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PRIORITIZATION OF WATERSHEDS FOR RUNOFF RISK AND SOIL LOSS BASED ON MORPHOMETRIC CHARACTERISTICS USING COMPOUND FACTOR AND TOPSIS MODEL

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ABSTRACT

This research was conducted to delineate the prioritization of watersheds for management in respect to runoff risk and soil loss, for that purpose, thirty watersheds within Sulaymaniyah Governorate/Iraq were studied using their morphometric characteristics of the linear, shape, and relief aspects. Since the watersheds were un-gauged, and no information about their hydrological behavior, the results of this study can be used as guidance for competent authorities to prepare flood mitigation and erosion control plans. Prioritization ranks for watersheds were conducted based on computation of compound factors and on the technique for order preference by similarity to ideal solution (TOPSIS). The results showed that the regression analysis designated that the priority rank from (TOPSIS) can be predicted from the priority rank from compound factor computation with a reasonable accurateness. Results of prioritization ranks showed that the studied watersheds those that falling under the very high level of priority includes (Bariey-Gawra, Biyara, Dolishahidan, Zharawa, Sedara, Shawr, and Jogasur), the watersheds of high priority level comprised (Ashkana, Darokhan, Galal, Zwrkan, Zaroon, Darashmana, and Khaldan). In contrast, the watersheds that are classified under moderate level involves (Bardasipi, Daragurgan, Darawyan, Zardagila, Kunamasi, Dolan, and Chawtan). The watershed lies under the low level of priority encompasses (Sactan, Khrisaraw, Bardarash, Miradie, Jublakh, Sirie, Chami-Astel, Haladin, and Bakhisarw). Hence, suitable measures are required in these watersheds to control the risk of runoff and preserve the soil from erosion.

INTRODUCTION

Rehabilitation and management of watersheds are of great importance to keep their resources for a long time. The watershed management concept recognizes the inter-relationships among the linkages between uplands and low lands, land use, geomorphology, slope and soil, (Tideman, 1996). The natural factors have an important role in the emergence and aggravation of desertification problems in Iraq, (Al-Youzbaki, and Al-Mshhdani, (2017). Soil erosion by water is a serious environmental problem that causes significant soil loss and increases the risk of flooding when sediment load is transported through the water courses. Soil erodibility is actually the quantitative measure of inherent soil susceptibility to erosion by susceptibility by water, (Hassan and Ibrahim, 2019). Hassan, *et al.*, (2017) showed that the most important factors controlling the rates of gully erosion head advance are mechanism of erosion and hydrological conditions. To avoid or mitigate this and numerous other undesirable consequences of soil erosion (e.g. siltation of accumulation and water pollution), it is necessary to implement measures and work in the watershed in a predefined order.

Due to the hard accessibility to all parts of the watersheds under study, as a result of existence of high altitudes from one hand, and lack of necessary data for rehabilitation and management of the watersheds in the studied area in the other hand resulted to the use of basin morphology to obtain an overview on watersheds regarding their exposure to natural risks such as flood and soil erosion. Soil hydrological information is required in simulation model applications for agricultural systems, groundwater dynamics, water erosion, soil conservation and other processes, (Alobaidy and Hassan, 2024). The hydrological process in watersheds can be interrelated with the physiographic characteristics of the watershed, such as size, shape, slope, drainage density, and length of the streams. In addition, these are useful to predict the relationship between different geomorphologic and hydrologic characteristics. According to studies conducted by Barry and Chorley, **(**2009) and Ward and Robinson, (2000), runoff behavior of a basin differs according to geomorphological characteristics of the basins. Since most of the basins are either un-gauged or sufficient data are not available for them, the study on geomorphologic characteristics of such basins becomes much more important. The linking of geomorphologic parameters with the hydrological characteristics of the basin provides a simple way to understand the hydrological behavior of different basins, (Meshram and Sharma 2017).

The morphometric characteristics of a given basin deal with its quantitative morphological study identification of the relation between basin area and dimensions and the quantitative analysis of the basin relief and its drainage density (El-Enin,1990). Such kinds of studies are very important for determining the volume of runoff in the intermittent and perennial streams and must be considered in developing programs and designing irrigation projects (Hassan, 2001). The quantitative attributes of landscapes include linear, areal and relief aspects of a watershed. Watershed morphometric parameters are either direct or inverse relationship of runoff, peak to discharge, lag time, soil erosion and sedimentation risks, and these can be used to identify and prioritize critical sub-watersheds, (Nooka *et al.,* 2005**)** and (Meshram and Sharma 2017).

As linear and shape parameters of watershed morphometric characteristics have direct and indirect relationship with soil erodibility, they can be used as basis for prioritization, (Farhan and Anaba, 2016). In a watershed management program due to time and financial limitation, it is difficult to make rehabilitation and conservation activities at one time in all places, thus it is important to study the watersheds of the area and make order by their risk of erosion, (Tripathi *et al.,* 2003). Development of land and water conservation measures necessitates morphometric analysis and prioritization of sub-watersheds within a basin, (Aher *et al.*, 2014).

Watershed prioritization is one of the most important processes in natural resource management system especially in areas of sustainable watershed development and planning. Prioritization concept can aid in evaluating the morphology of individual watersheds, (Javed *et al.,* 2009) and (Strahler, 1957). Thus, the watershed prioritization is the ranking of sub watersheds in a river basin according to the order in which they have to be taken for treatment and soil conservation measures, (Ranjana *et al.*, 2013). This prioritization process is a tool for the watershed manager to identify the priority pollutants, potential priority sources and targeted areas within the watershed. In this study, a total of 30 sub-watersheds across Sulaymaniyah governorate were prioritized according to their morphometric parameters using compound factor and TOPSIS models. The main objectives behind this study were: 1) Analysis morphometric characteristics of the studied watersheds to be used as basic parameters for management prioritization of un-gauged watersheds. 2) Prioritize the watersheds in respect to the degree of their exposure to runoff risk and soil loss by erosion, using compound factor method and TOPSIS model.

MATERIALS AND METHODS

Description of the study Area

Thirty different watersheds were selected for the morphometric studies. These watersheds are located between the latitudes of 35º 05′ N and 36º 30′) and between the longitudes of 44º 25′ and 46º 20′ E), they are situated in the east and northern east of Iraq within Sulaymaniyah governorate (Figure 1), those who drain into both Lesser Zab and Sirwan tributaries. The studied watersheds bounded by the Iraq-Iran border from the east and north, on the south by Dyala governorate, on the west by Erbil governorate and on the southwest by Kirkuk governorate. Geographically the studied area located between the latitudes of 35º 00′ and 36º 30′ N, and longitudes of 44º 25′ and 46º 20′ E. The climate of the studied area is under the effects of Mediterranean Sea climate. As well the climate is influenced by Iraq's location between the subtropical aridity of the Arabian Desert areas and the subtropical humidity of the Arabian Gulf. Minimum temperature recorded in January and the maximum temperature will be at July. The average annual temperature is 19.7 Celsius, and the average annual rainfall in the studied area is 678 mm, (Mazn, 2022). It is worthy to mention that the tributaries of the studied watersheds fed by the annually rainfall and snow besides to the existing springs.

