MCDM Approach for Mitigation of Flooding Risks in Odisha (India) Based on Information Retrieval

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ABSTRACT

Multi-criteria decision-making (MCDM) provides a suitable platform for groups as well as promotion of the participants' role in decision processes. This also enables the development of real participatory processes essential for the successful implementation and sustainable flood management programs. The present study contributes by applying two MCDM approaches for weighting the criteria related to the environmental impacts of flooding. Moreover, an attempt was made in this study by an extensive review of literature, and consultations with experts to identify the environmental impacts of flooding in Odisha State (India). Then, the Best Worst Method (BWM) followed by the Step-Wise Weight Assessment Ratio Analysis (SWARA) method was used to rank the environmental impacts which were considered as the risk factors. The result of this study will be useful to the governance system for an effective and proper planning, and implementation of flood mitigation projects.

KEYWORDS

BWM, Environmental Impacts, Flooding, MCDM, Odisha, SWARA

INTRODUCTION

In India, the climate of Odisha State is tropical which is characterized by high humidity, high temperature, medium to high rainfall, and short and mild winter. The normal rainfall in Odisha is 1451.2 mm, while the actual rainfall usually varies in different districts. During the period from June to September, about 84% of rainfall occurs. The distribution of rainfall during the monsoon period is highly uneven and unpredictable, although the rainfall quantum is quite high. Consequently, flood, drought, and cyclone of varying intensity occur frequently affecting adversely the social, economic as well as environmental scenario of the State. Flooding has been the most frequent visitor among the natural calamities in Odisha, and in most of the years the entire coastal line of 482 km is frequently exposed to flood and water logging. The heavy rain falls on the hills and the flood water from the neighboring regions of Odisha contribute flooding in coastal and deltaic areas. The flood is mostly aggravated because of high degree of siltation, erosion of soils, embankments breaching, and tidal

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flow of sea restricting disposal of flooded water. The flood water is normally carried to the sea by the major rivers such as Rusikulya, Brahmani, Subarnarekha, Vansadhara, Mahanadi, and their branches. Sometimes the cyclonic wind along with heavy rain falls and tidal flows also causes flooding in coastal areas damaging life & properties of habitats, and also affecting crop fields' & food security. The coastal districts of Odisha, prone to floods and requiring an effective approach for its mitigation are Balasore, Bhadrak, Kendrapara, Jagatsingpur, Puri, and Ganjam, respectively. Thus, there is a need to have proper flood risk reduction plans for the entire State, through adequate assessment of the critical & adverse impacts of flooding and prioritizing them based on the risk levels.

BACKGROUND

The frequency of disasters results in the weak economies in developing countries to subsequently become even weaker. For instance, it was reported that almost half the population of 110 million were directly affected by the flood in Bangladesh in the year 1988 (ESCAP, 1991). In the year 1993, the Meuse and Rhine river flood in Southern Netherland resulted in suspended matters in rivers with organic contaminants and trace metals, and the toxic chemicals also affected the biological organisms (Van Der Heijdt and Zwolsman, 1997). Similarly, the floods in Mozambique in 2000 and 2001 made homeless to two million peoples (IFRRS, 2002). In 2002 the Moldau/Elbe floods in Prauge, Czech Republic resulted in releasing heavy metals and chlorine from chemical plant, and debris from building materials and contents. The Elbe river flood in Germany caused spilling of diesel and other type of oils, and affecting the quality of water. It resulted in releasing of cyanide-contaminated liquid affecting the aquatic life and the drinking water was contaminated (Stuyt et al., 2003). The impact of cyclones and surges is increasing as a result of rapid growth of population and coastal infrastructures (Chittibabu et al., 2004). The flood management approaches in present scenario should have resiliency, economic feasibility, social acceptability, and environmental soundness, for protecting the benefits of future generations (Bruijn, 2005). The flood risk reduction projects are generally considered for major flooding events and often with financial support from national government or international sponsors on ad-hoc basis without proper planning and design that leads to the project failures (DFID, 2005; Schipper and Pelling, 2006). The flooding problems, socio-economical, environmental degradation, and inefficient flood mitigation assessment are due to the unplanned floodplain developments (DEFRA, 2007; QRA, 2012). The disasters having both social as well as physical dimensions occur because of extreme weather and climate events (IPCC, 2012). Hence, effective flood risk reduction planning and implementation are essential to ensure sustainable floodplain developments (AAGD, 2013). Zeleňáková and Zvijáková (2014) have made an attempt to streamline the "Environmental impact assessment (EIA)" process of water constructions through risk analysis evaluation of options for effective water management. Hegger et al. (2014) have recommended for appropriate measures and implements to accommodate water both horizontally and vertically for reducing the possibility and magnitude of floods. Some of the measures included use of flood walls or embankments, developing flood storage areas, sustainable urban drainage forms, creating wetlands, restoration of river corridors, and tree planting, respectively. Banihabib and Laghabdoost-Arani (2014) have used a non-compensatory MCDM model incorporating social, economic and environmental criteria, to rank the flood management alternatives with the aim to reduce flood damage in the Gorganrood River in Golestan Province of north Iran. Andino and Natalia (2015) have developed the framework considering economic, social, and environmental criteria, which will help the decision makers to forecast the flood risks and study the implementable alternatives for mitigation of flood. Khan et al. (2015) have discussed through a case study on Queensland, Australia about the post-flood road maintenance strategy. Vennapusa et al. (2016) have discussed the assessment, repair and mitigation approaches for flood related geo-infrastructure damages. Shah et al. (2016) have studied the sustainability issues of projects related to mitigation of flood in terms of sustained reduction of flood risks, social, economic, environmental, and policy-based factors, as

