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ORIGINAL ARTICLE

# A survey of water quality of Gharasou River, Kermanshah, Iran

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## Abstract

Water quality is essential for drinking, agricultural and industrial purposes, and sustainable water management. The Gharasou sub-basin is the primary water supply resource for the Karkheh River Basin (KRB), the third-largest and most productive river basin of Iran. This paper addressed the published papers about the water quality assessment of the Gharasou River. For this purpose, natural or anthropogenic pollution sources, land cover/land use, and soil erosion/runoff were considered. Water pollution indices, such as water quality index (WQI) and trophic diatom index (TDI), were also investigated. The suitability of the Gharasou River water for irrigation purposes was also studied. The results indicated that drought, weathering of bed sediments, and cation-exchange processes in the soil–water interface are natural sources of water pollution of the Gharasou River. A large-scale release of raw sewage and industrial chemicals, the geological texture, agricultural activities, and vehicles are anthropogenic sources of water pollution. WQI ranges from $33 \pm 3$ to $76 \pm 6$, and TDI ranges from $39.2 \pm 5$ to $71.3 \pm 15$, reflecting a significant level of pollution in the Gharasou River. USSL and FAO methods classified water as $C_2S_1$ (medium-salinity and low-sodium hazards). However, water quality indices indicated that there is a regional sodicity problem evidenced by a high risk for permeability index (PI) > 75%, $Ca^{2+}/Mg^{2+}$ ratio < 1, and magnesium ratio (MR) > 50 as well as nutritional and irrigation problems. Converting rangelands to rain-fed lands, overgrazing, and deforesting hilly land are the main factors affecting soil erosion/runoff, which consequently impacted the water quality of the Gharasou River.

**Keywords** Irrigation · Water pollution · Water quality indices · Soil erosion/runoff · Land cover/land use

## Abbreviations

| | |
|---|---|
| KRB | Karkheh river basin |
| WQI | Water Quality Index |
| TDI | Trophic Diatom Index |
| SOC | Soil organic carbon |
| EC | Electrical conductivity |
| TDS | Total dissolved solids |
| SAR | Sodium absorption ratio |
| MR | Magnesium ratio |
| RSC | Residual sodium carbonate |
| PI | Permeability Index |
| TSS | Total suspended solid |
| BOD | Biological oxygen demand |
| USSL | US salinity laboratory |

## Introduction

Water quality is defined as the physical, chemical, and biological characteristics of water (Ali 2010). The suitability of water for an anticipated use is influenced by its "characteristics." Water quality is also essential for sustainable irrigation management. For instance, irrigation with water characterized as reasonable quality may negatively affect the soil properties, such as salinity, sodicity, and permeability. In addition to the limitations of land for crop production, the water quality and its suitability should be considered (Ali 2010).

Rivers are mainly supplied to meet the drinking, agricultural, and industrial water demands. The quality of streams depends on many different factors, such as crossing from various regions and beds, as well as direct relationships with external environments (Banejad et al. 2013). Furthermore, water pollution, multiple-use, and increasing water demand also increase costs related to water treatments that influence water quality. Moreover, rapid urbanization and eutrophication are among the degradation factors of water bodies (Atazadeh et al. 2007; Madani 2014).

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Rivers play an important role in human development, particularly in semi-arid regions. They are the primary resources of irrigation water for agricultural production when rainfall is insufficient for crop growth in these regions (Jafar Ahamed et al. 2013; Sundaray et al. 2009). Agricultural activities use a considerable amount of water in the world. Irrigated agriculture is more productive than agriculture that depends on rain, mainly in arid and semi-arid regions. Therefore, water irrigation quality is crucial for agrarian production and environmental protection (Ağca 2014). The water quality for agricultural purposes is assessed by the problems that may potentially occur (Ağca 2014; Ayers and Westcott 1985). In irrigated agriculture, especially in arid climatic conditions, irrigation water with inferior quality poses a constant threat caused by the salt-water hazard. Crop yield, physical soil conditions, fertilizer requirements, performance, and long life of irrigation system, as well as the manner of water application, are affected by irrigation water quality (Ayers and Westcott 1985).

Pollutant sources of water pollution can be categorized as point and non-point sources. Besides, these pollution sources have a natural or anthropogenic origin. Various factors, such as soil weathering, soil erosion, land use, and human activities, have resulted in water pollution (He et al. 2019; Ren et al. 2021). Indeed, soil nutrient depletion and soil organic carbon (SOC) loss deliver several nutrients into the rivers (Heshmati et al. 2012). Nitrate and phosphate have been in the spotlight related to the eutrophication of water for a long time. Concerning human health, nitrate causes diseases, such as some of the digestive system and lymph nodes cancers in adults, and methemoglobinemia in infants (Fewtrell 2004; Law et al. 1999; Li et al. 2019; Powlson et al. 2008; Wu et al. 2020; Zhang et al. 2018).

On a basin scale, water quantity and quality downstream are affected by upstream changes. Therefore, for water quality assessment, a basin-scale approach is essential (Hessari et al. 2012). The KRB is considered one of the most productive agricultural areas in Iran. About 9% of the total irrigated area of Iran is located in the KRB, which produces about 10–11% of the country's wheat (Marjanizadeh 2008). The Gharasou sub-basin is the primary water supply resource for the Karkheh River Basin (KRB), the third-largest and most productive river basin of Iran. The major impetuses for studying the Gharasou River were: (i) Is there any information about the Gharasou River water quality? How is the quality of the Gharasou River? What are the issues with its quality if there are any? (ii) Is there any available information about the pollution sources of the Gharasou River? Are they point- or non-point pollution sources? Are the exact locations of point pollution sources known? (iii) How is the water quality of the Gharasou River affected by human activities? What is the role of industrial or agricultural activities? (iv) What solutions have been suggested for these problems, particularly for the Gharasou River Basin or similar basins in Iran? A review of the previous studies revealed that the available information is disorganized because investigations were focused on one aspect of the water quality of the Gharasou River, namely for agriculture purposes, drinking water, water pollution regarding point and non-point pollution sources (natural or anthropogenic), water quality index (WQI), and trophic diatom index (TDI), to the exclusion of the impact of land cover/land use and soil erosion/runoff. The main idea of this manuscript was to synthesize the information from different sources into a coherent whole; therefore, the Gharasou River was regarded as a basin scale or sub-basin of the KRB. The assessment of water quality is expensive and time-consuming. Modeling lowers costs and accurately predicts the desired parameters; however, it depends on the measured data for validation. This review provides a more accurate and comprehensive picture of the Gharasou River Basin circumstances, which may be used to model the Gharasou River Basin and investigate the techniques and policies used to manage the river. Moreover, the collected data help in determining which areas require additional research in future studies.

## Materials and methods

### General description of the study area

The Karkheh River is the third major river in Iran that originates from the Zagros Mountains and flows into the Persian Gulf (Haghiabi and Mastorakis 2009) (Fig. 1). The KRB is one of the major basins in western Iran. Furthermore, the KRB is a vital basin for water supply Kurdistan, Kermanshah, Hamadan, Lorestan, Ilam, Markazi, and Khuzestan provinces (Haghiabi and Mastorakis 2009; Samadi et al. 2012). The KRB with an area of 51,000 km$^2$ is located at 30–35° N and 46–49° E (Rientjes et al. 2013). The five sub-basins of the main rivers in the KRB include Gamasiab, Gharasou, Kashkan, Saymareh, and Karkheh (Ahmad and Giordano 2010). The Gharasou River is the primary resource of water supply for the Karkheh Reservoir (Fig. 2). The Gharasou River joins the Gamasiab River after running through the Kermanshah city and then delivers water collected from Kermanshah and Kurdistan provinces to the Saymareh River. The total length of the Gharasou River is 152 km (Atazadeh et al. 2007; Sayadi et al. 2014), and the area of the Gharasou River Basin is 5793 km$^2$. The range of height of the Gharasou River Basin ranges from 1237 to 3350 m, with a mean elevation of 1555 m (Omani et al. 2007). The average annual rainfall of this basin is about 447 mm, which ranges from 215 to 785 mm. The most rainfall takes place in February and the least in July. The annual mean temperature is about 14.6 °C. The average temperature

