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Research Article

Eco-hydro desktop assessment for determining rivers environmental flows in Urmia Lake Basin (case study: Simineh River)

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ABSTRACT

The main cause of the drying crisis of the internationally registered Urmia Lake, Iran, is the continuous declining of streamflows into the lake due to the overuse of water in agriculture over the past two decades. The determination of environmental water requirements for each of these rivers are necessary for rehabilitation of the Urmia Lake. This paper presents a hydrological desktop procedure to address a rapid evaluation of minimum environmental flows (EFs) of these rivers under which no specific bio-riverine data are available. Nine different eco-hydrological methods were considered to estimate the EFs for the second largest river in the Urmia Lake Basin, the Simineh River. The ecological flow needs were investigated in four different reaches of the river, upstream and downstream of the Simineh Dam site. The results indicate that the method of "Flow Duration Curve (FDC)-Shifting" is well adapted to the natural river flow regime. In order to improve the river environmental status one step up, a range of 20% to 30% of mean annual flow (MAF) is to be allocated in four different reaches of the river. The environmental water release from the Simineh Dam is to be revised and increased from prescribed value 10% to about 23% of MAF. This revision is guaranteed with the reduction of the dam height and reservoir capacity.

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INTRODUCTION

The protection of the environment and optimum utilization from the water resources is an important issue in the world. Water is an essential element of an ecosystem, both qualitatively and quantitatively. Water scarcity is a global threat to freshwater biodiversity, but connecting variation in streamflow to viability of imperiled faunas remains a challenge [1]. The riverine environment has a natural self-rehabilitation capacity and resilience to water shortages,

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but when these processes are inhibited, biodiversity is lost, livelihoods are affected, natural food sources (e.g. fishes) are damaged. The portion of water flows over different seasons which is necessary to maintain the functioning of fresh water dependent ecosystems in a river basin is often referred to as 'environmental flows (EFs)', 'environmental water requirements (EWR)' and 'environmental demand (ED)' [2]. However, environmental flows should provide a balance between the use of water for riverine community needs and the healthy functioning of ecosystem services [3]. The determination of EFs was highlighted due to the continuing negative environmental impacts of dams and other riverine structures (e.g. hydropower projects) on river biota downstream [3]. More than 200 methods have been developed that can be grouped into four categories: hydrological rules, hydraulic rating methods, habitat simulation methods, and holistic methodologies [4]. The decision to use a specific method depends on different factors such as: 1. Type of river (e.g. perennial, seasonal, high base flow, flashy); 2. Perceived environmental importance; 3. Complexity of the decision to be made; 4. Increased cost and difficulty of collecting large amounts of information; and 5. Severity of different resource developments [5].

Much attention has been paid to the analysis of eco-hydrological data for developing a better understanding of how flow regimes influence the structures and functions of riverine ecosystems [6, 7]. A range of methods exists for determination of water allocations for aquatic ecosystems which can provide answers at a higher spatial and temporal resolution than the rapid methods described above. Application of these methods in a specific river system can take anywhere from several months to several years, since they are generally data-intensive, require detailed ecological and hydrological surveys, and usually involve multi-disciplinary teams in numerical modelling studies. Therefore, modeling of complex relationships between variable biological and flow indicators is a major challenge [8]. McClain et al. [9] examined the relationship between potential annual flow regimes and selected riverine species in three gauging stations on the Mara River in Kenya and Tanzania. The results were compared with available knowledge of the life histories and flow sensitivities of the aquatic and riparian communities, and a dynamic environmental flow regime was determined to protect ecosystems in the region. Freshwater fish communities are acknowledged as indicators that can be adopted to assess the ecological conditions of rivers. Tsai et al. [7] examined the relationship between flow regimes and fish communities at 38 locations in 12 rivers in Taiwan, using soft computing techniques (i.e. self-organizing feature map and clustering methods). Results indicated that the flow regime characteristics at midstream reaches are critical for the population and diversity of fishes. Similar studies were conducted by Wheaton et al. [10] on the restoration actions for recovering salmonid population-level life cycle in the Columbia River Basin; and by Macura et al. [11] on the relation between flow rate and fish habitat in mountain rivers. The influence of dam-induced hydrological alterations and related ecological problems was investigated by Zhang et al. [8, 12] on large rivers in China. Results indicated that the biological diversity decreased after the construction of each of the dams. The relevance of river geomorphology with ecological functions of riverine habits and environmental flows are found to be meaningful by Tare et al. [13] and Tabatabai et al. [14].

