International Journal of Geography and Geography Education (IGGE)

To Cite This Article: Aalijahan, M., Salahi, B. & Hatami, D. (2021). Investigating the relationship between changes in atmospheric greenhouse gases and discharge fluctuations in the basin of Aras River. *International Journal of Geography and Geography Education (IGGE),* 44, 461-474.

Submitted: January 02, 2021 **Revised:** March 21, 2021 **Accepted:** May 13, 2021

INVESTIGATING THE RELATIONSHIP BETWEEN CHANGES IN ATMOSPHERIC GREENHOUSE GASES AND DISCHARGE FLUCTUATIONS IN THE BASIN OF ARAS RIVER

Mehdi AALIJAHAN[1]

Bromand SALAHI[2]

Dariush HATAMI[3]

Abstract

In this study, the relationship between changes in atmospheric greenhouse gases and discharge fluctuations was investigated in the basin of Aras river. To this end, we used two sets of data including greenhouse gases (carbon dioxide, methane and nitrogen oxide) and discharge data in the Aras river basin during a period of 41 years (1968-2009). Furthermore, Pearson correlation, linear and polynomial regression, standard Z scores and Mann-Kendall test were employed. The results of investigating the discharge changes in the basin indicate its monthly and annual decreasing trend. Also, the results of Pearson correlation revealed that the decreasing trend of discharge in the basin has a close relationship with the trend of changes in carbon dioxide and methane. At a confidence level of 99%, except in summer months, almost for all months, there was a negative correlation with discharge of the basin that refers to the decline of discharge in the basin along with the increase of these gases in the environment. The greatest effect of greenhouse gases was observed in the months of December, January, February, March, and April. Mann-Kendall indicated the significance of the change trend in the discharge of the basin. On a monthly or annual basis in all months of the year, this change trend is quite significant.

Keywords: Greenhouse Gases, Global Warming, Discharge, Mann-Kendall Test, Aras River Basin

[1] **Correspondence to:** Department of Physical Geography, Mohaghegh Ardabili University, Ardabil 5619911367, Iran; Department of Physical Geography, University of Marmara, Istanbul 34722, Turkey, *https://orcid.org/0000-0002-6936-0739.,* mehdi_alijahan@yahoo.com

[2] Department of Physical Geography, Mohaghegh Ardabili University, Ardabil 5619911367, Iran., *https://orcid.org/0000-0003-4826-6185.,* bromand416@yahoo.com@yahoo.com

[3] Department of Physical Geography, Kharazmi University of Tehran, Tehran 15719-14911, Iran., *https://orcid.org/0000-0003-4606-8177.,* dhatami68@yahoo.com

INTRODUCTION

Rivers are considered as the most important sources of water providence in rural and urban areas and to some extents are affected by climatic changes and global warming. More than 22 gases are involved in global warming and some of them called greenhouse gases including carbon dioxide (CO_2) and methane (CH_4) are more effective than others (Mohammad-Khorshiddost and Ghavidel-Rahimi, 2006). The average surface temperature of the earth continually increases due to the dispersion of greenhouse gases; therefore, recent scenarios of IPCC have predicted the increase of global average temperature about 0.76°C in the previous century, and it will reach 6.4˚C till 2100 (Change, 2007). During the past century, the average of global temperature rose about 7˚C due to the increase of greenhouse gas concentrations such as CO_2, CH_4, and N_2O (Marin-Muniz et al., 2015). Each year, the increase in mentioned above greenhouse gases is 0.3, 1, and 0.4, respectively which mainly happens due to human activities (WMO, 1985; Griggs, 2002). Greenhouse gases dispersion indirectly damages human society including water resources and hydrology of the rivers. Sun et al., (2014) believe that rapid economic development and urbanization has led to the release of more carbon to the atmosphere. Also, increase in the concentration of greenhouse gases has caused some changes in precipitation regime, temperature, and runoff (Mizyed, 2009). Currently, the impact of climatic changes on the hydrological cycle is the main challenge for sustainable development of water resources in many countries in the 21st century (Shen and Liu, 1998; Li et al., 2007).

In recent years, climatology of the effects of greenhouse gases on river discharge, hydrology, its dimensions and impact, especially from the perspective of climatic change and global warming, have been examined by a wide range of climatologists (Zeng et al., 2012; Sakaki et al., 2013; Sheng et al., 2014; Plampin et al., 2014; Martin-Gorriz et al., 2014; Burgos et al., 2015). In a global-scale study in New Jersey, Manabe et al., (2004) started to simulate the effects of global warming on discharge changes of the rivers. They found that increase in river discharge occurs in the Arctic and tropical regions. Also, its increase and decrease can be observed in tropical areas and mid-latitudes. After industrialization of the world, the amount of carbon dioxide and methane has increased about 0.26 and 0.148, respectively (WMO, 1985; Griggs, 2002). Several studies have investigated the impact of climatic changes on river discharge and discharge of the basins, and also, they have examined the effect of climatic changes on the changes of surface water resources in different parts of Iran (Sharifian and Habibi, 2013). In addition, some others have investigated the changes of river discharge through different climatic scenarios and climatic models (Esfandiari-Darabad et al., 2013).

Global warming has a significant effect on hydrology and water resources of watersheds (Esfandiari-Darabad et al., 2013). There is a strong and negative correlation between global warming and discharge of the Aras basin (Esfandiari-Darabad et al., 2013). From their point of view, this process especially from 1994 on, was clear and with increase in global warming, discharge of the Aras basin has shown a remarkable decline. With increase in greenhouse gases release into the atmosphere of the earth, global temperature will rise and major changes can be seen in hydrologic cycle. In addition, in different regions, precipitation pattern and discharge of watersheds would fluctuate and change (Khosravi et al., 2010). Also, some studies have been conducted regarding the effect of climatic changes on runoff and discharge of the rivers. For example, studying the effect of climate change on river basin indicated the increase of temperature, and then decrease in the level of precipitation and discharge of the basin (Fujihara et al., 2008).

Zeng et al., (2012) analyzed the discharge of Yangtze in different situations of dispersion scenarios and concluded that annual discharge of two hydrological stations did not have any specific trend and changes were minimal in each decade under the influence of three different dispersion scenarios. Mizyed, (2009) investigated the effect of climatic changes on water resources in the west bank of Jordan. He concluded that the predicted increase of temperature due to climate changes potentially could reduce the amount of groundwater about 21% of the existing rate.

Khoshakhlagh et al., (2010) investigated the impact of climate change on the hydrology of the Karun river. They concluded that the amount of annual precipitation didn't have satisfactory increasing and decreasing trends, while the temperature and discharge had an increasing trend. By non-parametric tests of Mann-Kendall and regression analysis, Sharifian and Habibi, (2013) analyzed the impact of climate changes on the trend changes of the discharge of rivers in Golestan province, Iran. Their study revealed that, in the last two decades, the annual discharge values at all stations of river basin had a downward trend. In the other research Toulabi-Nejad et al., (2015) statistically analyzed the role of greenhouse gases in the discharge of the Kashkan river. Their results indicated the existence of a strong and negative relationship between global warming and discharge of the Kashkan river. The Aras river is one of the most important rivers of Iran of significance hydrologically, politically, and geopolitically for water supply. Also, it plays an important role in agricultural fields, for tourist attraction, and positive impacts on ecosystem. The aim of this study was to statistically analyze the correlation between changes in atmospheric greenhouse gases and fluctuations of discharge in the Aras river using Pearson correlation, linear and polynomial regression, standard z scores, and Mann-Kendall test.

MATERIALS AND METHODS

Study Area

Aras river is one of the most important rivers in the basin of Caspian Sea. With an area of more than one hundred km^2, its basin covers parts of the territories of Turkey, Azerbaijan, Armenia, and Iran. That part of Aras basin in Iran is located in the extreme northwest of the country, on the right bank of the river and in the provinces of West Azerbaijan, East Azerbaijan, Ardebil, and a small part of Gilan province which approximately forms 41% of the total area of the Aras basin. Aras river has a total length of 1072 kilometers, and in its path, more than 160 large and small branches are joined. The basin covers an area of 39,897 km^2 and its discharge rate is equal to 5,700 million cubic meters per year. Figure 1 shows the map of the respective area.

