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Impact of climate changes on the hydrological regime of Teeb River, Missan governorate, south of Iraq.

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Abstract

This study investigates the applicability of the two-parameter climate elasticity of streamflow index to assess the impact of global warming on regional hydrology of Teeb river watershed, south of Iraq. The results indicate that the streamflow response to rainfall and temperature anomalies exhibits a non-linear relationship. A 50% rainfall increase in the Teeb watershed results in a 10% increase in streamflow at mean temperature, but no increase in streamflow for temperature increases of 1.5 °C. A 20% rainfall decrease results in a (20-30%) decrease in streamflow at mean temperature but only 10% decrease in streamflow if the temperature increases 1.5 °C.Results also indicate that the streamflow elasticity for climate changes is a useful index to assess the sensitivity of streamflow to both precipitation and temperature departure. Water resource issues in the Teeb watershed are likely to be more critical if the adopted climate changes scenarios are correct.

Key Words: Climate changes, Teeb River, Iraq, climate elasticity of streamflow.

1- Introduction

In the recent years, there is a proved scientific conviction that the global climate is changing as a result of the combined anthropogenic forces due to green-house gases, aerosols, and land surface changes. The Assessment of the Intergovernmental panel on climate change (IPCC, 1996) states that an increasing concentration of greenhouse gasses in atmosphere is likely to cause an increase in global average temperature of between 1 and 3.3 °C over the forthcoming century. This will lead to a more vigorous hydrological cycle, with changes in precipitation and evapotranspiration rates regionally variable. These changes will in turn affect water availability and runoff and thus may affect the discharge regime of rivers especially bigger one. As stated by Wurbs et al. (2005) plans of water resource management increasingly need to incorporate the effects of global warming to predict future supplies.

Numerous studies have documented the sensitivity of streamflow to climate change for basin across the world (Fu and Liu, 1991; Yates and Strzepek, 1998; Sankarasubramanian et al., 2001; McCarthy et al., 2001; Arnell, 2002; Chiew, 2006; and Fu et al., 2007a). Most of these studies involve estimation the climate elasticity of streamflow which was introduced by Schaake (1990) for evaluating the sensitivity of streamflow to changes in climate.

The main objective of this study is to investigate the climate changes on Teeb Riverstreamflow in northeastern Missan governorate, south of Iraq through the concept of climate elasticity of streamflow to better manage of this river. Examination of climate changes on this river discharge is needed to improve plans for future growth related to sustainable water policies.

HYDROLOG OF TEEB WATERSHED

Teebriver is an ephemeral stream emerges from Iran and the Iranian part of the river watershed has an extensive area and provides the majority of the total streamflow (Fig. 1). In Iraq, the stream has a southerly course and ends in Sanaf marsh. The total length of the river within the Iraqi territory is 65 km, the average width is of about 50 m, and the average river bank height is 10 m. The course of the river changes annually because it runs through alluvial fan which consists mainly of sand. Rainfall in Iranian territory is considered the only source of this stream. The average discharge of riveris variable depending on rainfall. Figure (2) shows the average monthly discharge of this stream for the period (1990 – 2007) (Ministry of Water Resources/ Missan). The stream attains maximum flows during winter months (January through March), while the minimum flows occur during summer months. The Teeb stream may flood the surrounding areas during winter months and causes damage to bridges and other engineering constructions such as roads. Table (1) reports the water quality analysis of the streams, in which the water quality is unfit for human consumption due to high salt content. Generally the salt content increases downstream indicating the ability of the streams to dissolve rocks and minerals through their journey from upstream to downstream.