Most of the EFs methods have been designed in developed countries with specific restoration aims and with utilizing biota data recording set. This is not the case in most of developing countries, and the lack of technical and institutional capacity is a major challenge in protecting rivers ecosystems [15]. There are a number of rapid methods available for estimation of water allocations for rivers and wetlands. "Rapid" means at a desktop level [16]. Most of these methods are based on the establishment of an empirical relationship between the flow rate in a river and the resulting structure and function of the associated aquatic ecosystem [4]. These methods generally require hydrological data for virgin and present-day flows of a river on annual, monthly or daily periods [17, 18]. Some methods attempt to provide greater accuracy by linking various hydrological statistics to ecosystem structure and function, such as: Flow Duration Curve-Shifting (FDC-Shifting), Desktop Reserve Model (DRM) and Range of Variability Approach (RVA). Other methods such as: Tennant and Flow Duration Curve (FDC) are usually subjective and provide only rough answers for minimum EFs, at the resolution of annual or seasonal flows, which can be useful in planning at the basin-macro scale [19]. One of the best-known rapid methodologies is the so-called "Montana method" (Tennant [20]), in which the proportion of the virgin mean annual runoff provided to a river ecosystem can be related empirically to the ecological condition of that ecosystem. This methodology relies on observations of ecological condition made by its developer in many North American rivers. This method is suitable only for northern temperate ecosystems, and cannot be applied with confidence elsewhere, especially in ecosystems where flows are strongly seasonal [21]. Modified version of Tennant method have been reported based on local field studies by Department of Water Affairs and Forestry (DWAF) in South Africa (DWAF 1997), and Sedighkia et al. [22] in Iran considering the Rainbow Trout as dominant species in the stream ecosystem.

In the literature, there is no general agreement on which method should well be adapted to any specific river environment. Also, the newly developed methods are not yet justified as the more appropriate ones. Therefore, the prescription of a specific method may not be appropriate for different rivers and/or different reaches of a river [23, 24].

The assessment of EFs in rivers is a challenging practice in Iran. The Urmia Lake is the second order of hypersaline water bodies in the world, and is an internationally registered wetland in the Ramsar Convention. The potential flows into the Urmia Lake are greatly provided by 10 perennial rivers, hosting 24 large dams. In the last decades, development of irrigation network and overuse of water is the main cause of desiccation of the Urmia Lake. In the steering operation of these dams, the allocations for downstream environmental needs are negligible. This lake is now a major threat to the local and international environments. In the recent attempt for the Urmia Lake restoration plan (ULRP), the allocation of environmental flows from the main rivers and security of water flows along these rivers towards the Urmia Lake is well recognized. In the lack of river-biota data set, the main aim of the present study is to present an identical methodology for hydrological desktop assessment of EFs in rivers delivering water into the Urmia Lake. In this study, the second major river in the south coast of the Urmia Lake, the Simineh River, was selected. The construction of a large dam on this river is also a potential threat to eliminate the downstream flows into the Urmia Lake.

MATERIALS AND METHODS

Study Area

The Simineh River (also known as Tataow River) is the second largest perennial river in the Urmia Lake Basin, located in north-west of Iran [25]. This river flows from Zagros mountain range, passes the cities of Bukan and Miyandoab and discharges into the Urmia Lake. Its drainage area is 3800 km^2, with full length of 200 km. The climate of the river basin is semiarid and cold. The annual precipitation varies in the range 200–500 mm with more than 60% concentrated in the spring. The potential of natural flows of the river basin is near to 500×10^6 m^3/s [25].

An existing agricultural water demand has been targeting the whole river flow capacity, and the inflow to the Urmia Lake is being limited. The Simineh Dam, under-construction, is also a near-future threat to the downstream environment, because over 90% of the water storage is planned for further agricultural development. This status is considered as a mismanagement of both the river system and the Urmia Lake Basin.