Figure 1: The Map of the Study Area

Data

To conduct the research, two sets of data were used. The first set of data are related to three greenhouse gases including carbon dioxide, methane, and nitrogen oxide. To study the impact of these gases, different time periods were used, because their measuring time was different. We used the statistics of carbon dioxide for 35 years, methane for 26 years, and nitrogen oxide for 10 years, respectively. Greenhouse gases related data were obtained from NOAA website and Mauna Loa Station of the U.S. (http://www.esrl.noaa.gov/gmd/dv/data). Table 1 shows characteristics of Mauna Loa Station in the U.S. The used greenhouse gas data are monthly averages and the annual time series diagram of the changes of mentioned greenhouse gases is shown in Figure (2). Discharge data in the Aras basin is the second set of data that was used in the research process. Discharge-related data of the basin recorded by hydrometric stations of West and East Azerbaijan and Ardebil were obtained and analyzed through Regional Water Organization of Ardebil. To study long-term changes, periodic changes as well as changes in trends in the discharge data series of the Aras river basin, a 41-year statistical period (1968-2007) was used. Moreover, to assess the relationship between the discharge of the basin and three greenhouse gases, the stated time intervals in the section of gases were employed.

Table 1: Specifications of the Mauna Loa Greenhouse Gas Measurement Station

Country	Established Year	Longitude	Latitude	Elevation (m)
The United States (Hawaii)	1957	155 57	19 53	3397

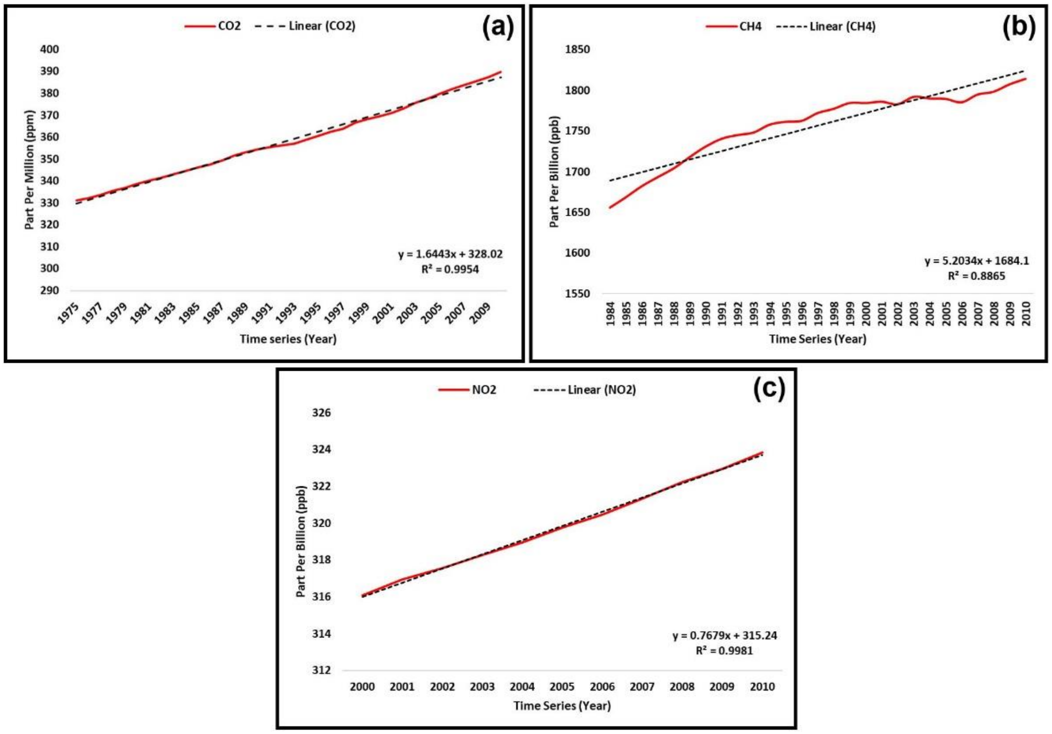

Figure 2: The Time-Series Diagram of Annual Greenhouse Gas Changes, a: CO_2, b: CH_4, and c: NO_2

Methods

To determine the relationship between greenhouse gases and discharge of the mentioned basin, Pearson correlation was employed. To compare abnormalities of discharge in the basin and changes of greenhouse gases and trend modeling of changes in them, both groups of data were standardized by using the following equation:

$$F_{sd} = (f_i - \bar{F}) / \sigma \quad (1)$$

In this equation, F_{sd} refers to the amount of standardized element in the discharge of the basin, f_i is the amount of discharge in the respective year, $\bar{F}$ is long time average, and σ refers to the standard deviation in the respective time interval (Esfandiari-Darabad et al., 2013). By the quantity of Z scores, differences in dispersion between a series of mean deviation can be modified by dividing mean deviation of each score $(f_i - \bar{F})$ to the standard deviation of those series of scores (σ). Then, the scores can become comparable (Hafeznia, 2010).

Linear regression and polynomial 6th degree were also used to study and analyze the trend in the data. Linear regression was used to analyze long-term changes in the time series of discharge data and 6th degree polynomial regression was used to analyze periodic changes and the detection of incremental and decremental periods.

Non-Parametric Test

Non-parametric statistics are usually much less affected by the presence of outliers and other forms of non-normality (Lanzante, 1996), and represent a measure of monotonic linear dependence (Davis, 1986; Rossi et al., 1992). The most frequently used non-parametric test for identifying trends in hydrologic, meteorology, environmental and climate variables is the Mann-Kendall (MK) test (Yadav et al., 2014; Pohlert, 2016). The statistical significance trend detected using a non-parametric model such as the Mann-Kendall (MK) test can be complemented with Sen's slope estimation to determine the magnitude of the trend.

Mann-Kendall test and Sen's slope estimator– trend detection

The non-parametric Mann-Kendall test is widely used in detecting trends of variables in meteorology and hydrology fields (Liang, el al., 2010; Ahn and Merwade, 2014; Wang et al., 2019). Statistic S can be obtained by Eq. (1).

$$s = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}\left(x_j - x_k\right) \tag{1}$$

$$\operatorname{sgn}\left(x_j - x_k\right) = \begin{cases} +1, if \left(x_j - x_k\right) > 0 \\ 0, if \left(x_j - x_k\right) = 0 \\ -1, if \left(x_j - x_k\right) < 0 \end{cases} \tag{2}$$

where n is the length of the sample, x_k and x_j are from k=1, 2, ..., n-1 and j= k+1, ..., n. If n is bigger than 8, statistic S approximates to normal distribution. The mean of S is 0 and the variance of S can be acquired as follows:

$$\operatorname{var}(s) = \frac{n(n-1)(2n+5)}{18} \tag{3}$$

Then the test statistic Z is denoted by Eq. (4).

$$z \begin{cases} \dfrac{s-1}{\sqrt{\operatorname{var}(s)}}, if \;\; s > 0 \\ 0, \qquad\quad if \;\; s > 0 \\ \dfrac{s+1}{\sqrt{\operatorname{var}(s)}}, if \;\; s < 0 \end{cases} \tag{4}$$

If Z>0, it indicates an increasing trend, and vice versa. Given a confidence level α, the sequential data would be supposed to experience statistically significant trend if |Z|>Z(1-α/2), where Z(1-α/2) is the corresponding value of P=α/2 following the standard normal distribution. In this study, 0.05 and 0.01 confidence levels were used. Besides, the magnitude of a time series trend was evaluated by a simple non-parametric procedure developed by Sen (Sen, 1968). The trend is calculated by

$$\beta = Median\left(\frac{x_j - x_i}{j - i}\right), \; j > i \tag{5}$$

where β is Sen's slope estimate. $\beta > 0$ indicates upward trend in a time series. Otherwise, the data series presents downward trend during the time period.

