Evaluation Of Annual And Seasonal Variation Trends Of Rainfall And Flow Rate In Atrak Water Basin

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ABSTRACT
Background: Rivers are one of the main resources of water supply. To better manage these resources, knowledge their flow rate trend and the factors causing this trend is necessary. Objective: This study objective is to analyze rainfall and flow rate trends in Atrak basin, which is one of low rainfall ones in north-east part of Iran. To do the present study, flow rate and rainfall data were obtained in all stations in Atrak basin from National Water Resource Research Institute (Tamab). After initial assessment of observation series of the variables in all hydrometric stations of the basin, those stations with more than 25 years experience of observation data, were selected for the trend test. Therefore, among 18 stations with common rainfall and flow rate, six stations which had the longest data period and proper dispersion in the basin, were selected in a statistic period from 1980 to 2010. In this study, trend of annual and seasonal variation of rainfall and flow rate in Atrak River was examined by non parametric tests (Mann-Kendal and Sen's Estimator) and parametric test (T-Test). Results: Results of rainfall and flow rate analysis showed that rainfall had a same increase and decrease trend in fall and winter. Rainfall increased in spring and summer in all stations; however, there is no increasing trend in flow rate data in any station. This was probably because of over extraction and consumption of river water. Demand for Water has been increased because of growing population. Conclusion: Therefore, utilize and control of water consumption and optimizing of its consumption, is one of the vital needs to overcome water crisis, regarding to the present study results.

INTRODUCTION

Climate change is one of the biggest challenges facing mankind [1]. The earth's climate is very variable [2]. According to IPCC reports, Global temperatures have risen since the beginning of the Industrial Revolution which resulted in melting ice and rising sea water level up to 70 cm [3]. Climate variation is not absolutely a natural process and is influenced by socio-economic conditions of the society. In recent years, it has been faster and encountered to an unknown trend [4].

Although global warming encompasses the entire world, this heating is more significant in some regions such as the northern hemisphere. Studies show that surface water flow has increased up to 4% and will change surface run off level, sediment load and river solutes against each one degree of centigrade increase in ambient temperature [5]. In general, world heating leads to enhance world water cycle and finally surface run off flow in high latitudinal regions such as north America, Canada and Northern Europe, but a different reaction is observed in lower latitudinal regions and arid and semi arid regions and the river flow rates are decreased [6]. In addition, storms, floods, droughts, cooling and heating will happen more severely and in shorter time.

Climate variation shows it's most negative influence on poor and developing countries, as they are more interacted with climate and their existence depends upon their natural and agricultural resources. On the other hand, their adaptive capacity is less against the environment [7].

Human activities and variations in land application and usage has changed the flow rate peak and base [8]. Also, average temperature increase of the world has resulted in abnormalities in weather and hydrologic variables, such as rainfall, evaporation and transpiration. For better management of water resources to have knowledge about river flow rate variations and the engaged factors is necessary. Therefore, assessment of these abnormalities as the trend determination against hydrologic and climatic variable time series in different regions and their relation should be noted as an important role. In recent years, many researches have been conducted

Corresponding Author: Fahimi Nezhad Elham, Department of Climatology, Faculty of Geography and Environmental science, Hakim Sabzevari University, Sabzevari, Iran. E-mail: elhamfahiminezhad@gmail.com
about possible influences of climatic variations on river flows, most of which consider long term average climatic variations and hydrologic properties. In general, these variations are studied in two ways of available recorded data analysis of rain fall and river flow and influence of different scenarios of climatic variations on river flows by hydrologic models.

The most common way to analyze hydrologic and climatic time series data is to assess presence and absence of a trend in them by using analytical tests. Principally, presence of a trend in these series may result from gradual natural variations, climatic change or human activities.

Different methods have been already presented for time series data analysis, divided into two parametric and non parametric ones, non parametric methods of which are more applicable than the parametric ones.

Jang and coworkers [9], have analyzed the trend in annual discharge and flow rates of suspended sediments of hydrometric stations on main Youngtzi River (four stations) and the main branches (3 stations) by using Mann-Kendal and linear regression tests. Their analysis results showed those annual discharge variation model and sediment loads are completely different in various parts of Youngezi water basin.