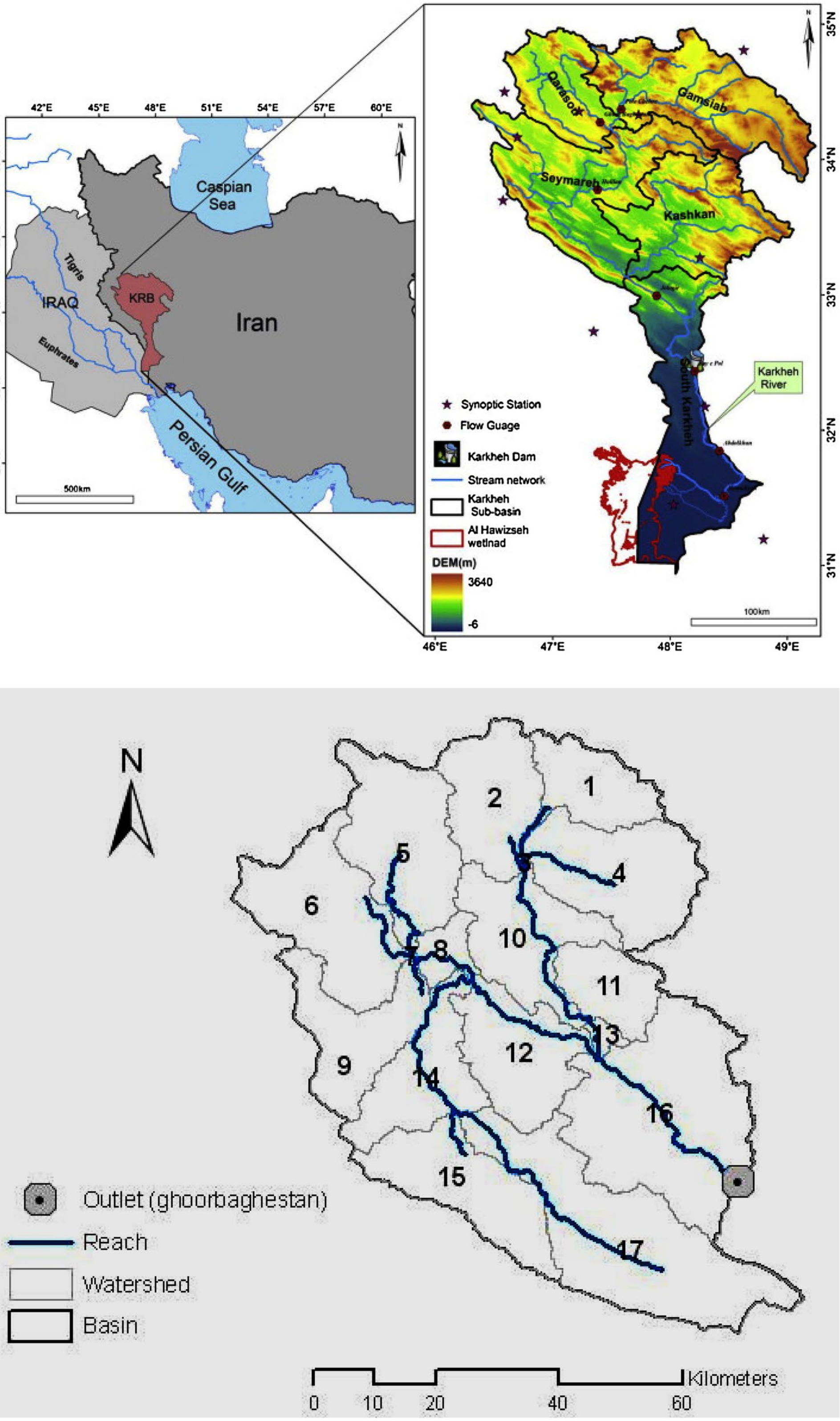


**Fig. 1** Karkheh River Basin (KRB) location in Iran (Ghobadi et al. 2015) and Gharasou River Basin in the northwest of KRB (Saadatpour 2014)

of the warmest and the coldest times of year is 26.95 °C and 1.15 °C in July and January, respectively. However, these temperatures could increase to the highest of 37.8 °C and decrease to the lowest of − 4.2 °C in these months. The annual mean potential evaporation is 2132 mm (Hosseini et al. 2016; Omani et al. 2007; Samadi et al. 2012).

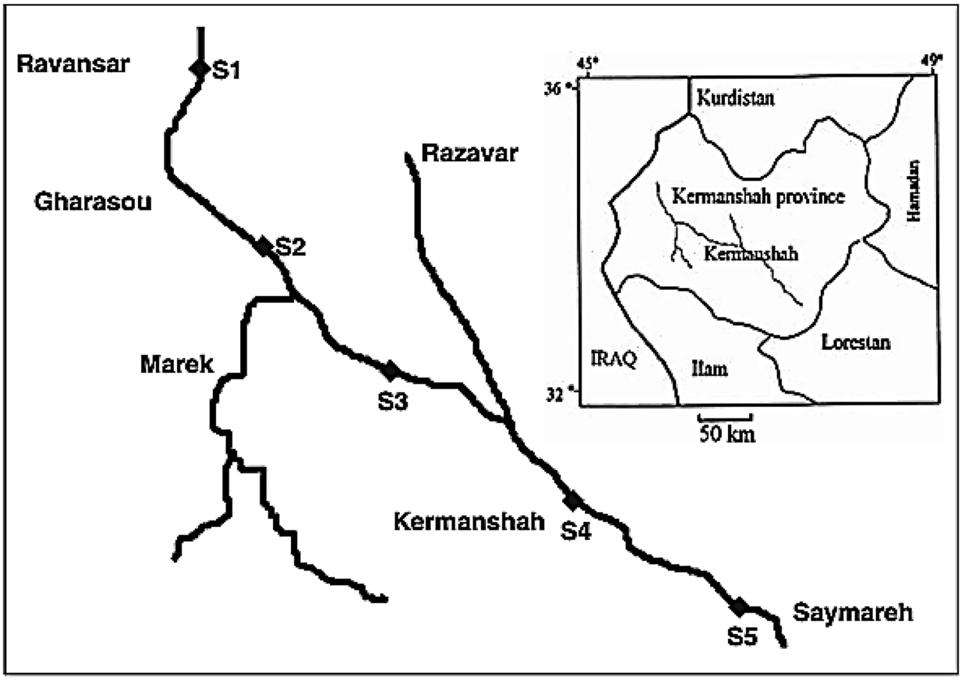


**Fig. 2** The geographical positions of stations in (Fatemi 2015) and (Rezaei and Sayadi 2015) studies (Atazadeh et al. 2007)

## Databases

In this study, local databases, including Irandoc and SID (Scientific Information Database) and international databases, such as Google Scholar, Springer, Elsevier, Taylor and Francis, and Wiley online library, were explored. In a primary search of the papers, it has been evident that there were different spellings of the name of the Gharasou River (among which a specific spelling has been chosen here). The results showed 478 papers with spelling, such as Qarasо, Qarasou, Gharasu, Gharasoo, and Gharaso. Moreover, there are two different rivers with the same name, which are located in Golestan and Ardabil provinces in the north and Northeastern area of Iran, respectively. Therefore, the papers related to the Gharasou River in the Kermanshah province were selected. Also, the studies which included the Gharasou River Basin as a sub-basin of the KRB were considered. Besides, the papers related to sub-basins of the Gharasou River Basin were also examined. The key terms for this study included “water quality,” “heavy metals,” “soil erosion,” and “land cover/land use.” The collected publications consist of 23 papers published from 2003 to 2016.

This paper discusses published papers in three major subjects include (i) water quality assessment for irrigation and drinking purpose, (ii) regarding pollution problems, and (iii) land cover/land use and soil erosion/runoff impacts on water quality of the Gharasou River. The available datasets for published papers listed below:

(i) Datasets for irrigation purposes include long-term datasets (between 17–37 years depending on the various establishment times of the stations). Data were provided by the city’s Hydraulic Works in 2009. Water quality characteristics were monitored monthly, and the geographical positions of stations are presented in Fig. 2 (Fatemi 2015). Pirsaheb et al. (2013) evaluated the quality of drinking water of a total of 165 water samples (from 128 wells, 25 water reservoirs, and 33 water distribution networks (tap water)) in Kermanshah city. The geographical positions of sample points are not well known. However, this study provides a general picture of drinking water quality in Kermanshah city regarding heavy metal concentrations.

