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Identification of Critical Watershed for Soil Conservation Using Game Theory-Based Approaches

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Abstract
Soil erosion causes significant damage to humans by reducing soil productivity and filling reservoirs from sediment deposition in Narmada Basin, India; hence, it is important to recognize soil erosion prone areas for preventive steps in this basin. In this research, prioritization of sub-watersheds of Narmada Basin has been done using game theory-based approaches such as Condorcet and Fallback bargaining. For this purpose, Digital Elevation Model (DEM) generated by Shuttle Radar Topography Mission (SRTM) was used to extract and analyze 12 morphometric parameters including linear, aerial, and relief parameters. Based on the Condorcet and Fallback bargaining methods, the Mohgaon watershed came at the first priority ranking, that means it's the most vulnerable watershed from the point of soil erosion (SE). Game theory was successfully implemented for prioritizing watersheds in term of SE. The findings showed that morphometric parameters and game theory approach have a high efficiency in recognizing areas that are vulnerable to erosion.

Keywords Game theory · Prioritization technique · Soil conservation · Watershed management

1 Introduction

Soil erosion is one of the major land loss problems in agricultural land and is regarded as a serious environmental hazard (Lu et al. 2003; Kim et al. 2005; Srinivasan et al. 2019). Water erosion risk is an environmental, economic and social issue that affects all countries (Meena et al. 2017). India's regions are not resistant to this type of natural hazards, whose soil loss is estimated at 147 M ha (Bhattacharyya et al. 2015).The average annual soil erosion for Narmada basin watershed (Shakkar River watershed) was estimated to be 10.04 t/ha/ year (Patil et al. 2015). Therefore, the problem needs to be addressed prudently and a systematic solution to reduce the extent of the problem needs to be pursued. To exploit land and water

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resources efficiently and sustainably, one needs to try to find a sustainable unit so that such resources can be effectively handled and controlled (Aghelpour and Varshavian 2020).

Soil attrition or erosion, excess water flow or runoff, changes in river geometry, degradation of streams, sediment accumulation in river and stream characters are related with morphometry (UNEP 1997). This suggests that the morphometry of a basin is fundamental to the basin hydrology. In present time, geo-morphometric analysis using a new technique i.e. remote sensing (RS) & geographical information system (GIS) being utilized as this tool gives flexibility to analyze spatial data in a new manner (Gajbhiye et al. 2014; Meshram and Sharma 2017).

To solve the problems of multifaceted situations, a technique has been evolved and is named as MCDM (Multi Criteria Decision Making) (Liu et al. 2006; Shih et al. 2007; Chang and Hsu 2009; Chang and Lin 2014; Salehi and Izadikhah 2014; Kobryń and Prystrom 2016; Mulliner et al. 2016; Mira et al. 2016; Yu et al. 2017; Shojaie et al. 2017; Raju et al. 2017; Meshram et al. 2020a, b; Dahmardeh Ghaleno et al. 2020; Alvandi et al. 2021).

The use of the game theory (GT) approach in modeling, morphometry parameters plays an important role in developing new methodologies for managing soil erosion with more professional solutions, in order to classify areas that should be prone to erosion (Mekonnen et al. 2017). Recently, the GT has been successfully employed to address disputes over different national/ international issues relating to natural resource management (Madani 2010; Teasley and McKinney 2011; Madani and Lund 2011).The GT has produced useful insights into the decision-making process in different areas of engineering and science, creating infrastructure and issue management (Zavadskas et al. 2004), urban public transport networks, and rapid transportation (Su et al. 2007; Sun and Gao 2007), and decision-making in complex structures (Basaran 2005) were tackled using GT. The GT was implemented for solution of several hydrological problems such as distribution of water resources (Wang et al. 2003; Kucukmehmetoglu 2012), eco-compensation of watershed (Cao et al. 2011), bi-objective watershed management optimization of reservoirs (Üçler et al. 2015), and regulation of water pollution (Shi et al. 2016) were also set on by applying the GT. Adhami et al. (2019) used GT approaches to assess the effects of land use management scenarios on runoff and sediment generation at the Galazchai Watershed, Iran. Adhami et al. (2020) used game theory-based approach for the best soil co-management practices for two watersheds in Germany and Iran.

The aim of this study is to explore the application of Fallback bargaining and Condorcet methods in modelling morphometric parameters to prioritize the erosion vulnerability of sub-watersheds of Narmada basin, India. Soil erosion causes severe ecological problems that are close to rising soil development and filling basins by Narmada Basin sedimentation. Our analysis will generate vast information that will help water resource consultants detail more fertile soil and future water conservation designs in the basin (Meshram et al. 2019). The understanding of the above-mentioned facts in the basin was still discussed, however, and no such scientific evaluations have been published for a basin so far. The results of this study are therefore novel and important in terms of water resources for the authorities concerned.