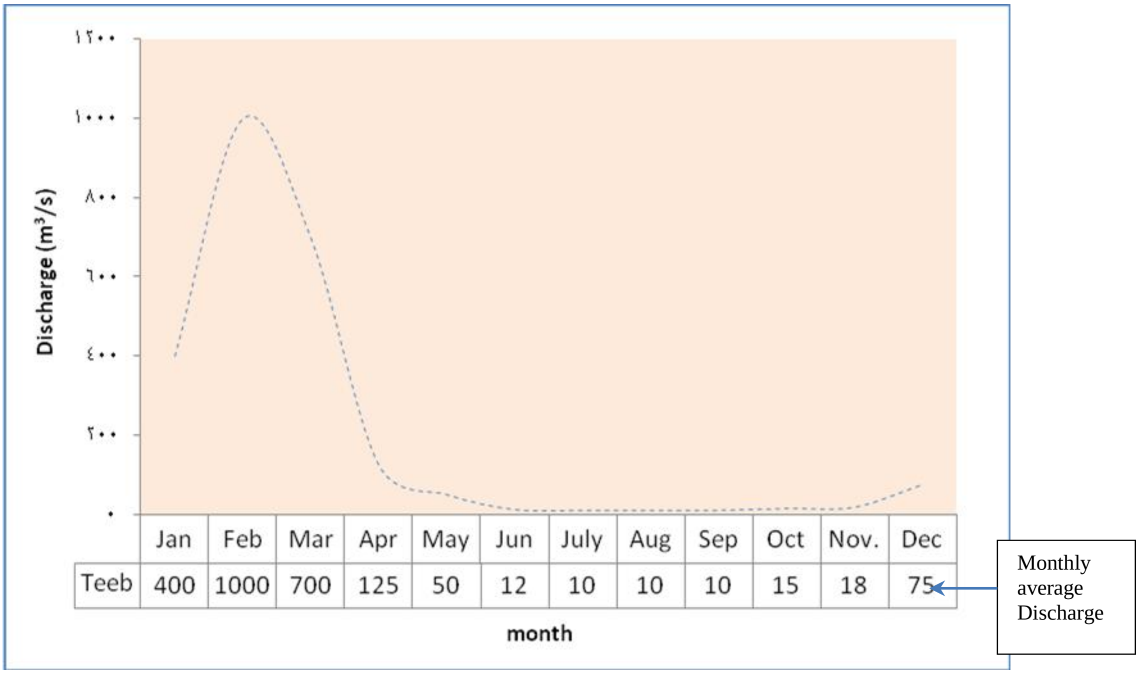

Fig. 1:Mean monthly of Teeb discharge for the period (1995-2007)

Table (1): Water quality analysis of Teeb River (annual average)

Stream	Chemical constituents										
	pH	EC	TDS	Na^+	K^+	Ca^{+2}	Mg^{-2}	Cl^-	SO_4^{-2}	HCO_3^-	TH
Teeb	7.4	6122	3055	176	2.6	576	186	1183	1337	130	2207