Mann-Kendall test - mutation detection

Mann-Kendall test can also be used to detect the abrupt changes of climate and hydrological data (Li et al., 2007; Tian et al., 2009; Ye et al., 2013; Zhang, 2018). First, building an order serial S_k:

$$s_k = \sum_{i=1}^{k} \sum_{j}^{i=1} a_{ij} \quad \left(k = 2, 3, \ldots, n\right) \tag{6}$$

where a_{ij} = 1 when $x_i > x_j$; a_{ij} = 0 when $x_i \le x_j$.

Test statistic can be expressed as:

$$U^{'}I = \left[s_k - E\left(s_k\right)\right] / \left[Var\left(s_k\right)\right] \quad \left(k = 1, 2, \ldots, n\right) \tag{7}$$

where $E(S_k) = n(n - 1/4)$; $Var(S_k) = n(n - 1)(2n + 5)/72$. U'I is the forward sequence and follows the normal distribution. UI can then be denoted by reversing the series of data based on the same equation. The null hypothesis (no abrupt change point) will be rejected if the U'I values are greater than the confidence interval, and the approximate time of occurrence of the change point can be located according to the intersection between U'I and UI within the confidence interval. Here, the successive values of UI and U'I from Mann-Kendall results are displayed graphically. In this display, if UI and U'I values overlap each other for several times, changes or trends can’t be observed, but where the curves intersect each other, intersection of starting point in the trend and changes are approximately shown. If curves intersect each other within the range of (±1.96), it refers to the start of a sudden change. But if they intersect each other outside of the critical area, it refers to the existence of a trend in time series (Feyzi, 2009). Before performing this technique, the Run test was conducted on the data to make sure that the data were not digressive.

RESULTS AND DISCUSSION

Figure 3 shows the annual discharge of the Aras river basin. Due to the trend of discharge in this river, in the long run, we will witness a severe decrease of discharge of about 44%. Discharge of the basin during the 41 sample years of the study has decreased with a steep slope. The linear regression fully confirms this process. By considering the polynomial regression during the sample period, two decline periods and a period of rise can be observed in time series of discharge in the basin. From 1968-1969 and 1975-1976, for 9 years the discharge has decreased in the basin and from this year to 1985-1986 for 11 years it has increased. From this year till the end of the study sample intervals, it has experienced a declining trend. Table 2 shows the correlation relationships of monthly and annual discharge of the Aras river basin with greenhouse gases. According to this Table, there isn’t any significant relationship between discharge and NO_2. However, there is a significant relationship between CO_2 and CH_4. According to Table 2, at the significance level of 0.01, a negative correlation can be observed between annual discharge of the Aras basin and CO_2 and CH_4; its correlation coefficients are 0.70 and -0.702%, respectively. Their coefficients of determination are 0.49 and 0.493%, respectively. According to the coefficients of determination, it can be claimed that 49% of changes in annual discharge of the Aras basin were related to changes of gases. There is an important point in Pearson correlation that this method only depicts the linear relationship between variables and it does not mean that there is no conditional or nonlinear relationship between the variables.

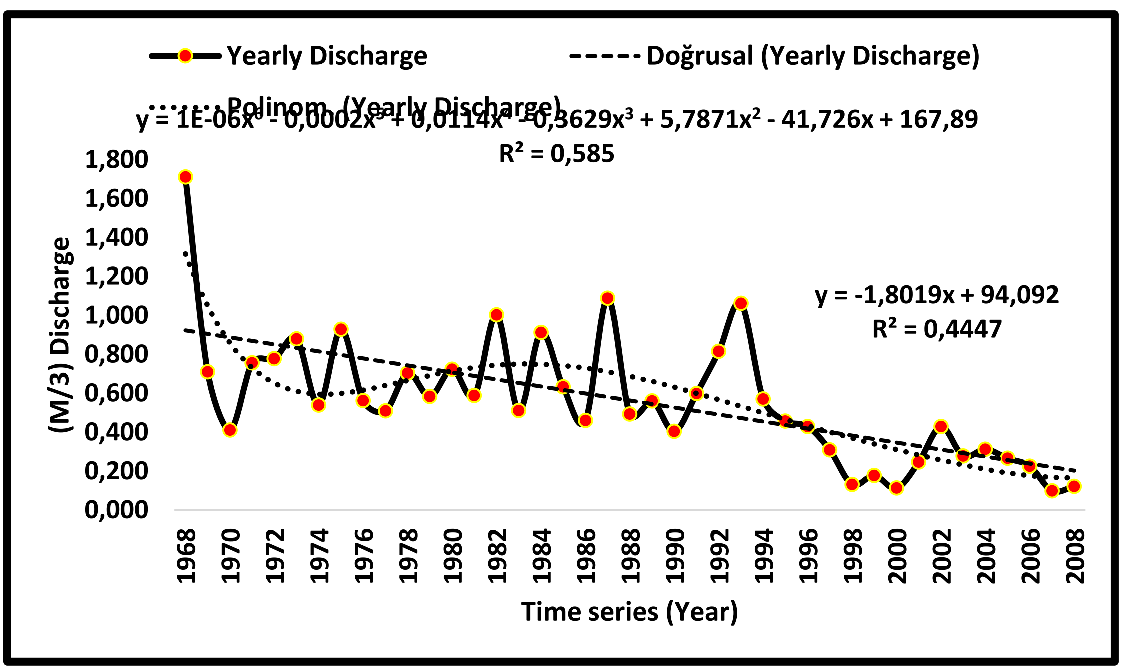

Figure 3: Average Annual Trend Rate of the Aras River Basin

Table 2: Correlation Between Greenhouse Gases With Mean Discharge of Aras River Basin

Month	CO_2	CH_4	NO_2	Month	CO_2	CH_4	NO_2
Jan	-0.711	-0.708**	-0.528	Jul	-0.260	-0.250	0.478
Feb	-0.822**	-0.836**	-0.214	Aug	-0.077	-0.172	0.029
Mar	-0.699**	-0.733**	-0.154	Sep	0.115	-0.020	0.225
Apr	-0.64**	-0.749**	-0.279	Oct	-0.370*	-0.425*	0.167
May	-0.434**	-0.402*	-0.278	Nov	-0.549**	-0.653**	-0.078
Jun	-0.556**	-0.313	-0.32	Dec	-0.691**	-0.616**	-0.332
*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.				Annual	-0.700**	-0.702**	-0.369

Figures 4 and 5 show standardized comparative charts of annual changes in the discharge of the basin with CO_2 and CH_4. According to the mentioned forms in the above Table, CO_2 and CH_4 gases during the period of study have experienced a linear increasing trend and this point is more evident in CO_2. After 1993, the trend of annual discharge in the basin has significantly decreased and the obtained results from correlation analysis and having a reverse correlation relationship with CO_2 and CH_4 gases demonstrate and confirm this point.

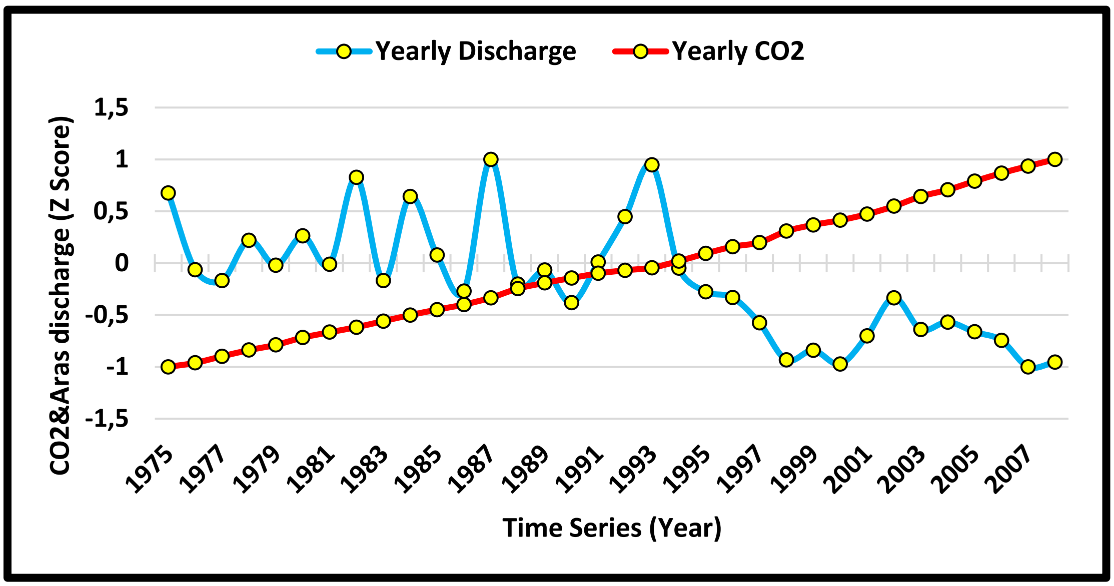

Figure 4: Comparative & Standardized Graph for Annual Changes Between CO_2 and Mean Discharge of Aras River Basin

