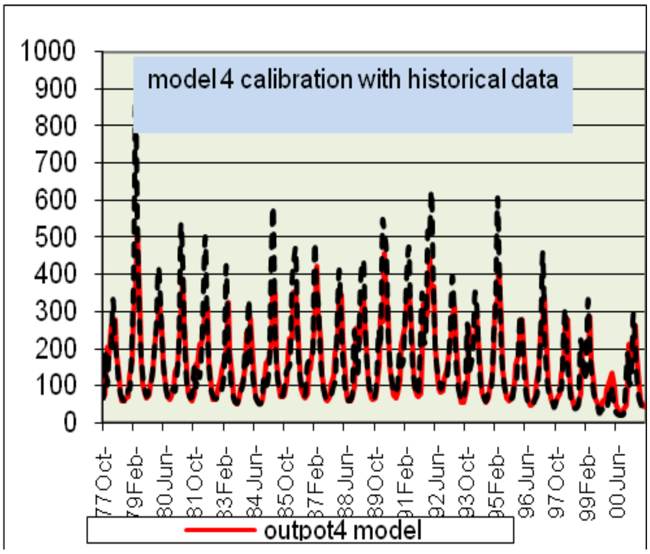


Fig. (6) EMR model 1, model 2, model 3 and model 4 calibration with real historical data

V. FUTURE MONTHLY SCENARIOS

Monthly precipitation scenarios for next 90 years are downloaded from 28 different models of CCCSN database. The data are downscaled by RGAM method to be useful in study region. The list of 28 models is presented bt Tab. 4.

Tab. 4. Used models, scenarios and emission scenarios

Sce. No.	scenario name and emission scenario	No. of grids
1	AR4 (2007) - GFDLCM2.0 (Run 1) - SR-A1B	one grid
2	AR4 (2007) - GFDLCM2.0 (Run 1) - SR-A2	
3	AR4 (2007) - GFDLCM2.0 (Run 1) - SR-B1	
4	AR4 (2007) - GFDLCM2.1 (Run 1) - SR-A1B	
5	AR4 (2007) - GFDLCM2.1 (Run 1) - SR-A2	
6	AR4 (2007) - GFDLCM2.1 (Run 1) - SR-B1	
7	AR4 (2007) - GISS-EH (Mean) - SR-A1B	
8	AR4 (2007) - GISS-ER (Run 1) - SR-A1B	
9	AR4 (2007) - GISS-ER (Run 1) - SR-A2	
10	AR4 (2007) - GISS-ER (Run 1) - SR-B1	
11	AR4 (2007) - CSIROMk3.0 (Run 1) - SR-A1B	two grids
12	AR4 (2007) - CSIROMk3.0 (Run 1) - SR-A2	
13	AR4 (2007) - CSIROMk3.0 (Run 1) - SR-B1	
14	AR4 (2007) - CSIROMk3.5 (Run 1) - SR-A1B	
15	AR4 (2007) - CSIROMk3.5 (Run 1) - SR-A2	
16	AR4 (2007) - CSIROMk3.5 (Run 1) - SR-B1	
17	AR4 (2007) - ECHAM5OM (Mean) - SR-A1B	
18	AR4 (2007) - ECHAM5OM (Mean) - SR-A2	
19	AR4 (2007) - ECHAM5OM (Mean) - SR-B1	
20	AR4 (2007) - HADGEM1 (Run 1) - SR-A1B	
21	AR4 (2007) - HADGEM1 (Run 1) - SR-A2	
22	AR4 (2007) - NCARCCSM3 (Mean) - SR-A1B	
23	AR4 (2007) - NCARCCSM3 (Mean) - SR-A2	
24	AR4 (2007) - NCARCCSM3 (Mean) - SR-B1	
25	AR4 (2007) - INGV-SXG (Run 1) - SR-A1B	four grids
26	AR4 (2007) - INGV-SXG (Run 1) - SR-A2	
27	AR4 (2007) - MIROC3.2 hires (Run 1) - SR-A1B	
28	AR4 (2007) - MIROC3.2 hires (Run 1) - SR-B1	

In Fig. 7 monthly precipitation variation at the end of 2010 and at the end of each 30 years periods 2020s (2011-2040), 2050s (2041-2070) and 2080s (2071-2100) is presented.