2 Materials and Methods

2.1 Study Area

In the Indian peninsula, Narmada is the biggest west-flowing river. This river is very important for the country. The Narmada River was born in the Amarkantak Plateau located in Shahdol district of

Madhya Pradesh with an altitude of 1057 m above sea level, latitude: 22°40' N and longitude:81° 45′ E. The river flows 1312 km before it reaches to Cambay Gulf in the Arabian Sea near Bharuch in Gujarat (Gajbhiye et al. 2013a, b). The Narmada Basin covers an area of 98,796 km^2 and it is located between longitudes from 72°32'E to 81°45'E and latitudes from 21° 20'N to 23°45' N. To conduct the study, four watersheds selected based on the data availability is shown in Fig. 1.The flowchart of the methodology is illustrated in Fig. 2.

2.2 Parameter Selection

For making any analysis and thereby the prioritization of any watershed, stream configuration or its network is needed. In this study, watersheds of Narmada river basin are chosen for investigations. Digital Elevation Model (DEM) can be generated by digitizing stream network in GIS environment or prepared DEM data of Shuttle Radar Topography Mission (SRTM) can be used so, here DEM generated by SRTM (the spatial resolution is 90 m) was used for stream generation and further investigation (Fig. 3). Arc-GIS were involved in finding the number of streams & their lengths, watershed lengths, perimeter and area. Basic parameters including stream density & frequency, circulatory ratio, elongation ratio, and form factor were calculated by means of given formulae (Table 1).

2.3 Application of Game Theory-Based Methods

The GT includes study of interaction problems and is composed of four main sections namely decision-makers, potential solutions, choices and outcomes (or benefit). This strategy creates a group pursuing approaches to prioritization, viability and optimization to reach informed decisions. The games' strategy makers are allowed to develop through repeated play over