In Iran, some research have been conducted on analysis of different hydrologic and weather variable trends, such as Kaviani and Asakarch [10], who studied annual temperature in Jask, while Masoudian [11], studied monthly temperature variations all around Iran and Asakareh [12], also studied annual temperatures of Tabriz in terms of rain fall, Khalili and Bazrafshan [13], studied rain fall trend in 5 old Iran stations and Razie and coworkers [14]. studied rain fall trend in arid and semi-arid regions of central and eastern parts of Iran by using 76 climatologic and synoptic stations’ data of Iranian Meteorological Organization, in a 36 years statistic period (1965-2000) through statistical non parametric tests. The study results showed that there observed 10 evidence of climatic variations in the studied region.

About flow rate trend, Ghayoor and Rahimi[15]. studied estimation of flow rate variations in Upstream Karon basin, by using time series transformation functions of Armand station and resulted that annual flow rate data of Armand station had no ascending trend. The present study purpose was to reveal existence and value of flow rate and rain fall trend in Atrak water basin in north-east of Iran, which is known as low rain fall regions of Iran.

MATERIALS AND METHOS

Study Area:

Atrak water basin is located in north-east and northern Khorasan region between longitude 54°-59° E and latitude 36° - 38° N. This basin limited to Turkmenistan Republic in the north, Garganrood and Kalshoor basins (central desert) in the south, GharehGhom basin in the east and Caspian Sea in the west (figure 1). Total area of Atrak basin, except one small part located in Turkmenistan, is about 25627 Km². The main river is about 520 km and its main flow direction is east to west which finally flows into the Caspian Sea. Rivers Shirabad, Hotan, Ghatlish, Darkeh, Samalqan and BabaAman are of the main branches of this water basin.

Atrak basin has two plain and mountain parts, and has a continental and variable weather. Atrak basin rainfall has severe variations for its mountaineer region. The rainfall level is ranged from lower than 200 mm in north-west plain regions to more than 500 mm in mountaineer southern regions. Maximum height of the basin is about 2903m from the sea level in Tabarak branch and the minimum is about -22m from the sea level in coastal regions. Also average slope of Atrak basin is 3.2% and the average water ways slope is estimated 2.7%.

Fig. 1: Position of Atrak water basin and the studied hydrometric stations
Regarding to topographic and weather conditions of Atrak basin, a surface flow ranges from partially snowy regime in western part, to a full rainy one in coastal parts of the basin.

Methodology

To do the present study, flow rate and rainfall data of all the current stations of Atrak basin were prepared from National water resource research institute (Tamab). Six stations were chosen which had the longest statistic period of flow rate and rainfall and had appropriate dispersion in the basin area (Table.1). shows the stations properties.

Table 1: Geographic properties of the studied stations

<table>
<thead>
<tr>
<th>stations</th>
<th>Elevation from sea level(m)</th>
<th>Geographic coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghatlish</td>
<td>560</td>
<td>Longitude</td>
</tr>
<tr>
<td>Babaaman</td>
<td>1010</td>
<td>57-16</td>
</tr>
<tr>
<td>Shirabad</td>
<td>850</td>
<td>57-26</td>
</tr>
<tr>
<td>Darkesh</td>
<td>1040</td>
<td>56-55</td>
</tr>
<tr>
<td>Hotan</td>
<td>100</td>
<td>56-44</td>
</tr>
<tr>
<td>Samalghan</td>
<td>680</td>
<td>55-44</td>
</tr>
</tbody>
</table>

To do the present study, at the first step, seasonal and annual rainfall and flow rate data of each station were prepared and then existence of trend was examined in each station using Man-Kendal and Sen's Estimator test.