(ii) Mahmoudi et al. (2010) studied the changes in cations and anions contents, sodium absorption ratio (SAR), total dissolved solids (TDS), electrical conductivity (EC), and pH in the KRB in two periods (1988 and 2002). The data obtained from the Deputy of Watershed Management of Jihad Agriculture in 2004 were collected from hydrometric stations along the Karkheh River length. They also studied these factors’ changes from datasets obtained from the Ghor Baghestan station located in the Gharasou River sub-basin. The Ghor Baghestan is the central gauge station located in the outlet of the Gharasou River sub-basin and receives the drainage from the total area of 5370 km$^2$. Sayadi et al. (2014) and Rezaei and Sayadi (2015) used datasets monthly during 2009–2010. Pirsaheb et al. (2015) investigated the concentrations of heavy metals in Iranian surface water resources according to reviewing papers gathering from local and international databases. The duration of these studies was over the last 20 years, from 1992 to 2012. Zeinoldini et al. (2014) reported Fe, Zn, Mn, and Pb concentrations in five samples' points on the Gharasou River. Atazadeh et al. (2007) investigated the water quality index (WQI) by analyzing the physicochemical characteristics of the Gharasou River between April and September 2005. They compared these parameters along the Gharasou River at five stations. Two stations (including a station in Ravansar city) are located in mountainous terrain with little human disturbance. While another station (i.e., Kermanshah station) was close to petrochemical and oil-related facilities. Atazadeh et al. (2007) also used this dataset to calculate the TDI to indicate water pollution in the Gharasou River.

(iii) Samadi et al. (2012) estimated the area of different land cover in the Gharasou River Basin by (Landsat 1993) data. For soil erosion rates, there were no available data in the whole the Gharasou River Basin but the Merek sub-basin. Heshmati et al. (2012) studied the soil erosion rate in the Merek sub-basin in three agro-ecological zones consisting of agriculture, rangeland, and forest. The Merek sub-basin is a part of the Gharasou River Basin, with an area of 23,038 ha that lies between 34° 00′ 38″ to 34° 09′31″ N and 47° 04′ 25″ to 47° 22′ 18″ E.

## Water quality assessment for irrigation and drinking purposes

An integrated hydrochemical method to assess the quality of water for irrigation requires USDA and FAO methods. For this purpose, major cations, anions, and other parameters, such as EC (Ayers and Westcott 1985; U.S. Salinity Laboratory Staff 1954) and TDS, were analyzed. SAR was calculated by Eq. 1:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{(Ca^{2+}+Mg^{2+})}{2}}} \tag{1}$$

The $SAR_{adj}$ (Ayers and Westcott 1985; Suárez 1981) considers the solution at equilibrium relating to the calcite instead of the bulk solution (Eq. 2):

$$SAR_{adj} = SAR \times [1 + (8.4 - pH_c)] \tag{2}$$

$$pH_c = (pK_2' - pK_s') + p(Ca^{2+} + Mg^{2+}) + p(Alk) \tag{3}$$

$$(pK_2' - pK_s') = f(\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+} + \mathrm{Na}^{+});$$
$$\mathrm{p(Alk)} = f\left(\mathrm{CO}_3^{2-} + \mathrm{HCO}_3^{-}\right)$$

where $pK_2{}'$ and $pK_s{}'$ are the negative logarithms of the second dissociation constant of carbonic acid and the solubility constant of calcite, respectively (corrected for ionic strength); and pAlk is the negative logarithm of the alkalinity (Suárez 1981).

To determine the risk of soil degradation, magnesium ratio (MR), %sodium (%Na), residual sodium carbonate (RSC) (Ayers and Westcott 1985; Suárez 1981), permeability index (PI), and $Ca^{2+}/Mg^{2+}$ ratio were calculated by following equations:

$$RSC = (HCO_3^{-} + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}) \tag{4}$$

$$\%\ \mathrm{Na} = \frac{(Na^{+} + K^{+})}{\sqrt{(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})}} \times 100 \tag{5}$$

$$PI = \frac{(Na^{+} + \sqrt{HCO_3^{-}})}{\sqrt{(Ca^{2+} + Mg^{2+} + Na^{+})}} \times 100 \tag{6}$$

$$MR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \times 100 \tag{7}$$

All the ionic concentrations in the above equations are expressed in meq $L^{-1}$, and % Na and PI in percentages.

According to the FAO method, the potential irrigation problems were evaluated by the French degrees (∘fH) (Eq. 8), Langelier index (Is) (Eq. 9), and $Ca^{2+}/Mg^{2+}$ ratio by clogging of irrigation systems (Table 1). To calculate Is, pHc is calculating by Eq. 3.

$$^{o}\mathrm{fH} = \left(2.5\ \mathrm{Ca}^{2+} + 4.12\ \mathrm{Mg}^{2+}\right)/10 \tag{8}$$

$$\mathrm{Is} = pH - pH_c \tag{9}$$

SAR values were plotted in the U.S. Salinity Laboratory Staff diagram (U.S. Salinity Laboratory Staff 1954). Besides, measured cations and anions, including $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $K^{+}$, $HCO_3^{-}$, $Cl^{-}$, and $SO_4^{2-}$ were plotted in the trilinear piper by AquaChem (2011) (Fig. 3).

## Pollution sources

Pollution processes, either natural or anthropogenic, are responsible for rapidly declining water quality (Ağca 2014; Zhou et al. 2012). The pollution sources of water can be categorized as either point or non-point sources. Pipes, wells, or channels contributed to point source pollution. The non-point or diffuse pollution sources include atmospheric deposition, agriculture, forest, mining, construction, municipal, and residential sources. For instance, wastewater treatment plants, stormwater

**Table 1** Different risks related to the irrigation water quality for Gharasou River water according to the FAO method and water quality indices and soil degradation risk (Fatemi 2015)

| Potential irrigation problems | Units | Risk-gradation | | |
|---|---|---|---|---|
| | | Low | Medium | High |
| Nutritional disorder | | | | |
| Sodium ($Na^+$) | | | | |
| Surface Irrigation | meq $L^{-1}$ | < 3.0 | 3.0–8.7 | > 8.7 |
| Sprinkler Irrigation | meq $L^{-1}$ | < 3.0 | > 3.0 | |
| Chloride ($Cl^-$) | | | | |
| Surface Irrigation | meq $L^{-1}$ | < 4.0 | 4.0–10.0 | > 10.0 |
| Sprinkler Irrigation | meq $L^{-1}$ | < 2.9 | > 2.9 | |
| Bicarbonate ($HCO_3^-$) | | | | |
| Overhead Sprinkling | meq $L^{-1}$ | < 1.5 | 1.5–8.5 | > 8.5 |
| $Ca^{2+}/Mg^{2+}$ ratio | | > 1 | – | < 1 |
| Clogging irrigation systems | | | | |
| French degrees | ° fH | < 1.7 | 1.7–12 | ≥ 12 |
| RSC | meq $L^{-1}$ | < 1.25 | 1.25–2.5 | > 2.5 |
| Langelier index (pH–$pH_c$) | | < 0 | | > 0 |
| Ca/Mg ratio | – | > 1 | – | < 1 |
| Soil degradation | | | | |
| Salinity (EC) | dS $m^{-1}$ | < 0.7 | 0.7–3.0 | > 3.0 |
| Infiltration | | | | |
| SAR and EC = | | | | |
| 0–3 | dS $m^{-1}$ | > 0.7 | 0.7–0.2 | < 0.2 |
| 3–6 | dS $m^{-1}$ | > 1.2 | 1.2–0.3 | < 0.3 |
| 6–12 | dS $m^{-1}$ | > 1.9 | 1.9–0.5 | < 0.5 |
| 12–20 | dS $m^{-1}$ | > 2.9 | 2.9–1.3 | < 1.3 |
| 20–40 | dS $m^{-1}$ | > 5.0 | 5.0–2.9 | < 2.9 |
| % Na | % | < 20 | 4–60 | > 80 |
| PI | | < 25 | 25–75 | > 75 |
| MR | | | | > 50 |
| Ca/Mg ratio | – | > 1 | – | < 1 |

discharges, and runoff from lawns and gardens can be considered as non-point pollution sources of water (Ali 2010; Lai et al. 2017).

### Point and non-point pollution sources

Compared with non-point pollution sources, point pollution sources are localized and can be more easily monitored and controlled (Smith et al. 1999). Sayadi et al. (2014) and Rezaei and Sayadi (2015), utilizing multivariate statistical analyses, including factor analysis (FA), revealed some sources of pollutants of the Gharasou River. They used surface water quality datasets consist of EC, pH, TDS, $HCO_3^-$, $Cl^-$, $SO_4^{2-}$, $Ca^{2+}$, $Mg^{2+}$, and $Na^+$ parameters that were monitored (Table 2).