EC measured in mmohs/cm, other constituents in ppm

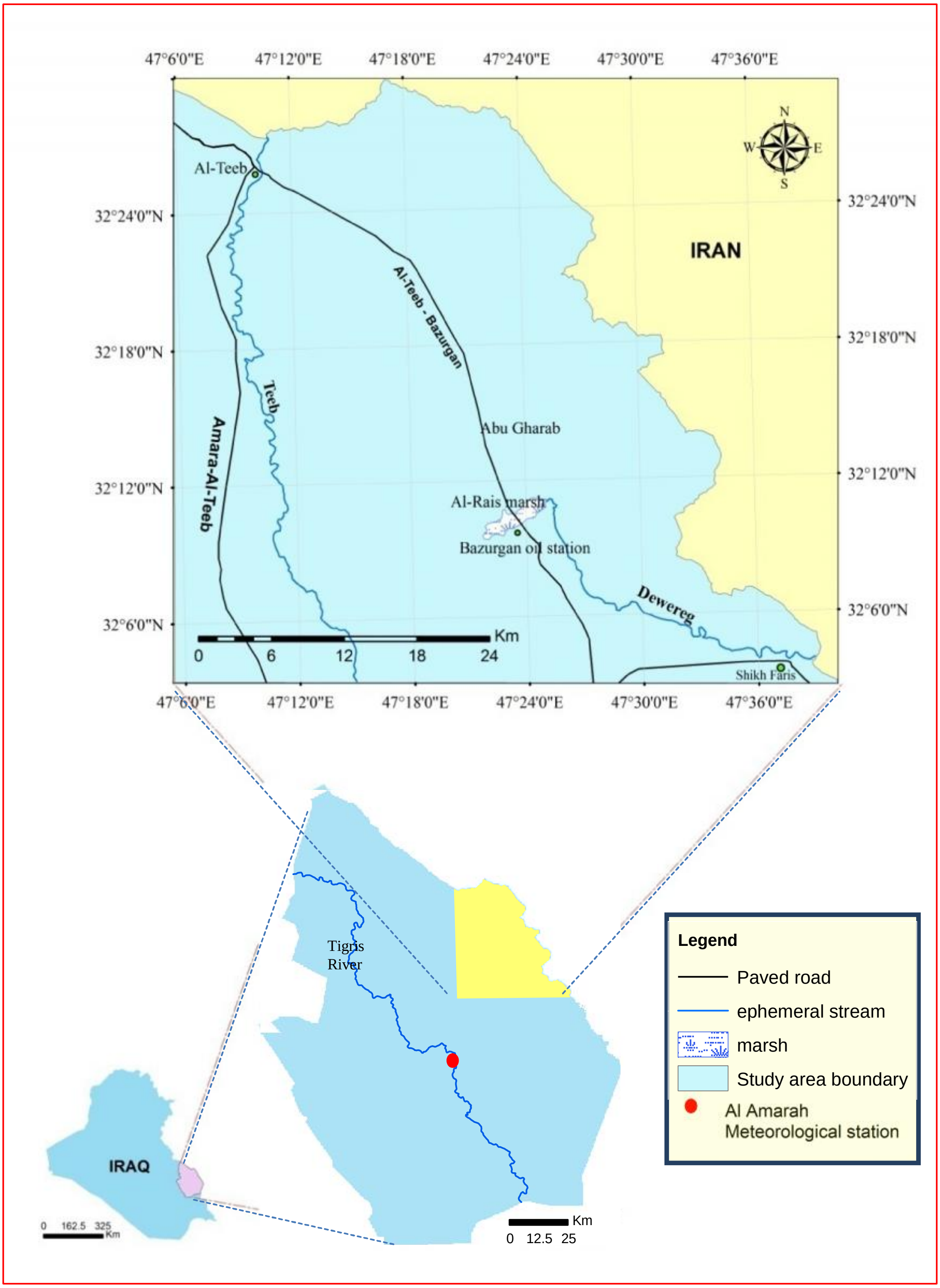

Fig. 1: Location of the study area and meteorological station.

DATA SET

A time series of monthly total streamflow since 1990 was provided by the General Commission of Irrigation/Missan branch. The only meteorological station close to the study area is the Al-Amarah station. The longest running station goes back to 1970 although the station does not have continuously records. The location of this station is shown in Fig. (1). Table (2) summarizes the data set available for this station including the years of record. Monthly rainfall and temperatures averages for this station were provided by the General Commission of Weather/ Baghdad. Analysis of the climatic data (i.e. rainfall and temperature) indicates that rainfall average has experiences significant decreasing trend in recent years (Fig. 2 and 3). At the same time, temperature has had an increase trending (about 1 °C).

Table (2) Some climatic characteristics of Al-Amara station.

Month	rainfall (mm)	Temperature (îC)	Relative Humidity (%)	Wind Speed (m/s)	Sunshine Duration (h/d)
Oct.	6.32	27.12	27.12	3.09	8.8
Nov.	19.45	19.15	19.15	3.04	7.19
Dec.	34.73	13.33	13.33	2.77	6.14
Jan.	34.87	11.51	11.51	2.8	6.31
Feb.	24.55	14.01	14.01	3.36	7.44
Mar.	32.9	18.5	18.5	3.79	7.45
Apr.	14.66	24.84	24.84	3.87	8.68
May	3.99	31.29	31.29	4.15	9.97
Jun	0.03	35.26	35.26	5.8	11.95
Jul.	0	37.49	37.49	5.73	11.76
Aug.	0	36.74	36.74	5.19	11.6
Sep.	0.02	33.13	33.13	4.02	10.5