Morphometric parameters

Twelve morphometric parameters have been applied for the studied watersheds comprise linear aspects such as (stream frequency, drainage density, bifurcation ratio, length of overland flow, and texture ratio), relief aspects include (ruggedness number, watershed relief and relief ratio) and shape aspects which include (form factor, elongation ratio, circularity ratio, and compactness coefficient) Table (1). The studied parameters have direct or inverse relationship with runoff and soil erosion risks. GIS technique was used for determining the linear aspects, topographic maps and field visits was done to the watersheds of the studied area for measuring and computing some of the studied parameters. The topographic maps with the scale of 1:50 000 were used to delineate the watershed’s border. Five linear, four shapes and three relief parameters were used in this study for the process of prioritization using compound factor and TOPSI model.

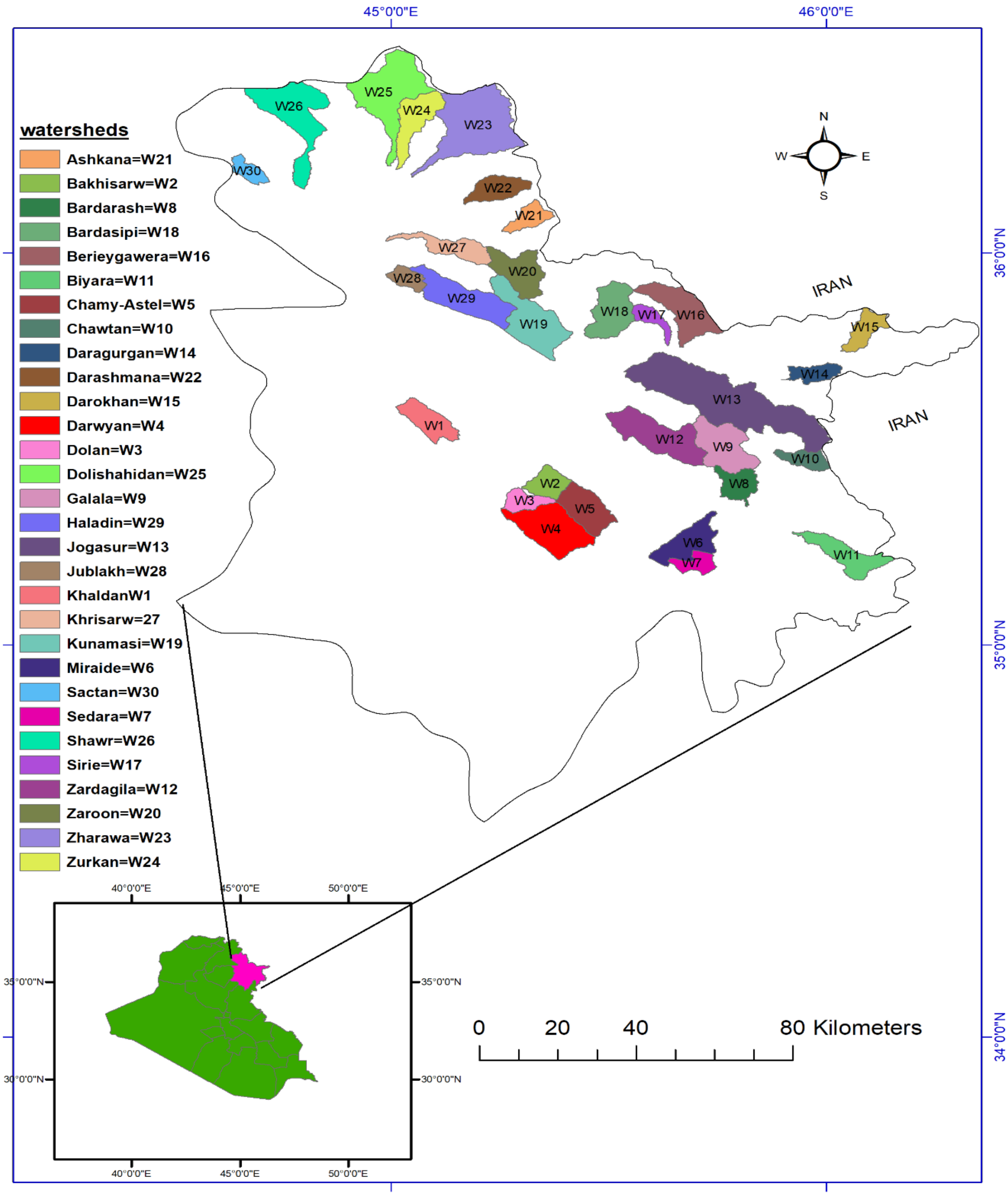

Figure (1): Location map of the studied watersheds

Prioritization using Compound Factor method

1. Measuring the studied morphometric parameters for each of the watersheds.
2. The weighted value of each parameter was computed.
3. The parameters which have the direct proportional with increase the amount of runoff and soil loss, and has the highest value among its values in the rest studied watersheds, takes the order number one, while the highest value of each of those parameters which has the inverse proportion with the amount of runoff risk and soil loss takes the highest number of orders among its values in the rest studied watersheds.

4. The ordered values of all the studied parameter in each watershed as it were mentioned in the item No. 3 were summed and the result divided by the number of the studied parameters to obtain the value of compound factor for that watershed, in which the watershed of the lowest value of the compound factors takes the highest number of the priority rank.

Table (1): Calculations of the studied morphometric parameters

#	Parameters	Formulae/methods	Units	References
Basic parameters	Area (A)	GIS	Km^2	
	Perimeter (P)	GIS	km	
	Maximum elevation (H)	GIS	m	
	Minimum elevation (h)	GIS	m	
	Stream length	Lu=Lu1+Lu2+⋯+Lun	km	Horton, 1945
	Lb = length of watershed (km)	$Lb = 1.312\ 9\ A^{0.568}$	km	Nooka, et.al. 2005
Linear aspects	Drainage density (Dd)	$Dd = \frac{\sum Lu}{A}$	Km^{-1}	Horton, 1945
	Length of over land flow (Lo)	$Lo = \frac{1}{2Dd}$	km	Horton, 1945
	Bifurcation ratio (Rb)	$Rb = \frac{Nu}{Nu + 1}$	Dimensionless	Strahler, 1957
	Stream frequency (F)	$F = \frac{\sum Nu}{A}$	km^{-2}	Horton, 1932
	Texture ratio (Tr)	$Tr = \frac{N}{P}$	Km^{-1}	Horton 1945
Shape aspects	Circularity ratio (Rc)	$Rc = \frac{A}{Ac}$	Dimensionless	Miller, 1953
	Elongation ratio	$Re = \frac{2}{L}\left(\frac{A}{\pi}\right)^{0.5}$	km	Schumm, 1956
	Compactness coefficient (Cc)	$Cc = \frac{P}{Pc}$	Dimensionless	Sharma, 1979
	Form factor (Rf)	$Ff = \frac{A}{L^2}$	Dimensionless	Horton, 1945
Relief aspects	Basin relief (R)	R= H-h	meter	Hadley and Schumm, 1961
	Relief ratio (Rr)	$Rr = \frac{H}{L}$	Meter	Schumm, 1956
	Ruggedness number (Rn)	$Rn = \frac{DdH}{1000}$	Dimensionless	Strahler, 1957