### Water quality index (WQI)

Water quality assessment needs multiple parameters; while, managers and decision-makers on the water quality need a comprehensible and straightforward tool (Bordalo et al. 2006). Since 1978, many efforts have been made to present water quality by a defined number based on summarized water quality data (Asadollahfardi 2015). WQI is a method of expressing water quality, which could be used to interpret the principal characteristics of water quality. Different parameters result in the numerical ranking according to selected control values. Then, the standardized distance from the control values is computed for each parameter. Finally, an index of water quality is calculated by a weighted average of variables:

$$WQI = \sum_{i=1}^{n} W_{\mathrm{i}} \times Q_{\mathrm{i}} \tag{10}$$

where $W_{\mathrm{i}}$ represents the weight, and $Q_{\mathrm{i}}$ is the quality score of the variable *i*.

Turbidity, pH, conductivity, nitrate–N ($N–NO_3$), phosphate-P ($PO_4$), total suspended solids (TSS), TDS, dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), and temperature can be used for calculating a WQI. The WQI ranges between 0 and 100, with high values indicating cleaner water (Atazadeh et al. 2007).

### Trophic diatom index (TDI)

Water quality assessment can also be evaluated by biological methods such as the trophic diatom index (TDI). TDI value varies from 0 to 100. The low TDI values indicate cleaner water. The eutrophication process happens by increasing the nutrient supply of water bodies. This term is mostly used commonly in freshwater lakes and reservoirs; however, it can also be applied to flowing waters, estuaries, and coastal marine waters (Edmondson 1995). Kelly and Whitton (1995) introduced TDI to evaluate the impact of nutrients on ecosystems and freshwaters by monitoring taxonomic changes.

## Water quality influenced by land cover/ land use and soil erosion/runoff

As mentioned in "Databases", for land cover predominant in the Gharasou River Basin, Samadi et al. (2012) used (Landsat 1993). Heshmati et al. (2012) investigated the different kinds of soil erosion, the soil erosion rate, and the amount of eroded SOC, N, P, and K in the basin using a MPSIAC model. The MPSIAC model is a modified version of the PSIAC model presented in 1982. PSIAC (Pacific Southwest Inter-Agency Committee) was introduced in 1968.

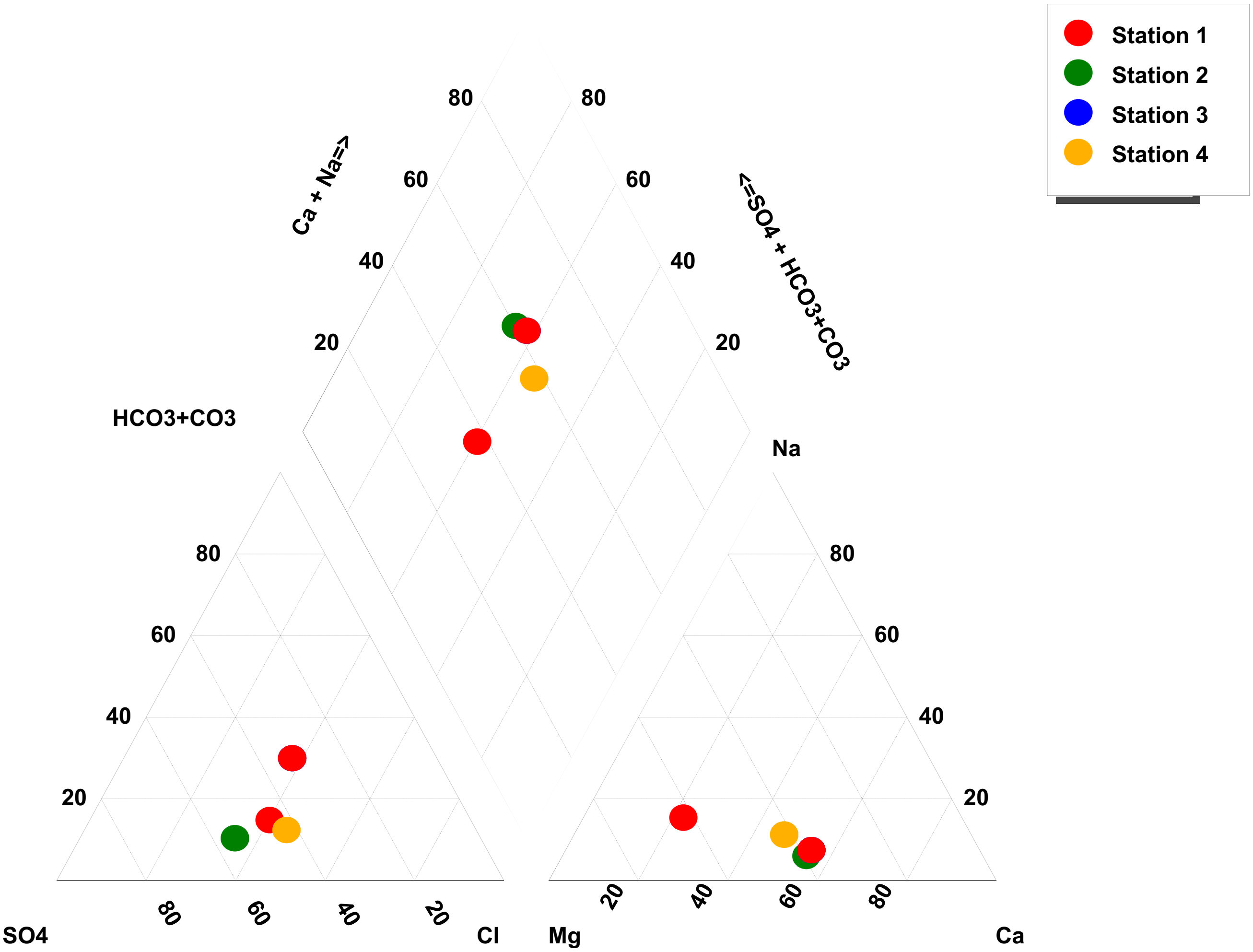


Fig. 3 Piper diagrams for water type classification (Back and Hanshaw 1965) by (Fatemi 2015)

This model is capable of predicting erosion and sediment yields at the basin scale. The amount of nutrients depletion was calculated by multiplying eroded soil (ton $ha^{-1}$ $yr^{-1}$) by nutrient contents (g $kg^{-1}$). They estimated and scored factors of the MPSIAC model for each geomorphological facies within the agriculture area, rangeland, and forest zones. To determine the surface geology, they used a geology map. They used computerized RUSEL software (RUSEL, SWCS; 1.04) to estimate the soil K factor of the universal soil loss equation (USLE). For this purpose, five sub-factors factors are required including silt plus very fine sand (%), coarse sand (%), organic matter (%), soil structure, and soil permeability. They calculated the climatic factor based on rainfall intensity (mm $h^{-1}$) with a 2-year return period from Kermanshah Weather Station data as the nearest weather station and the estimated runoff factor from the $X_4 = 0.006R + 10Q_p$ equation. Where R is the runoff coefficient and $Q_p$ is peak discharge of overland flow ($m^3$ $s^{-1}$). To estimate $Q_p$, they used $Q_p = 0.278CIA$ equation. Here, $Q_p$ is peak discharge, A facies or sub-basin area ($km^2$), and I rainfall intensity (mm $h^{-1}$) with a 1-year return period. They calculated the average slope (%) of each geomorphological facies by a GIS-prepared slope map. They used quadrate plots (5–10) within each geomorphological facies to estimate the percentages of bare soil and canopy cover. They estimated surface soil erosion using the $X_8 = 0.25$ SSF equation. SSF is a surface soil factor that the Bureau of Land Management (BLM), USA provided it (Heshmati et al. 2012).

## Results and discussion

### Water quality assessment for irrigation and drinking purposes

Salinization due to irrigation is a widespread concern globally, especially in semi-arid and arid regions, which should respond to the increased food needs of a growing population.