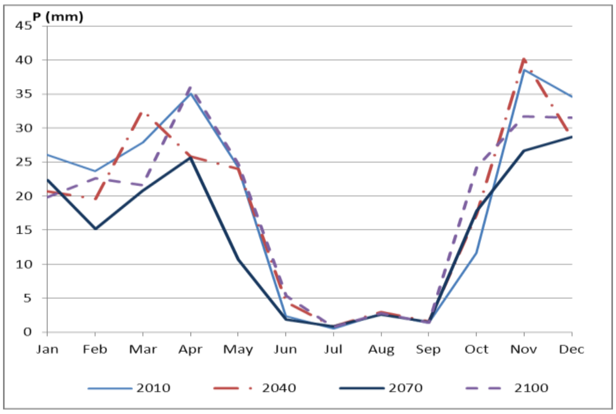


Fig. (7) Average of monthly precipitation of 28 scenarios at the end of periods

Fig. 8 presents the comparison of the average of 30 years periods. It is seen that average monthly precipitation in period 2020s is more than 2050s and in period 2050s is more than 2080s. The figure shows that the maximum reduction in 2020s would happen in March with amount of 16%, while for 2050s and 2080s maximum reduction would be in February with 10% and 23% respectively.

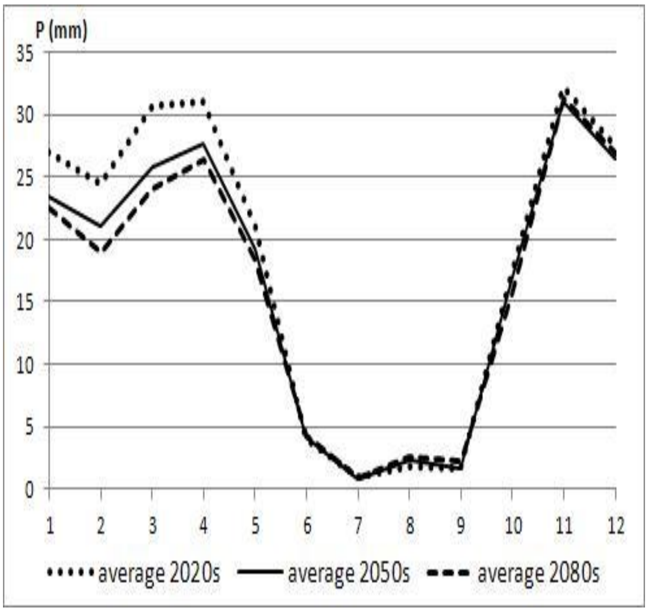


Fig. (8) Average monthly precipitation variation in periods

Monthly temperature scenarios for 28 models and emission scenarios as listed in Tab. 3 are downloaded and downscaled by RGAM method. Fig. 9 compares 30 years period monthly temperature with historical data. As Fig. 9 shows except November and December other months would have experience hotter weather in average.