The assessment of minimum environmental flows in the Simineh River is of major national concern for the restoration of the Urmia Lake. Four river reaches along the Simineh River were selected from upstream to downstream, for which four existing gauging stations (Gizil Gonbad, Bukan Bridge, Dashband and Miyandoab) represent the normal flow regime at these reaches for about 40-year period before the river degradation has begun (i.e. 1970-2012). A plan view of the Urmia Lake- Simineh River- gauging stations and the Simineh Dam is presented in Figure 1. General information of the four river reaches and corresponding hydrometry stations are also shown in Table 1.

Eco-Hydrological Methods

Nine different eco-hydrological desktop methods were used to evaluate environmental flows in the Simineh River. The Tennant (Montana) method developed by Tennant [20]

Figure 1. Plan view of Urmia Lake, Simineh River, Gauging stations and the Dam location.

Table 1. Characteristics of selected river reaches along the Simineh River [25]

River reach	Distance from Urmia Lake (km)	Drainage area (km^2)	Gauging station information			Mean annual flow (m^3/s)	Mean annual runoff (10^{6}m^3)
			Elevation (m)	Longitude	Altitude		
Gizil Gonbad	133	770	1372	45° 57 ′	36° 25 ′	5.2	162
Bukan Bridge	100	1818	1328	46° 11 ′	36° 31 ′	9.0	284
Dashband	82	2425	1311	46° 10 ′	36° 39 ′	14.3	452
Miyandoab	32	3370	1290	46° 03 ′	36° 57 ′	15.2	480

is the most common hydrological method applied worldwide [4]. Tennant method was partially modified by the Ministry of Energy, Iran, to adapt to the Iran's hydrological regime. In this approach, the acceptable environmental level is 30% of mean annually runoff (MAR) for April to September, and 10% of MAR for March to October. With the derivation of seasonal offers of Tennant method, Tessman [26] uses the combination of mean monthly flow (MMF) and mean annually flow (MAF) to determine minimum monthly flow as environmental water requirement (EWR).

Another common hydrology-based methodology applied worldwide in its general form is the Flow Duration Curve Analysis (FDCA) method. This method uses the low-flow indices of Flow Duration Curve (FDC) ranges between 70% and 99% (denoted as Q70 and Q99, respectively). The Q90 and Q95 are frequently used as indicators of low flow and have been widely used to set minimum EFs [27]. The low-flow index is interpreted as the 7-day low flow with a 2&10-year return period (7Q2&10), using daily discharge data from the river reach under study [26]. The 7Q10 flow is the second most widely used hydrological method for the evaluation of EF [4]. This flow rate is considered to be the minimum EFR throughout the year. In this study, daily discharge data and minimum 7-day moving average for each of the years in the period of 1970–2012 were used to calculate 7Q2&10 using SMADA software (2016).

Smakhtin et al. [28] further referred to low-flow requirement (LFR) and the high-flow requirement (HFR) in a procedure known as Smakhtin method. LFR is believed to approximate the minimum requirement of water of the fish and other aquatic species throughout the year. HFR is important for river channel maintenance, as a stimulus for processes such as migration and spawning, for wetland flooding and recruitment of riparian vegetation. The sum of LFR and HFR forms the total EWR [27].

Smakhtin and Anputhas [29] developed a hydrological method known as FDC-Shifting. This method presents a tool for qualitative classification of river management status (i.e. six EMCs ranging from A to F), based on the exploration of the river basin potentials and threats [30]. The EMCs are similar to those described by DWAF [30]. In the present study, global environmental flow calculator (GEFC) was used to analyze the data and to estimate environmental flow requirements.

Desktop Reserve Model (DRM) is a hydrology-based, planning-type EFR methodology developed in South Africa by Hughes and Hannart [16]. The parameters of DRM model have been determined empirically for South African rivers, and DRM parameter values must be modified for other conditions. In computing process, the model assumes that the primary dry-season months are June to August and the primary wet season months are January to March, as occurs over much of South Africa. This assumption cannot be altered within the model [30]. In the case of the Simineh River Basin's climatology, March to June and July to February represent the wet and dry seasons, respectively. To reflect these key months, the input data were shifted by 2 months (i.e. January became March and so forth) and the results were then readjusted.

