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A BLUEPRINT FOR ELEMENTARY REPRESENTATIVE WATERSHED SPECIFICATION

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ABSTRACT

Provision of ecosystem services is necessary for our quality of life. In this vein, it is critical to develop a baseline to monitor the ecosystem behavior using monitoring, mapping, and modeling indicators of landscape condition. The representative watersheds (RWs) can therefore be considered as such decision blueprint to implement the best management practices to conserve and consequently improve ecosystem services. There are few researches for the selection of RWs. However, the comprehensive and of course applicable methodologies still are lacked particularly in developing countries where concentration and proper directing of conservation measures are further needed owing to investments constraints. Therefore, in the present study, an intensive watershed selection process was undertaken to identify RW across the Gharesoo-Gorgan River Basin (ca. 12987 km^2), Golestan Province, Iran. This study aimed to adopt the Laize's approach in Gharesoo-Gorgan Watershed for identifying the representative sub-watershed. Towards this, four GIS-based layers of elevation, slope, rainfall erosivity and land use were selected for sub-watersheds characterization. The representative watershed index (RWI) was then calculated and mapped using MATLAB 2016 and ArcGIS 10.3 softwares, respectively. The RWI was calculated pixel wise for all nine individual sub-watersheds and the entire watershed as reference area with the help of matrix combinations of four study layers. Ultimately, RWIs obtained from 21.3 to 62.6 with mean of 44.94±14.49 and coefficient of variation of 32.25% were used for sub-watershed prioritization. Accordingly, the sub-watershed 8 in north east with RWI of 56.8 was proposed as the final RW for the whole Gharesoo-Gorgan Watershed. The results of the study is helpful to be used by authorities for launching monitoring systems in the RW to collect behavioral indicators leading to designation of reasonable eco-environmental restoration strategies.

Keywords: *Environment protection, geographic information system, integrated watershed management, watershed prioritization.*

INTRODUCTION

Nowadays, the world is facing set of ecosystems problems caused by unsustainable development, demand increasing, limited resources and raising pressures on ecosystems. The effect of these problems in connection with adverse impacts of natural disasters and climate change undermine the natural resources and ecosystem services (Shotadze and Barnovi, 2011; Webb, 2012; Debnath, 2016). Globally, the focus of managerial strategies has shifted from high resources usage in terms of unsustainable development to understanding and quantifying the ecosystems benefits in order to reach sustainable management goals (Pickard *et al.*, 2015; Campbell, 2016; Raum, 2018). In respect to achieve these goals, developing a decision blueprint to identify the representative watersheds (RWs) as a benchmarking and monitoring baseline to implement the best management practices (BMPs) is very valuable to conserve and consequently improve ecosystem services (Shotadze and Barnovi, 2011, Montenegro *et al.,* 2014; Jackson *et al.,* 2016). RW is introduced as a typical and instrumented watershed, as well as candidate of the general situation having a general stability in all factors of the reference areas aiming at monitoring natural changes (AGU, 1965; Toebes and Ouryvaev, 1970; Arbor, 2010; Hillman and Rothwell, 2016). There are few researches in regards to developing approaches for representative watershed selection. Whist, more comprehensive and applicable methodologies are needed worldwide particularly in developing countries where concentration and proper directing of conservation measures are further required owing to investments constraints. Towards this, the present study was therefore formulated to characterize the representative watershed index (RWI) based on four common and important criteria of elevation, slope, rainfall erosivity and land use for the Gharesoo-Gorgan Watershed, Iran.

MATERIAL AND METHODS

The study was carried out for the Gharesoo-Gorgan Watershed, Golestan Province, in north-east of Iran with nine sub-watersheds. The Gharesoo-Gorgan Watershed is located in eastern part of Alborz range (55° 00′ to 56° 29′ E longitude and 36° 36′ to 37° 47′ N latitude) with some 12987 km^2 in area. The maximum and minimum temperatures are +49 and –28 °C, respectively. Moving from the north toward the south of study watershed, the temperature decreased. The average monthly humidity varies between 47 to 89 %. The rainfall in mountainous parts of the study area is about 574.8 mm (Bordbar *et al.*, 2018). Figure 1 illustrates general location and distribution of sub-watersheds, climatologic and hydrometric stations of the Gharesoo-Gorgan Watershed.