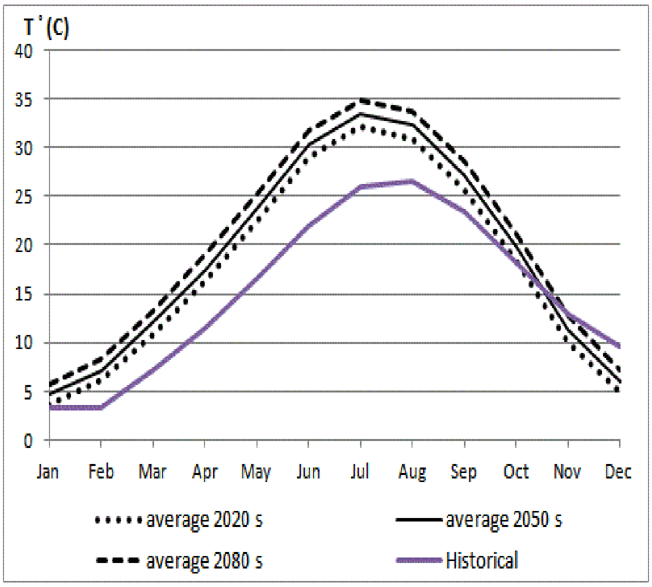


Fig. (9) Monthly temprature variation at the end of periods compare to historical rec

Monthly temperature would increase continually during next 90 years, but the gradient of increase would be different. As Fig. 10 shows, at the end of 2040 temperature would increase more than other periods with respect to 2010, but from 2070 to 2100 the condition would be some different and the gradient of temperature would rise less than before.

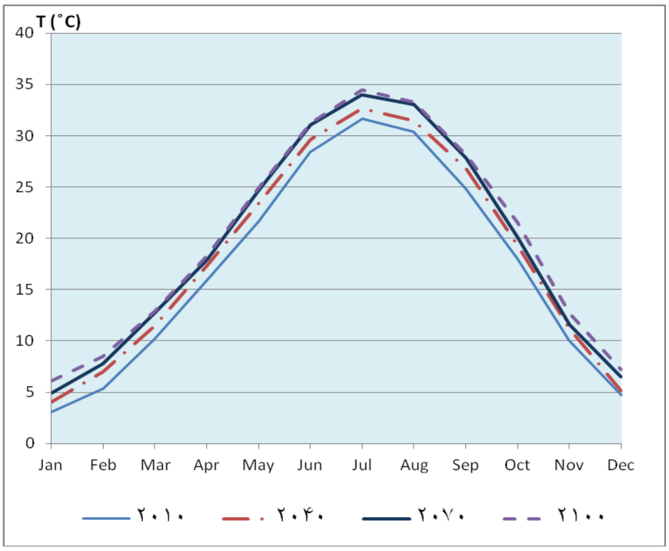


Fig. (10) Monthly temperature at the end of periods

Future monthly evapotranspiration scenarios are computed by equations listed in Tab. 4 and by using temperature downscaled scenarios as inputs. Different scenarios present different values for evapotranspiration.

Fig. 11 shows the values of the most optimistic (scenario 20) and the most pessimistic scenario (scenario 7) for evapotranspiration. The average of 28 scenarios and also historical average graph is presented in Fig. 10.

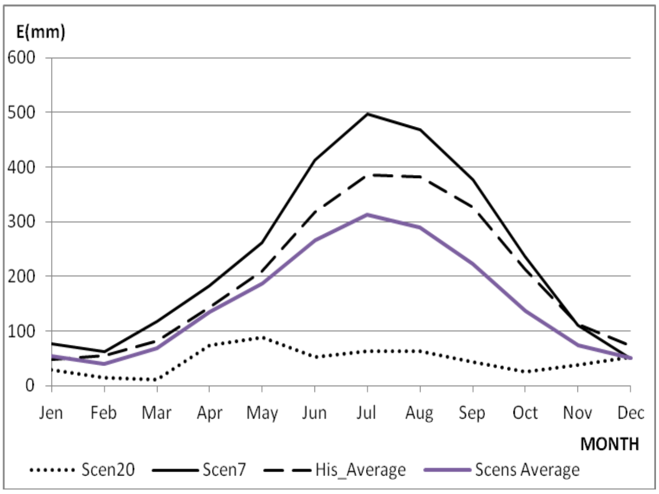


Fig.(11) Evapotranspiration of optimistic and pessimistic scenarios

VII. DISCHARGE SCENARIOS

Selecting EMR model from several models that some of them are listed in Tab. 2 is a challenge that should be described. In general, parsimony is the principle that the simplest explanation that can explain the data is to be preferred and Akaike Information Criterion (AIC) deals with the trade-off between the goodness of fit of the model and the complexity of the model. Following the parsimony principle and AIC, considering EMR models (Tab. 2), because of having less variable and high correlation coefficient, model number 4 is selected. Using monthly precipitation and temperature scenarios, monthly discharge scenarios are computed by model 4. Fig. 12, 13 and 14 present average, maximum and minimum monthly discharge variation and 12 months moving average discharge according to the average of all 28 scenarios, respectively.