RVA method has developed by Richter et al. [32] as a complex approach for setting stream flow-base river ecosystem management targets. The proposed approach derives from aquatic ecology theory concerning the critical role of hydrological variability, and associated characteristics of timing, frequency, duration and rates of change, in sustaining aquatic ecosystems. The indicators of hydrologic alteration software (IHA) was used to evaluate EWRs in RVA method. In this model, the effects of dam reservoir on regulating the river flows can be investigated. At least twenty years of daily flow records are required for calculations by IHA.

The influence of water quality parameters in determining EFs was investigated using the Q-Equation 1 [33]. Different water quality parameters may be considered using this equation such as TDS (Total Dissolved Solids), DO (Dissolved Oxygen), BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), pH (Potential of Hydrogen).

$$\left(Q_1 + Q_c\right) \times C_0 = \left(Q_2 + C_2\right) + \left(Q_1 + C_1\right) \tag{1}$$

where, Q_1 and Q_2 are the initial and secondary discharges; C_1 and C_2 are corresponding concentration of each of the quality parameters; and C_0 is the interested concentration value of the parameter. The water chemical statistics of the Simineh River were investigated in the three gauging stations. Among different parameters, COD was selected as representative of water quality, and the EPA standard was used as the reference for acceptable values of COD.

RESULTS AND DISCUSSION

The rivers in the Urmia Lake Basin have different ecological values and management status. In the present study, an extensive field observation indicated that the environmental status of the Simineh River is seriously and critically degraded. With reference to the qualitative classification of river environmental management classes (i.e. six EMCs ranging from A to F), the river condition is likely to be described within the two classes E and F. Hence, management interventions are necessary to restore the Simineh River flow regime and to move this river to a higher environmental category such as class C or B in the EMCs. Currently, it is considered that one-step up in the river improvement plan is feasible. However, more attribution for environmental flows requires less water available for agricultural uses and more social-induced pressures.

The potential use of nine different hydro-ecological methods and the choice of the most appropriate method are investigated for the Simineh River Basin. The prediction results for minimum environmental flow requirements are presented in Table 2 for four different reaches of the river. The predicted annual EFs are also compared with the prescribed value of environmental flow allocation in the Simineh Dam plant.

The Tennant method proposes different percentages of annual flow as EFRs. Based on the national standard, 10% of MAF in dry-season (October–March) and 30% of MAF in wet-season (April–September) were considered as EFs. However, these two seasons do not have conformity with hydrological condition of the Simineh River Basin. Therefore, it was modified to 10% of MAF for Jun–March as dry-season, and 30% of MAF for April–May as wet-season. The results for monthly distribution of flows from 'modified Tennant method' are presented in Table 2. In FDCA method, the environmental requirements were assessed by six different percentages of flow occurrences ranging from 70% to 95%, as presented in Table 2. Flows exceeding 90% or 95% of occurrence are almost nothing, and not capable of running through the river for the ecosystem enhancement. The 7-day flow with 2&10-year return periods (7Q2&10) were used as common low-flow indices in determining EFRs. This method might be compatible with perennial