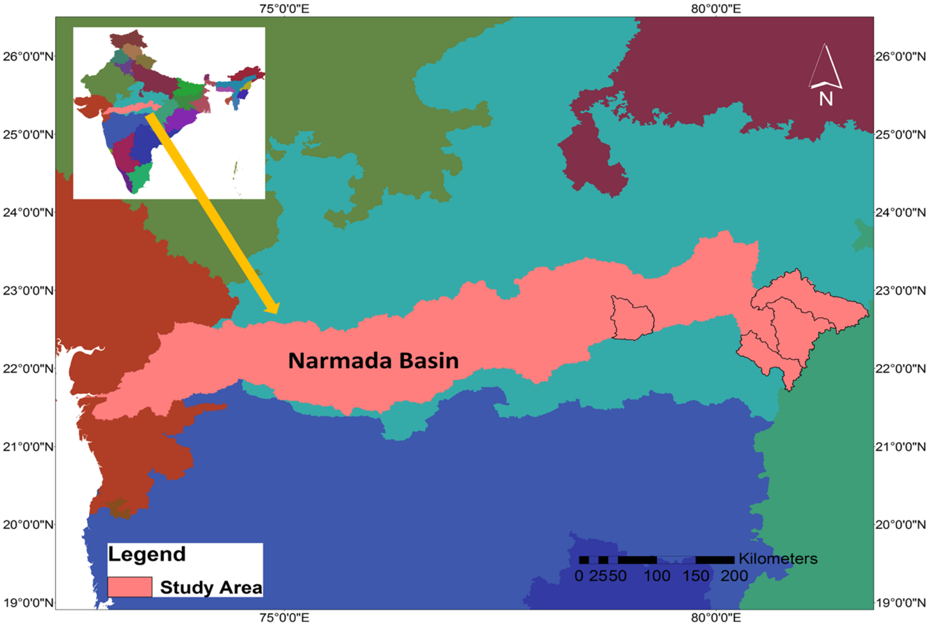

Fig. 1 Location of the study area

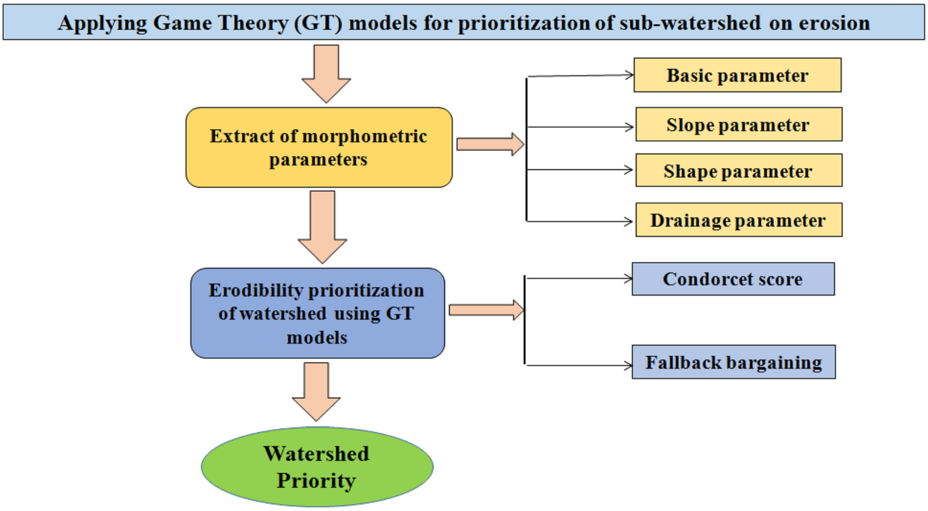

Fig. 2 Flow-chart of the methodology

time and the players usually have no contact before playing (Madani 2010). The GT discusses the disputes by modeling decision-makers; estimating the state of equilibrium, and forecasting coalition stability (Madani et al. 2014).

In the present study, GT approaches (Condorcet and Fallback bargaining strategies) were implemented not only to compare the outcomes but also to search the solution taking into account two distinct conditions.

2.3.1 Condorcet Method

The Condorcet technique is structured to coordinate group selection involving all the individual goals. The current method identified the preferred options by comparing all the alternatives