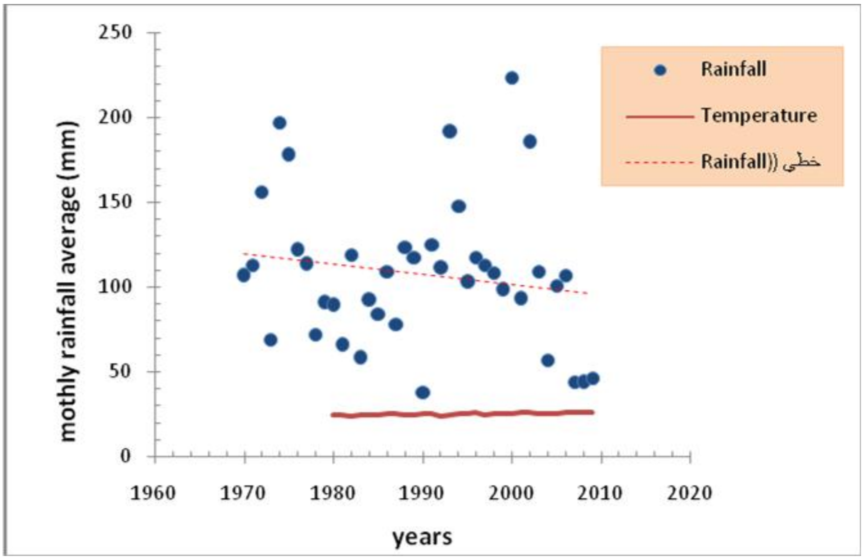

Fig. 2: Trend of monthly average of rainfall since 1970. (Al-Amara station)

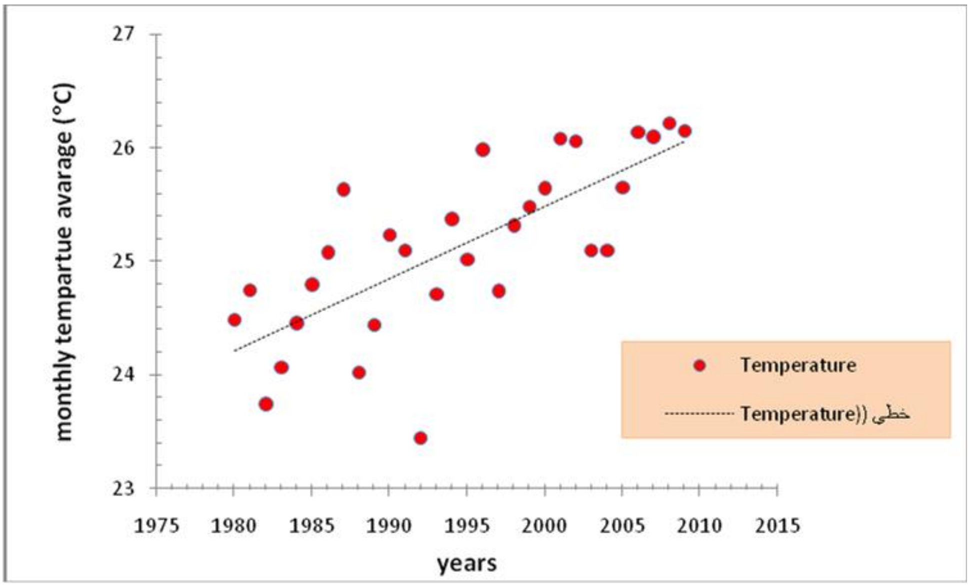

Fig. 3: Trend of monthly average of temperature since 1970. (Al-Amara station)

METHODOLOGY

The climate elasticity of stream flow is defined as the proportional change in stream flow, Q, to the change in a climate variable such as precipitation, P. It is defined mathematically as: (Sankarasubramanian et al., 2001)

$$£_p(P,Q)=\frac{dQ/Q}{dP/P}=\frac{dQ}{dP}\frac{P}{Q} \qquad \textbf{(1)}$$

The climate elasticity of streamflow is often estimated from hydrological models. The difficulty is the hydrological model building and validation remains a fundamental challenge. In order to solve this problem, Sankarasubramanian et al (2001) introduced a specific case of (1) at the mean value of the climatic variables:

$$£_p(«_p,«_Q)=\left.\frac{dQ}{dP}\right|_{P=«_P}\frac{«_P}{«_Q} \qquad \textbf{(2)}$$

where $«_P$ and $«_Q$ denote mean values of precipitation and stream flow.