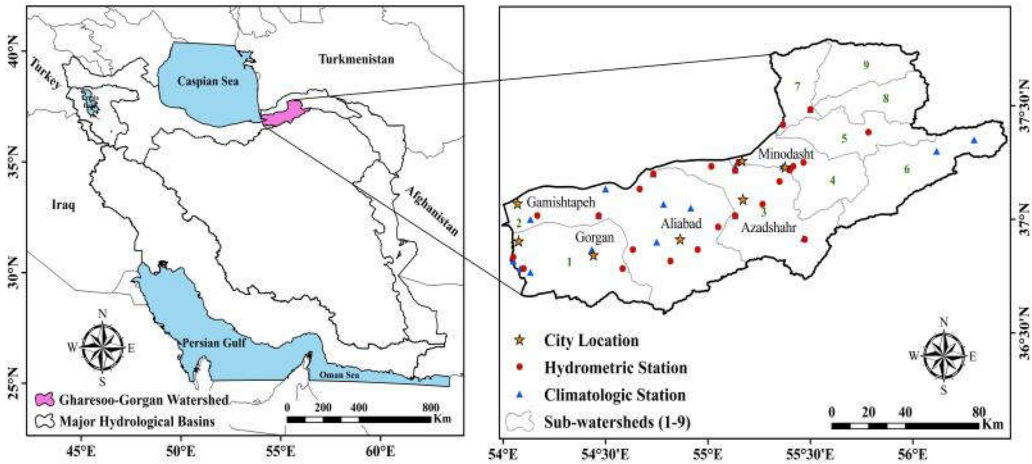

Fig 1. Distribution of sub-watersheds, climatologic and hydrometric stations of the Gharesoo-Gorgan Watershed, Iran

The paper aims to introduce an initiative and practical approach in field of RW determination stemmed on Laize's approach (Laize, 2004). To conduct the present research, firstly, the basic maps of elevation, slope and land use were prepared from previous researches conducted as part of the National Mega Project on the Integrated Watershed Management (Khaledi Darvishan *et al*., 2017). In addition, the rainfall erosivity (t m ha^{-1} cm h^{-1}) as the rainfall potential to generate soil erosion was also provided from Sadeghi and Hazbavi (2015), Zabihi *et al*. (2016) and Sadeghi *et al.* (2017). Secondly, by using Geographical Information System (GIS) software (Version 10.3), the raster map of the mentioned datasets were integrated in order to characterize the relationship between spatial datasets within each individual sub-watershed and reference area (i.e., the entire Gharesoo-Gorgan Watershed). Thirdly, the raster datasets were prepared at the same scales and pixel sizes (30×30 m) and a quadri-partite dimensioned desired category. Fourthly, numbers of combined pixels in different classes of layers were calculated. Fifthly, appropriate matrices were developed between the reference and each sub-watershed on a cell-by-cell basis in order to calculate the RWI of each sub-watershed as described in Eq. (1). To achieve the RWI as seen in Eq. (1), the absolute value of differences (D) of normalized pixels between compound values of reference (j) and sub-watersheds (i) were calculated as explained in Eq. (2). To this end, the normalized value of pixels of the matrices was obtained by dividing every combined class to total pixels of every layer, as well. The RWIs were then calculated for all individual sub-watersheds ranging from zero to 100 and prioritized accordingly.

$$RWI = (1 - 0.5 \times D) \times 100 \tag{1}$$

$$D = \sum_{i,j}\left(\left|V_{i,j}(sub\_watershed) - V_{i,j}(reference)\right|\right) \tag{2}$$

RESULTS AND DISCUSSION

The representative watershed (RW) was identified based on matrices developed for four datasets of elevation, slope, rainfall erosivity and land use for all nine sub-watersheds of the Gharesoo-Gorgan Watershed as summarized in Table 1.

Table 1. Representative Watershed Index (RWI) in quadri-partite dimensional matrix combinations of the study determinant variables for the Gharesoo-Gorgan Watershed, Iran

Sub-watershed No.	RWI (Out of 100)	Area (km^2)
1	36.0	1780.9
2	54.6	3490.2
3	62.6	2060.2
4	42.2	1103.8
5	39.4	879.8
6	22.1	1482.4
7	21.3	658.5
8	56.8	714.0
9	38.4	816.8

For the present study, a threshold of acceptance of 70th percentile of RWIs was also considered to examine any other potential candidates in other different viewpoints. Ultimately, RWIs obtained from 21.3 to 66.2 with mean 44.94±14.49 and coefficient of variation of 32.25% were used for sub-watersheds prioritization. Spatial distribution of the RWIs in the Gharesoo-Gorgan Watershed has been depicted in Figure 2. The higher RWI shows the better status of the sub-watershed for representing the whole watershed. Nonetheless, the RWIs with more than 70th percentile of 46.6 were considered as the basis for final selection of practical RWs in real condition.