Table 2. Estimation of environmental flows from different methods, Simineh River

Methods		Environmental Water Requirement: EWR (m^3/s)			
		Gizil Gonbad	**Bukan Bridge**	**Dashband**	**Miyandoab**
FDC Shifting	Class A	4.58	5.94	9.89	10.05
	Class B	2.83	3.33	5.74	5.94
	Class C	1.65	1.71	3.30	3.50
	Class D	0.93	0.81	2.01	2.13
	Class E	0.52	0.36	1.15	1.37
	Class F	0.26	0.18	0.72	0.91
DRM	Class A	2.28	3.98	6.34	7.00
	Class A/B	1.94	3.38	5.50	5.94
	Class B	1.59	2.77	4.44	4.85
	Class B/C	1.33	2.33	3.73	4.07
	Class C	1.07	1.86	2.98	3.25
	Class C/D	0.87	1.53	2.44	2.67
	Class D	0.67	1.17	1.94	2.12
Tennant	Apr – May	1.55	2.70	4.30	4.57
	Jun – Mar	0.52	0.90	1.43	1.52
Tessman		2.52	4.10	6.73	7.36
Smakhtin		1.03	1.80	2.87	3.37
Low Flows Indices	7Q10	-	0.02	0.08	0.35
	7Q 2	-	0.13	0.35	1.33
FDC	Q70	0.20	0.66	0.88	2.08
	Q75	0.00	0.40	0.69	1.59
	Q80	0.00	0.02	0.49	1.16
	Q85	0.00	0.01	0.34	0.67
	Q90	0.00	0.01	0.00	0.33
	Q95	0.00	0.00	0.00	0.03
RVA	Low RVA	-	-	6.32	7.14
Water quality	Q Equation	-	3.20	2.79	19.00
Dam report	March-May	-	1.00	-	-
	Jun.–Feb	-	0.50	-	-
Recommended in this study	FDC Shifting Class C	1.65	1.71	3.30	3.50

rivers with considerable base flows in humid areas, but may not respond well to rivers with considerable variable flows in cold, semiarid regions such as the Simineh River.

The DRM calculates the EFR by considering ecological characteristics of the study area in different ecological management categories. The evaluated EFs by DRM method in different management classes are presented in Table 2. The ecological class C (i.e. moderately modified condition of the river) was considered as more feasible target for the restoration of the Simineh River using DRM method.

Calculation of the environmental flows with FDC Shifting method was made using GEFC software. The MMFs of the period of 1970–2012 were introduced to this model. The EWRs in each of the four river reaches were investigated for different ecological classes (class A to class F). The ecological management class C was chosen, based on field observation and recommendation from ecological experts in the local Department of Environment. In the concept of class C (i.e. moderately modified condition of the river), multiple disturbances (e.g. water diversions, habitat modification, and reduced water quality) associated with the need for socioeconomic development in agriculture have been acting on the river system. Thereby, habitats and dynamics of the biota have been disturbed, but basic ecosystem functions are still intact; some sensitive species are lost and/or reduced in extent; alien species present. The status of River Management Class C demands 20% to 30% of mean monthly flow as EF. The monthly distributed flows adapt well with the natural monthly flow regime in the Simineh River, and are hydraulically capable enough to flow down the river. Difference between the natural flow and EF hydrographs at any particular time of the year ideally considers as water available for other uses in the region (such as urban, agricultural, industry and etc).

IHA model was used to calculate EFs by RVA method. Since the Simineh Dam is still under construction, the effects of dam reservoir on regulating the river flows cannot be investigated, hence the single period analyses was used in this model. The lack of sufficient daily flow data at the first two stations, only the predicted results from the two downstream stations (i.e. Dashband and Miyandoab in Table 1) are presented in Table 2.

The quality method (the Q equation: Equation 1) was used to investigate the influence of water quality on the quantity of the EFs in three reaches (quality data was unavailable for Gizil Gonbad station). The values of COD were the most critical parameters among others, according to the national standard of surface water quality in Iran. The targeting value of COD (as a critical index) was set to calculate the minimum monthly flow rates (Table 2). The minimum required flow at the downstream station (Miyandoab Station) is about 19 m^3/s which is greater than the mean annual flow (15.2 m^3/s in Table 1), and in most months of the year is out of the potential natural flows of the river. Discharge of the urban wastewater to the river is an obvious reason for the hyper chemical contamination of the river downstream of the Miyandoab City. However, with the current management, the required flowing rate of freshwater is not expected down the river, and urban wastewater treatment would be necessary.