Prioritization using TOPSIS model

As well in this study the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) model was carried out to classify the watersheds according to the

priority for runoff risk and soil loss using the procedure proposed by, (Nitheshnirmal *et al.*, 2019), which is also used by Mohammed and Karim, (2020), as follow:
The normalized matrix (R) was calculated from the decision matrix as follow

$$Rij = \frac{\text{Xij}}{\sqrt{\sum_{i=1}^{m}(Xij)^2}} \qquad (1)$$

After that, and to compute the weighted normalized matrix (V), each column of normalized matrix multiplies by the corresponding weight, as follow:

$$\text{vij} = \text{Rij} * \boldsymbol{Wj} \qquad (2)$$

To calculate the positive ideal solution from the weighted normalized matrix, the following formula was used for each of the studied watersheds:

$$Si^{+} = \sqrt{\sum_{j=1}^{n}(vij - vj^{+})^2} \qquad (3)$$

And to obtain the negative ideal solution from the weighted normalized matrix, the following formula was used for each of the studied watersheds:

$$Si^{-} = \sqrt{\sum_{j=1}^{n}(vij - vj^{-})^2} \qquad (4)$$

The Relative Closeness to the Ideal Solution Calculated as follow

$$Ci^{+} = \frac{Si^{-}}{Si^{+} + Si^{-}} \qquad (5)$$

Finally, a set of alternatives can now be preference, ranked according to the descending order of *ci*.

RESULTS AND DISCUSSION

Morphometric parameters

Linear aspects

1. Stream frequency (F)

In this study, W15 has the highest while W19 has the lowest stream frequency value, Table (2). Low values of stream frequency (1.0–3.5) indicate that the stream is controlled by fractures, and high stream frequency (4–10) signifies low impermeability and more surface runoff, (Melton, 1958). Stream frequency has a direct relationship with the susceptibility to flooding, (Mutawkil *et al.*, 2021); therefore, using the compound factor method for ranking the priority, sub-watershed W15 was given the highest rank, whereas sub-watershed W19 was given the lowest rank of 30.

2. Bifurcation ratio (Rb)

Bifurcation ratio is related to the branching pattern of a drainage network which shows degree of integration between streams of various orders, (Horton, 1945). Table (2) shows that the Rb value is the highest and lowest at W5 (5.5637) and W6 (3.3492) respectively. This refers to that the W1, W6, W8, W11, W17, W19 and SW25 are relatively less disturbed, while the remaining sub-watersheds considered as more disturbed watersheds. It can also be seen that the majority of the values lie within the range of 3 – 4 this implies that the geologic structures did not distort the drainage pattern of most of the study watersheds, (Chow, 1964). Furthermore, the low bifurcation ratio for W6 is a good index of the high permeability of the rock formations from which it is composed, (Barzinji, 2003).

3. Length of overland flow (Lg)

The length of overland flow values was lesser than 0.2 denotes very low water potential for water flow and infiltration, (Ali and Ikbal, 2015). For this study, W26 was observed to have the highest propensity to erosion while W7 has the least due to the inherent highest length of overland flow value in the former sub-watershed, Table (2). The length of overland flow value of 0.38 in W26 implies more water potential for overland flow and moderate infiltration over the area. This parameter is a measure of soil edibility which independently affects the formation of the hydrologic and physiographic characteristics of the watershed (Rama, 2014). Previous studies disclosed that the shorter the length of overland flow, the faster the surface runoff from the streams.

4. Drainage Density (Dd)

A high drainage density (Dd) reflects a highly dissected drainage basin with a relatively rapid hydrological response to rainfall events, while a low drainage density means a poorly drained basin with a slow hydrologic response, (Melton, 1958). Sharma, (1979) cited by Barzinji, (2003) showed that the high value of drainage density indicates well developed network and torrential runoff likely to cause violent flood, while a low value signifies a less developed net-work and a modest runoff which is explained by high permeability of the terrain.

In this study the Highest value of drainage density appeared in W7 followed by the W16, as the lowest value of drainage density was at the W26, and the value of the remain watersheds lies between the mentioned highest and lowest values, Table (2). It can be inferred from the above discussion that this parameter is considered as an important criterion in morphological and hydrological studies because it reflects the nature of the runoff flow that is affected by geological formations and structures.

5. Texture ratio (Tr)

Texture ratio is an important factor in drainage morphometric analysis, which depends on the underlying lithology, infiltration capacity and relief aspect of the terrain, (Meshram and Sharma, 2017). Table (2) reveals that the value of texture ratio varies from a minimum of 1.2143 for W19 to a maximum of 4.1476 for W13. Texture ratio is classified into four categories: < 4 per km coarse, 4–10 per km intermediate, 10–15 per km fine and > 15 per km very-fine, (Choudhari *et al.*, 2018). Based on these categories the watersheds W13 has the intermediate texture whereas the remaining watersheds have the coarse texture which indicates high infiltration and lower runoff and soil erosion. Tr value is higher in circular watersheds, while elongation watershed shows lower values, (Utlu and Ghasemlounia, 2021).

Shape aspects

1. Compactness coefficient (Cc)

It is an independent of watershed size, but it depends on the slope. In the present study, value of Cc is lowest at W28 which was 1.2236, and the highest value was at the W14 which was 2.1868 whereas the Cc value for the rest watersheds located between the above two values, Table (2). The high value for this parameter indicates that the basin perimeter is characterized by possessing high degree of zigzagging and occurrence of low floods, (El-Enin, 1990). Lower values of this parameter denote more elongation of the basin and less erosion, while higher values indicate less elongation and high erosion. It can be said that the majority of the studied watersheds possess a moderate value of Cc.

2. Form factor (Ff)

From the data presented in Table (2) appeared that the value of form factor ranges from lower value of 0.1097 for W1 to the higher value of 0.4888 for W7. El-Enin, (1990) showed that a watershed with a form factor in the range of 0.1- 0.4 can be classified as a watershed close to triangular, while a watershed with a form factor in the range of 0.40 –0.60 is classified as close to square.
Based on the data of form factor in Table (2) it can be observed that with the exception of W7 and W10 almost all of the studied watersheds have triangular shape, whereas W7 and W10 classified as close to square. Smaller the value of form factor, more the elongated watershed (Strahler, 1964). A watershed with higher form factor has high peak discharge in a short period of time, (Horton, 1945).