To study the effect of climate change for a single basin, Risbey and Entekhabi (1996) used the observed data of annual precipitation, temperature, and stream flow. They presented their results in contour format by using the adjustable tension continuous curvature surface grid algorithm. Fu et al. (2007) extended this work by using different interpolation techniques using Geostatistical analyst of ArcGIS software. The annual percentage departure for streamflow $\left(\frac{Q_t-\overline{Q}}{\overline{Q}}\times 100\%\right)$, precipitation $\left(\frac{P_t-\overline{P}}{\overline{P}}\times 100\%\right)$, and temperature $\left(T_t-\overline{T}\right)$ for a specific basin were calculated and plotted on precipitation-temperature plane, such that each point in a plane represent one year of observed data. The contours of stream flow percentage change were then interpolated from these points and transferred to a regular grid for contouring using interpolation techniques (deterministic or stochastic). The streamflow-precipitation- temperature relationship is converted to a climate elasticity of stream flow using the following formula: (Fu et al., 2007)

$$e_{P,¢T}=\left(\frac{Q_{P,¢T}-\overline{Q}}{P_{P,¢T}-\overline{P}}\frac{\overline{P}}{\overline{Q}}\right) \qquad \textbf{(3)}$$

where $¢T=\left(T-\overline{T}\right)$ is the temperature departure.

RESULTS AND DISCUSSION

The precipitation-temperature-streamflow for the Teeb watershed is shown in Fig. (4) in which there is a slightly positive relationship between precipitation change and streamflow change while there is a slightly negative relationship between temperature change and stream flow change. However, as temperature changes occur concurrently with changes in precipitation characteristics such as seasonality, spatial distribution, and intensity, these results do not completely separate the effect of temperature from that of precipitation (Yu et al., 2010).

The impacts of temperature on streamflow change are obvious in Fig. (3). For example, a 50% precipitation increase in the Teeb watershed results in a 10% increase in streamflow at mean temperature (red line), but no increase in streamflow for a temperature increase of 1.5 °C (blue line). A 20% precipitation decrease results in a (20-30%) decrease in stream flow at mean temperature, but only 10% decrease in stream flow if the temperature increases 1.5°C.

For estimating climate elasticity of streamflow for Teeb watershed, the long – term mean annual precipitation, stream flow and temperature are 174.2 mm $(\overline{P})$, 202.1 $m^3 (\overline{Q})$, and 24.2 °C $(\overline{T})$, respectively. For an arbitrary year, say the annual precipitation and temperature are 220 mm (a 30% increase over the long term mean) and 26.7 °C (1.5 °C increase over the long-term mean). From the streamflow- precipitation- temperature interpolated surface (Fig. 3), the estimated annual streamflow is about 90 m^3 for this precipitation and temperature combination. By applying Eq. (3), the estimated climate elasticity of streamflow for this scenario is about 0.70. Thus for a future climatic change scenario, given the precipitation and temperature changes, the climate elasticity of stream flow can be used to estimate the annual streamflow.