The overall results for the calculation of minimum annual EFRs from the nine eco-hydro methods are presented in Table 2. Typical monthly distribution of EFRs are also presented and compared in Figures 2 and 3 for two major reaches of the Simineh River (i.e. Bukan Bridge and Miyandoab), respectively. Comparative results indicate that the estimation of EFs from FDC-Shifting method, considering the river management class C, is sufficiently adapted with the monthly variability of the natural flow regime, the desired water quality, and the resilience of the reduction of water usage for agriculture with minimum socio-economic tension in the river basin. Although very much dependent on engineering judgment, the FDC-Shifting method gives a lot of flexibility for water allocation in dry- and wet-seasons, particularly in rivers with dominant seasonal flow regime in semi-arid regions such as the Urmia Lake Basin, and enables rapid estimation of

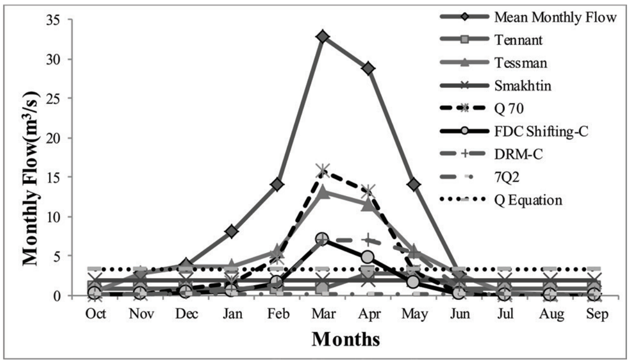

Figure 2. Comparison of EFs methods for the Simineh River at the Bukan Bridge Station.

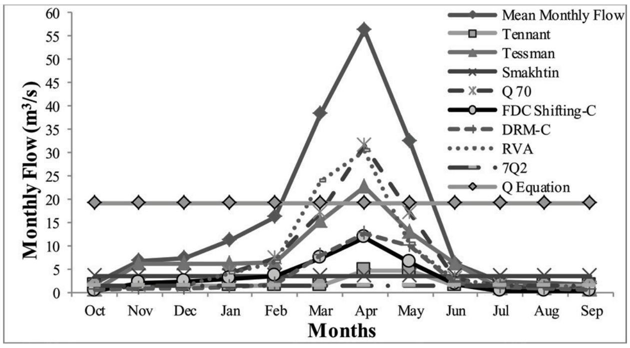

Figure 3. Comparison of EFs methods for the Simineh River at the Miyandoab Station.

Table 3. Allocation of environmental flows for the four reaches along the Simineh River

River reach (Gauging station)	Distance from Urmia Lake	Mean Annual Flow (MAF)	Minimum annual environmental flow		Remarks
	(km)	(m^3/s)	(m^3/s)	MAF (%)	
Gizil Gonbad	133	5.2	1.65	32	U/S of Dam
Bukan Bridge	100	9.0	1.71	20	D/S of Dam
Dashband	82	14.3	3.3	23	D/S of Dam
Miyandoab	32	15.2	3.5	23	D/S of Dam

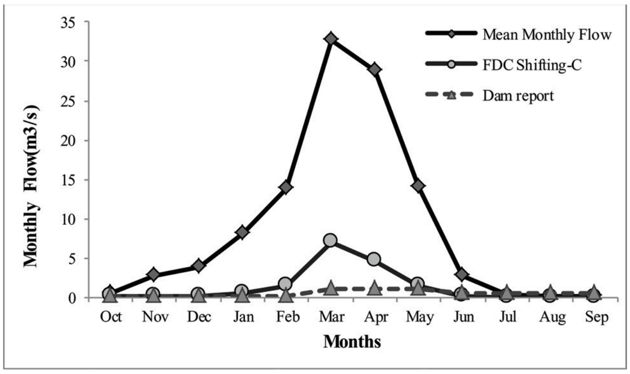

Figure 4. Comparison of distribution of mean monthly flows in Bukan Bridge station, Prescribed dam's monthly releases and recommended monthly flows.

EFRs with less information for prescribed environmental management scenarios.

The values of annual EFRs from the selected method (i.e. FDC Shifting- Class C) are ranging from 1.7 m^3/s (equivalent to 32% of MAF) at upstream to 3.5 m^3/s (corresponding to 23% of MAF) at downstream reach of the Simineh River. The allocation of EFRs is critical in the 4-month summer period (July-October).

Figure 4 demonstrates the monthly EFs of the selected method (i.e. FDC-shifting) at the Bukan Bridge station (just downstream of the Simineh Dam location) in compare with the prescribed flow releases from the dam. The mean monthly flow (MMF) curve is shown in this figure as a boundary line for representing the potential flows in the river. The results indicate that the allocated monthly flow rates in the dam operation rule doesn't have flexibility with the natural flow regime, and are to be revised to provide sufficient preservative support for both the Simineh River and the Urmia Lake.

