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Estimation of Minimum Ecological Water Level of GooriGol Wetland Using a Multi-Objective Programming Model

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ABSTRACT: Estimation of the ecological level of water bodies is crucial to protect aquatic ecosystems and has become a major issue in sustainable water resources planning. In recent decades, several methods are utilized to estimate the minimum ecological flow in rivers and the minimum ecological level in lakes and wetlands. In this research, a multi-objective programming model is used to determine the ecological level of the GooriGol wetland. The proposed model has two objective functions with two indices of water and ecosystem indicators. The wetland water level has been selected as a water index and three species of important ducks of the wetland have been chosen as the ecosystem indices. The first objective function is to minimize the wetland water level, so that more water is provided to meet the needs of human societies, while the second objective function ensures the maximum ecosystem indices, so that more habitats are provided for aquatic ecosystems. Therefore, the aim of this model is to provide circumstances for the largest ecological services with the least amount of water. The used data in the multi-objective programming model are the storage water volume, wetland surface water area and water levels from 2003 to 2017 and the number of three important species of ducks from 2003 to 2017 as well. In order to solve this multi-objective optimization model, the sum of weighting technique is used and Benson method is used to verify the obtained results for situation in which white-head duck is chosen as the ecosystem indicator. The results indicated that the minimum ecological water level of GooriGol wetland is 1912.6 meter and the corresponding water storage volume of wetland is 503000 cubic meters. The field observations during the recent decade are in agreement with the obtained result of this research and indicates the decreasing the water level from 1912.6 m causes considerable declining in the ecological performance of the wetland.

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1. INTRODUCTION

Of the total water available on Earth, 97.5% is found in the seas and oceans, and what is found in rivers, lakes and reservoirs for human essential uses is not more than, 0.007% of the total water. Freshwater, although a renewable resource, is very limited and vulnerable [1]. This issue is notable and requires detailed programming for water resources utilization. One of the most important issues in optimal use of freshwater is the optimal utilization of water resources in water bodies, such as rivers and inland wetlands. Besides the importance of rivers, lakes and wetlands as water resources, they provide valuable aquatic ecosystems [2]. About 5% to 8 % of the Earth's surface, i.e. 7 to 8 million square kilometers, is covered by wetlands and should be protected due to their special function as a natural habitat [3-5]. Investigations have shown that the value of ecosystem services in the wetland is 24 times more than that of forests and 9 times more than the pastures [6]. In order to optimal utilization of wetlands and sustainable operation of these valuable habitats, it is required to estimate the ecological level of wetlands. Different procedures have been introduced to estimate the ecological levels of lakes and wetlands [7]. Many of these methods are limited to hydraulic and hydrological conditions, and the ecological aspects of wetlands are rarely considered. All ecological aspects of wetlands that play important roles in their services, can be considered in the present model. Hence, Iran is located in the arid and semi-arid region of the world and the climate change effects intensify the water deficits in such regions, it is necessary to use the most scientific methods to optimize the utilization of inland waters while keeping the ecosystem services in an acceptable level. In this research, to determine the MEWL[1] of the GooriGol wetland, a MOP model [8] is used to balance the human water consumption while supplying the water needs of this aquatic ecosystem. In this model, two target functions are: water index for human needs and habitat index for ecosystems. The first objective

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1 Minimum Ecological Water Level

Table 1. MEWL with three ecological indices

scenarios	λ_1	λ_2	λ_3	λ_4	λ_5	L
۱	۰/۳	۰/۷	۰/۶	۰/۲	۰/۲	۱۹۱۲/۵۹۷
۲	۰/۳	۰/۷	۰/۲۵	۰/۵	۰/۲۵	۱۹۱۲/۵۸۱
۳	۰/۳	۰/۷	۰/۳	۰/۲	۰/۵	۱۹۱۲/۵۸۹
۴	۰/۳	۰/۷	۰/۴۵	۰/۲	۰/۳۵	۱۹۱۲/۵۹۳
۵	۰/۴	۰/۶	۰/۶۵	۰/۱۵	۰/۲	۱۹۱۲/۵۹۰
۶	۰/۴	۰/۶	۰/۲۵	۰/۶	۰/۱۵	۱۹۱۱/۸۰۵
۷	۰/۴	۰/۶	۰/۱	۰/۲	۰/۷	۱۹۱۲/۵۶۷
۸	۰/۴	۰/۶	۰/۳۵	۰/۳	۰/۳۵	۱۹۱۲/۵۷۸

function is to minimize the water index, so that more water is provided to human, while the second objective function is to maximize the habitat index, so that more aquatic ecosystems are provided. In other words, targeting of this model is to prepare the largest habitat with the least water. This model provides a general analytical procedure for the ecological use of various aquatic systems and is used to determine the minimum ecological flow or water level by appropriate selection of water and habitat indices.