**Table 2** Water quality parameters of Gharasou River at different locations (Rezaei and Sayadi 2015)

| Stations | EC $\mu S\ cm^{-1}$ | pH | TDS $mg\ L^{-1}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ |
|---|---|---|---|---|---|---|---|---|---|
| Station1 | | | | | | | | | |
| Minimum | 172 | 6.53 | 108 | 2.31 | 0.16 | 0.1 | 1.91 | 0.56 | 0.09 |
| Maximum | 437 | 8.57 | 280 | 5.06 | 1.10 | 1.29 | 3.41 | 2.24 | 0.91 |
| Mean | 372 | 7.8 | 2.4 | 3.3 | 0.52 | 0.49 | 2.7 | 1.3 | 0.36 |
| Std | 53.8 | 0.46 | 35.2 | 0.55 | 0.22 | 0.27 | 0.42 | 0.38 | 0.17 |
| Variance | 290 | 0.21 | 1.24 | 0.31 | 0.05 | 0.07 | 0.18 | 0.15 | 0.03 |
| Station2 | | | | | | | | | |
| Minimum | 329 | 6.70 | 211 | 2.56 | 0.16 | 0.14 | 2.01 | 0.78 | 0.16 |
| Maximum | 661 | 8.52 | 423 | 5.43 | 0.96 | 0.92 | 3.55 | 2.80 | 1.16 |
| Mean | 437 | 7.7 | 280 | 3.73 | 0.56 | 0.49 | 2.9 | 1.47 | 0.43 |
| Std | 96 | 0.46 | 61 | 0.8 | 0.25 | 0.27 | 0.43 | 0.65 | 0.31 |
| Variance | 91.70 | 0.22 | 37.45 | 0.6 | 0.06 | 0.07 | 0.19 | 0.42 | 0.09 |
| Station3 | | | | | | | | | |
| Minimum | 320 | 7.04 | 205 | 2.30 | 0.38 | 0.20 | 2.37 | 0.81 | 0.25 |
| Maximum | 540 | 8.40 | 346 | 5.11 | 0.91 | 1.36 | 3.37 | 2.40 | 0.59 |
| Mean | 404 | 7.79 | 285 | 3.43 | 0.66 | 0.59 | 2.94 | 1.42 | 0.38 |
| Std | 56.61 | 0.36 | 36.18 | 0.68 | 0.14 | 0.28 | 0.42 | 0.42 | 0.08 |
| Variance | 321 | 0.13 | 130 | 0.46 | 0.02 | 0.081 | 0.18 | 0.18 | 0.01 |
| Station4 | | | | | | | | | |
| Minimum | 312 | 7.19 | 199 | 2.10 | 0.22 | 0.16 | 1.41 | 0.56 | 0.06 |
| Maximum | 663 | 8.66 | 424 | 6.46 | 1.00 | 2.71 | 3.49 | 3.00 | 2.20 |
| Mean | 434 | 7.86 | 275 | 3.58 | 0.52 | 0.72 | 2.77 | 1.56 | 0.55 |
| Std | 111 | 0.37 | 71.51 | 0.93 | 0.22 | 0.52 | 0.50 | 0.58 | 0.53 |
| Variance | 124 | 0.13 | 51.14 | 0.87 | 0.05 | 0.28 | 0.25 | 0.34 | 0.28 |
| Station5 | | | | | | | | | |
| Minimum | 340 | 7.32 | 320 | 3.44 | 0.36 | 0.64 | 2.80 | 1.00 | 0.39 |
| Maximum | 520 | 7.80 | 390 | 4.38 | 0.50 | 1.11 | 3.13 | 2.50 | 0.49 |
| Mean | 494 | 7.37 | 336 | 4.00 | 0.43 | 0.91 | 3.00 | 1.94 | 0.45 |
| Std | 491 | 0.13 | 199 | 0.29 | 0.04 | 0.14 | 0.08 | 0.41 | 0.03 |
| Variance | 241 | 0.02 | 397 | 0.08 | 0.01 | 0.02 | 0.01 | 0.17 | 0.00 |

The geographical positions of stations are presented in Fig. 2

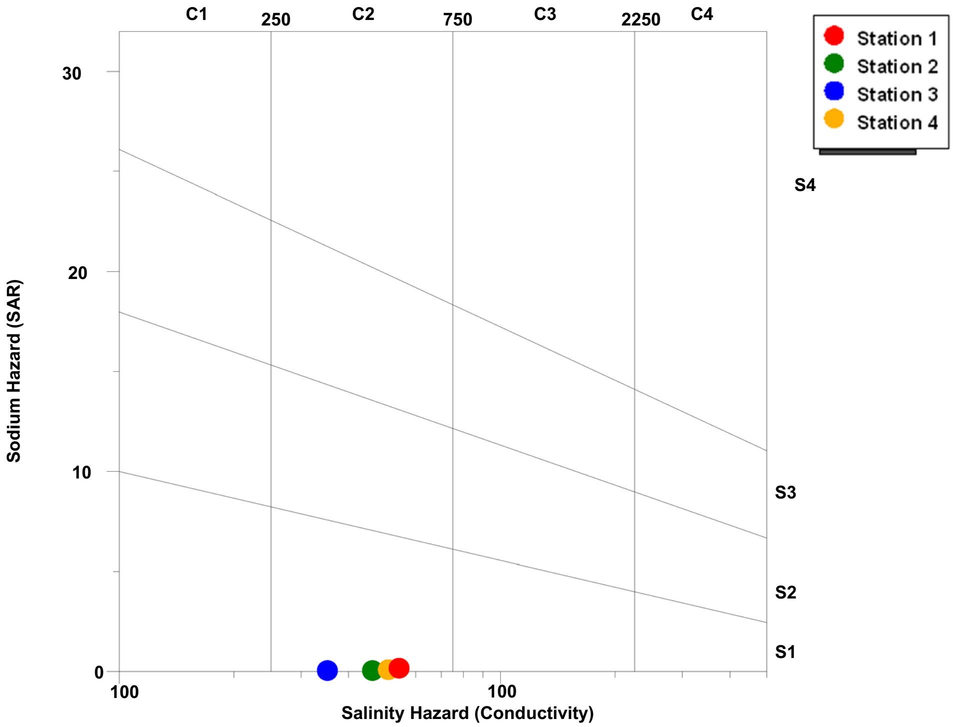
Sustainable irrigated agriculture in these regions is achievable by considering salt balance in the soil, which depends on the water quality (Peragón et al. 2015). Also, soluble salts that can enrich the soil might cause insoluble salts precipitation, which will further alter the composition of exchangeable cations on the soil surface or increase sodicity (Keren 2012). The presence of potentially toxic elements and nitrate amounts should also be evaluated to avoid plant toxicity problems. An imbalanced nitrogen (N) supply to crops or algal development in irrigation reservoirs should also be considered. These factors are included in the FAO practical guidelines for assessing irrigation's water quality (Table 1) (Ayers and Westcott 1985; Peragón et al. 2015).

Fatemi (2015) evaluated water quality and potential degradation risk of soil irrigated by the Gharasou River by calculating some hydrochemical parameters and graphical representations. The results are discussed as the following three subjects entitled below.

Salinity problems: the Gharasou River's water is considered the alkaline earth ($Ca^{2+} + Mg^{2+}$) than alkaline ($Na^+ + K^+$) type. Its water belongs to the class with medium-salinity and low-sodium hazards ($C_2S_1$) (Fig. 4). Therefore, the Gharasou River's water can be used for irrigation without any particular salinity control practices.

Sodicity problems: different indices indicated a regional sodicity problem for soil at station 1. The high risk was expected for PI (> 75%), $Ca^{2+}/Mg^{2+}$ ratio (< 1), and MR (> 50) (Table 1). Based on these results, except for station 1, the values of RSC fell in the safe zone; the class of PI was class II (25–75%). $Ca^{2+}/Mg^{2+}$ ratio showed no special problems (i.e., > 1), and MR was lower than the permissible limit (< 50) (Tables 1 and 3).

**Fig. 4** Plotting SAR against Electrical Conductivity (reported by (Fatemi 2015)



Nutritional disorders: potential nutritional disorders derived from $Cl^-$, $HCO_3^-$, and $Na^+$ concentrations, or $Ca^{2+}$/$Mg^{2+}$ ratio of the Gharasou River's water, were examined. By precipitation of $Ca^{2+}$(and, or $Mg^{2+}$) with $HCO_3^-$, the concentration of $Na^+$ in solution will increase; therefore, pH increases (Al-Bassam and Al-Rumikhani 2003), and micronutrients uptake decreases (especially $Fe^{2+}$ and $Zn^{2+}$) (Ayers and Westcott 1985). The results showed that no nutritional disorders for all stations would be expected except for station one because of the high $Ca^{2+}$/$Mg^{2+}$ ratio (Tables 1 and 3).

Irrigation problems: ◦fH, Is, and $Ca^{2+}$/$Mg^{2+}$ ratio evaluated the participation of $Ca^{2+}$ and $Mg^{2+}$ compounds and carbonate precipitation (Peragón et al. 2015). The results indicated that a low risk of clogging irrigation systems was anticipated by considering the negative Langelier index. Also, ◦fH showed a moderate risk rating, a medium risk of precipitation of $Ca^{2+}$ and $Mg^{2+}$ compounds, and a high $Ca^{2+}$/$Mg^{2+}$ ratio (Peragón et al. 2015) in station 1 (Tables 1 and 3).