The current environmental flow allocation from the Simineh Dam (under construction) is only 24×10^6 m^3/s (about 10% of MAF). It is necessary to revise the prescribed steering operation of the dam. The dam-flow releases are to be increased to ensure the environmental flow requirements by 110×10^6 m^3/s (about 23% of MAF), considering proper distribution of monthly flows down the river. Summary of the results for the environmental water requirements for the four reaches of the Simineh River is presented in Table 3. In this table, the abbreviations "U/S" and "D/S" refers to the upstream and downstream of the proposed dam site on the Simineh River, respectively.

Similar investigations in the Urmia Lake Basin indicate the portion of EFs in the range between 20% and 40% of the potential annual flows [24]. For example, the flow releases from the Bukan Dam (on the Zarrineh River) is to be increased from currently 9% to 35% of MAF; and for the Nazloo River Dam (on the Nazloo River) is in the order of 26% of MAF.

CONCLUSIONS

Urmia Lake is currently suffering from the lack of adequate water due to overuse of agricultural water in the basin. The restoration of the Urmia Lake demands a proper order of potential flows of the basin rivers to flow along the rivers and towards the lake. In the Urmia Lake Restoration Plan (ULRP), the reduction of 40% of agricultural water use has been targeted, and a vast investment for developing efficient irrigation practices is being running in the region. This is promising, because saving agricultural water provides with sufficient resource for the rivers flows down to the Urmia Lake.

A framework was developed for desktop assessment of minimum environmental flow allocation of the rivers basin using hydrology-based methods. This procedure is applied to the Simineh River, in four different reaches from upstream to downstream. The detailed results are presented in Table 2 and Figures 2 to 4. Monthly distribution of the river EFs is also demonstrated, and compared with the prescribed allocation of EFs at the Simineh Dam on this river.

The results indicate that the method of FDC-Shifting is well adapted to the natural flow regime of this river. In order to maintain the river at minimum acceptable environmental status, the order of 20% to 30% of the mean annual flow

(MAF) is to be allocated in different reaches of this river. This portion is about 23% of MAF (equivalent to 3.5 m^3/s in average) for the downstream reach of Miyandoab, close to the recipient Lake of Urmia. The environmental water release from the Simineh Dam is to be increased from prescribed value 10% to about 23% of MAF. It is necessary to revise the geometry of the dam (i.e. the reduction of the dam height and reservoir capacity) to ensure that the connectivity of environmental flows is guaranteed along the river in the future.

NOMENCLATURE

BOD	Biochemical oxygen demand, mg/l
C_0	Interested concentration value of quality parameters, mg/l
C_1	Initial concentration of quality parameters, mg/l
C_2	Secondary concentration of quality parameters, mg/l
COD	Chemical oxygen demand, mg/l
DO	Dissolved oxygen, mg/l
DRM	Desktop reserve model
DWAF	Department of Water Affairs and Forestry
ED	Environmental demand
EFs	Environmental flows, m^3/s
EMCs	Environmental management classes
EWR	Environmental water requirement, m^3/s
EWR	Environmental water requirements, m^3/s
FDC	Flow duration curve
FDCA	Flow duration curve analysis
GEFC	Global environmental flow calculator
HFR	High-flow requirement, m^3/s
IHA	indicators of hydrologic alteration
LFR	Low-flow requirement, m^3/s
MAF	Mean annual flow, m^3/s
MAR	Mean annually runoff, m^3/s
MMF	Mean monthly flow, m^3/s
pH	Potential of hydrogen
Q_1	Initial discharges, m^3/s
Q_1	initial water discharge, m^3/s
Q_2	Secondary discharge, m^3/s
Q_2	secondary water discharge, m^3/s
Qxx	Water discharge in which the xx percent of time, discharges are equaled or exceeded, m^3/s
RVA	Range of variability approach
TDS	Total dissolved solids, mg/l
ULRP	Urmia Lake restoration plan

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DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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