well as institutions associated with the projects. The framework for sustainability assessment was developed considering five key stages of the project management cycle such as contextualization of the project with respect to sustainable development at regional level, assessment during planning and implementation, assessment during flood event for evaluating the performance and additional issues for sustainability, periodic assessment to check the achievement and compliance with sustainable development plans, and assessment during modifications or changing/upgrading to new project. Fournier et al. (2016) have identified five criteria of adaptive governance based on a comprehensive literature review, and then applied these to six European countries such as Belgium, England, France, the Netherlands, Poland, and Sweden, to evaluate the flood mitigation governance by examining the arrangements of current governance with respect to adaptive governance. It was concluded that the stimulating role of adaptive governance was strongest in England and Belgium, respectively. Parikh et al. (2017) have analyzed the impacts of flooding in Surat city of Gujarat in India, using HEC-RAS model. The west and north zone were found to be highly prone to flood, while south zone was least. Mallick et al. (2017) have developed a methodology and tool to assess the vulnerability of roadway damages due to flood. Shah et al. (2017) have adopted a multi-criteria analysis approach in the designed framework using sustainability criteria and indicators, to determine the sustainability index that will enhance decision making for sustainability of projects for flood mitigation. Dan-Jumbo et al. (2018) have assessed the historical and future land-use/land-cover dynamics in the Niger Delta River State region, using multi-source data of the study area for 1986, 1995, and 2003, as well as projected conditions in 2060. It was found that “historical urbanization occurred rapidly”, “due to planned urban development, the urban expansion could increase by 80% in 2060”, and “at the expense of agricultural land, 95% of the conversions to urban land occurred mainly”. An Adaptation Tipping Point (ATP) approach was used to assess the vulnerability to flood of Dhaka city in Bangladesh, which revealed that when social tipping points are considered, the assessed vulnerability to flood increases (Ahmed et al., 2018). Moghadas et al. (2019) have made an assessment of resilience focusing on the intrinsic characteristics as well as capabilities of Tehran in view of flash floods, from overflowing rivers or surface water. The approach of measurement for flood resilience was based on making a composite index derived from six dimensions of resilience, such as social, institutional, economical, infrastructure, community environment, and community capital. This study was followed by using both the AHP and TOPSIS tools for ranking urban districts in Tehran on the basis of resilience levels.