3. Elongation Ratio (Er)

This parameter expresses the proximity of basin shape to a rectangular shape. It is a very significant index in the analysis of basin shape, which helps to give an idea about the hydrological character of a drainage basin. A value near 1.0, implies that the watershed shape is close to circular, while, Er <1.0, it implies that the basin is elongated, (Chow, 1964). El-Enin, (1990) classified the values of this parameter, to the following classes: (0.3 – 0.5) is high, (0.5 – 0.7) is medium, (0.7 – 0.9) is non-rectangular, and (> 0.9) non-rectangular at all, (Er) values ranges from 0.3739 W1 to 0.7891 W7 and the Re value for the rest watersheds lies between those two values, Table (2). Based on El-Enin, (1990) classification, it can be noticed that the W1, W12, W13, W14, W15, W19, W24, W26, and W27 classified under high class of elongation ratio, whereas W2, W7, and W10 located in the non-rectangular class, while the rest watersheds fells in the medium class.

4. Circularity ratio (Cr)

Circulatory ratio (Cr) is influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin, (Meshram and Sharma, 2017). This ratio is important due its role in reveling basin average geomorphic period and lineaments control of drainage pattern, (Jawad, 2019). In the current study the highest value of circularity ration in the Table (2) appeared in the watershed W17 and the lowest value occurred in W14. It was appeared from the mentioned tables that the values of circularity ration for all of the studied watersheds were less than 0.5 except to W5, W7, W9, W18, W21, and W28 where their Cr values were a little more than 0.5. If the circularity ratio is in the range of 0.4–0.5 indicated to high infiltration rate due to that the watershed shape tends to elongate more than circular, (Ali *et al.,* 2018) and (Aparna *et al.,* 2015). Whereas the value of Cr close to 1 indicates that there is not enough time for surface runoff to infiltrate and thus flooding.

Relief aspects

1. Basin relief (Bh)

This factor is used as an indicator of the result of the impact of weathering and erosion processes on geologic formations and geologic structures of the basin from the evolution of the basin up to the present time (El-Enin, 1990). In other words, high relief reflects the severity of degree of erosion and the weakness of geologic structures upon which it acted for a long period of time, (Hassan, 2001). From the results of Table (2) demonstrates that watershed W2 showed the lowest values that related to low runoff. Watershed W25 disclosed the highest Bh values, which indicate to the increase in relief values, steeper slopes, and high stream bed slopes, and consequently increases the peak flow, (Utlu and Ghasemlounia, 2021).

2. Relief ratio (Rr)

Relief ratio measures the overall steepness of the watershed and it is an indicator of the intensity of erosion operating on the hill slopes of the landscape, (Soni, 2017) and (Javed et al., 2009). Low values of relief ratio imply lesser soil erodibility which is primarily due to resistant underlying rocks of the watershed and the low degree of slope, (Meshram and Sharma, 2017).

In this study, W21 (0.1052) and W13 (0.0173) were found to have the highest and the lowest relief ratio values respectively, Table (2). High Rr values, denote short lag time, abrupt peak discharge, and thus high potentiality of flash flood occurrence, (Abuzied *et al.,* 2016) and (Ameri *et al.*, 2018).

3. Ruggedness number (Rn)

Ruggedness number conjoins slope steepness and length. Its higher values appeared when slopes are steep and long as well. In this study the higher value of (Rn) occurred in W16, and it has lower value at W27 and Rn for the rest studied watersheds lies between these two values, Table (2).

Ranking and prioritization of watersheds

1- Prioritization of watersheds using compound factor method

The linear and relief parameters have a direct relationship with runoff and soil erodibility, whereas shape parameters have an inverse relationship with runoff and soil erodibility (Nooka *et al.*, 2005). By prioritization of watersheds, one can conclude which watershed can lead higher amount of discharge due to excessive amounts of rainfall. In this study, watersheds are prioritized for soil and water conservation planning based on morphometric analysis of the linear, relief, and shape parameters. Therefore, a watershed showed the highest value in linear and relief parameters has rated at first rank, second higher value has rated as second rank and so on; and the least value has taken the last rank. In the contrary, the shape parameters have inverse relationship with soil erodibility, where the lowest value was given a rating of 1, next lower value was given rating of 2 and so on, Table (3), the lowest their value the most erodible soil in a watershed.

For watershed ranking based on every specific parameter, the ranking values for all parameters of each watershed have added and divided by the number of all parameters; in this case it has divided by twelve; to obtain the value of compound factor.