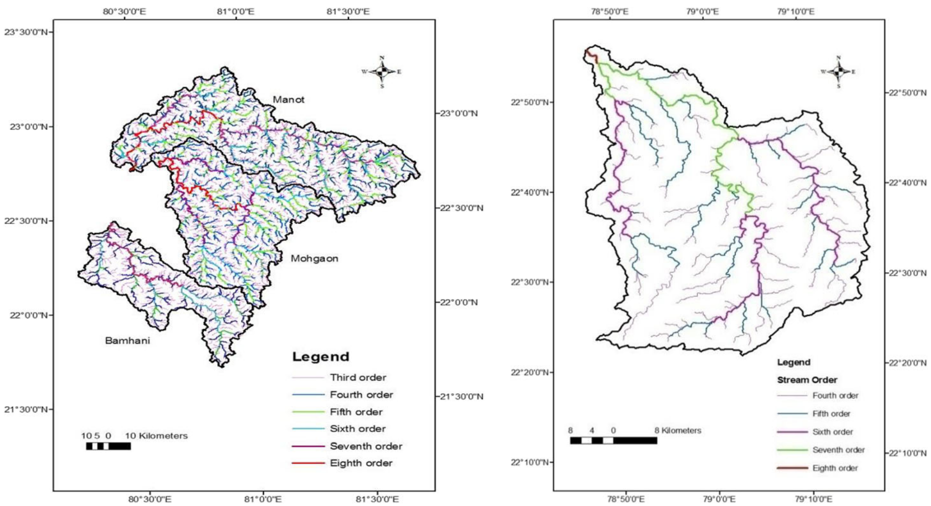

Fig. 3 Drainage map of the study watershed

Table 1 Formulae for computation of morphometric parameters

Morphometric parameters	Formula	Reference
Stream order (u)	Hierarchical rank	Strahler (1964)
Stream length (Lu)	Length of the stream	Horton (1945)
Mean stream length(Lsm)	Lsm=Lu/Nu where Lsm=Mean stream length Lu=Total stream length of Order u Nu=Total number of stream segment of order u	Strahler (1964)
Bifurcation ratio (R_b)	$R_b=Nu/N_{u+1}$ where, Rb=Bifurcation ratio Nu=Total number of stream segment of order u N_{u+1}=Number of stream segment of next higher order	Schumn (1956)
Mean bifurcation ratio (R_{bm})	R_{bm}=Average of bifurcation ratio of all orders	Strahler (1964)
Basin length (L_b)	$L_b=1.312*A^{0.568}$ where, L_b=Length of basin (km) A=Area of basin (km^2)	Nookaratnam et.al (2005)
Drainage density (D_d)	$D_d=Lu/A$ where D_d=Drainage density Lu=Total stream length of all order A=Area of the basin	Horton (1945)
Stream frequency (Fs)	Fs=Nu/A where Nu=Total number of stream of all order A=Area of the basin (km^2)	Horton (1945)
Texture ratio (T)	T=Nu/P where Nu=Total number of stream of all order P=Perimeter (km)	Horton (1945)
Form factor (Rf)	$Rf=A/L_b^2$ where Rf=Form factor A=Area of the basin (km^2) L_b^2=Square of the basin length	Horton (1945)
Circulatory ratio (Rc)	$Rc=4\pi A/P^2$ where Rc=Circularity ratio A=Area of the basin (km^2) P=Perimeter (km)	Miller (1953)
Elongation ratio (Re)	$Re=(2/L_b)*(A/\pi)^{0.5}$ whereRe=Elongation ratio L_b=Length of basin (km) A=Area of the basin (km^2)	Schumn (1956)
Compactness constant (Cc)	$Cc=0.2821P/A^{0.5}$ whereCc=Compactness ratio A=Area of the basin (km^2) P=Perimeter of the basin (km)	Horton (1945)
Length of overland Flow (Lo) (km)	$L_o=1/2D_d$ whereD_d=Drainage density	Horton (1945)
Relief ratio (R_h)	$R_h=H/L_b$ where H=Total relief of the watershed L_b=Maximum length of the watershed	Schumm (1956)
Relief relief (R_r)	$R_h=H/L_p$ where H=Total relief of the watershed L_p=Perimeter of the watershed	Schumm (1956)
Ruggedness number (R_N)	$R_N=H*D_d$ where H=Total relief of the watershed D_d=Drainage density	Moore et al., (1991)
Average slope of watershed (Sa)	$Sa=H*L_{ca}/10*A$ where H=Total relief of the watershed L_{ca}=Average length of all contours	Nautiyal (1994)

Table 1 (continued)

Morphometric parameters	Formula	Reference
	A = Watershed area	
Hypsometric Integral (HI)	HI = ($Elev_{mean}$-$Elev_{min}$)/ ($Elev_{max}$-$Elev_{min}$) whereElev$_{mean,}$ $Elev_{min}$ and $Elev_{max}$ are the mean, minimum and maximum elevations	Langbein (1947)

pair-by-pair comparisons for each person (a total of $\eta * (\eta - 1)/2$ comparisons for n alternatives) (Elkind et al. 2011). For the majority of participants, a Condorcet winner is an option with the maximum preferred (Sheikhmohammady et al. 2010). In a head to head contrast the winner option beats the other options. The ranking for an alternative is tipped by the number of times the alternative ranks above the other. That is, $\mathcal{O}_i(\mathcal{A}_{j,} \mathcal{A}_k) = 1$,if and only if $\mathcal{A}_j > i.\mathcal{A}_k$ and $\mathcal{O}(\mathcal{A}_j)$ is summed over ņ alternatives and individuals:

$$\mathcal{O}(\mathcal{A}_j) = \sum_{i=1}^{m} \sum_{k=1}^{\eta} \mathcal{O}_i\ (\mathcal{A}_{j,}\mathcal{A}_k)$$

The preferences of three voters from high to low are expected to be given below rows:

Elector 1: $\mathcal{ABC}$
Elector 2: $\mathcal{BAC}$
Elector 3: $\mathcal{CBA}$

The Condorcet matrix frames have the structure below due to the aforementioned scheme:

$$\begin{bmatrix} \mathcal{A}-\mathcal{B} & \mathcal{C} \\ \mathcal{A}-\ \mathcal{B} & \mathcal{A} \\ \mathcal{B}\ \mathcal{B}\ - & \mathcal{B} \\ \mathcal{C}\ \mathcal{A} & \mathcal{B}- \end{bmatrix}$$

The existence of each alternative, based on pair comparisons, emphasizes the superior of that case to another. The winner is determined by number of candidate presences (Adhami and Sadeghi 2016). In the example provided, the winner is candidate with the "B" symbol with scores of 4.

2.3.2 Fallback Bargaining

The Fallback process of negotiating focuses on minimizing discontent among bargainers (stakeholders). The bargainers seek to withdraw from their most preferred role to achieve a majority verdict (Mahjouri and Bizhani-Manzar 2013). They initially rate their priorities and create a matrix $(\mathcal{X}\times\mathcal{Y})$ with an alternative of $\mathcal{X}$ stakeholder and $\mathcal{Y}$. If the agreement fails, then negotiators will begin to jump back with their first target to the second, third, and so on until a negotiation is achieved (Adhami and Sadeghi 2016).

The Fallback bargaining procedure leads to the realization of those alternatives which obtain the consent of all voters. This approach has the function of optimizing all elector fulfillments (Mahjouri and Bizhani-Manzar 2013). Primarily both voters express the structure of their desires, eventually they withdraw in lockstep to the point where everyone agrees. The steps in which agreement occur representing varying opinions, needs and interests. While this approach reduces the individual fulfillment of stakeholders but decreases the common conflicts (Madaniet al. 2011).