Mann-Kendal Test (MK):

One of the most applicable non-parametric methods to analyze data trend is Man-Kendal test. MK test has been used by many researchers among different nonparametric tests as the best option to study the existence of data uniform trend. In fact, this test was first provided by Mann in 1945 and then developed by Kendall in 1966. The method was confirmed by WMO in those years. Like other statistic tests, this test was also based on comparison between 0 and 1 hypos and finally acceptance or reject of the assumed zero hypo will be decided. Hypo 0 of the test is based on randomness and lack of trend in data series and acceptance of hypo 1 (reject of hypo zero) means presence of a trend in data series. Non parametric Mann-Kendal test, despite parametric tests, like linear regression, doesn't assume a certain distribution function for data series, while its recognition power is the same as parametric one. Of the other advantages of Mann-Kendal test is the bit influence of limitation values on it which is seen in time series data. In this method, data are sorted by time occurring and each data is compared with all ones following it. The test stages are as follow:

\[ S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \text{sign}(x_i - x_j) \]

\[ \text{sign}(\theta) = \begin{cases} 1 & \text{if } \theta > 0 \\ 0 & \text{if } \theta = 0 \\ -1 & \text{if } \theta < 0 \end{cases} \]

For random independent variables which have a uniform distribution without node (two or more data with the same numerical values, which sorted in series, and successively) average and variances are as follow:

\[ E(s)=0 \]

\[ \text{Var}(s)=\frac{n(n-1)(2n+5)}{18}, n \leq 10 \]

Where \( n \) is the number of observation data series. If there is duplicate data in the series, variance will be measured as follow:

\[ \text{Var}(s)=\frac{n(n-1)(2n+5)}{18} \sum_{i=1}^{n} t_z(i)(i-1)(2i+5) \]

\[ n > 10 \]

Where \( t \) is the number of nodes with capacity \( i \). For example, if there are only two numbers with the same values in a data series, there will be a node with capacity 2 (\( tz=1 \)). If number of a series data is more than 10, \( S \) will follow normal distribution and the standard stations index (Z) is as follow:
Therefore, in a mutual test, Hypo zero will be registered to realize the trend, if \( Z_s \geq Z \)

Sen's Estimator

Sen’s Estimator is also based on a discrepancy between observations of a time series, just as in Mann-Kendall method. In this method the slope between each pair of data is measured and the mean of the obtained slopes is extracted. This test is easily usable when there are lots of data. The relation is as follow:

\[
\hat{\beta} = \frac{x_t - x_s}{t - s}
\]

Positive amount (\( \hat{\beta}_{med} \)) shows the increasing trend and the negative one shows its decreasing.

Regression Analysis

In this method, number of the year are input on horizontal axis in a coordinate system and data related to the year are input on vertical axis and a linear line is plotted with the points by equation \( y = a + bx \). a and b are regression coefficients which are measured by least square method. By obtaining T with a freedom degree of n-2 through the following relation, significance of the regression slope is tested:

\[
T = \frac{b}{\sqrt{\text{MSE}/S_{xx}}}
\]

Where MSE in the mean square error and Sxxis obtained as follow:

\[
S_{xx} = \sum_{i=1}^{n}(x_i - \bar{x})^2
\]

If n-2and \( |T| > t_{\alpha}/2 \), regression slope is considered meaning less and slope b, significantly non-zero, shows presence of trend.

Data Analysis and Discussion

The study purpose is to analyze flow rate and rainfall trend in Atrak water basin which is a low rainfall basin in north-east of Iran.

To conduct the present study, flow rate and rainfall data of all present stations of the basin were prepared by National water resources research institute (Tamab). After initial assessment of the observation series of variables in all hydrometric stations, those groups of stations with more than 25 years observation data were selected to do trend test. Therefore, among 18 stations with the same rainfall and flow rate data, 6 stations with the longest similar statistic duration for rainfall and flow rate had an appropriate dispersion over the basin, were selected from the statistic period 1980-2010. In this study annual and seasonal variations of flow rate and rainfall of Atrak River were evaluated using non parametric Mann-Kendal and Sen's Estimator test and also parametric T-tests (regression analysis).

Trend is one of the main non-static factors, which one is a gradual change in time series. Different factors can cause it, either externally or internally. For example, development of agriculture lands and more harvesting decrease of the river flow downstream (as internal factors), also long term climatic variations (such as heat increase) as an external factor can be followed by similar results. Of course, to prove a significant trend in hydrometeorology time series can’t be the only reason to climate variation, but can enhance its possibility to occur. The reason of this uncertainty is the great number of effective influences on climatic systems. Mann-Kendal test, Sen’s Estimator and regression analysis results have been reported in table 2 and 3 for seasonal rainfall of the studied stations and in tables 4 and 5 for seasonal flow rate of the studied stations.