Table (2): Morphometric parameters for the studied watersheds

Watershed		F	D	Rb	Tr	Lg	Ff	ER	Cc	Cr	Bh	Rn	Rr
code	Name												
W1	Khaldan	2.4625	2.1675	3.7208	2.2720	0.2307	0.1097	0.3739	1.9717	0.2572	651	1.4110	0.0241
W2	Bakhisarw	1.6202	2.1585	4.1333	1.7778	0.2316	0.3986	0.7126	1.4246	0.4928	455	0.9821	0.0379
W3	Dolan	2.2055	2.6165	4.1429	1.7250	0.1911	0.3153	0.6337	1.7868	0.3132	634	1.6589	0.0564
W4	Darawyan	2.1663	2.2862	3.7702	3.3702	0.2187	0.2906	0.6084	1.4821	0.4552	866	1.9798	0.0417
W5	Chami-Astel	2.0815	2.1459	5.5637	3.7284	0.2330	0.3757	0.6918	1.1837	0.7137	469	1.0064	0.0298
W6	Miradie	2.3266	2.4191	3.3492	2.7273	0.2067	0.3076	0.6259	1.4925	0.4489	503	1.2168	0.0335
W7	Sedara	3.1710	5.8695	5.4568	3.3714	0.0852	0.4888	0.7891	1.4126	0.5012	611	3.5863	0.0611
W8	Bardarash	2.3745	1.8670	3.3911	2.7892	0.2678	0.2971	0.6152	1.5201	0.4327	477	0.8906	0.0303
W9	Galal	1.5860	2.1847	4.0333	3.2480	0.2289	0.3101	0.6285	1.4075	0.5048	1458	3.1853	0.0648
W10	Chawtan	2.0833	3.4970	3.3889	1.2667	0.1430	0.4779	0.7802	1.6327	0.3751	600	2.0982	0.0800
W11	Biyara	1.6812	3.2957	3.4417	2.5333	0.1517	0.2292	0.5404	1.4561	0.4716	1609	5.3027	0.0757
W12	Zardagila	1.6208	2.6212	4.6524	2.7581	0.1908	0.1873	0.4885	1.6125	0.3846	718	1.8820	0.0271
W13	Jogasur	1.8036	3.6868	4.8502	4.1476	0.1356	0.1614	0.4535	1.8547	0.2907	844	3.1116	0.0173
W14	Daragurgan	1.9325	3.0653	4.8137	1.3267	0.1631	0.1427	0.4050	2.1868	0.2217	595	1.8239	0.0317
W15	Darokhan	3.4567	3.4513	4.6689	2.3273	0.1449	0.1646	0.4040	1.8895	0.2733	750	1.8568	0.0441
W16	Barieygawra	3.4424	4.6281	3.9389	2.6813	0.1080	0.2092	0.5162	1.8715	0.2855	1216	5.6278	0.0811
W17	Sirie	1.5899	3.0970	3.3813	3.1429	0.1614	0.2296	0.5408	1.0306	0.9415	625	1.9356	0.0313
W18	Bardasipi	1.4554	3.2479	5.0779	2.2974	0.1539	0.3695	0.6861	1.4140	0.5157	1000	3.5727	0.0677
W19	Kunamasi	0.8183	2.6121	3.1909	1.2143	0.1914	0.1858	0.4866	1.6661	0.3602	1018	2.6591	0.0370
W20	Zaroon	1.5408	2.1249	5.0567	2.2884	0.2353	0.3539	0.6715	1.5220	0.4317	1352	2.8728	0.0807
W21	Darashmana	1.1323	1.7536	3.9333	1.5000	0.2851	0.2913	0.5890	1.3088	0.5838	1310	2.6108	0.1052
W22	Ashkana	1.4283	1.9930	4.0667	1.4648	0.2509	0.2706	0.6091	1.4848	0.4536	1657	2.9057	0.1048
W23	Zharawa	1.5017	1.9511	4.6107	2.7644	0.2563	0.3045	0.6229	1.9759	0.2630	1925	3.7559	0.0653
W24	Zurkan	1.0615	1.4679	5.3667	1.5256	0.3406	0.1954	0.4989	1.5249	0.4300	1608	2.3603	0.0715
W25	Dolishahidan	0.9795	1.5480	3.7652	1.8222	0.3230	0.2030	0.5085	1.7151	0.3325	2471	3.8252	0.0760
W26	Shawr	0.8717	1.2935	5.1596	1.3838	0.3865	0.1707	0.4663	1.8857	0.2812	2014	2.6050	0.0601
W27	Khrisaraw	0.9831	1.6897	4.0641	0.8848	0.2959	0.1442	0.4285	1.8972	0.2778	497	0.8398	0.0234
W28	Jublakh	1.9600	2.2462	4.0111	2.0190	0.2226	0.3664	0.6832	1.2236	0.6679	714	1.6097	0.0714
W29	Haladin	0.8642	1.8196	4.6667	1.5837	0.2748	0.2440	0.5575	1.4428	0.4804	779	1.4175	0.0321
W30	Sactan	1.0281	1.5668	4.6111	1.4857	0.3191	0.2138	0.5219	1.4729	0.4610	948	1.4853	0.0436

Accordingly, the watershed with the least compound value takes number 1, has appointed at the highest priority, the next higher value has taken number 2 and so on, Table (3), then the watershed that got the highest compound value has assigned at the lowest priority. According to the results of Table (3), the watershed Bariey-Gawra which was W16 took the first number of ranking which indicate to that the watershed falling under highest priority and faced high runoff risk and sever soil erosion, followed by Jogasur watershed W13 where it took the second rank of prioritization, while the watershed Bakhisarw W2 took the latest rank of prioritization which was number 30 that means to has the lowest priority for management and soil and water conservation. By this method, the watershed of the lower number of priority rank, means exposing that watershed to the greatest degree of runoff, and soil erosion risks, while watersheds falling under high priority have very slight erosion and less exposure to runoff risk. Thus, it is important to make a true plan for soil and water management practices in each watershed as per their sensitivity ranks.

2- Prioritization of watersheds based on TOPSIS Model:

The same morphometric parameters as they were used for compound factor method were exploited to compute the prioritization rank using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) model, The normalized decision matrix R was calculated by equation (1) and the results were presented in Table (4), The weighted normalized matrix was obtained via multiplying each normalized decision matrix R by the related weight of (0.0833) as it was showed by Table (5). Severance measures from the positive ideal Si^+ and the negative ideal Si^- solutions were calculated for all of the studied watersheds according to Eqs. (3and4). It is worthy to mention that the minimum values of the shape factors considered as negative criteria and are in favor of runoff risk and high erodibility, and the reverse was true for the linear and relief parameters. The relative closeness to the ideal solution attained by the Eq. (5) and the results were shown in the last column of Table (6). Lastly the ranking of the relative closeness of the watersheds was applied to obtain the prioritization of the watersheds, where the watershed with the highest value of the relative closeness to the ideal solution took the first number of ranking, and has appointed at the highest priority, the next higher value has taken the second number and so on, whereas the watershed that got the least value of the relative closeness to the ideal solution took the highest number of ranking and has assigned as the last priority number, as presented in the Table (6).

It was appeared from Table (6) that the watershed W16 (Bariey Gawra) took the first number of rankings which indicate to that the watershed falling under high priority and faced high runoff and severe soil erosion, followed by W11 (Biyara) watershed which acquired the second rank of priority, and so on. However, the watershed W2 (Bakhisarw) designated as the rank of number 30, which was the last rank of priority, so it can be said that has little risk of runoff and slight erosion. Hence and based on this method the watersheds falling under high priority are facing runoff risk and very severe erosion. While watersheds falling under low priorities have very slight erosion and runoff risk. The studied watersheds have classified into four groups namely (very high, high, moderate and low) levels of priority based on the ranges of the values of the relative closeness to the ideal solution as presented in column 6 of Table (6), where the watersheds falling under the very high level of priority includes (W16, W11, W25, W23,W7, W26, W13), the watersheds of high priority level comprised (W22, W15, W9, W24, W20, W21, W1), the watersheds that are classified under moderate level involves (W18, W14, W4, W12, W19, W3,W10) and the watershed lies under the low level of priority encompasses (W30, W27, W8, W6, W28, W17, W5, W29, W2).

Comparison between compound factor method and TOPSIS model for prioritization

When the ranks of prioritization in Table (3) compared with the prioritization rank of Table (6), evidenced that they have similar results, which means that the obtained prioritization ranks from using the both methods verify that the studied morphometric parameters of the watersheds have computed accurately, another outcome of this comparison is that in case of using either methods of compound factor or TOPSIS model for prioritization will give real results.