3 Results and Discussion

3.1 Morphometric Analysis

The objective of the morphometric analysis is to describe the formation, orientation, and quantitative comparison of four watersheds, viz., Bamhani, Mohgaon, Manot and Shakkar based on morphological parameters shown in Table 2. The Manot watershed is the largest in size (4884 km^2) in comparison to Mohgaon (3978 km^2), Bamhani (2542 km^2) and Shakkar (2220 km^2) watersheds. In broader perspective, these watersheds show varying organization schemes of drainage patterns on account of geological variations as discussed subsequently (Fig. 3).

3.2 Shape Parameters

Streamflow and its hydrograph are very much influenced by the circulatory ratio, elongation ratio & from factor which can be termed as the shape characteristics of any basin. Bamhani and Manot have elongated shapes whereas Mohgaon watershed is less elongated. Form factor and elongation ratio values, and circulatory values of Shakkar watershed are indicative of its circular shape. A circular basin is more productive than an elongated basin in runoff discharge (Gajbhiye et al. 2014). Compactness coefficient values of the watersheds are low, indicating that the watersheds are less compact. However, while comparing these watersheds, Bamhani shows more compactness than Manot and Mohgaon watersheds. Further, Shakkar also shows more compactness of watershed.

3.3 Drainage Parameters

A bifurcation ratio greater than 5 suggests structurally regulated drainage network growth (Strahler 1957). The Bifurcation ratio (R_b) of these watersheds is found to be below 5.0, suggesting that geomorphic and lithological control on the drainage network is more than structural control.

Drainage density is vital parameter and influenced by drainage length & watershed area. Drainage density (D_d) is a direct indication of permeability of underlying rock formation. Low drainage density ($D_d = 2.46$ km/km^2) of Bamhani watershed indicates higher infiltration rates

Table 2 Morphometric parameters of watersheds

Watershed	R_h	R_N	R_b	D_d	F_s	R_c	R_f	R_e	L_o	C_c	S_a	HI
Bamhani	0.004	1.119	4.476	2.465	3.989	0.223	0.200	0.505	0.203	0.002	5.490	0.420
Manot	0.004	2.151	4.437	3.099	7.463	0.207	0.183	0.483	0.161	0.001	10.340	0.500
Mohgaon	0.004	1.868	4.536	3.161	7.803	0.292	0.188	0.490	0.158	0.001	9.740	0.500
Shakkar	0.008	2.618	4.076	3.116	7.247	0.388	0.204	0.509	0.160	0.002	11.160	0.500

and lower surface flow velocity (Yalcin 2008). The value of D_d for Mohgaon ($D_d = 3.161$ km/km^2) and Manot ($D_d = 3.099$ km/km^2) watersheds is much higher than for Bamhani watershed. Bamhani watershed has higher average length of higher order stream which is evident from Table 2. The Bamhani watershed has 29.88 km for 6th order and 96.13 for 7th order whereas Manot has 6.98 and 49.91 km, and Mohgaon has 13.20 and 33.83 km, respectively. This as such validates the hypsometric integral analysis. Of the three basins, only Bamhani has passed the mature stage. Decrease in drainage density and increase in the length of streams are characteristic phenomenon of post-maturity drainage networks. Higher drainage density of Shakkar watershed ($D_d = 3.116$ km/km^2) indicates the dominance of channel flow over the overland flow ($L_o = 0.160$ km). The value of D_d in Shakkar watershed is also an indicator of soft rock formation in the watershed. Disposal of runoff is also likely to be quick in the watershed.

The stream frequency relates to permeability, infiltration capability, and relief of watershed. Values of stream frequency of sub-watershed area exhibits positive correlation with drainage density values of the area indicating the increase in drains population with respect to drainage density. It is clear from Table 2 that the Mohgaon watershed has denser drainage pattern (3.161 km/km^2) and higher stream frequency (7.803 no./km^2) than the Manot and Bamhani watersheds.

Texture ratio (T) is a significant factor in morphometric analysis of drainage that influences on the topography's underlying lithology, infiltration ability and relief dimension. It is evident from the values of texture ratio of the watersheds under study that Mohgaon (T = 74.795) has more resistant underlying geology as compared to Manot (T = 27.723) and Bamhani (T = 26.485) watersheds. The drainage density of Shakkar watershed also has positive correlation with its drainage frequency. The texture ratio of Shakkar watershed (59.807) may be attributed to the erosive system in the lower reaches where the gully-channel-ravine formation is prominent. This inference is consistent with the available geological information of the study area.