A wide range of plans are used in flood management to reduce the destructive effects of flood on the society, economy and environment. This includes different structural alternatives for controlling a flood as well as different non-structural alternatives without controlling but mitigating the damages due to floods. The selection of the optimal flood management alternative is a multiple criteria decision-making issue, and thus, the selection of appropriate multi-criteria decision-making models (MCDM) is essential for the assessment of each alternative with respect to several social, economic, and environmental criteria. A limited number of multiple criteria decision-making approaches are used in risk management of floods (Meyer et al., 2008). For instance, the use of both simple weighting method and analytical hierarchy process (Costa et al., 2004; Dang et al., 2010; Kubal et al., 2009). The main objective of the present study was to identify different environmental impacts because of flooding in Odisha (India), and ranking them based on their adverse impacts by using MCDM methods. In any MCDM problem for the selection of the best alternatives, a number of alternatives are evaluated with respect to a number of criteria. The present study aims at utilizing an integrated approach of the Best Worst Method (BWM) for calculating the optimized weight values and the SWARA (Step-wise Weight Assessment Ratio Analysis) method developed by Kersuliene et al. (2010), for ranking of environmental risk factors. The BWM method was developed by Rezaei (2015), and the major advantages of BWM, in comparison with other existing MCDM methods are: it requires less comparison of data and also it leads to more consistent comparisons. Moreover, the BWM has been used by several scientific papers. For instance: for evaluating the sustainability of supply chains (Ahmadi et al., 2017), evaluating the performance of “Research & Development Firms” (Salimi

and Rezaei, 2018), and evaluating the sustainability for design of product packages (Rezaei et al., 2018). Similarly, different studies have also recommended the SWARA methods to solve the MCDM problems. An integrated SWARA and VIKOR analysis were used as two multiple attribute decision-making (MADM) methods for agile-supplier selection in view of four criteria including performance, cost, flexibility and technology (Alimardani et al., 2013). Likewise, both SWARA and COPRAS were used in a study in Iran, for decision and policy making of high-tech industries (Zolfani and Bahrami, 2014). Yazdani et al. (2016) have used an integrated model using SWARA, QFD and WASPAS for the problem of supplier selection. Kafle and Shakya (2018) have studied the flood risks along with the sediment management of Koshi River in Nepal. The estimation of criteria weights for each measure was made by the use of “Entropy, AHP & AHP-Entropy techniques”. While, prioritization of the preference ranking of alternatives was carried out by the use of ELECTRE, TOPSIS & SAW as the MCDM methods. A newer MCDM approach such as the “Rough Step-wise Weight Assessment Ratio Analysis” approach was suggested in order to better manage the subjectivity in addition to the uncertainties of real decision problems. Then this approach was verified through a sensitivity analysis, by comparing the acquired results with other two methods such as “Rough Best Worst method” and “Rough Analytic Hierarchy Process” for obtaining the weight values (ZAVADSKAS et al., 2018). Similarly, an extended version of SWARA for criteria evaluation in decision making process was proposed by Zolfani et al. (2018). For sustainable designing of domestic furnishing materials, both SWARA and BWM methods were used as two approaches in MADM methods for weighting the related criteria (Zolfani and Chatterjee, 2019).

Steps in Best Worth Method (BWM)

One of the multi criteria decision making methods is the “Best Worst Method (BWM)” using two vectors of pair-wise comparisons for determining the weights of criteria. Initially, by the decision-makers the best and the worst criteria” are identified such as “most desirable or most important” and “least desirable or least important criteria”, respectively. Then, the preference of the best criteria over all other criteria in addition to the preference of all the criteria over the worst criteria is determined. After that by considering the maximum absolute difference between the weight ratios, a nonlinear min-max model is used for identifying the weights and the minimization of their corresponding comparisons is obtained. The following steps are involved in BWM method (Rezaei, 2015):

Step 1: Determination of a set of decision criteria.

In this step, the decision maker identifies n criteria $\{C_1, C_2, \dots, C_n\}$ based on literature review and expert opinion that are used to make a decision.

Step 2: Determining ‘the best and the worst criteria’, such as “most desirable or most important” and “least desirable or least important criteria”, respectively.

Step 3: Determining the preference of the best criteria’s over all other criteria by using a number between 1 and 9. The obtained best to others (BO) vector would be:

$$A_B = \{a_{B1}, a_{B2}, \dots, a_{Bn}\}$$

where, a_{Bj} denotes the preference of the best criterion B over criterion j , and it is clear that $a_{BB} = 1$.