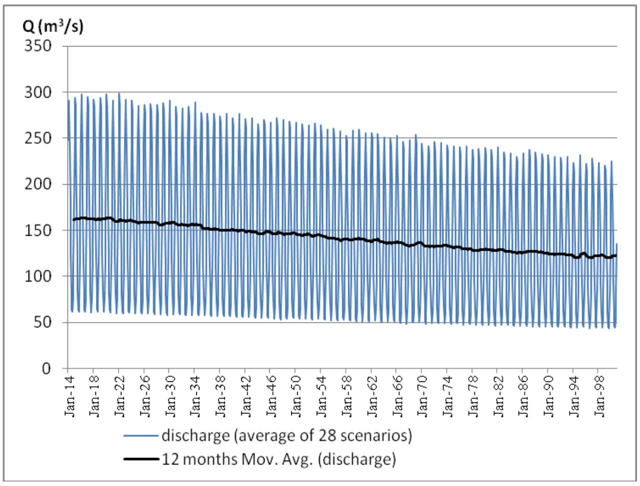


Fig. (12) Average monthly discharge of 28 scenarios and 12 months moving average

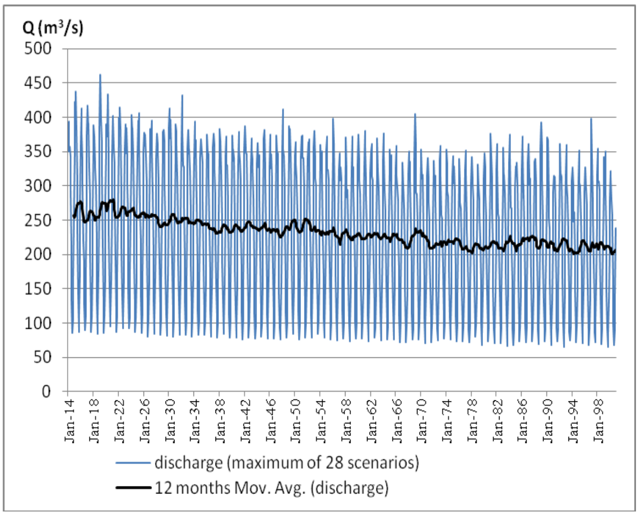


Fig. (13) Maximum monthly discharge of 28 scenarios and 12 months moving average

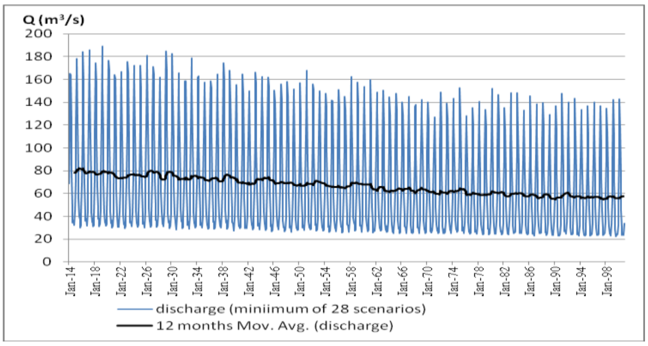


Fig. (14) Minimum monthly discharge of 28 scenarios and 12 months moving average

Considering scenario values, it is understood that scenario 25 is the most pessimistic one and predicts low values and scenario 3 as the most optimistic scenario predicts high values for monthly and annual discharges. Fig. 15 shows annual discharge scenarios and the average scenario. In the figure Scenarios 3 and 25 are indicated as blue and red in color respectively. It is seen that all of the scenarios present a decreasing trend for annual discharge.