Seasonal Rainfall Variation Trend:

Mann-Kendal test and regression analysis results have been reported in table 2 for fall and winter rainfall of the stations. According to the results, fall rainfall has had an increasing trend in four stations; BabaAman, Ghatlish, Darkshe and Shirabad and a decreasing one in two stations Samalqan and Hootan, while according to the parametric test results of regression analysis fall rainfall amount has had a decreasing trend in BabaAman and Darkshe stations in addition to Samalqan and Hootan ones. According to the reported results in table 2 winter rainfall amount has had an increasing trend in two stations BabaAman and Ghatlish according to Mann-Kendall test results and a decreasing trend in four stations Darkshe, Shirabad, Samalqan and Hootan, while
winter rainfall amount has increased in Darkesh station according to the parametric test results of regression analysis. Regarding to table 2 rainfall amount has decreased in three stations Shirabad, Samalqan and Hootan in this season.

### Table 2: Mann-Kendal test, Sen’s Estimator and regression analysis results for seasonal rainfalls

<table>
<thead>
<tr>
<th></th>
<th>Spring</th>
<th></th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Z</td>
<td>Bmed</td>
<td>T</td>
</tr>
<tr>
<td>BabaAman</td>
<td>0.825</td>
<td>0.83</td>
<td>0.8</td>
</tr>
<tr>
<td>Ghatlish</td>
<td>0.8</td>
<td>0.35</td>
<td>0.82</td>
</tr>
<tr>
<td>Darkesh</td>
<td>0.63</td>
<td>1.23</td>
<td>0.08</td>
</tr>
<tr>
<td>ShirAbad</td>
<td>1.08</td>
<td>1.05</td>
<td>0.79</td>
</tr>
<tr>
<td>Samalqan</td>
<td>0.35</td>
<td>0.24</td>
<td>0.39</td>
</tr>
<tr>
<td>Hootan</td>
<td>0</td>
<td>-0.008</td>
<td>0.05</td>
</tr>
</tbody>
</table>

### Table 3: Mann-Kendal test, Sen’s Estimator and regression analysis results for seasonal rainfalls

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th></th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Z</td>
<td>Bmed</td>
<td>T</td>
</tr>
<tr>
<td>BabaAman</td>
<td>0.581</td>
<td>-0.32</td>
<td>0.64</td>
</tr>
<tr>
<td>Ghatlish</td>
<td>0.619</td>
<td>0.416</td>
<td>0.37</td>
</tr>
<tr>
<td>Darkesh</td>
<td>0.35</td>
<td>-0.56</td>
<td>-0.8</td>
</tr>
<tr>
<td>ShirAbad</td>
<td>0.54</td>
<td>0.56</td>
<td>0</td>
</tr>
<tr>
<td>Samalqan</td>
<td>-1.12</td>
<td>-0.52</td>
<td>-1.2</td>
</tr>
<tr>
<td>Hootan</td>
<td>-0.18</td>
<td>-0.05</td>
<td>-0.2</td>
</tr>
</tbody>
</table>

### Table 4: Mann-Kendal test, Sen’s Estimator and regression analysis results for seasonal flow rate

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th></th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Z</td>
<td>Bmed</td>
<td>T</td>
</tr>
<tr>
<td>BabaAman</td>
<td>-1.97*</td>
<td>-0.38</td>
<td>-1.5</td>
</tr>
<tr>
<td>Ghatlish</td>
<td>-1.27</td>
<td>-0.02</td>
<td>-1.22</td>
</tr>
<tr>
<td>Darkesh</td>
<td>-1.84</td>
<td>-0.007</td>
<td>-1.76</td>
</tr>
<tr>
<td>ShirAbad</td>
<td>-1.46</td>
<td>-0.01</td>
<td>-1.6</td>
</tr>
<tr>
<td>Samalqan</td>
<td>-2.3*</td>
<td>-0.06</td>
<td>-4.1</td>
</tr>
<tr>
<td>Hootan</td>
<td>-</td>
<td>-0.72</td>
<td>-4.08</td>
</tr>
</tbody>
</table>