3.4 Slope Parameters

As can be seen from Table 2, total relief (H) of Manot (H = 694 m) and Mohgaon (H = 591 m) watersheds is much higher than Bamhani (H = 454 m). The Ruggedness number (R_N) expresses the roughness of watershed. Bamhani watershed ($R_N = 1.119$) is less rough than the Manot ($R_N = 2.151$) and Mohgaon ($R_N = 1.868$). Shakkar watershed ($R_N = 2.618$) has high roughness. Average slope (S_a) of watersheds indicates that Bamhani watershed ($S_a = 5.94\%$) slope is less than those of the Mohgaon ($S_a = 9.74\%$) and Manot ($S_a = 10.34\%$). Shakkar watershed has high average slope. Hypsometric integral values indicate that all the watersheds are in equilibrium stage (HI between 0.35 and 0.60).

3.5 Erodibility Criteria for Watersheds Prioritization by Game Theory Approach

For taking any soil conservation program, it cannot be started from any sub-watershed of the watershed, there should be a prioritization scheme means which sub-watershed should be taken at top priority for taking soil conservation measures. So, in this study a priority scheme has been adopted as taken by Thakker and Dhiman (2007), Biswas et al. (2002) Gajbhiye et al. (2014), which says that values of ruggedness number, relief ratio & relative relief if higher of any sub-watershed they should be taken at priority and lower values of form factor, elongation ratio & circulatory ratio of sub-watersheds should be taken at priority as these values have effect on soil erosion. Morphometric parameters as estimated are given in Table 2 and priority ranking is presented in Table 3 to use for further game theory approach. Homochromatic cells present parameters with equal priority. For example, in Bamhani watershed, R_b and L_o have the first priority. This means R_b of this watershed has the highest amount in comparison with the other three watersheds. The amount of L_o in this watershed is the highest as well (Table 2). Among 12 parameters, in Bamhani only R_b and L_o have the first priority. Then, both of them have the same color which occupies the first cells (blue color in each row presents first priority). The second priority of each row contains parameters in cells with second color (orange color). The third and fourth priorities are shown in green and yellow colors, respectively. In Bamhani watershed, 12 study criteria are placed in four priority classes. The number of priority classes for Manot, Mohgaon and Shakkar watersheds are three, four and four, respectively.

3.5.1 Condorcet Method

In this method, linear priority of parameters (Table 3) was followed by developing a Condorcet matrix which compares the priority of all parameters together (Table 4). Table 3 includes the results of single parameter comparison in four study areas but Table 4 represents had by had comparison of 12 parameters.

For example, comparison of drainage density and bifurcation ratio is explained. In how many watersheds the priority of drainage density is more than bifurcation ratio? In Mohgaon and Shakkar sub-watersheds, D_d was placed before R_b (high priority), in Manot watershed, both have green color (third priority) and in the case of Bamhani, R_b was more important than D_d. There upon, the importance of drainage density is more than of bifurcation ratio and drainage density in the intersection cell of D_d and R_b is replaced. In other words, D_d is winner in this one by one comparison. In some cases, the number of priorities of two parameters is equal and they have same importance, then, & symbol is used in such conditions. R_b and R_N are examples. At the end, the sum number of each parameters' presence in the matrix (the number of wins) was calculated which is symbolized as Condorcet score (Table 5).

In order to prioritize watersheds, Condorcet scores of parameters were used. In each watershed, parameters were arranged according to their priority. Equal priority was observed in some cases. For example, in the Bamhani watershed, R_b and L_o have the first priority. In other words, these parameters are more important because of their high amount and high effect on erosion. Equal importance is presented by isochromatic cells (Table 3). At the next step, hierarchy weights were applied for watershed score calculation. Scores were considered in a 1–12 range. Parameters with equal priority earn the

Table 3 Linear prioritization of morphometric parameters

Bamhani	R_b	L_o	R_h	R_c	C_c	HI	R_f	R_e	R_n	D_d	F_s	S_a
Manot	R_c	R_f	R_e	C_c	HI	R_h	R_n	F_s	L_o	S_a	R_b	D_d
Mohgaon	D_d	F_s	C_c	HI	R_h	R_b	R_f	R_e	R_n	R_c	S_a	L_o
Shakkar	R_h	R_n	S_a	HI	D_d	C_c	F_s	L_o	R_b	R_c	R_f	R_e

Note: Blue: 1st priority, Orange: 2nd priority, Green: 3rd priority and Yellow: 4th priority