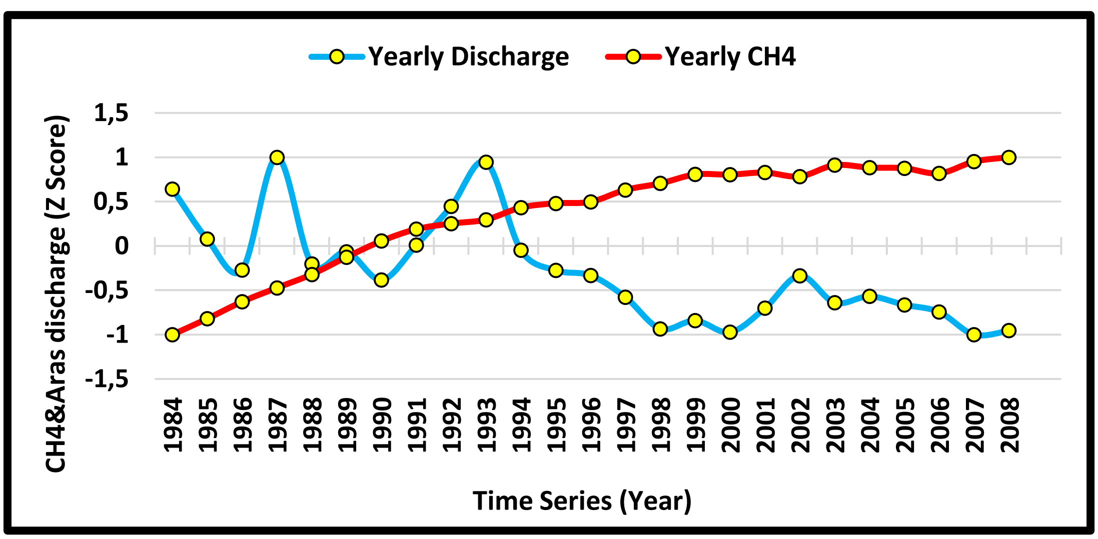

Figure 5: Comparative & Standardized Graph for Annual Changes Between CH_4 and Mean Discharge of Aras River Basin

Mann-Kendall was used to evaluate the significance of the trend changes in annual discharge of the Aras river basin (Figure 6). According to Figure 6, the significance of the changes can be clearly confirmed in time series of discharge in the Aras river basin. According to this chart in 1993, a turning point can be observed in the trend of the basin flow. UI and U'I lines intersected each other in 1996, and with UI line egression from the range of ±1.96, it can be claimed that the trend of changes in the discharge of the river basin is quite significant. The trend of discharge in this river from 1993 was decreasing which refers to its sharp drop.

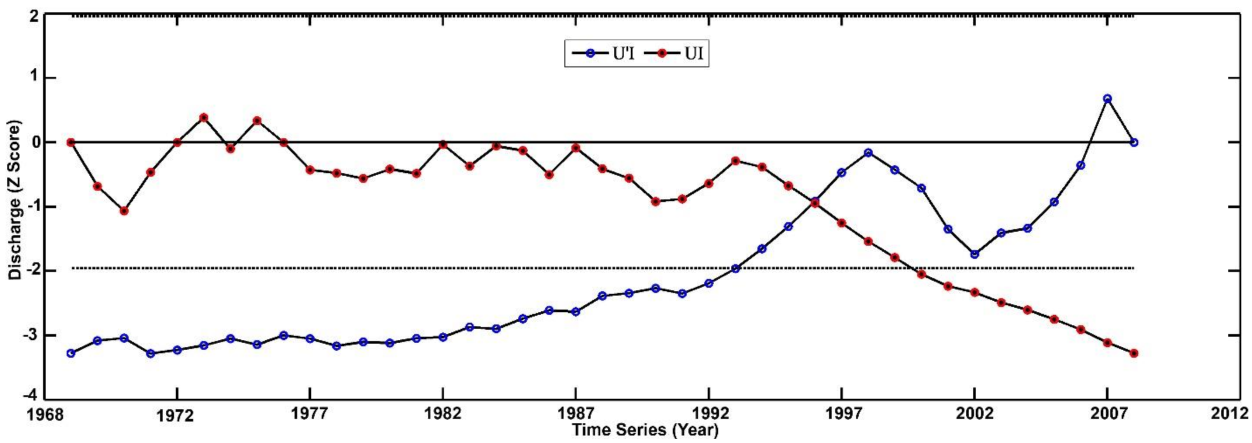

Figure 6: Mann-Kendall Graph for Annually Mean Discharge of Aras River Basin

The trend of monthly time series in the discharge of the Aras river during 41 years of study period showed a decrease in all months of the year. In other words, in all months of the year, discharge of the basin has reduced and in the long run it shows a decreasing trend. During the months of year, the greatest level of decrease was observed in February, January, and November, respectively. Among the examined months, July, August, and September had the highest level of fluctuation and short-term volatility. These months that represent discharge situation of the Aras river basin in summer seasons, refer to the largest amount of short-term fluctuations during the study time interval. In this season, lack of precipitation and its fluctuation compared to other seasons is a reason for sharp fluctuations of the Aras discharge in the respective months. Figures 7 to 10 present time series for discharge of the Aras river basin in February, April, July, and November. Trend of discharge in the respective months is decreasing that is representative of different seasons. The highest decline of discharge is in February and the least is in August.

According to the trend of time-series in months of year, discharge of the Aras river basin can experience the highest level of drop and decline in winter, spring, autumn, and in late summer, respectively. The occurrence of this process wasn't without a reason and according to the obtained results from correlation test between discharge and studied gases; it can be argued that parts of decline and decreasing flow rate of discharge are influenced by the increase of greenhouse gases. According to the correlation table (Table 2), it can be observed that there isn't any significant difference between NO_2 and discharge of the Aras river basin. In contrast, the highest amount of influence can be observed between CO_2 and CH_4. In both of the above-mentioned gases, the greatest influence can be observed in February about -0.82 and -0.836, respectively in CO_2 and CH_4. Both of these gases have a negative correlation relationship with discharge of the Aras river basin at the confidence level of 0.99. Coefficients of determination were 0.67 and 0.698%, and it can be said that, 67 and 69% of discharge decline in the basin of Aras river weren't irrelative to gas changes. After February, discharge of the Aras basin in January with -0.71 in CO_2 and in April with -0.745 in CH_4 had the greatest influence of the mentioned gases. Approaching summer with respect to both gases, any significant relationship can't be seen between discharge and CO_2 and CH_4. During this time, because of the presence of dynamically high-pressure flows next to sub-tropical areas in the sky of Iran, less precipitation flows enters into the country and the study area; hence the level of precipitation would decrease. This process can reduce a large amount of the severity of greenhouse gases influence on the discharge of the Basin. Therefore, there is no correlation between them and discharge of the Aras basin. Decrease of discharge in the Aras basin in these months of the year has occurred mostly due to the impact of planetary factors on regional precipitation. According to correlation coefficients, it can be argued that the impact of carbon dioxide is more than methane on the discharge of the Aras basin.