Based on this study's findings, to diminish the sodicity problem for land irrigated with water from station 1, leaching requirements (LR) should be considered to avoid harmful salt accumulation. Besides, the application of water amendments (e.g., gypsum, $Ca^{2+}$-containing fertilizers) and manure application instead of fertilizer chemicals were recommended to reduce the risk of infiltration problems (Fatemi 2015).

Pirsaheb et al. (2013) measured concentrations of aluminum (Al), molybdenum (Mo), vanadium (V), antimony (Sb), arsenic (As), mercury (Hg), copper (Cu), cobalt (Co), manganese (Mn), selenium (Se), zinc (Zn), cadmium (Cd), lead (Pb), chromium (Cr), ferrous (Fe), and nickel (Ni) in all water samples. The average of Al in wells, water reservoirs, and water distribution networks was 64.65 ± 63.64, 18.73 ± 15.03, and 40.54 ± 60.74 µg $L^{-1}$, respectively. The average concentration of Fe in wells, water reservoirs, and water distribution network reported as 37.07 ± 55.50, 53.68 ± 62.74, and 55.66 ± 52.58 µg $L^{-1}$, respectively. Besides, Mn concentration on average ranged from 2.07 ± 10.95, 1.99 ± 2.20, and 1.45 ± 1.36 µg $L^{-1}$ in wells, water reservoirs, and water distribution networks, respectively. Results indicated that concentrations of Al, Fe, and Mn in some studied samples were beyond the national and WHO standards (200, 300, and 500 µg $L^{-1}$, respectively). As the results indicated the standard deviations for these metals are quite significant, and that there is a vast spread in the values. They illustrated this wide variety of heavy metal concentrations in water based on the regional sources of pollution. They also reported two primary origin sources of pollution located within or out of the city. The geological texture and agricultural activities are water sources' pollution out of the city. For instance, some agricultural activities include fertilizers and chemical pesticides containing metals, such as As, Co, and Cr. Discharging wastewater of workshops and small industrial units to the water and vehicle traffic is the water pollution source within the city. Also, the higher concentrations of some mentioned heavy metals in distribution networks might be due to the water pipelines' corrosivity

**Table 3** The average of chemical composition and irrigational quality parameters of water of stations (Fatemi 2015)

| Parameter | EC | pH | TDS | $HCO_3^-$ | $Cl^-$ | $SO_4^{2-}$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | SAR | $SAR_{adj}$ | $pH_c$ | RSC | %Na | PI | Ca/Mg | MR | French degrees | Langelier index (Is) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Geographical positions of stations | $dS\ m^{-1}$ | | $mg\ L^{-1}$ | $meq\ L^{-1}$ | | | | | | $(meq\ L^{-1})^{½}$ | | | $meq\ L^{-1}$ | % | | | | °fH | |
| $S_1$ 47° 44′ N 34° 30′E | 0.54 | 8.0 | 346.8 | 0.46 | 0.74 | 1.11 | 2.19 | 3.65 | 1.69 | 0.99 | 1.29 | 8.1 | − 5.38 | 28.9 | 86.30 | 0.6 | 62.50 | 2.1 | − 0.1 |
| $S_2$ 47° 47′ N 34° 33′E | 0.46 | 7.8 | 299.0 | 0.16 | 0.32 | 0.68 | 2.96 | 1.29 | 0.36 | 0.25 | 0.17 | 8.7 | − 4.09 | 8.5 | 35.40 | 2.3 | 30.35 | 1.3 | − 0.9 |
| $S_3$ 47° 00′ N 34° 29′ E | 0.35 | 7.9 | 225.7 | 0.27 | 0.2 | 0.23 | 2.33 | 0.96 | 0.35 | 0.27 | 0.25 | 8.5 | − 3.02 | 10.6 | 45.58 | 2.4 | 29.18 | 1.0 | − 0.6 |
| $S_4$ 47° 15′ N 34° 14′E | 0.51 | 7.8 | 325.4 | 0.23 | 0.5 | 0.63 | 2.82 | 1.51 | 0.76 | 0.52 | 0.41 | 8.6 | − 4.10 | 17.6 | 54.94 | 1.9 | 34.87 | 1.3 | − 0.8 |

**Table 4** The results of rotated factor loadings matrix of factor analysis for water quality parameters of Gharasou River

| Variables | Factor 1 | Factor 2 | Factor 3 |
|---|---|---|---|
| EC | 0.831 | 0.360 | 0.087 |
| pH | − 0.180 | 0.180 | − 0.687 |
| TDS | 0.858 | 0.306 | 0.102 |
| $HCO_3^-$ | 0.102 | 0.844 | 0.422 |
| $Cl^-$ | 0.220 | 0.720 | − 0.221 |
| $SO_4^{2-}$ | 0.740 | − 0.184 | 0.198 |
| $Ca^{2+}$ | − 0.040 | 0.389 | 0.716 |
| $Mg^{2+}$ | 0.240 | 0.820 | 0.046 |
| $Na^+$ | 0.829 | 0.361 | − 0.136 |

Loading factors > 0.75 is strong; 0.75–0.50 is considered moderate, and 0.50–0.30 as weak (Rezaei and Sayadi 2015)

(Pirsaheb et al. 2013). The other pollution sources of the Gharasou River are discussed in "Water quality of the Gharasou River influenced by pollution sources".

## Water quality of the Gharasou River influenced by pollution sources

### Non-point pollution sources

Natural pollution: natural pollution, including the external supply of cations and anions of water, originates from both point and non-point sources. Non-point sources are much more challenging to monitor and control (Smith et al. 1999). Mahmoudi et al. (2010) results indicated a significant difference ($P < 0.05$) of physical, chemical, and hydrological characteristics of Karkheh River in sub-regions stations in both periods of 1988 and 2002. In the Gharasou River sub-basin, SAR remained almost constant, but cations, anions, TDS, EC, and pH increased by about twice. Mahmoudi et al. (2010) reported that an annual discharge of the Karkheh River is an influential factor on water quality in KRB. In the studied period, the annual discharge of the KRB decreased to 121.6 $m^3\ s^{-1}$ because of a drought that happened in 1999 – 2000. The annual study of river discharges is an influential factor for assessing water quality (Mahmoudi et al. 2010).

Anthropogenic pollution: the Sayadi et al. (2014) and Rezaei and Sayadi (2015) results showed that 73.1% of the dataset's variance explained by three significant factors generated by FA. They also found a positive loading in EC, TDS, $SO_4^{2-}$, and $Na^+$ in the first factor (Table 4). They reported an increase in EC, TDS, and $SO_4^{2-}$ concentrations due to non-point pollution from agricultural areas. In general, sources of dissolved $SO_4^{2-}$ in natural river water might be natural or anthropogenic inputs. Natural sources include the dissolution of sedimentary sulfates, oxidation of sulfide minerals, and mineralization of soil organic matter

(SOM). However, Rezaei and Sayadi (2015) revealed that $SO_4^{2-}$ has an anthropogenic source. Sulfate fertilizers were used by local farmers and released to the stream by surface runoff and irrigation water. On the contrary, the contribution of $Na^+$ to this factor has natural sources, i.e., cation-exchange processes in the soil–water interface. Factor 2 was positively correlated with $HCO_3^-$, $Cl^-$, and $Mg^{2+}$ (Table 4). They reported that the second factor represents the contribution of anthropogenic activities and the physico-chemistry of the stream. Point pollution, domestic wastewater, or influents into the river water were responsible for the increase of $Cl^-$concentration. Factor 3 with $Ca^{2+}$ and pH introduced as hydro-geochemical variables (Table 4). The $Ca^{2+}$ presence in water could be explained by the weathering of bed sediments (soils) and cation-exchange processes in the soil–water interface.

### Point pollution sources

Sharifi and Hosseini (2003) reported that a large-scale release of raw sewage and industrial chemicals has drastically changed the water quality of the Gharasou River. The main urban center in the Gharasou River Basin is Kermanshah city, the capital of Kermanshah province, with a population of over 1,000,000 (Samadi et al. 2012). Sharifi and Hosseini (2003) reviewed many studies and they reported that the primary contributors to the toxicity of freshwaters in more populated areas in Iran appear to be heavy metals and some chlorohydrocarbons, particularly DDT.

Pirsaheb et al. (2015) found out the concentrations of Pb, Cd, Ni, Cr, and Fe in surface water resources were above the standard level. The ranges of Pb, Cd, Ni, Cr, and Fe in the surface water resources of Iran were 0.012–7.500, 0.002–4.850, 0.001–0.480, 0–780, and 0.019–10.980 mg $L^{-1}$, respectively. It is worthy to note that the Iranian and World Health Organization (WHO) standards for Pb, Cd, Ni, Cr, and Fe in surface water resources are 0.01, 0.003, 0.02, 0.05, and 0.3 mg $L^{-1}$, respectively. The concentrations of As, Zn, Se, Co, Mn, Cu, and Hg were lower than Iranian and WHO standards.