Table 4 Condorcet matrix of parameters

	Condorcet matrix of parameters											
	R_h	R_N	R_b	D_d	F_s	R_c	R_f	R_e	L_o	C_c	S_a	HI
R_h	–	R_h	R_h	R_h	R_h	R_h	R_h	R_h	R_h	C_c	R_h	HI
R_N	R_h	–	R_b&R_N	R_N	R_N&F_s	R_c	R_f	R_e	R_N	C_c	R_N&S_a	HI
R_b	R_h	R_b&R_N	–	D_d	F_s	R_b	R_b&R_f	R_b&R_e	L_o	C_c	R_b&S_a	HI
D_d	R_h	R_N	D_d	–	D_d&F_s	D_d&R_c	D_d&R_f	D_d&R_e	D_d&L_o	C_c	S_a	HI
F_s	R_h	R_N&F_s	F_s	D_d&F_s	–	F_s&R_c	F_s&R_f	F_s&R_e	F_s&L_o	C_c	F_s&S_a	HI
R_c	R_h	R_c	R_b	D_d&R_c	F_s&R_c	–	R_c&R_f	R_c&R_e	R_c&L_o	C_c	R_c	HI
R_f	R_h	R_f	R_b&R_f	D_d&R_f	F_s&R_f	R_c&R_f	–	R_f&R_e	R_f&L_o	C_c	R_f	HI
R_e	R_h	R_e	R_b&R_e	D_d&R_e	F_s&R_e	R_c&R_e	R_f&R_e	–	R_e&L_o	C_c	R_e	HI
L_o	R_h	R_N	L_o	D_d&L_o	F_s&L_o	R_c&L_o	R_f&L_o	R_e&L_o	–	C_c	S_a	HI
C_c	C_c	C_c	C_c	C_c	C_c	C_c	C_c	C_c	C_c	–	C_c	HI
S_a	R_h	R_N&S_a	R_b&S_a	S_a	F_s&S_a	R_c	R_f	R_e	S_a	C_c	–	HI
HI	HI	HI	HI	HI	HI	HI	HI	HI	HI	HI	HI	–
Score	**18**	**7**	**6**	**7**	**9**	**9**	**10**	**10**	**7**	**20**	**7**	**22**

average score. For instance, R_b and L_o in the Bamhani watershed occupied first priority cells. The hierarchy score for both of them is 11.5. The hierarchy score of R_b is 11.5 and Condorcet score of R_b is 6. Then the final score was 11.5*6. This process was applied for each parameter. At the end, the sum of scores for parameters provides watersheds' score. The watershed with the high score has critical condition and high priority for managerial goals. Current procedure highlights the most important parameters in the majority of watersheds. Hence, controlling the parameters with high scores will restrain soil erosion in the huge part of the study area.

Based on the results, Hypsometric Integral is known as the most effective parameter in four study watersheds. Watersheds as voters elected HI as the parameter which affects soil erosion procedure effectively. Most of the voters (watersheds) have consensus on this decision. Of course, all watersheds do not confirm this. Thereby, the Condorcet diagnosis the most effective parameter emphasized by the majority of the decision makers (watersheds). Accordingly, the watershed with high value of important parameters is chosen as critical watershed which should be managed in the first step. Mohgaon watershed with the score of 971 has the highest priority.

3.5.2 Fallback Bargaining Method

In the Fallback bargaining method, linear priority arrangement of parameters (Table 3) was used again. In the second step, election of parameters as the first, second, third and fourth

Table 5 Condorcet score and final priority of watersheds

Watershed	Calculation of watershed's score using Condorcet score of parameters												Condorcet score	Priority
	R_h	R_N	R_b	D_d	F_s	R_c	R_f	R_e	L_o	C_c	S_a	HI		
Bamhani	69	80.5	153	76.5	170	187	55	55	17.5	17.5	22.5	17.5	921	4
Manot	90	100	100	200	220	90	35	45	35	35	9	10.5	969.5	2
Mohgaon	73.5	94.5	210	231	117	39	65	65	21	27	21	7	971	1
Shakkar	189	73.5	73.5	231	52.5	150	49.5	38.5	15	22.5	25	25	945	3

Table 6 Fallback bargaining score of parameters

	Fallback bargaining												Cumulative score of parameters 1st to 4thdepth
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	
R_h	1	**4**	4	4	4	4	4	4	4	4	4	4	13
R_N	1	2	3	4	4	4	4	4	4	4	4	4	10
R_b	1	2	3	4	4	4	4	4	4	4	4	4	10
D_d	1	2	3	4	4	4	4	4	4	4	4	4	10
F_s	1	2	3	4	4	4	4	4	4	4	4	4	10
R_c	1	2	3	4	4	4	4	4	4	4	4	4	10
R_f	1	2	3	4	4	4	4	4	4	4	4	4	10
R_e	1	2	3	4	4	4	4	4	4	4	4	4	10
L_o	1	2	3	4	4	4	4	4	4	4	4	4	10
C_c	2	**4**	4	4	4	4	4	4	4	4	4	4	14
S_a	1	2	3	4	4	4	4	4	4	4	4	4	10
HI	3	**4**	4	4	4	4	4	4	4	4	4	4	15