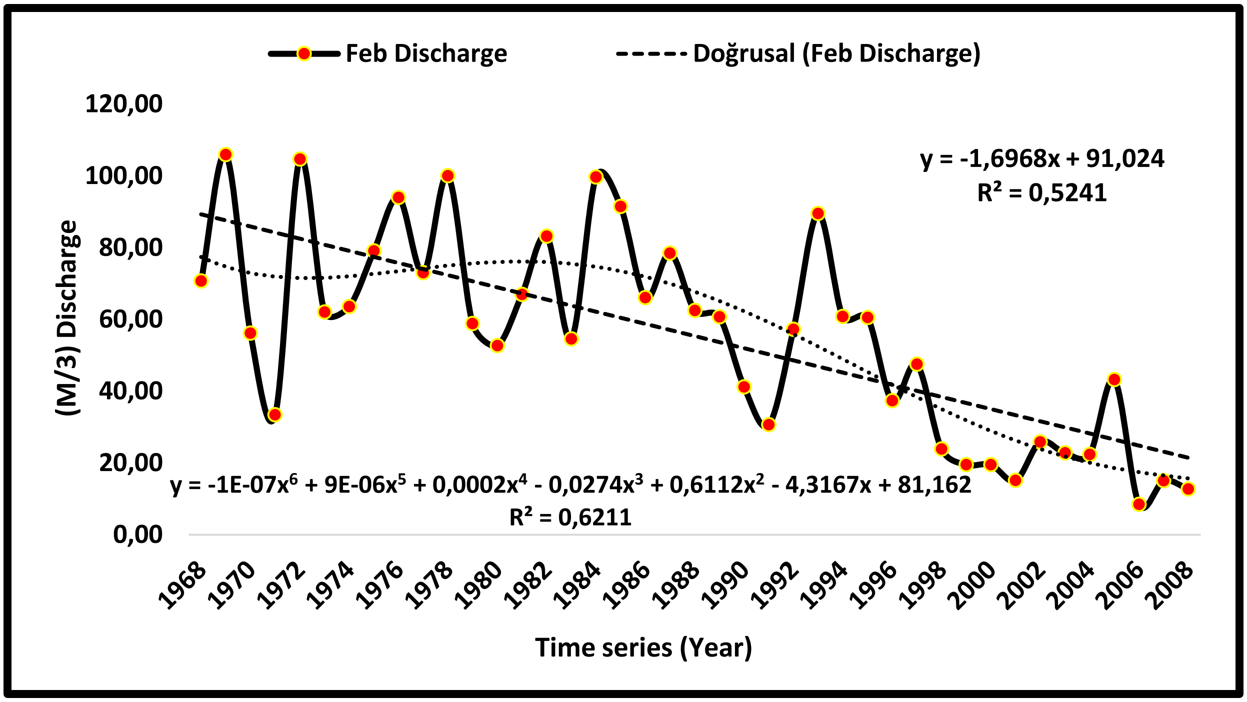

Figure 7: Time Series Graph for Mean Discharge of Aras River Basin in February

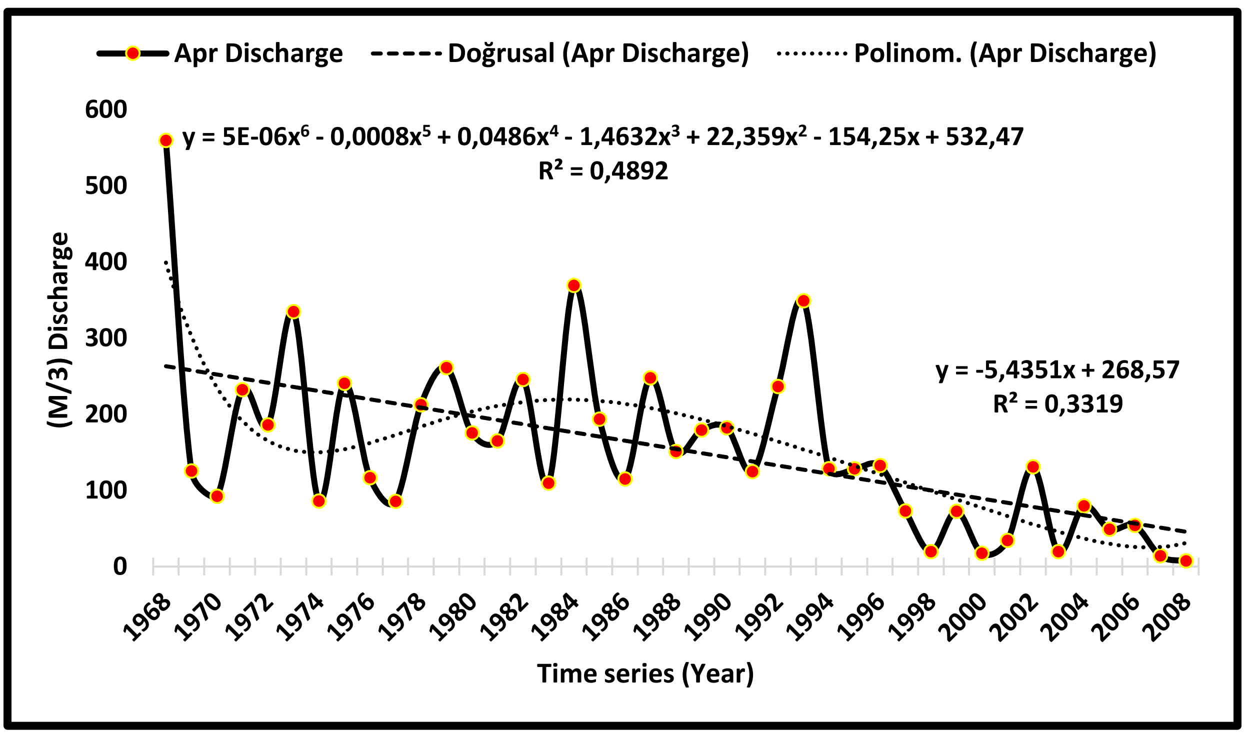

Figure 8: Time Series Graph for Mean Discharge of Aras River Basin in April

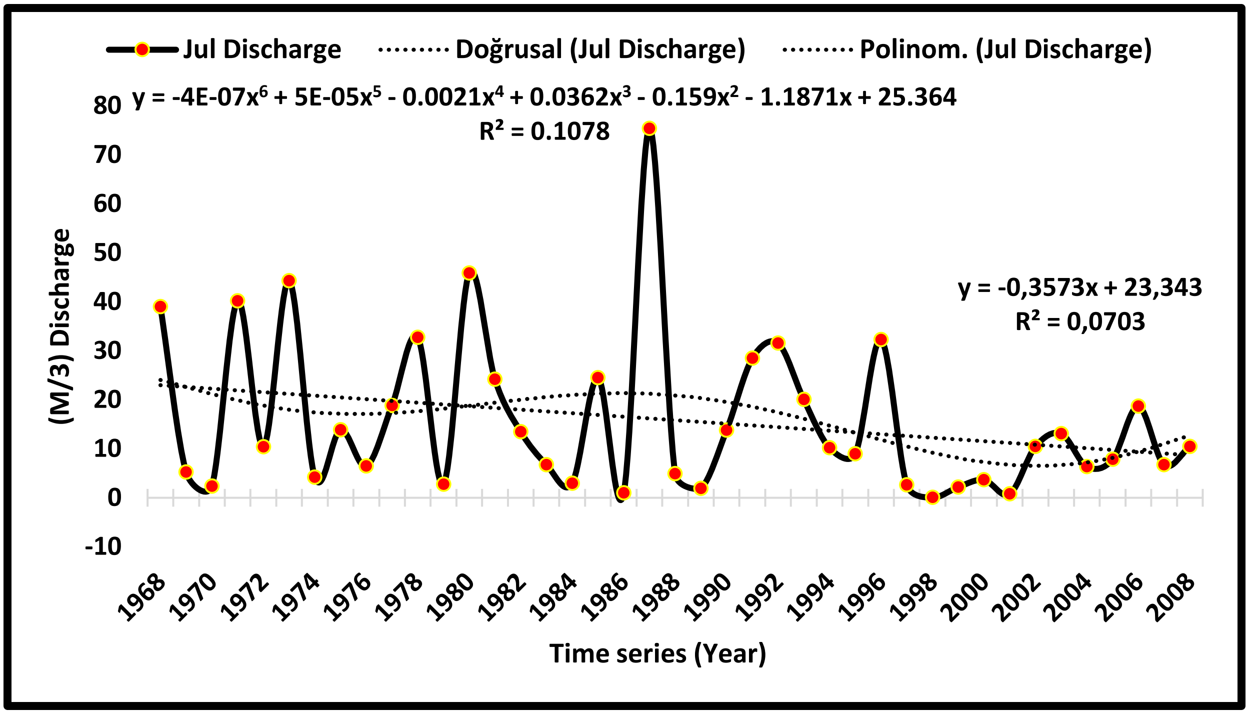

Figure 9: Time Series Graph for Mean Discharge of Aras River Basin in July

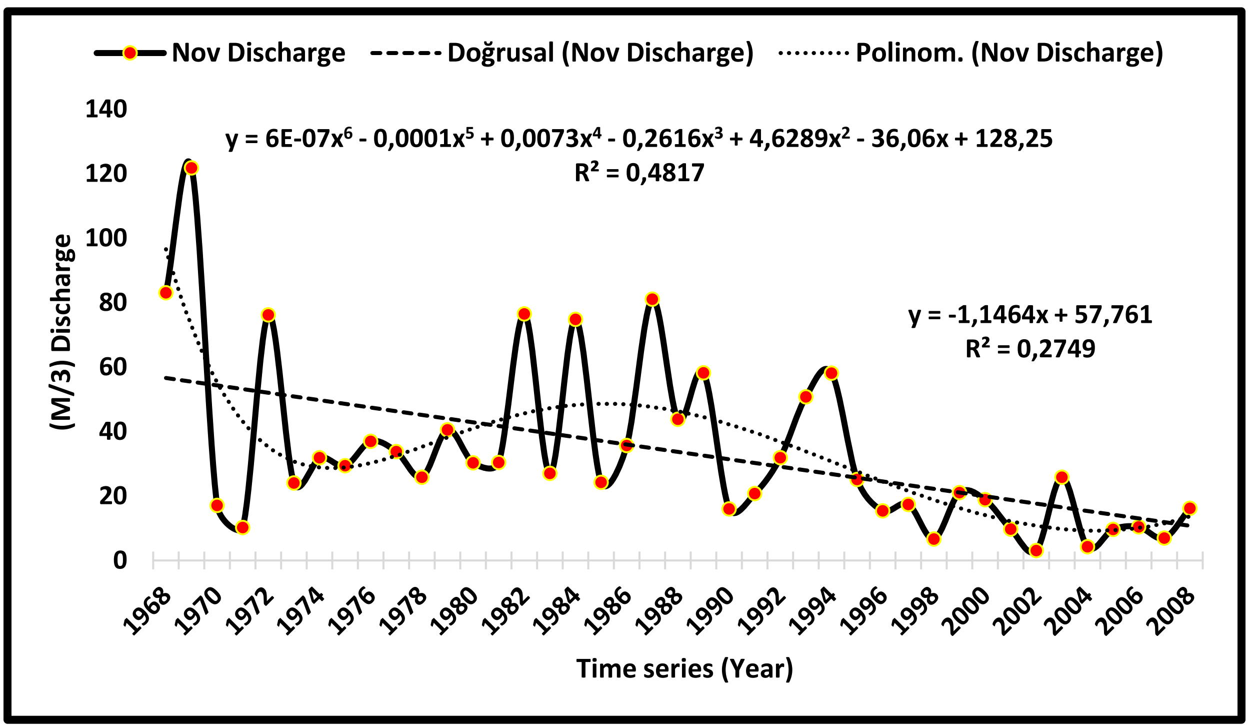

Figure 10: Time Series Graph for Mean Discharge of Aras River Basin in November