### Table 5: Mann-Kendal test, Sen’s Estimator and regression analysis results for seasonal flow rate

<table>
<thead>
<tr>
<th></th>
<th>Spring</th>
<th></th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Z</td>
<td>Bmed</td>
<td>T</td>
</tr>
<tr>
<td>BabaAman</td>
<td>-0.46</td>
<td>-0.03</td>
<td>-1.26</td>
</tr>
<tr>
<td>Ghatlish</td>
<td>-1.18</td>
<td>-0.05</td>
<td>-1.43</td>
</tr>
<tr>
<td>Darkesh</td>
<td>-1.35</td>
<td>-0.05</td>
<td>-0.37</td>
</tr>
<tr>
<td>ShirAbad</td>
<td>-1.29</td>
<td>-0.07</td>
<td>-0.32</td>
</tr>
<tr>
<td>Samalqan</td>
<td>-1.93</td>
<td>-0.07</td>
<td>-3.78</td>
</tr>
<tr>
<td>Hootan</td>
<td>-2.1*</td>
<td>-0.85</td>
<td>-2.16</td>
</tr>
</tbody>
</table>
Mann-Kendall test and regression analysis results have been recorded in table.3 for spring and summer. Spring rainfall trend has been increasing in all stations according to Man-Kendall and regression analysis results. In the summer, rainfall trend has been also reported increasing in all the stations, regarding to Mann-Kendall and regression analysis results, except in Shirabad station which shows a decreasing trend according to regression analysis test results.

Flow Rate Variation Trend:

Mann-Kendall and regression analysis test results have been reported in table.4 for flow rate of fall and winter in the studied stations. According to the results flow rate amount has been decreased in fall and winter. According to Mann-Kendall test results, fall flow rate has been decreased in all the stations and has become significant in two stations BabaAman and Samalqan in a 95% confidence level and in Hootan station in a 99% confidence level, while in regression analysis test, a decreasing trend has been confirmed in two stations Samalqan and Hootan in a 99% confidence level and in BabaAman station in a 95% confidence level. In stations BabaAman, Ghatlish, Darkesh, Shirabad, Samalqan and Hootan, Reduced flow rate has had a decreasing trend of 1.7, 1.2, 1.6, 1.5, 2.3 and 3.2 $m^3$ / decade, respectively.

According to table.4, significant decreasing trend has been reported in a 95% and 99% level for three BabaAman, Ghatlish, and Samalqan stations and for Hootan station, respectively. In winter flow rate time series, the observed decreasing trends by regression analysis is similar to Mann-Kendall results, but there is a difference that significance of decreasing trend in two stations Samalqan and Hootan was confirmed in a confidence level of 99%.

Mann-Kendall and regression analysis results have been reported in table.5 for spring and summer. According to the table, summer and spring flow rate values have decreased in all stations, except Ghatlish station in the summer which has increased 0.4 $m^3$ / decade according to regression analysis test results. According to regression analysis and Mann-Kendall test, all station flow rates have decreased in the spring and according to Mann-Kendall test, it has been significant in a confidence level of 95% in Hootan station, while in regression analysis it was confirmed in a confidence level of 99% in Samalqan and Hootan stations.

Spring flow rate has decreased down to 1.2, 0.4, 0.3 and 1.2 $m^3$ / decade in BabaAman, Ghatlish, Darkesh, Shirabad, Samalqan and Hootan, respectively.

According to table.5, no significant decrease trend has been confirmed in summer flow rate time series. The observed decreasing trend by regression analysis are similar to Mann-Kendall results, but there is a significance level of 99 %of decreasing trend in stations Samalqan and Hootan and winter flow rate has been 1.4,0.8,0.2,4, and 0.7 for BabaAman, Darkesh, Shirabad, Samalqan and Hootan, respectively. Flow rate has also increased only in Ghatlish station in the summer for 0.4 $m^3$ / decade.