priority in the study watersheds is important. For example, among parameters HI is the most important parameter in 3 of 4 watersheds because of its presence in the first priority in 3 watersheds. Accordingly, at the first depth, the score of the HI is 3. At the second depth, it is placed in second priority color in the fourth watershed. Then, the cumulative number of its presence in two surveyed priorities is four. Then the complete score (4) is gained in depth 2 (Table 6). Because of equal priority of some parameters, final score was earned in fourth depth for all study parameters.

The Fallback bargaining score of the parameters is calculated using cumulative score of each parameter (Table 7). Once again, the hierarchy weights as coefficient in watershed score calculation were considered. As a result, parameters were ranked relying on election of all watersheds. Then, control of most important parameters will improve whole study area condition.

Relying on the results, the R_h, C_c and HI are presented as Fallback bargaining winners which gained 4 votes of voters in the 2nd depth. HI earned the consensus of 3 watersheds in the first depth but because of the rules of utilized method, agreement of all watersheds is essential. Hence, another fallback is needed. At the second step, two more parameters were elected as effective ones. The other parameters had equal value for voter. Mohgaon and Shakkar watersheds have high priority. Employing both Condorcet and Fallback bargaining methods, the Mohgaon watershed has the highest while the Bamhani watershed has the least priority (Table 8 and Fig. 4).

Based on the final prioritization of watersheds (Table 2) it is obvious that deciding about Mohgaon, Manot and Bamhani watersheds is not complicated. However different priority of

Table 7 Fallback bargaining score and final priority of watersheds

Watersheds	Calculation of watershed's score using Fallback bargaining score of parameters												Fallback bargaining score	Priority
Bamhani	115	115	110.5	85	119	127.5	55	55	25	25	25	25	882	3
Manot	100	100	100	140	150	65	50	50	50	50	15	15	885	2
Mohgaon	105	105	147	157.5	84.5	65	65	65	30	30	30	10	894	1
Shakkar	136.5	105	105	157.5	75	105	55	55	25	25	25	25	894	1

Table 8 Final priority of watersheds

Priority	1	2	3	4
Condorcet	Mohgaon	Manot	Shakkar	Bamhani
Fallback bargaining	Mohgaon, Shakkar	Manot	Bamhani	–

Shakkar watershed using two methods forces the manager to consider the conditions of the study area, accessible sources, found and energy. Despite the urgently management of Shakkar watershed will satisfy all decision makers (watersheds), but maybe devoting the same fund and energy to the Manot watershed control erosion more sensitively. In some cases, investing in a limited segment has significant results and the Condorcet method diagnosis such areas. The reason of two different methods with basically distinct functions was considering various conditions which the manager is dealing with.

The findings of this study may be used as guidance for water resource managers and planners in deciding the strength and form of treatments in the Narmada basin's various sub-watersheds. Mechanical measures such as contour bunds and brush wood check dams may be recommended on appropriate locations of very high and high priority sub-watersheds where soil erosion is high and the slope is steep. The location of the check dam and percolation tank may be determined by the suitability of medium and low priority sub-watersheds.

4 Conclusion

In the presented study, the morphometric parameters of Narmada Basin watersheds were estimated using GIS tool. For easiest way to develop watersheds of Narmada basin prioritization ranking was made using Condorcet and Fallback bargaining methods.

The cumulative scores of watersheds applying the methods of Condorcet and Fallback bargaining were the preferred areas for paying more attention and getting sources of management. Watersheds were prioritized on the basis of Condorcet and Fallback bargaining methods. The first priority relates to critically formed watersheds and the last priority contains the areas with better condition in terms of soil erosion. The outcomes of the Condorcet and fallback bargaining methods revealed that the Mohgaon watershed was found in the first priority while the Bamhani watershed indicated the last priority. Therefore, the necessary technical and managerial steps for soil and water conservation can be based and implemented in sub-watersheds with first priority. These

Fig. 4 Final priority of watersheds

results undoubtedly help local planners, analysts and decision-makers allocate investment and even resources to more vulnerable sub-watersheds in an economically effective and technologically productive manner. However, further studies with extended and more complete databases are required to be subjected to other techniques to game theory in order to encourage for a more comprehensive conclusion to be drawn.

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Data Availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Compliance with Ethical Standards

Ethics Approval and Consent to Participate Not applicable.

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