Table (3): Priority ranking of the studied watersheds using compound factor

Watershed code	F	D	Rb	Lg	Tr	Bh	Rn	Rr	Ff	Er	Cc	Rc	Sum	Ave.	Ranking using Compound factor
W1	4	17	24	14	16	20	25	28	1	1	28	2	180	15.0000	15
W2	16	18	15	13	19	30	28	19	28	28	8	23	245	20.4167	30
W3	7	11	14	20	20	21	21	15	23	23	22	9	206	17.1667	21
W4	8	14	22	17	4	14	16	18	17	18	12	19	179	14.9167	14
W5	10	19	1	12	2	29	27	26	27	27	2	29	211	17.5833	24
W6	6	13	29	18	10	26	26	21	21	22	14	17	223	18.5833	27
W7	3	1	2	30	3	23	5	13	30	30	6	24	170	14.1667	10
W8	5	23	26	8	7	28	29	25	19	19	15	16	220	18.3333	26
W9	18	16	18	15	5	7	7	12	22	21	5	25	171	14.2500	11
W10	9	4	27	26	28	24	15	5	29	29	19	12	227	18.9167	28
W11	14	6	25	25	12	5	2	7	13	13	10	21	153	12.7500	4
W12	15	10	11	21	9	17	18	27	8	8	18	13	175	14.5833	13
W13	13	3	7	27	1	15	8	30	4	5	23	8	144	12.0000	2
W14	12	9	8	22	27	25	20	23	2	3	30	1	182	15.1667	16
W15	1	5	9	28	13	18	19	16	5	2	26	4	146	12.1667	3
W16	2	2	20	29	11	10	1	3	11	11	24	7	131	10.9167	1
W17	17	8	28	23	6	22	17	24	14	14	1	30	204	17.0000	20
W18	21	7	5	24	14	12	6	10	26	26	7	26	184	15.3333	17
W19	30	12	30	19	29	11	11	20	7	7	20	11	207	17.2500	22
W20	19	20	6	11	15	8	10	4	24	24	16	15	172	14.3333	12
W21	23	25	21	10	23	9	12	2	18	16	4	27	190	15.8333	18
W22	22	21	16	6	25	4	9	1	16	18	13	18	169	14.0833	9
W23	20	22	13	9	8	3	4	11	20	20	29	3	162	13.5000	8
W24	24	29	3	2	22	6	14	9	9	9	17	14	158	13.1667	5
W25	27	28	23	3	18	1	3	6	10	10	21	10	160	13.3333	6
W26	28	30	4	1	26	2	13	14	6	6	25	6	161	13.4167	7
W27	26	26	17	5	30	27	30	29	3	4	27	5	229	19.0833	29
W28	11	15	19	16	17	19	22	8	25	25	3	28	208	17.3333	23
W29	29	24	10	7	21	16	24	22	15	15	9	22	214	17.8333	25
W30	25	27	12	4	24	13	23	17	12	12	11	20	200	16.6667	19

Table (4): Estimated normalized decision matrix for the studied parameters

Watershed Code	F	D	Rb	Lg	Tr	CC	ER	Cr	Ff	Bh	Rn	Rr
W1	0.2352	0.1451	0.1569	0.1816	0.1733	0.2232	0.1174	0.1029	0.0706	0.1043	0.0960	0.0750
W2	0.1547	0.1445	0.1743	0.1824	0.1356	0.1612	0.2238	0.1972	0.2565	0.0729	0.0669	0.1180
W3	0.2106	0.1752	0.1748	0.1505	0.1316	0.2023	0.1990	0.1253	0.2029	0.1015	0.1129	0.1753
W4	0.2069	0.1531	0.1590	0.1722	0.2570	0.1678	0.1911	0.1822	0.1870	0.1387	0.1348	0.1298
W5	0.1988	0.1437	0.2347	0.1835	0.2843	0.1340	0.2173	0.2856	0.2417	0.0751	0.0685	0.0926
W6	0.2222	0.1620	0.1413	0.1627	0.2080	0.1689	0.1966	0.1797	0.1979	0.0806	0.0828	0.1043
W7	0.3028	0.3930	0.2302	0.0671	0.2571	0.1599	0.2478	0.2006	0.3145	0.0979	0.2441	0.1901
W8	0.2268	0.1250	0.1430	0.2109	0.2127	0.1721	0.1932	0.1732	0.1911	0.0764	0.0606	0.0942
W9	0.1515	0.1463	0.1701	0.1802	0.2477	0.1593	0.1974	0.2020	0.1995	0.2335	0.2168	0.2016
W10	0.1990	0.2341	0.1429	0.1126	0.0966	0.1848	0.2450	0.1501	0.3075	0.0961	0.1428	0.2489
W11	0.1606	0.2206	0.1452	0.1195	0.1932	0.1648	0.1697	0.1887	0.1475	0.2577	0.3610	0.2356
W12	0.1548	0.1755	0.1962	0.1502	0.2103	0.1825	0.1534	0.1539	0.1205	0.1150	0.1281	0.0844
W13	0.1723	0.2468	0.2046	0.1068	0.3163	0.2099	0.1424	0.1163	0.1038	0.1352	0.2118	0.0539
W14	0.1846	0.2052	0.2030	0.1284	0.1012	0.2475	0.1272	0.0887	0.0918	0.0953	0.1242	0.0987
W15	0.3301	0.2311	0.1969	0.1141	0.1775	0.2139	0.1269	0.1094	0.1059	0.1201	0.1264	0.1373

Watershed Code	F	D	Rb	Lg	Tr	CC	ER	Cr	Ff	Bh	Rn	Rr
W16	0.3288	0.3099	0.1661	0.0851	0.2045	0.2118	0.1621	0.1143	0.1346	0.1947	0.3831	0.2522
W17	0.1518	0.2073	0.1426	0.1271	0.2397	0.1167	0.1698	0.3768	0.1477	0.1001	0.1318	0.0972
W18	0.1390	0.2174	0.2142	0.1212	0.1752	0.1601	0.2155	0.2063	0.2377	0.1602	0.2432	0.2106
W19	0.0782	0.1749	0.1346	0.1507	0.0926	0.1886	0.1528	0.1442	0.1195	0.1630	0.1810	0.1152
W20	0.1472	0.1423	0.2133	0.1853	0.1745	0.1723	0.2109	0.1728	0.2277	0.2165	0.1956	0.2511
W21	0.1081	0.1174	0.1659	0.2245	0.1144	0.1481	0.1850	0.2336	0.1874	0.2098	0.1777	0.3273
W22	0.1364	0.1334	0.1715	0.1975	0.1117	0.1681	0.1913	0.1815	0.1741	0.2654	0.1978	0.3260
W23	0.1434	0.1306	0.1945	0.2018	0.2108	0.2237	0.1956	0.1052	0.1959	0.3083	0.2557	0.2030
W24	0.1014	0.0983	0.2264	0.2682	0.1163	0.1726	0.1567	0.1721	0.1257	0.2575	0.1607	0.2223
W25	0.0935	0.1036	0.1588	0.2543	0.1390	0.1941	0.1597	0.1330	0.1306	0.3957	0.2604	0.2365
W26	0.0833	0.0866	0.2176	0.3044	0.1055	0.2134	0.1464	0.1125	0.1098	0.3226	0.1773	0.1870
W27	0.0939	0.1131	0.1714	0.2330	0.0675	0.2147	0.1346	0.1112	0.0928	0.0796	0.0572	0.0728
W28	0.1903	0.1504	0.1668	0.1753	0.1540	0.1385	0.2145	0.2673	0.2357	0.1144	0.1096	0.2221
W29	0.0825	0.1218	0.1968	0.2164	0.1208	0.1633	0.1751	0.1922	0.1570	0.1248	0.0965	0.0999
W30	0.0982	0.1049	0.1945	0.2513	0.1133	0.1667	0.1639	0.1845	0.1376	0.1518	0.1011	0.1356

In addition to that the high correlation between the prioritization ranks from these two approaches revealed close conformity between them (R^2= 0.907), Figure (2). It was appeared from Figure (2) that the priority rank from (TOPSIS) can be predicted from the priority rank from compound factor computation with a reasonable accurate.