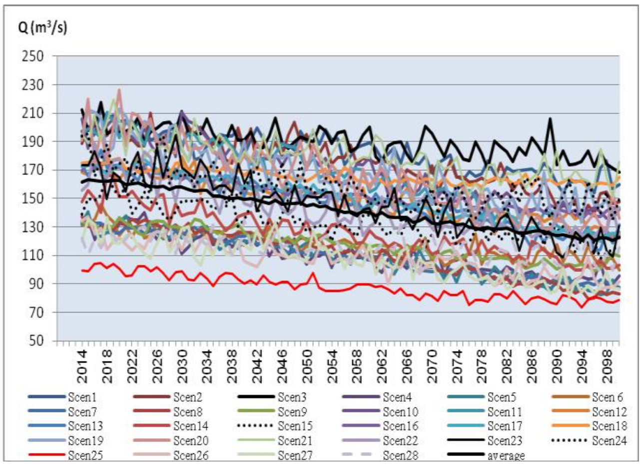


Fig. (15) Annual discharge scenarios and average scenario

Annual discharge scenarios are computed from monthly discharge scenarios. Fig. 16 shows the average scenario of annual scenarios and the maximum and the minimum of the scenarios. The results show all of the annual discharge scenarios indicate discharge would decrease continually for next 90 years. The average scenario presents a reduction of 27.8% in annual discharge.

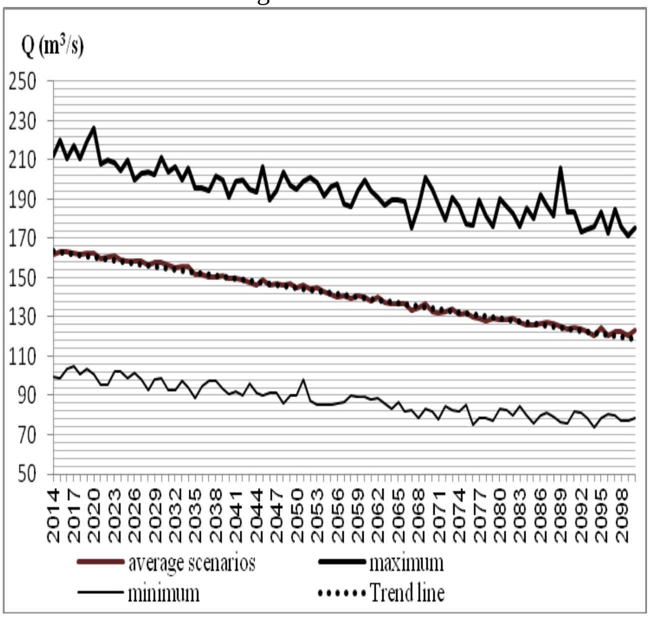


Fig. (16) Annual absolut average, maximum and minimum discharge of the scenarios and trend line

The average, absolute maximum and minimum annual discharge of scenarios for all future 90 years is calculated. Fig. 17 shows the result. The maximum annual discharge is predicted by scenario 20 at 2020 and the minimum annual discharge is predicted by scenario 25 at 2094.