Figure 11 and 12 show comparative graphs of the Aras basin discharge in February with carbon dioxide and methane. According to the mentioned figures, trend of gases during study period was ever-increasing and ascending and the stated process in CO_2 is closer to a linear mode. Since 1985, a sharp drop can be observed in the discharge of February to the end of the study period that has a quite reverse trend with the changes of CO_2 and CH_4.

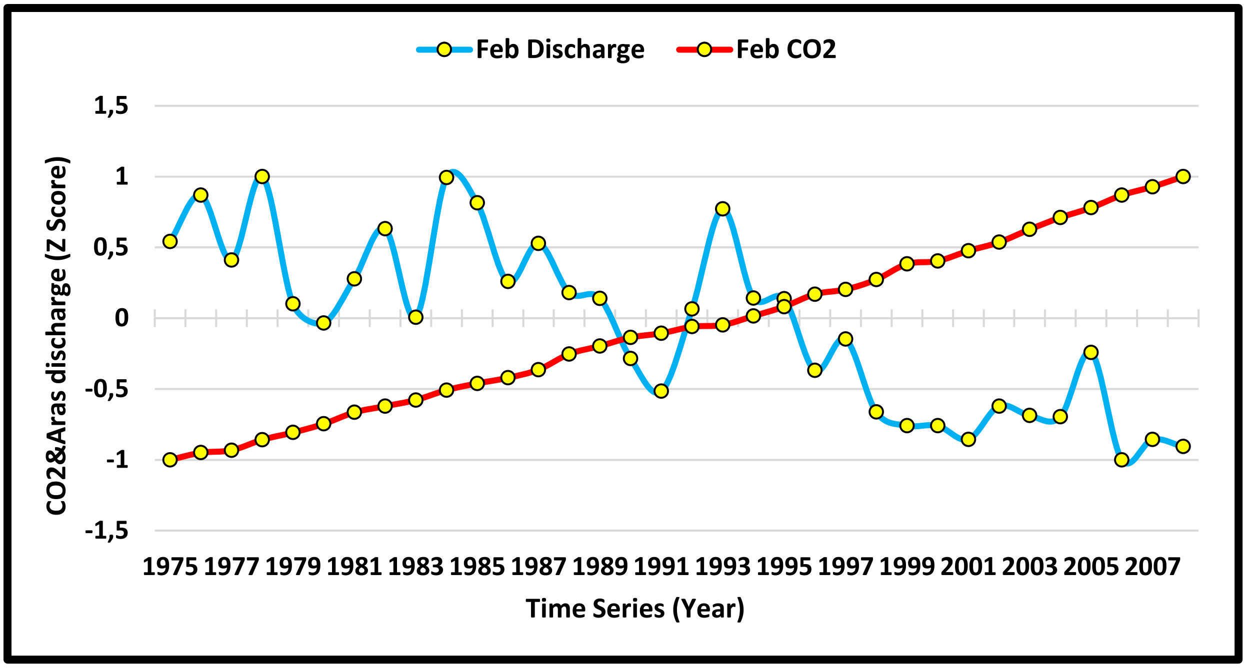

Figure 11: Comparative Graph Between CO_2 and Mean Discharge of Aras River Basin in February