Step 4: Determining the preference of all the criteria’s over the worst criteria by using a number between 1 and 9. The obtained others to worst (OW) vector would be:

$$A_W = \{a_{1W}, a_{2W}, \dots, a_{nW}\}^T$$

where, a_{jw} denotes the preference of the criterion j over the worst criterion W , and it is clear that $a_{ww} = 1$.

Step 5: Calculation of the optimal weights as $\{w_1^*, w_2^*, \dots, w_n^*\}$.

The main objective in this step is to determine the optimal weights of the criteria such that the maximum absolute differences $\{|w_B - a_{BjWj}|, |w_j - a_{jw} w_w|\}$ for all j is minimized. This can be translated to the following minimax model:

$$\text{Minimax } \{|w_B - a_{BjWj}|, |w_j - a_{jw} w_w|\}$$

subjected to:

$$\sum_j w_j = 1$$

$$w_j \geq 0, \text{ for all } j \quad (1)$$

Model (1) can be converted to following linear model as:

$$\text{Min } \xi^*$$

subjected to:

$$|w_B - a_{Bj} w_j| \leq \xi^*, \text{ for all } j \quad |w_j - a_{jw} w_w| \leq \xi^*, \text{ for all } j \quad \sum_j w_j = 1$$

$$w_j \geq 0, \text{ for all } j \quad (2)$$

Solving the above model (2), the optimized weights $\{w_1^*, w_2^*, \dots, w_n^*\}$ and optimal value ξ^* can be obtained. Consistency (Ksi^*) of comparisons also needs to be determined as shown in Equation (3). According to Rezaei (2016) a value closer to 0 is required for consistency. A consistency index (CI) helps to calculate the Ksi^* value, as shown in Table 1:

$$Ksi^* = \frac{\xi^*}{CI} \quad (3)$$

Table 1. The values of CI for BWM method

a_{BW}	1	2	3	4	5	6	7	8	9
CI ($\max \xi^*$)	0	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

Steps in Step-Wise Weight Assessment Ratio Analysis (SWARA) Method

In SWARA method, the most significant criterion is given first rank, while the least significant criterion is given last rank. Then overall ranking to the experts group is determined on the basis of rank values. The following steps are involved in SWARA method (Kersulienė et al., 2010; and Stanujkic et al., 2015):

Step 1: Criteria were sorted in accordance with their significance.

In this step the criteria's were ranked by the experts according to their relative significance; where the most significant was placed in the first place, while the least significant was placed in the last place.

Step 2: Relative significance of average values (s_j) were determined.

In this step the significant values were determined, which was started from the second ranked criterion, i.e. how much the criterion c_j was more important than the criterion c_{j+1} .

Step 3: The coefficients (k_j) were calculated as follows:

$$k_j = \begin{cases} 1, & j = 1 \\ s_j + 1, & j > 1 \end{cases} \quad (4)$$

Step 4: The recalculated weights (q_j) were determined as follows:

$$q_j = \begin{cases} 1, & j = 1 \\ \frac{q_{j-1}}{k_j}, & j > 1 \end{cases} \quad (5)$$

Step 5: The relative weights (w_j) of the evaluation criteria were determined as follows:

$$w_j = \frac{q_j}{\sum_{k=1}^n q_k} \quad (6)$$

where, n denotes the number of the criteria.

The procedure for expressing the relative importance between criteria and the determination of the weights of criteria is illustrated in Figure 1.

RESEARCH METHODOLOGY

The present study included an extensive review of literature, and consultations with experts to identify the environmental impacts because of flooding in Odisha (India). Moreover, the experts participated in the decision-making process were selected covering all the six different coastal districts in Odisha, such as Balasore, Bhadrak, Kendrapara, Jagatsingpur, Puri, and Ganjam, respectively. Then, an attempt was made to augment the decision-making process by integrating two different multiple criteria decision-making approaches. As the number of criteria identified by the help of experts' were few in numbers,

Figure 1. The determination of the weights of criteria based on the application of the SWARA method (Kersulienė et al., 2010)

hence the BWM method was used which requires less pair-wise comparisons, and the best as well as the worst criteria considering the environmental impacts as risk factors were selected. The optimized weights of all the criteria as well as consistency value were obtained by using “BWM-Solver.xlsx” software (Rezaei, 2016). Further, another approach of MCDM was used, i.e. the SWARA method for ranking the entire criterion as well as the sub-criteria based on their prioritizations. In the SWARA method, the comparison of the value importance (S_j) for criteria was based on the obtained optimized weight values by BWM method, and then for sub-criteria was obtained by experts. The experts participated in the process of decision making in both BWM and SWARA methods were as illustrated in Table 2.