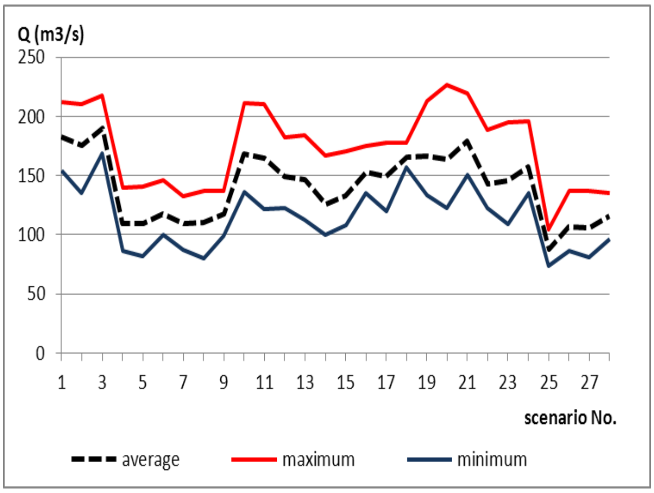


Fig. (17) Absolut average, maximum and minimum annual discharge

The absolute monthly maximum discharge is predicted by scenario 21 and would happen at February 2019 with a amount of 461.80 m^3/s and the absolute monthly minimum discharge is predicted by scenario 22 at August 2099 with a amount of 22.47 m^3/s. Fig 18 presents variation of average and absolute maximum and minimum monthly future discharge.

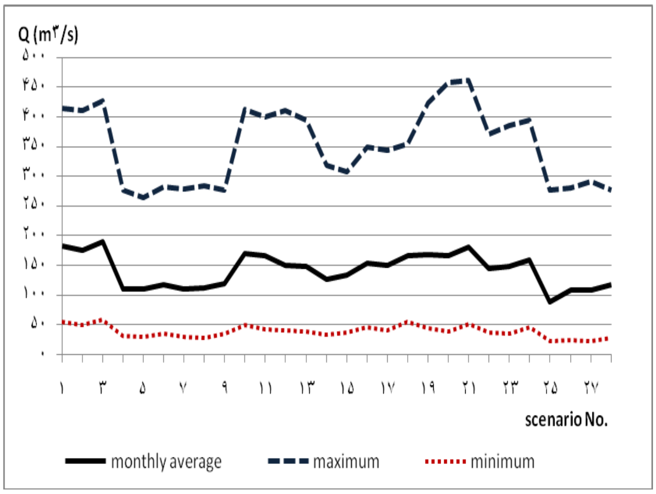


Fig. (18) Monthly absolute average, maximum and minimum discharge of the scenarios

VIII. SURFACE WATER RESOURCES

For a certain period; river discharge, direct precipitation and evapotranspiration are the main factors that affect surface water resources. Using discharge, precipitation and evapotranspiration scenarios, the monthly surface resources storage scenarios are calculated. In this calculation it is assumed that there in no use from resources (obviously it is not the real case). In the case of use of resources it should be taken into account in the equation of storage calculation. From the point of monthly storage, scenario 25 is the most pessimistic one and scenario 15 is the most optimistic scenario. Fig. 19 shoes monthly surface storage that would be generated by scenarios 15.

Fig. 20 presents storage scenario No. 25. The average of storage scenarios is presented in Fig. 21. In Fig. 22 the most optimistic and pesimistic storage scenarios(scenarios 15 and 25) in compare to average storage scenario is presented.