Zeinoldini et al. (2014) reported Fe, Zn, Mn, and Pb concentrations ranged 0.06–0.12, 0.01–0.02, 0.01–0.25, 0.03–0.09 mg $L^{-1}$ in five samples' points on the Gharasou River. The concentrations of Cu, Cd, and Ni were less than the detection limit of the measurement method. The concentrations of Fe and Zn were lower than the standard levels for surface water and irrigation. They revealed that the Mn concentration in the sample point near the local oil refinery company was close to the standard levels for surface water resources (i.e., 0.1 mg $L^{-1}$). While for two sample points, on nearby agricultural lands, the Mn and Pb concentrations were above the standard levels for surface water (the standard level of Mn and Pb are 0.1 and 0.005 mg $L^{-1}$, respectively). The proximity of these agricultural lands to industrial units and a decline in the water discharge because of drought were considered as reasons.

### Water quality index (WQI)

Atazadeh et al. (2007) reported WQI from 33 ± 3 to 76 ± 6 related to Kermanshah and Ravansar stations, respectively. These low levels of WQI revealed a significant level of pollution in the Gharasou River. They observed the progressive increases in TSS, TDS, $NO_3$–N, $PO_4$–P, COD, BOD, and turbidity in the Gharasou River from Ravansar station to Kermanshah station. The amounts of TSS, TDS, $NO_3$–N, $PO_4$–P, COD, BOD, and turbidity in Ravansar station were 56 ± 5 mg $L^{-1}$, 45 ± 25 mg $L^{-1}$, 0.5 ± 0.1 mg $L^{-1}$, 0.03 ± 0.01 mg $L^{-1}$, 35 ± 3.6 mg $L^{-1}$, 18 ± 2.3 mg $L^{-1}$, and 5 ± 2 NTU, respectively. While TSS, TDS, $NO_3$–N, $PO_4$–P, COD, BOD, and turbidity in Kermanshah station were 311 ± 215 mg $L^{-1}$, 548 ± 75 mg $L^{-1}$, 6 ± 2.5 mg $L^{-1}$, 1.6 ± 0.5 mg $L^{-1}$, 76 ± 9 mg $L^{-1}$, 48 ± 7.1 mg $L^{-1}$, and 52 ± 8 NTU, respectively. The unregulated and direct releases of industrial and municipal waste into the river were reported as crucial factors for the water pollution of the Gharasou River.

The River Gharasou joins the Gamasiab River, the largest river in Hamedan province. Sharifi and Hosseini (2003) investigated N-$NO_3$, $PO_4$, TSS, TDS, DO, COD, BOD, pH, and temperature in six sites with varying degrees of human impact Gamasiab River. The results indicated a significant increase in TSS and BOD and a reduction in DO downstream. There were minor changes in temperature and water quality characteristics upstream. As a result, these changes in water characteristics, simultaneously the results of in situ sediment toxicity test, revealed that the Gamasiab River water is toxic to macroinvertebrate, *Garnrnarus sp*. The survival of *Gamrnarus sp* at three sites downstream was lower compared to the control site upstream.

### Trophic diatom index (TDI)

Atazadeh et al. (2007) reported TDI values 39.2 ± 5 and 71.3 ± 15 for Ravansar and Kermanshah stations, respectively. They could establish relationships between TDI and both physical and chemical variables and the other biological measurements of eutrophication. They found a significant positive correlation between values of the TDI and $PO_4$–P ($TDI = 26.122\ PO_4–P + 35.462$, $R^2 = 0.82$) and $NO_3$–N ($TDI = 6.9865\ NO_3–N + 41.934$, $R^2 = 0.70$) and a negative correlation with WQI ($TDI = -0.738\ WQI + 92.621$, $R^2 = 0.85$).

Inorganic N pollution in ground and surface waters has adverse effects on human health and the economy (Camargo and Alonso 2006). Camargo and Alonso (2006), after synthesis of the published scientific literature, addressed three major environmental problems related to inorganic N pollution: (i) acidification of freshwater ecosystems due to increasing the concentration of hydrogen ions without much acid-neutralizing capacity, (ii) eutrophication of aquatic ecosystems, and (iii) the aquatic animals' ability to survive, grow and reproduce are damaged when it reaches toxic levels. The inorganic N forms include ammonium-N ($NH_4$-N) and both particulate and dissolved organic N, and nitrate ($NO_3$-N) (Johnes and Heathwaite 1997). Inorganic phosphorus (P) pollution in aquatic ecosystems is entirely different from inorganic N. The inorganic P compounds are predominantly insoluble. Therefore, the only way to export P to surface water bodies is sediment transport. On the other hand, P leaching losses are small. Besides, P can transform into a rapidly taken-up form for the biota (Johnes and Heathwaite 1997).

## Water quality influenced by land cover/land use and soil erosion/runoff

### Land cover/ land use

Sediment transfers pollutants in irrigation and drinking water into farmlands and dams. Moreover, sedimentation in water channels clogs the waterways (Sarmadian et al. 2010). Soil erosion and sediment transport in arid and semi-arid areas of Iran are widespread, which have become one of the most critical concerns (Hosseini and Ashraf 2015). In the Zagros Mountains, sparse vegetation cover is the main factor in the transportation of millions of tons of soil by water to downstream basins. Moreover, development strategies led to land use changes and exposed shale and marl to soil erosion, which are known as sensitive geological formations (Hosseini and Ashraf 2015).

The topography of the Gharasou River Basin consists of highlands (48%) and plains (52%), including Mahidasht-Sanjabi (1463 $km^2$), Kamyaran-Bilevar (356 $km^2$), and Kermanshah (984 $km^2$) Plains (Hosseini et al. 2016). Predominant land uses of the Gharasou River Basin are agricultural and rangelands (Saghafian et al. 2012). Wheat and barley are the major crops grown in the rangelands. Samadi et al. (2012) estimated the area of agricultural lands to be about 67% of the Gharasou River Basin, according to (Landsat 1993) data.

Agriculture is the main activity of people in the Gharasou River Basin. Farmers change the natural land cover because of the agricultural land's need (Omani et al. 2007). The rangeland is converted to rain-fed crops and overgrazed. Deforestation also is a significant concern that led to the degradation of soil and environmental problems. However, the deforestation rate has been accelerated in Iran during the last half-century due to intensive cultivation and mismanagement (Abu Bakar et al. 2014). It is worthy to note that soil erosion is the most significant problem in the west of Iran. In general, in the Gharasou River Basin, soil erosion is caused by rainfall intensity and geomorphology. However, removing of natural vegetation cover accelerates soil erosion in a large area of this basin (Omani et al. 2007). The effect of converting land cover/land use on the water quality of the Gharasou River discusses in Land cover/ land use and Soil erosion/runoff.

### Soil erosion/runoff

At the basin scale, the relative contributions of pollution sources are affected by land use and local human population densities (Smith et al. 1999). Surface water quality is negatively influenced by soil erosion. SOC and soil nutrients depleted from soil cause eutrophication. The Gharasou River Basin is primarily located in the Zagros Mountains region, which is considered a climatically sensitive region (Samadi et al. 2012).

The Heshmati et al. (2012) results showed that in the Merek sub-basin, the leading cause of extensive soil erosion is land degradation. Land degradation occurs mainly within the forest and rangeland located on the sloping land. Gully, inter-rill, and landslide were reported as the three main soil erosional features among the six kinds of erosional features in the study area. However, inter-rill erosion is the most critical factor affecting land degradation in the Merek sub-basin, although its area is small (about 20%). Land degradation is promoted by deforestation and overgrazing of livestock.

Moreover, improper agricultural activities enhance the rate of soil erosion. Dominant erosional features are gully and rill in the agricultural lands, whereas landslide occurs in the forest. The reported erosion rates were 14.47, 16.60, and 18.57 t $ha^{-1}$ $yr^{-1}$ in the agriculture area, rangeland, and forest, respectively (Fig. 5a). In the Merek sub-basin, it was estimated the annual SOC, N, P, and K depletions by erosion in the agriculture area were 147.24, 15.6, 0.172, and 4.47 kg $ha^{-1}$ $yr^{-1}$, respectively. The annual depletion of estimated SOC, N, P and K in the rangeland was 176.92, 18.73, 0.170, and 4.65 kg $ha^{-1}$ $yr^{-1}$, respectively. Moreover, the amounts of depleted SOC, N, P, and K in the forest were 306.10, 23.75, 0.165, and 5.15 kg $ha^{-1}$ $yr^{-1}$, respectively (Figs. 5b–e). Heshmati et al. (2012) reported the lowest decline in P by soil erosion and the highest depletion of SOC, N, and K in the forest. The steepest decline in P and the lowest depletion of SOC, N, and K have occurred in the agriculture area. Moreover, the presence of smectite mineral in the soil of sloping land is subjected to deforestation and overgrazing, which results in depleting soil nutrients and SOC in the Merek sub-basin.