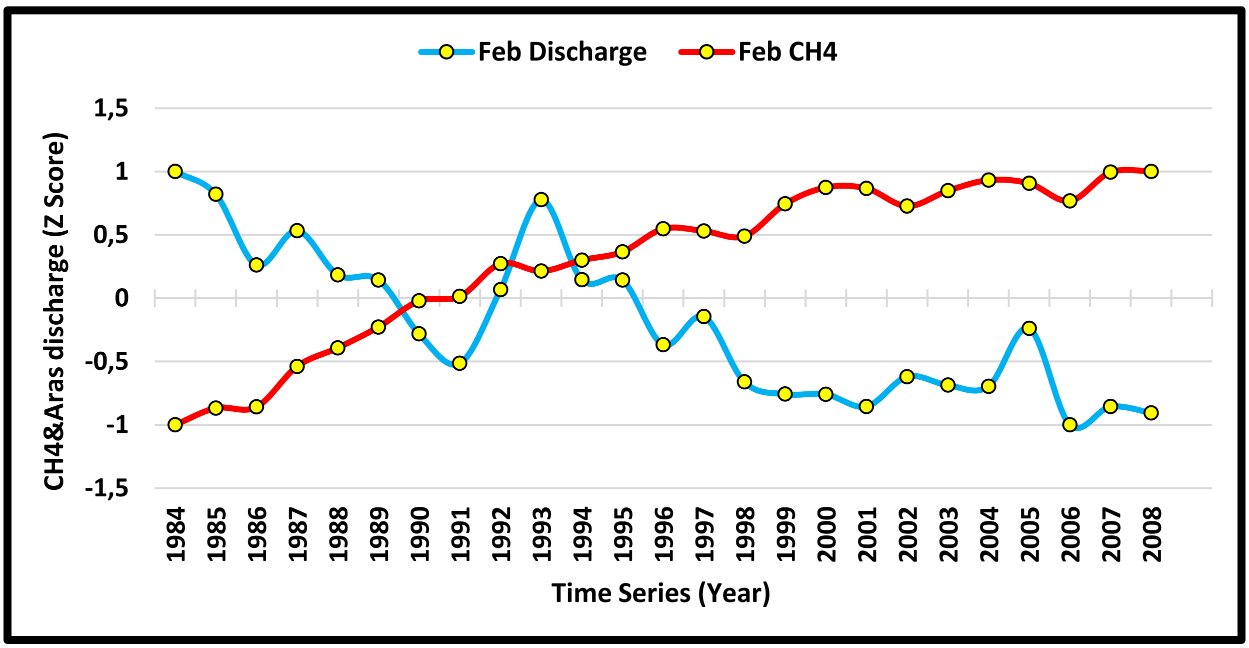

Figure 12: Comparative Graph Between CH_4 and Mean Discharge of Aras River Basin in February

According to the obtained results from the changes of trend in Mann-Kendall test, in all months, the changes in trends are completely significant. In all months, UI line with intersecting U'I line comes out from the range of ±1.96 that confirms the significance of changes in the trend. Figure 13 and 14 show Mann-Kendall graphs in November and April. In November 1996, a turning point was observed in the discharge of the Aras, and in this year UI and U'I lines intersect each other and UI comes out from the range of ±1.96. According to the obtained results, it can be claimed that the changes in the trend are significant. In 1998, a turning point was observed in the trend of time series in the Aras river basin. UI line after intersecting U'I line comes out from the range of ±1.96 and this process confirms the significance of changes in the trend.

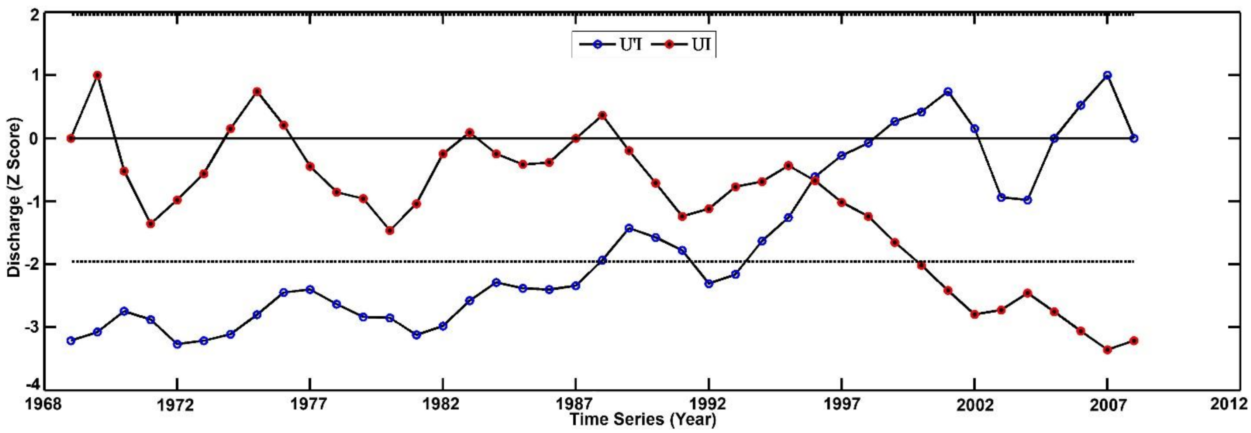

Figure 13: Mann-Kendall Graph for Mean Discharge of Aras River Basin in November

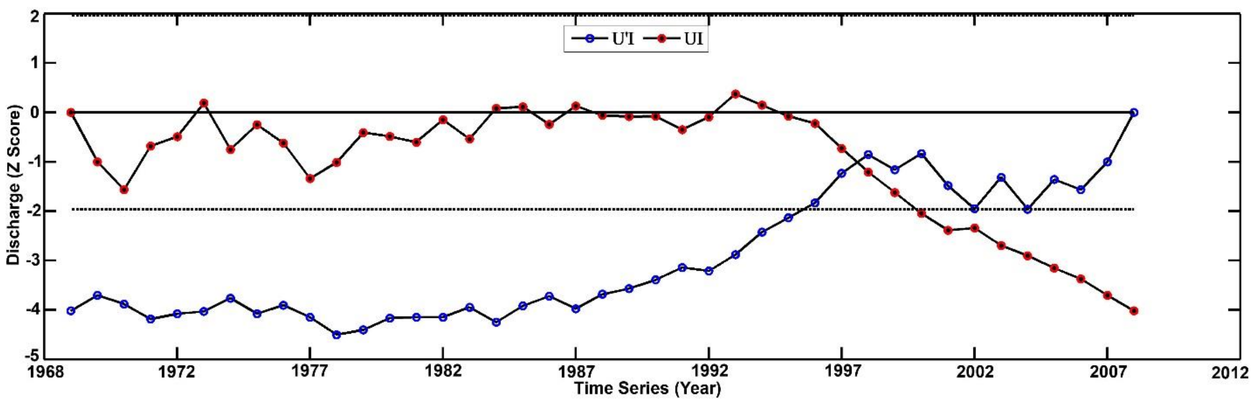

Figure 14: Mann-Kendall Graph for Mean Discharge of Aras River Basin in April

CONCLUSION

We did the present study to investigate the effect of greenhouse gases on the discharge of the Aras basin river. The results from investigation of changes in the discharge of the Aras river indicated a decreasing trend. This decreasing trend can be observed on a monthly basis and annually in the basin of Aras river. According to Pearson correlation results, this decreasing trend of discharge wasn't irrelative and among the three examined greenhouse gases, it has a close relationship with carbon dioxide and methane that are considered the most important greenhouse gases.

Nitrogen dioxide didn't have any relationship with the decreasing trend of the Aras basin. But two other greenhouse gases, except in summer, at a confidence level of 99% often had a negative correlational relationship with the discharge of the Aras basin that refers to the decline of discharge in the basin with the increase of these gases in the environment. The greatest effect of greenhouse gases can be observed in the months of December, January, February, March, and April which indicates the increase of temperature in cold months and also decrease in precipitation and discharge. Mann-Kendall test indicated the significance of the trend changes in the discharge of the Aras river basin. In all months of the year, the monthly or annual changes in the trend, due to the intersection of UI and U'I lines and egression of UI lines from the range of ± 1.96 are quite significant. The results of this research are in line with the researches in this field and confirm the results obtained from them. According to studies, researchers have concluded that the increase in greenhouse gases and global warming has a positive effect on temperature and has led to an increase. But on the other hand, it has a negative effect on the precipitation and discharge of rivers in catchments and has led to a decrease (Manabe et al., 2004; Fujihara et al., 2008; Esfandiari Darabad et al., 2013; Sharifian and Habibi, 2013; Toulabi Nejad et al., 2015). Especially this process is most common in the mid-latitudes. The cases mentioned above have also occurred in the study area and a decrease in discharge has been observed in recent years in the Aras river basin. With the formation of this trend, the quick decrease in discharge in this basin is expected in the upcoming years and North West of country that is highly dependent on the river water will face serious problems. Therefore, respected managers can be provided with the results of this study to give them a clear approach to plan and exploit and make better use of rich sources of fresh water and avoid a host of problems in this regard in the future.

ACKNOWLEDGEMENT

The authors would like to thank Dr. Vali Mohammadi, University of Mohaghegh Ardabili, Ardabil, Iran, for his kind and valuable help in preparing the manuscript.