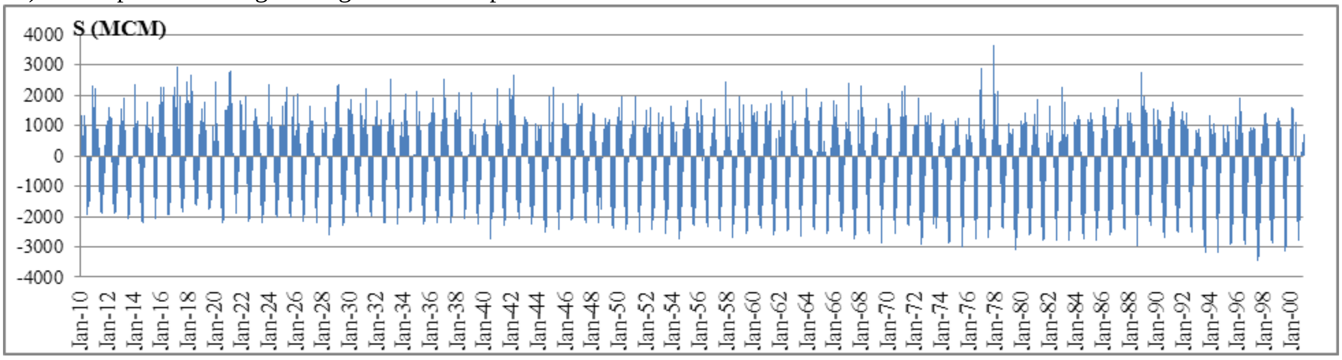


Fig. (19) Storage scenario No. 15, as the most optimistic scenario

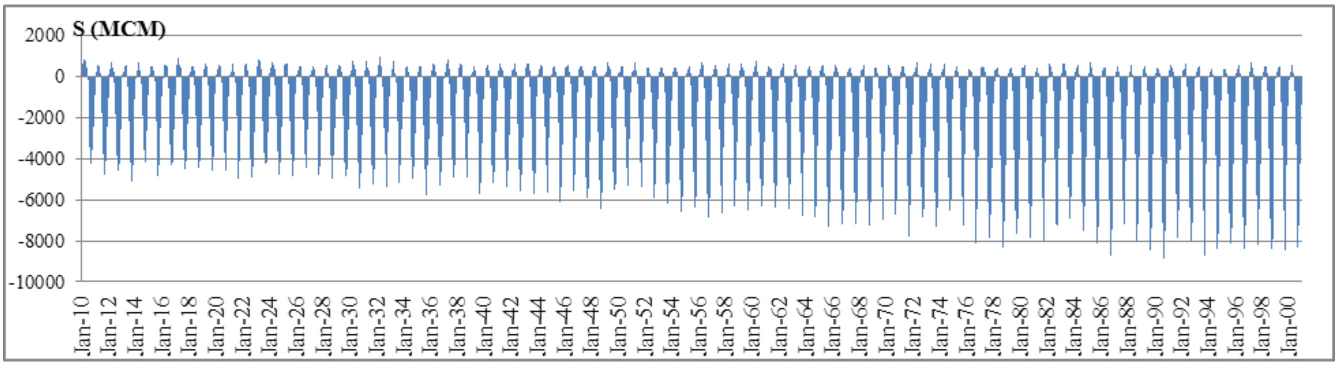


Fig. (20) Storage scenario No. 25, as the most pesimistic scenario

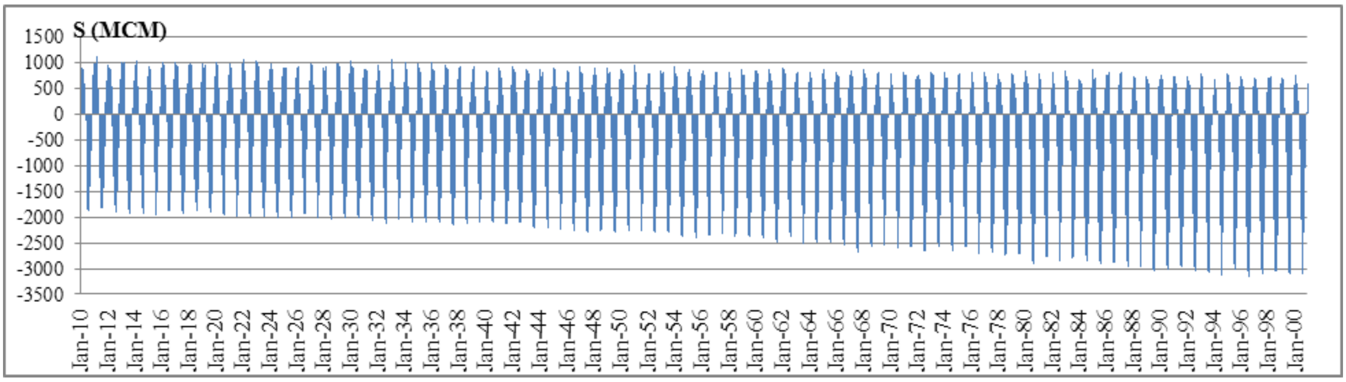


Fig. (21) Average storage scenario (period 2010-2100)