The rate of soil erosion by the MPSIAC model in the Gamasiab basin, one of the sub-basins of the KRB, was

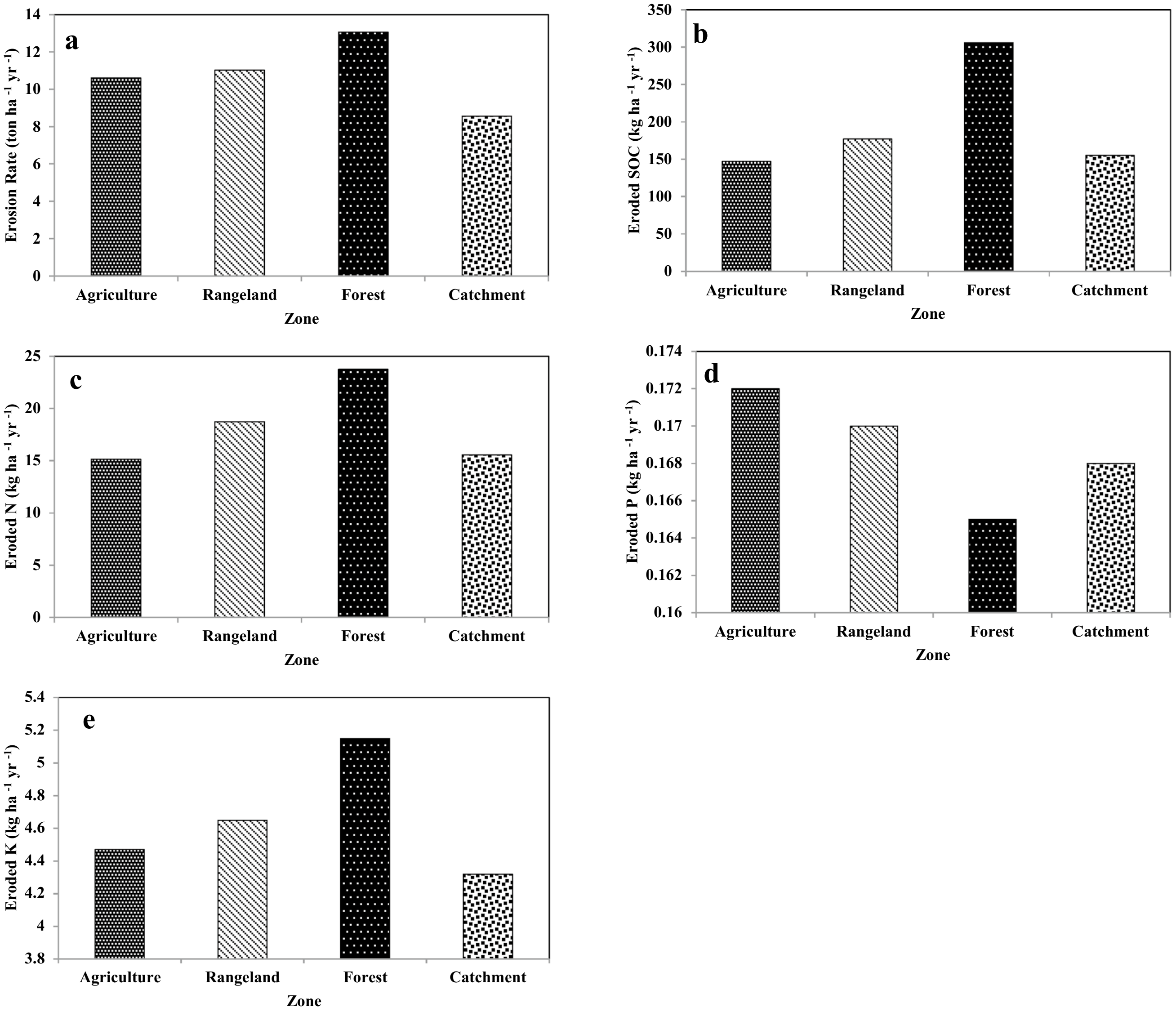


**Fig. 5** Rates of soil erosion (**a**), SOC (**b**), N (**c**), P (**d**) and K (**e**) depletion in the Merek basin (reproduce from data reported by (Heshmati et al. 2012)

investigated by (Ilanloo 2012). The Gamasiab basin is located between the longitude 47° 3′ to 48° 10′ N and latitude 34° 49′ and 34° 56′ E. The results indicated that the soil erosion rate is high in the northern, eastern, and southeastern parts of the studied area compared with the southern region. The reasons for this finding were explained by the geology, steep slopes, and less vegetation cover of the northern part. The steep slopes, low soil depth, overgrazing, farming in the hilly areas and the marl formation were contributing factors in eastern and southeastern regions. Finally, the proper agricultural activities, and gentle slopes, were reported as the reasons for lower soil erosion rates in the south part of the Gamasiab sub-basin.

## Conclusion

This paper considered the results of published papers in different aspects of water quality assessment of the Gharasou River at a basin scale as a sub-basin of the KRB. According to the review of the current literature for the evaluation of water quality, some conclusions are presented as follows:

1. Different methods and indices were evaluated for the evaluation of the Gharasou River quality for irrigation. The USSL and FAO methods classified water for all

stations as $C_2S_1$ (moderate-salinity hazard and low-$Na^+$ hazard) and unrestricted. Water quality indices introduced a more precise definition to categorize water quality in regional scales. The indices indicated that water in one station (No.1) had sodicity problems. Soil degradation risk was low in the study area, and potential nutritional plant disorders arising from irrigation are not expected. The application of the water amendment and manure application avoids soil degradation and plant disorders, which is likely to take place by continuous irrigation.

2. Drought, the geological texture, and weathering of bed sediments and soils, as well as cation-exchange processes in the soil–water interface, are considered natural non-point pollution sources of the Gharasou River. In the meantime, anthropogenic activities are the sources of non-point and point pollution. These include agricultural activities, the release of raw sewage and industrial chemicals from the local oil refinery company, and industries such as the Sahra dairy company (Fereidoon and Khorasani 2013). Furthermore, small industrial units and workshops dramatically changed the water quality of the Gharasou River. The high concentrations of some heavy metals (Mn and Pb) and low amounts of water quality indices, such as WQI and TDI, reflect the pollution of the Gharasou River's water.
3. Predominant land uses in the Gharasou River Basin are agricultural and rangelands (about 67% of the Gharasou River Basin area (Landsat 1993)). About 52% of the Gharasou River Basin areas are plains, and the rest of the agricultural fields (about 15%) are located in the highlands. The need for agricultural land has led to the removal of the natural land cover and changed rangeland into rain-fed crops. Improper tillage practices in the rain-fed areas and application of chemical fertilizers in the irrigated lands are the main reasons leading to SOC loss, reduction of soil aggregate stability, and increasing the amount of soil erosion and runoff.
4. Converting rangeland to rain-fed crops, overgrazing of livestock, and deforestation resulted in extensive soil erosion and depletion of soil nutrients and SOC in the agriculture, rangeland, and forest zones of the Merek sub-basin of the Gharasou River Basin.

## Study limitations

1. In this study, the concentrations of heavy metals, except for Fe, Zn, Mn, and Pb for all regions along the length of the Gharasou River, were not available.
2. During a recent survey completed in Ravansar, it was observed that ten years ago, about 500 ha of hilly land converted to forest. The impact of this conversion on soil erosion, runoff, sediment yield, and water quality should be considered for future research.
3. There is no information about pesticides, herbicides, and other organic pollutants in the Gharasou River water used by farmers.
4. Parameters considered here as factors affecting the quality of the Gharasou River Basin contain different sampling locations, different time frames, and different sets of parameters. This issue prevented comparing data during the time, different locations and there is a need to consider for future studies. However, it is necessary to regard these factors on a basin scale and a comprehensive plan not as individual and disorganized researches. It would help to conduct outputs as inputs to models which predict parameters time-consuming and costly.

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