References

Ahn, K. H. & Merwade, V. (2014). Quantifying the relative impact of climate and human activities on streamflow. *Journal of Hydrology*, 515, 257-266.

Burgos, M., Sierra, A., Ortega, T. & Forja, J. M. (2015). Anthropogenic effects on greenhouse gas (CH4 and N2O) emissions in the Guadalete River Estuary (SW Spain). *Science of the Total Environment*, 503, 179-189.

Change, I. C. (2007). *The Physical Science Basis*. IPCC report.

Davis, J. C. & Sampson, R. J. (1986). *Statistics and Data Analysis in Geology.* (Vol. 646). New York: Wiley.

Esfandiari Darabad, F., Alijahan, M., Rahimi, M. & Mehrvarz, A. (2013). Statistical detection of the effect of global warming on discharge of Aras River. *Quantitative Geomorphology Research*, 1(4), 43-60.

Feyzi, V. (2009). *Analysis of spatial-temporal distribution of climate change in Iran*. (Master's degree in climatology, Tarbiat Modares University, Faculty of Literature and Humanities, Department of Physical Geography, Tehran, Iran).

Fujihara, Y., Tanaka, K., Watanabe, T., Nagano, T. & Kojiri, T. (2008). Assessing the impacts of climate change on the water resources of the Seyhan River basin in Turkey: Use of dynamically downscaled data for hydrologic simulations. *Journal of Hydrology*, 353(1-2), 33-48.

Griggs, D. J. & Noguer, M. (2002). Climate change 2001: The scientific basis. Contribution of working group I to the third assessment report of the intergovernmental panel on climate change. *Weather*, 57(8), 267-269.

Hafeznia, M. R. (2010). *Introduction to the Research Method in the Humanities*. (7th ed.). Tehran: SAMT Publication. (In Persian).

Khoshakhlagh, F., Afsharmanesh, H., Shafiei, Z. & Aghaalkhani, M. (2010). Evaluation of the Effect of Climate Change on Surface Water Hydrology, Case Study: Karun River, 14th Iranian Geophysical Conference, Geopolitics Association of Iran, Tehran, Iran.

Khosravi, M., Esmaeil Nejad, M. & Nazaripour, H. (2010). Climate Change and Its Influence on Middle East Water Resources, Proceedings of the Fourth International Congress of the Geographers of the Islamic World, pp. 1-8.

Lanzante, J. R. (1996). Resistant, robust and non-parametric techniques for the analysis of climate data: Theory and examples, including applications to historical radiosonde station data. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, 16(11), 1197-1226.

Li, L. J., Zhang, L., Wang, H., Wang, J., Yang, J. W., Jiang, D. J., ... & Qin, D. Y. (2007). Assessing the impact of climate variability and human activities on streamflow from the Wuding River basin in China. *Hydrological Processes: An International Journal*, 21(25), 3485-3491.

Li, X. X., Qin, D. H. & Li, J. Y. (2007). *National Assessment Report of Climate Change*. Beijing: Science Press.

Liang, L., Li, L. & Liu, Q. (2010). Temporal variation of reference evapotranspiration during 1961–2005 in the Taoer River basin of Northeast China. *Agricultural and Forest Meteorology*, 150(2), 298-306.

Manabe, S., Milly, P. C. D. & Wetherald, R. (2004). Simulated long-term changes in river discharge and soil moisture due to global warming/Simulations à long terme de changements d'écoulement fluvial et d'humidité du sol causés par le réchauffement global. *Hydrological Sciences Journal*, 49(4).

Marín Muñiz, J. L., Hernández, M. E. & Moreno Casasola, P. (2015). Greenhouse gas emissions from coastal freshwater wetlands in Veracruz Mexico: Effect of plant community and seasonal dynamics. *Atmospheric Environment*, 107, 107-117.

Martin Gorriz, B., Soto García, M. & Martínez Alvarez, V. (2014). Energy and greenhouse-gas emissions in irrigated agriculture of SE (southeast) Spain. Effects of alternative water supply scenarios. *Energy*, 77, 478-488.

Mizyed, N. (2009). Impacts of climate change on water resources availability and agricultural water demand in the West Bank. *Water Resources Management*, 23(10), 2015-2029.

Mohammad Khorshiddost, A. & Ghavidel Rahimi, Y. (2006). Simulation of double effects of atmospheric carbon dioxide on Tabriz climate change using the GFDL model. *Journal of Environmental Study*, 39, 1-10. (In Persian).

Plampin, M., Illangasekare, T., Sakaki, T. & Pawar, R. (2014). Experimental study of gas evolution in heterogeneous shallow subsurface formations during leakage of stored CO2. *International Journal of Greenhouse Gas Control*, 22, 47-62.

Pohlert, T. (2016). Non-parametric trend tests and change-point detection. CC BY-ND, 4.

Rossi, R. E., Mulla, D. J., Journel, A. G. & Franz, E. H. (1992). Geostatistical tools for modeling and interpreting ecological spatial dependence. Ecological Monographs, 62(2), 277-314.

Sakaki, T., Plampin, M. R., Pawar, R., Komatsu, M. & Illangasekare, T. H. (2013). What controls carbon dioxide gas phase evolution in the subsurface? Experimental observations in a 4.5 m-long column under different heterogeneity conditions. *International Journal of Greenhouse Gas Control*, 17, 66-77.

Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's tau. *Journal of the American statistical association*, 63(324), 1379-1389.

Sharifian, H. & Habibi, A. (2013). The Effect of Climate Change on Surface Water Changes in a part of Golestan Province Basin. First National Conference on Water and Agriculture Water Challenges. Iran Irrigation and Drainage Association, Islamic Azad University, Khorasgan Branch, Isfahan, Iran. (In Persian).

Shen, D. J. & Liu, C. M. (1998). Response of hydrology and water resources system for climate change. *Geography Research*, 17, 435-443.

Sheng, Q., Zhao, B., Huang, M., Wang, L., Quan, Z., Fang, C. & Wu, J. (2014). Greenhouse gas emissions following an invasive plant eradication program. *Ecological Engineering*, 73, 229-237.

Sun, M., Yuan, Y., Zhang, J., Wang, R. & Wang, Y. (2014). Greenhouse gas emissions estimation and ways to mitigate emissions in the Yellow River Delta High-efficient Eco-economic Zone, China. *Journal of Cleaner Production*, 81, 89-102.

Tian, F., Yang, Y. & Han, S. (2009). Using runoff slope-break to determine dominate factors of runoff decline in Hutuo River basin, North China. *Water Science and Technology*, 60(8), 2135-2144.

Toulabi Nejad, M. & Naserzadeh, M. H. (2015). The role of greenhouse gases on fluctuations of discharge of Kashkan-Roud. *Hydro-Geomorphology*, 2, 135-117. (In Persian).

Wang, X., He, K. & Dong, Z. (2019). Effects of climate change and human activities on runoff in the Beichuan River basin in the Northeastern Tibetan Plateau, China. *Catena*, 176, 81-93.

WMO Global Ozone Research, & Monitoring Project. (1986). Atmospheric Ozone, 1985: Assessment of Our Understanding of the Processes Controlling Its Present Distribution and Change (Vol. 1). National Aeronautics and Space Administration.

Yadav, R., Tripathi, S. K., Pranuthi, G. & Dubey, S. K. (2014). Trend analysis by Mann-Kendall test for precipitation and temperature for thirteen districts of Uttarakhand. *Journal of Agrometeorology*, 16(2), 164.

Ye, X., Zhang, Q., Liu, J., Li, X. & Xu, C. Y. (2013). Distinguishing the relative impacts of climate change and human activities on variation of streamflow in the Poyang Lake catchment, China. *Journal of Hydrology*, 494, 83-95.

Zeng, X., Kundzewicz, Z. W., Zhou, J. & Su, B. (2012). Discharge projection in the Yangtze River basin under different emission scenarios based on the artificial neural networks. *Quaternary International*, 282, 113-121.

Zhang, X., Li, P. & Li, D. (2018). Spatiotemporal variations of precipitation in the southern part of the Heihe River basin (China), 1984-2014. *Water*, 10(4), 410.