Table (5): Weighted normalized decision matrix for parameters of the studied watersheds

Watershed Code	F	D	Rb	Lg	Tr	CC	ER	Cr	Ff	Bh	Rn	Rr
W1	0.0196	0.0121	0.0131	0.0151	0.0144	0.0186	0.0098	0.0086	0.0059	0.0087	0.0080	0.0063
W2	0.0129	0.0120	0.0145	0.0152	0.0113	0.0134	0.0186	0.0164	0.0214	0.0061	0.0056	0.0098
W3	0.0176	0.0146	0.0146	0.0125	0.0110	0.0169	0.0166	0.0104	0.0169	0.0085	0.0094	0.0146
W4	0.0172	0.0128	0.0132	0.0144	0.0214	0.0140	0.0159	0.0152	0.0156	0.0116	0.0112	0.0108
W5	0.0166	0.0120	0.0195	0.0153	0.0237	0.0112	0.0181	0.0238	0.0201	0.0063	0.0057	0.0077
W6	0.0185	0.0135	0.0118	0.0136	0.0173	0.0141	0.0164	0.0150	0.0165	0.0067	0.0069	0.0087
W7	0.0252	0.0328	0.0192	0.0056	0.0214	0.0133	0.0207	0.0167	0.0262	0.0082	0.0203	0.0158
W8	0.0189	0.0104	0.0119	0.0176	0.0177	0.0143	0.0161	0.0144	0.0159	0.0064	0.0051	0.0079
W9	0.0126	0.0122	0.0142	0.0150	0.0206	0.0133	0.0164	0.0168	0.0166	0.0195	0.0181	0.0168
W10	0.0166	0.0195	0.0119	0.0094	0.0081	0.0154	0.0204	0.0125	0.0256	0.0080	0.0119	0.0207
W11	0.0134	0.0184	0.0121	0.0100	0.0161	0.0137	0.0141	0.0157	0.0123	0.0215	0.0301	0.0196
W12	0.0129	0.0146	0.0163	0.0125	0.0175	0.0152	0.0128	0.0128	0.0100	0.0096	0.0107	0.0070
W13	0.0144	0.0206	0.0170	0.0089	0.0264	0.0175	0.0119	0.0097	0.0087	0.0113	0.0177	0.0045
W14	0.0154	0.0171	0.0169	0.0107	0.0084	0.0206	0.0106	0.0074	0.0077	0.0079	0.0103	0.0082
W15	0.0275	0.0193	0.0164	0.0095	0.0148	0.0178	0.0106	0.0091	0.0088	0.0100	0.0105	0.0114
W16	0.0274	0.0258	0.0138	0.0071	0.0170	0.0177	0.0135	0.0095	0.0112	0.0162	0.0319	0.0210
W17	0.0127	0.0173	0.0119	0.0106	0.0200	0.0097	0.0142	0.0314	0.0123	0.0083	0.0110	0.0081
W18	0.0116	0.0181	0.0178	0.0101	0.0146	0.0133	0.0180	0.0172	0.0198	0.0133	0.0203	0.0175
W19	0.0065	0.0146	0.0112	0.0126	0.0077	0.0157	0.0127	0.0120	0.0100	0.0136	0.0151	0.0096
W20	0.0123	0.0119	0.0178	0.0154	0.0145	0.0144	0.0176	0.0144	0.0190	0.0180	0.0163	0.0209
W21	0.0090	0.0098	0.0138	0.0187	0.0095	0.0123	0.0154	0.0195	0.0156	0.0175	0.0148	0.0273
W22	0.0114	0.0111	0.0143	0.0165	0.0093	0.0140	0.0159	0.0151	0.0145	0.0221	0.0165	0.0272

Watershed Code	F	D	Rb	Lg	Tr	CC	ER	Cr	Ff	Bh	Rn	Rr
W23	0.0120	0.0109	0.0162	0.0168	0.0176	0.0186	0.0163	0.0088	0.0163	0.0257	0.0213	0.0169
W24	0.0084	0.0082	0.0189	0.0223	0.0097	0.0144	0.0131	0.0143	0.0105	0.0215	0.0134	0.0185
W25	0.0078	0.0086	0.0132	0.0212	0.0116	0.0162	0.0133	0.0111	0.0109	0.0330	0.0217	0.0197
W26	0.0069	0.0072	0.0181	0.0254	0.0088	0.0178	0.0122	0.0094	0.0092	0.0269	0.0148	0.0156
W27	0.0078	0.0094	0.0143	0.0194	0.0056	0.0179	0.0112	0.0093	0.0077	0.0066	0.0048	0.0061
W28	0.0159	0.0125	0.0141	0.0146	0.0128	0.0115	0.0179	0.0223	0.0196	0.0095	0.0091	0.0185
W29	0.0069	0.0102	0.0164	0.0180	0.0101	0.0136	0.0146	0.0160	0.0131	0.0104	0.0080	0.0083
W30	0.0082	0.0087	0.0162	0.0209	0.0094	0.0139	0.0137	0.0154	0.0115	0.0127	0.0084	0.0113

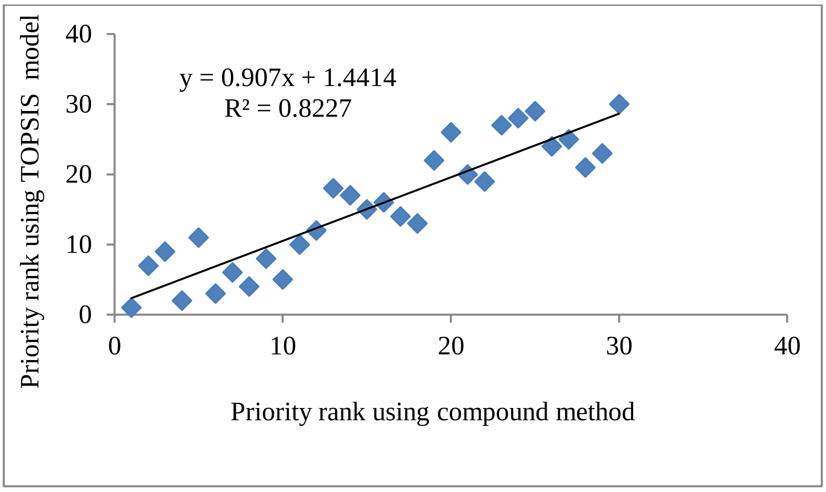

Figure (2): Correlation between the priority ranks from Compound factor and TOPSIS model