RESULTS AND DISCUSSION

The environmental impacts of flooding were identified from the extensive study of literature and consultation with experts. Then the criteria and sub-criteria of environmental impacts due to flood

Table 2. The characteristics of decision-making experts

Field	Gender		Education Level		
	Male	Female	Bachelor	Master	Doctor
Agriculture	2	0	0	1	1
Health and Medicine	0	1	0	1	0
Environmental	1	0	0	0	1
Industrial engineering	1	2	0	1	2

were identified accordingly as shown in Table 3. It can be seen that the criteria were pattern of flooding due to environment, environmental damages, and environmental losses. While the sub-criteria under the criteria of pattern of flooding due to environment were level of flood, changing of flood outside the affected areas, and creation of new type of flooding. The sub-criteria under the criteria of environmental damages were damages in commercial sectors, damages in agricultural sectors, and damages of properties. Similarly, the sub-criteria under the criteria of environmental losses were criticality in the survival and restoration of habitats, environmental pollutions, generation of debris due to floods, and susceptibility of landslides in the affected areas, respectively.

APPLICATION OF BEST WORTH METHOD FOR CALCULATION OF WEIGHTS OF CRITERION

The best and worst criteria were selected by the help of experts' opinion from all the three criteria such as pattern of flooding due to environment (A), environmental damages (B), and environmental losses (C), based on its impact in Odisha. The optimized weights of all the criteria as well as consistency value were obtained using "BWM-Solver.xlsx" software, where the preference of best criteria over all other criteria's as well as the preference of other criteria's to the worst criteria was determined by

Table 3. Environmental criteria and sub-criteria of flooding

Symbols	Criteria and Sub-Criteria
C_1	Pattern of flooding due to environment.
C_{1-1}	Level of flood.
C_{1-2}	Changing of flood outside the affected areas.
C_{1-3}	Creation of new type of flooding.
C_2	Environmental damages.
C_{2-1}	Damages in commercial sectors.
C_{2-2}	Damages in agricultural sectors.
C_{2-3}	Damages of properties.
C_3	Environmental losses.
C_{3-1}	Criticality in the survival and restoration of habitats.
C_{3-2}	Environmental pollutions.
C_{3-3}	Generation of debris due to floods.
C_{3-4}	Susceptibility of landslides in the affected areas.

on a scale of 1-9. The obtained optimized weights of all the criteria's, and consistency value were $\{w_A^* = 0.1898, w_B^* = 0.3038, \text{ and } w_C^* = 0.5063\}$, and $Ksi^* = 1.5189$, respectively, as shown in Table 4, Table 5, Table 6, Table 7, and Table 8. Then based on the corresponding optimized weight values of different criteria, the graph was plotted (Figure 2) taking criterions on X-axis and optimized weight values on Y-axis, respectively.

Application of SWARA Method for Ranking

Based on the result of BWM method, the obtained optimized weight values for the three environmental criteria were as follows: optimized weight of pattern of flooding due to environment (A) = 0.1898, environmental damages (B) = 0.3038, and environmental losses (C) = 0.5063. Subsequently, the SWARA method was used to calculate the weights and corresponding ranking of the criteria and sub-criteria. The weights of criteria and sub-criteria calculated by using SWARA were as shown in Table 9, Table 10, Table 11, and Table 12. The final weights of sub-criteria were based on the weights of criteria. The assessment scale was based on 5 percent steps in which the experts indicated

Table 4. Selection of criteria

Criteria Number = 3	Criterion 1	Criterion 2	Criterion 3
Names of Criteria	A	B	C

Table 5. Selection of best and worst criteria

Select the Best	Select the Worst
A	C

Table 6. Comparison of best criteria (A) to others

Best to Others	A	B	C
A	8	5	3

Table 7. Comparison of other criteria to worst criteria (C)