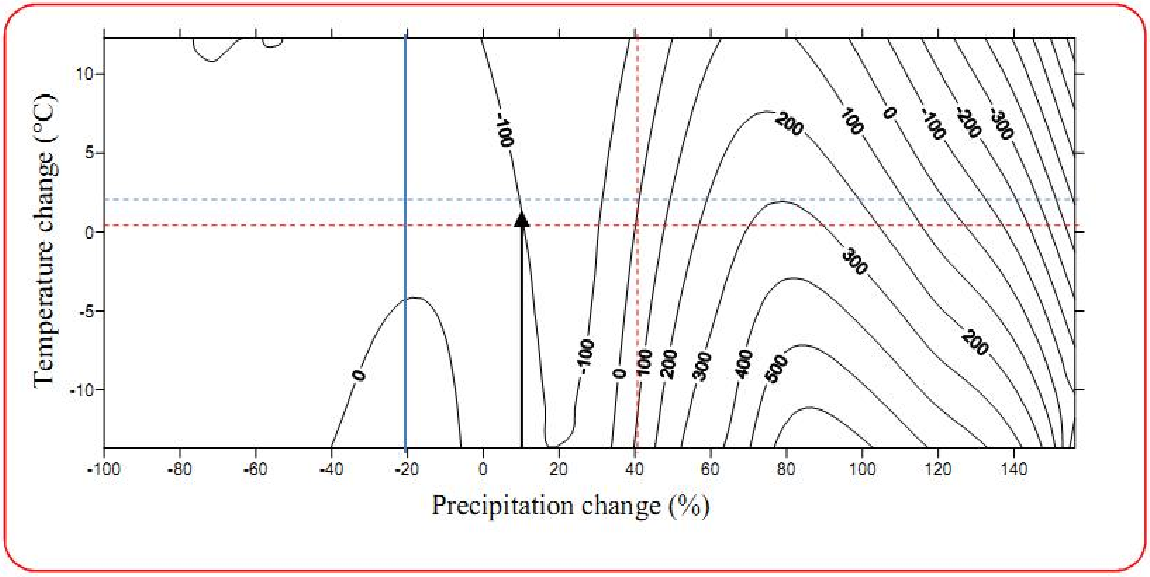

Fig. (4): Contour plot of percentage streamflow(solid line) change as a function of percentage precipitation change and temperature departure for the Teeb watershed.

CONCLUSION

The analysis of streamflow response to climate changes is investigated using the concept of streamflow elasticity of climate change index. Results exhibits that a 50% precipitation increase in the Teeb watershed results in a 10% increase in streamflow at mean temperature, but no increase in streamflow for a temperature increases of 1.5 °C. A 20% precipitation decrease results in a (20-30%) decrease in streamflow at mean temperature but only 10% decrease in stream flow if the temperature increases 1.5 °C. The results indicate that the streamflow response to rainfall and temperature anomalies exhibits a non-linear relationship. The method adopted here can be easily implemented to different watershed across the country.

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أثر التغيرات المناخية على النظام الهيدرولوجي لنهر الطيب في محافظة ميسان، جنوب العراق

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الخلاصة

يتحرى البحث الحالي عن امكانية تطبيق معامل مرونة الجريان المناخي ذي العاملين (درجة الحرارة والامطار) للتحري عن تأثير الاحترار العالمي على هيدرولوجية حوض الطيب في محافظة ميسان في جنوب العراق. بينت النتائج بان استجابة نظام الجريان للتغيرات في معدلات درجات الحرارة والامطار هي علاقة لا خطية، فالزيادة في معدلات الامطار بمقدار 50% في حوض الطيب ستزيد الجريان في مجرى حوض النهر بمقدار 10% في حالة كون درجة الحرارة في معدلاتها الطبيعية بينما لا تحدث اي زيادة في معدلات الجريان عند زيادة درجة الحرارة بمقدار 1.5 °C. كما وضحت النتائج ايضاً بان 20% نقصان في معدلات الامطار ستنتج ما مقداره (20–30%) نقصان في معدلات الجريان عند معدل درجة الحرارة الاعتيادية وفقط 10% نقصان في معدل الجريان اذا زاد معدل درجة الحرارة 1.5 °C. بينت النتائج ايضاً بان معامل مرونة الجريان المناخي دليل مهم لتقييم حساسية الجريان للتغيرات المناخية. ان إدارة الموارد المائية لحوض نهر الطيب ستكون اكثر صعوبة اذا كانت التنبؤات العالمية بالتغيرات المناخية صحيحة.