Table (6): Computation of the relative closeness to the ideal solution

Watershed code	Watershed name	S^-	S+	sum	Ci^+	Ranking from TOPSIS
W1	Khaldan	0.037998	0.049622	0.08762	0.433668	14
W2	Bakhisarw	0.02306	0.055987	0.079047	0.291728	30
W3	Dolan	0.03083	0.04849	0.07932	0.388677	20
W4	Darawyan	0.032104	0.045375	0.077479	0.414361	17
W5	Chami-Astel	0.028562	0.054656	0.083218	0.343217	28
W6	Miradie	0.028855	0.051249	0.080103	0.360218	25
W7	Sedara	0.044279	0.043963	0.088241	0.50179	5
W8	Bardarash	0.030323	0.05278	0.083102	0.364884	24
W9	Galal	0.035618	0.039484	0.075103	0.474261	10
W10	Chawtan	0.031249	0.050716	0.081965	0.381246	21
W11	Biyara	0.044022	0.033825	0.077847	0.565498	2
W12	Zardagila	0.032604	0.04785	0.080454	0.405253	18
W13	Jogasur	0.042116	0.043256	0.085372	0.493327	7
W14	Daragurgan	0.036235	0.050133	0.086369	0.419542	16
W15	Darokhan	0.041442	0.043486	0.084928	0.487965	9
W16	Bariey Gawra	0.052907	0.030509	0.083416	0.634252	1
W17	Sirie	0.027954	0.053177	0.081131	0.344559	27
W18	Bardasipi	0.0325	0.042752	0.075252	0.431884	15
W19	Kunamasi	0.031979	0.049061	0.08104	0.39461	19
W20	Zaroon	0.034797	0.041477	0.076275	0.456211	12
W21	Darashmana	0.036164	0.045189	0.081353	0.444533	13
W22	Ashkana	0.039457	0.040904	0.080361	0.490996	8
W23	Zharawa	0.042215	0.037254	0.079469	0.531218	4
W24	Zwrkan	0.038781	0.043684	0.082465	0.470277	11

Watershed code	Watershed name	S^-	S+	sum	Ci^+	Ranking from TOPSIS
W25	Dolishahidan	0.047437	0.038737	0.086173	0.55048	3
W26	Shawr	0.044279	0.044035	0.088314	0.501376	6
W27	Khrisaraw	0.03373	0.058157	0.091887	0.367084	23
W28	Jublakh	0.026483	0.049988	0.076471	0.346315	26
W29	Haladin	0.027369	0.053567	0.080936	0.338151	29
W30	Sactan	0.030851	0.051134	0.081985	0.376297	22

CONCLUSIONS

The quantitative morphometric analysis was carried out in thirty watersheds using twelve morphometric parameters of linear, relief and shape parameters, the linear aspects such as (stream frequency, drainage density, bifurcation ratio, length of overland flow, and texture ratio), relief aspects which include (ruggedness number, watershed relief and relief ratio) and shape aspects which comprises (form factor, elongation ratio, circularity ratio, and compactness coefficient). The morphometric analysis of different parameters was executed and their relation to create runoff risk and soil erodibility was explained. Compound factor method and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) model was applied in this study for making prioritization of watersheds for runoff risk and soil erosion. Results of prioritization ranks by using morphometric analysis show that the studied watersheds those that falling under the very high level of priority includes (W16, W11, W25, W23,W7,W26, W13), the watersheds of high priority level comprised (W22, W15, W9, W24, W20, W21, W1), the watersheds that are classified under moderate level involves (W18, W14, W4, W12, W19, W3,W10), and the watershed lies under the low level of priority encompasses (W30, W27, W8, W6, W28, W17, W5, W29, W2). Hence, suitable soil erosion control measures are required in these watersheds to control the risk of runoff and preserve the land from erosion.

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CONFLICT OF INTEREST

The researcher declare that he does not has any competing tests and there is no conflict of interest.

تحديد اولوية الاحواض النهرية لمخاطر الجريان السطحي وفقدان التربة بناء على الخصائص المورفومترية باستخدام طريقتي Compound Factor ونموذج TOSIS

خالد طيب محمد

قسم الموارد الطبيعية / كلية علوم الهندسة الزراعية / جامعة السليمانية / السليمانية / العراق

الخلاصة

اجريت هذه الدراسة لتحديد اسبقية احواض الانهر لإدارتها بخصوص مخاطر الجريان السطحي وتعرية التربة. تمت دراسة ثلاثين حوض نهري ضمن محافظة السليمانية/ العراق باستخدام الخصائص المورفومترية

لكل من السمات الخطية والشكلية والتضاريسية. بما ان الاحواض النهرية المدروسة لا توجد فيها محطات القياس ولا توجد معلومات حول العمليات الهيدرولوجية التي تحدث فيها، لذا فان نتائج هذه الدراسة يمكن استخدامها من قبل اصحاب القرار لاعداد خطط لتخفيف مخاطر الفيضان والسيطرة على التعرية. تم ترتيب اولوية الاحواض النهرية بخصوص الجريان السطحي وتعرية التربة باستخدام طريقتي Compound Factor ونموذج TOSIS. اظهرت النتائج بان كلا الطريقتين اعطيت تشابها تقريبا في نتائجها. وبين تحليل الانحدار بانه بالامكان التنبوء بالترتيب المتحصل عليه من نموذج TOSIS من خلال حسابات طريقة Compound Factor وبدقة معقولة. ان ترتيب الاولوية باستخدام التحاليل المورفومترية اظهرت بان الاحواض المدروسة التي تقع تحت صنف اولوية عالية جدا تشمل (باريي كةورة، بيارة، دولي شهيدان، زاروه، سيدارة، شاور، جوكة سور). والاحواض النهرية التي تقع تحت مستوى اولوية عالية تتضمن (اشكنة، داروخان، كلال، زوركان، زةرون، دارةشمانة، خالدان). والاحواض النهرية التي صنفت تحت اولوية متوسطة شملت (بةردةسبي، دةرةكوركان، درويان، زردةكلة، كونة ماسي، دولان، جوتان). بينما الاحواض النهرية التي تقع تحت مستوى الاولوية الواطئة هي (سكتان، خري سراو، بردةرش، جوبلاخ، سيري، جمي استيل، هةلةدن، باخي سرو). من هنا اتضحت لنا بان التدابير المناسبة مطلوبة لهذه الاحواض النهرية للسيطرة على مخاطر الجريان السطحي وحماية التربة من التعرية.

الكلمات المفتاحية: تعرية، جيومورفولوجي، الترتيب، علاقة، التقنية.

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