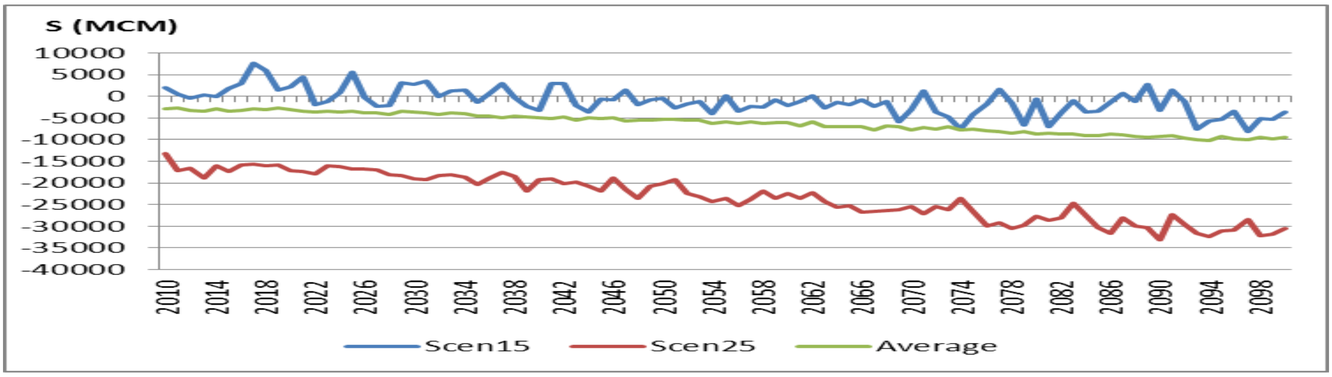


Fig. (22) The most optimistic and pesimistic storage scenarios in compare to average storage scenario

Fig. 23 showes the average scenario of storage during period 2010 to 2100. Along this period the surface storage capacity would reduce continually and in average it would experince an reduction more than 25%.

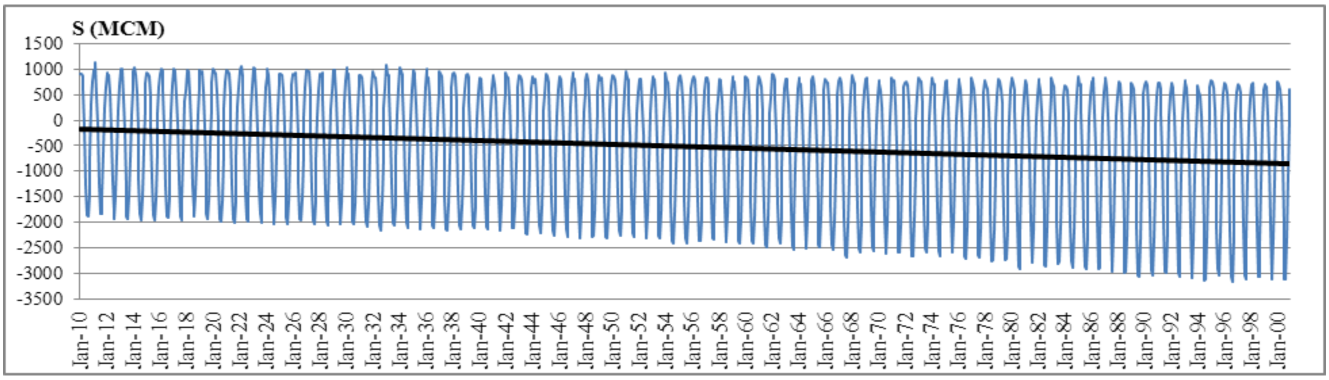


Fig. (23) Average storage scenario and trend line

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