Rainfall and Flow Rate Annual Variation Trend

According to table.6, annual rainfall trend has been increasing in all the stations, regarding to results from Mann-Kendall test, except in Hootan station, which has decreased. But results from regression analysis have been different and decreased in two stations Shirabad and Samalqan.

Mann-Kendall and regression analysis tests results have shown a decreasing trend for all stations for annual flow rate. The only difference in two test results is that in Mann-Kendall test, annual flow rate trend is significant in two stations Samalqan and Hootan in a Confidence level of 99% and in regression analysis test, Samalqan and Hootan stations have been significant in a confidence level of 95% and 99%, respectively.

<table>
<thead>
<tr>
<th>Flow rate</th>
<th>Z</th>
<th>Bmed</th>
<th>T</th>
<th>P-value</th>
<th>b</th>
<th>Z</th>
<th>Bmed</th>
<th>T</th>
<th>P-value</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>BabaAman</td>
<td>-1.7</td>
<td>-0.18</td>
<td>-1.7</td>
<td>0.092</td>
<td>-1.6</td>
<td>0.562</td>
<td>0.857</td>
<td>-0.2</td>
<td>0.83</td>
<td>-0.2</td>
</tr>
<tr>
<td>Ghatlish</td>
<td>-1.29</td>
<td>-0.121</td>
<td>-0.8</td>
<td>0.43</td>
<td>-0.7</td>
<td>1.57</td>
<td>2.3</td>
<td>1.64</td>
<td>0.114</td>
<td>1.56</td>
</tr>
<tr>
<td>Darkesh</td>
<td>-1.55</td>
<td>-0.062</td>
<td>0.74</td>
<td>0.46</td>
<td>-0.7</td>
<td>0.35</td>
<td>0.468</td>
<td>0.364</td>
<td>0.717</td>
<td>0.36</td>
</tr>
<tr>
<td>ShirAbad</td>
<td>-0.8</td>
<td>-0.08</td>
<td>-0.2</td>
<td>0.85</td>
<td>-0.2</td>
<td>0.6</td>
<td>1.53</td>
<td>-0.04</td>
<td>0.96</td>
<td>-0.04</td>
</tr>
<tr>
<td>Samalqan</td>
<td>-2.7**</td>
<td>-0.213</td>
<td>-2.4</td>
<td>0.023*</td>
<td>-2.2</td>
<td>0.5</td>
<td>0.696</td>
<td>-0.07</td>
<td>0.95</td>
<td>-0.07</td>
</tr>
<tr>
<td>Hootan</td>
<td>-3.8**</td>
<td>-2.53</td>
<td>-3.5</td>
<td>0.002**</td>
<td>-2.9</td>
<td>-0.02</td>
<td>-0.03</td>
<td>-0.22</td>
<td>0.83</td>
<td>-0.22</td>
</tr>
</tbody>
</table>
Introduction:

Climate change is one of the biggest challenges for the human. Climatic variation is not a completely natural process and is also, influenced by Socio-economic conditions of the community and has had a more non-certain trend speed during the recent years [4]. Green House Gas increase such as CO2, CH4, NOx and air pollutant particles have affected the world heat from which the atmosphere CO2 has played the most important role [16]. In this study, annual and seasonal variation trends of flow rate and rainfall in Atrak water basin have been analyzed from 1980 to 2010. To do this, by applying flow rate and rainfall data of hydrometric and pluviometry data of the stations BabaAman, Ghatlish, Darkesh, Shirabad, Samalqan and Hootan, trend of the mentioned data has been assessed by using non parametric Mann-Kendall and Sen’s Estimator tests and also parametric regression analysis tests.

In general, rainfall trend is increasing in all data series except in Hootan station, which is negative for all annual and seasonal data.

Flow rate trend has had a decreasing trend in all stations which is probably because of water removal and consumption increase from the river. Therefore, human has tried to utilize and control water resources by constructions of dams and cultivation of more lands. It is suggested to remove water from Atrak water basin, with more appropriate and controlled considerations for the decreasing of flow rate in this basin.

REFERENCES