According to Figure 2, sub-watersheds 2, 3, and 8 with respective RWI of 54.6, 62.6 and 56.8 stand at top priority of RW candidates in the Gharesoo-Gorgan Watershed. For determination of superior RW, additional criteria viz. hydrological independency, availability of hydrometric and meteorological stations and ultimately the general location of the candidate sub-watersheds were also considered in the selection process. Accordingly, the sub-watershed eight in north-east with RWI of 56.8 was proposed as the final RW for the whole Gharesoo-Gorgan Watershed. In this regard, the result showed watershed size influenced the RWI; because larger watersheds were more likely to encompass the reference area than smaller ones. This finding proved that choosing available datasets and their pixel size were very important in performance of model and reducing of processing time. Allocation further budget in field of instrumentation and monitoring of the proposed superior RW is strongly recommended for the better evaluation of the watershed behaviour to different driving forces. It is expected that the selected RW could be considered as a baseline for unmonitored watersheds as issues of monitoring deficiency as noted by Laize (2004) and Hannaford *et al.* (2013). Evaluating various alternative criteria like effect of upstream and downstream watersheds against a set of environmental, socio-economic and governance is also suggested for future researches on developing more comprehensive RW determination approaches.

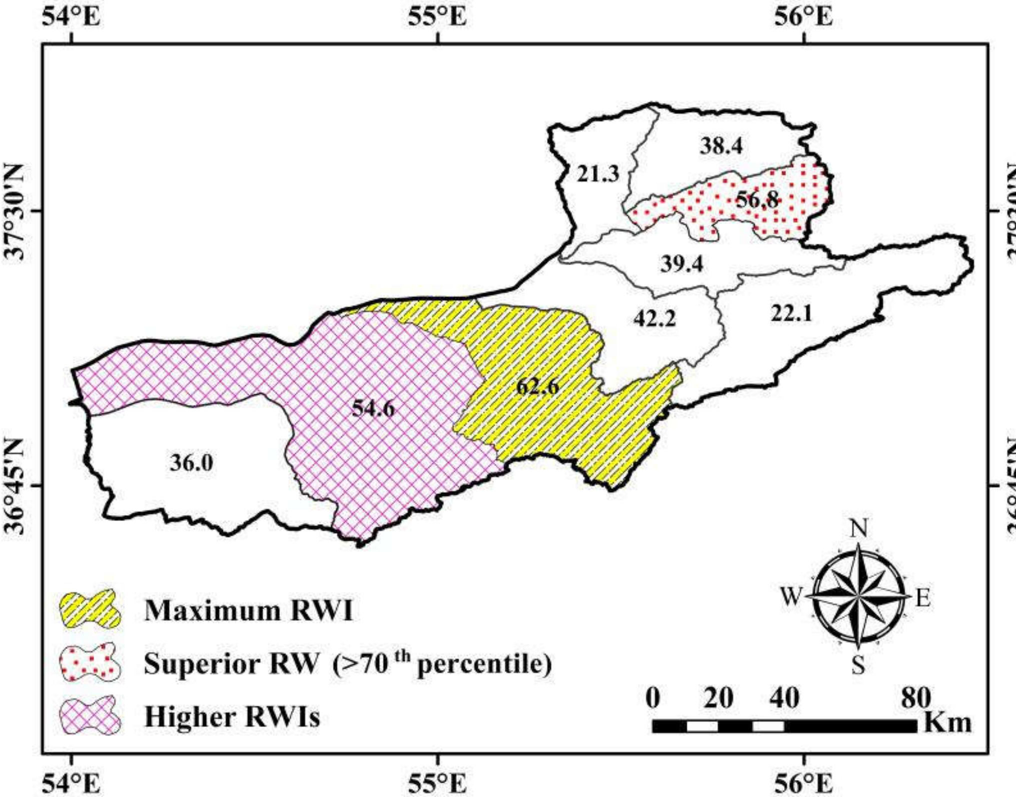

Fig 2. Spatial distribution of the representative watershed index (RWIs) in the Gharesoo-Gorgan Watershed, Iran

CONCLUSION

To get a global picture of identifying the RWs in an area, developing comprehensive method and applying proper and exact variables are necessary to make local issues meaningful for decision makers. The RWI allows watersheds to be ranked according to their level of representativeness and their influence on regionalisation procedures. When RWI scores are combined with indices relating to other characteristics they constitute a powerful decision support mechanism to make proper decision. In this study, the RWI scores were successfully calculated based on overlaying the multi-dimensional matrices namely elevation, slope, rainfall erosivity and land use for the Gharesoo-Gorgan Watershed in Iran. It is accordingly recommended that the watershed management authority at regional and national scales and even the running projects like the National Mega Project on the Integrated Watershed Management would focus on the behaviour of the selected sub-watershed as a representative area for the Gharesoo-Gorgan Watershed to monitor and assess the effects of natural and anthropogenic driving forces on the outcome of the watershed.

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