2. METHODOLOGY

To carry out this research, the hydrological data related to the wetland were gathered from the regional water company of East Azarbaijan. These data include the bathymetric data of the wetland and its water levels, which were gathered by monitoring the hydrometric station located in the wetland during 5417 days from 2003 to 2017. Then, based upon the wetland experts observations and the migration season of different ducks, May was chosen as the target month to assess the impact of the water level on the number of ducks in studied years. Also, the ecological data of the wetland, including the number of three important species of ducks, i.e. White-head Duck, Ferruginous Duck and Pochard Duck, were taken from the Division of Natural Environment of Environmental Organization of the province. The aim of this study is to estimate the MEWL of GooriGol wetland to provide sustainable ecological services of the wetland while other stakeholders, e.g. farmers, can maximize their water uses. In order to achieve these aims, target functions include the wetland's water level and three species of the ducks during the studied years. MOP[1] models were executed by means of WSM[2] and then Benson test was utilized to ensure the efficiency of the procedure [8]. The MEWL of the wetland is estimated using two methods, the surface-volume method and the MOP one. The MEWL of GooriGol wetland is computed with number of three different ducks, as ecological indices. The multi-objective programming problem is as follows:

$$\begin{cases} \min & z_1 = f(x) \\ \min & z_2 = 1 - g_1(x) \\ \min & z_3 = 1 - g_2(x) \\ \min & z_4 = 1 - g_3(x) \\ s.t. & 0 \le x \le 1 \end{cases} \quad (1)$$

1 Multi-Objective Programming
2 Weighted Sum Method

In order to solve the problem presented in eq (1), the WSM has been used, which the mono-objective optimization problem is of the form,

$$\begin{aligned} \min \quad & d(x) = \lambda_1 f(x) + \lambda_2 \begin{bmatrix} \lambda_3(1 - g_1(x)) \\ +\lambda_4(1 - g_2(x)) \\ +\lambda_5(1 - g_3(x)) \end{bmatrix} \\ s.t. \quad & 0 \le x \le 1 \end{aligned} \quad (2)$$

in which:

$$\lambda_1 + \lambda_2 = 1 \ , \ \lambda_3 + \lambda_4 + \lambda_5 = 1 \ \ \lambda_i \ge 0$$

and the results of the problem solving eq (2) for 8 scenarios are given in Table 1.

3. RESULTS AND DISCUSSION

The MEWL of GooriGol wetland was estimated using two methods which are the level-volume method and MOP model. The MEWL obtained by level-volume method and MOP model are 1912.3 m and 1912.6 m, respectively. In other words, the results indicated that the MEWL of the GooriGol wetland is a level between 1912.3 m and 1912.6 m.

4. CONCLUSIONS

Studies have shown that considering the hydrological conditions is not suitable for estimating the MEWL of wetlands and the ecological conditions of the wetland should also be taken into account. Unlike the level-volume method that cannot meet this requirement, the MOP model also considers ecological conditions. Therefore, it seems that the results of this method are closer to the reality than the hydrological methods. Considering that the MOP model has not been yet utilized to estimate the ecological minimum water level of GooriGol wetland, it is recommended the authorities to use this method for estimating the ecological water level of lakes and wetlands and the minimum ecological flow of rivers as well. Obviously, other methods, such as Tenant method [9], which for many years have been utilized as the basic method for estimating the environmental flow of rivers in Subsidiaries of the Ministry of Energy [10], are not able to provide an accurate estimate of the ecological water level and river flow. The presented model has two objective functions with two indices of water and ecosystem indicators. The level of water was selected as a water index and three important species of ducks were chosen

as the ecosystem indices. The first objective function is to minimize the water index, while the second objective function is to maximize the ecosystem indices. Therefore, this model provides the highest ecological potential with the minimum amount of water. The problem was solved by MOP, which is an efficient alternative and then the validity of the model was confirmed by Benson test. The obtained results indicated that the minimum ecological water level of the wetland is 1912.6 meter and the corresponding water storage volume of wetland is 503000 m^3. The field observations during the recent decade are in agreement with the obtained result of this research and indicates the decreasing the water level from 1912.6 m causes considerable declining in the ecological performance of the wetland. It is obvious that the accuracy of the model depends strongly on quantity and quality of the available hydrological and ecological data.

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