Others to the Worst	C
A	2
B	7
C	5

Table 8. Optimized weights of criteria

Criteria	Weights	Ksi*
A	0.1898	1.5189
B	0.3038	
C	0.5063	

Figure 2. Optimized weight distribution of criteria using BWM method

Table 9. Final weights of criteria

Criteria	Comparative Importance of Average Value (s_j)	Coefficient $(k_j = s_j + 1)$	Recalculated Weight $\left(w_j = \frac{x_{j-1}}{k_j}\right)$	Weight $\left(q_j = \frac{w_j}{\sum w_j}\right)$
C_3		1	1	0.890
C_2	0.30	1.30	0.769	0.684
C_1	0.19	1.19	0.646	0.575

Table 10. Final weights of sub-criteria of pattern of flooding due to environment

Sub-Criteria	Comparative Importance of Average Value	Coefficient	Recalculated Weight	Weight	Final Weights
C_{1-1}		1	1	0.390	0.224
C_{1-3}	0.19	1.19	0.840	0.328	0.188
C_{1-2}	0.17	1.17	0.718	0.280	0.161

Table 11. Final weights of sub-criteria of environmental damages

Sub-Criteria	Comparative Importance of Average Value	Coefficient	Recalculated Weight	Weight	Final Weights
C_{2-1}		1	1	0.381	0.260
C_{2-3}	0.15	1.15	0.869	0.332	0.227
C_{2-2}	0.16	1.16	0.749	0.286	0.195

Table 12. Final weights of sub-criteria of environmental losses

Sub-Criteria	Comparative Importance of Average Value	Coefficient	Recalculated Weight	Weight	Final Weights
C_{3-1}		1	1	0.293	0.261
C_{3-2}	0.12	1.12	0.892	0.261	0.232
C_{3-3}	0.11	1.11	0.804	0.235	0.209
C_{3-4}	0.13	1.13	0.711	0.208	0.185

a comparative and value differences on the basis of 5 percent increments: 5%, 10%, 15% and so on. Final numbers in this part were calculated from the arithmetic average of experts' ideas.

Subsequently, weights of criteria and sub-criteria along with relative ranking of both criteria and sub-criteria on the basis of final weight values were summarized as in Table 13.

It was found from the ranking as shown in Table 13 that the most important environmental impacts of flooding in Odisha were: environmental losses, environmental damages, and pattern of flooding due to environment, which were based on the criterions. While, on the basis of ranking on the prioritization of sub-criteria, the environmental impacts of flooding were found as criticality in the survival and restoration of habitats, followed by damages in commercial sectors, environmental pollutions, damages of properties, level of flood, generation of debris due to floods, damages in agricultural sectors, creation of new type of flooding, susceptibility of landslides in the affected areas, and changing of flood outside the affected areas, respectively.

Table 13. Summary of the weights of criteria and sub-criteria

Symbols	Criteria and Sub-Criteria	Final Weights	Ranking of Criteria Based on Final Weights	Ranking of Sub-Criteria Based on Final Weights
C_1	Pattern of flooding due to environment	0.575	3	
C_{1-1}	Level of flood.	0.224		5
C_{1-2}	Changing of flood outside the affected areas.	0.161		10
C_{1-3}	Creation of new type of flooding.	0.188		8
C_2	Environmental damages	0.684	2	
C_{2-1}	Damages in commercial sectors.	0.260		2
C_{2-2}	Damages in agricultural sectors.	0.195		7
C_{2-3}	Damages of properties.	0.227		4
C_3	Environmental losses	0.890	1	
C_{3-1}	Criticality in the survival and restoration of habitats.	0.261		1
C_{3-2}	Environmental pollutions.	0.232		3
C_{3-3}	Generation of debris due to floods.	0.209		6
C_{3-4}	Susceptibility of landslides in the affected areas.	0.185		9

*Final weights of sub-criteria, $C_{3-1} = 0.293 \times 0.890 = 0.2607 = 0.261$, and $C_{2-1} = 0.381 \times 0.684 = 0.2606 = 0.260$

CONCLUSION

The possibilities of option comparison is offered to the users by a well-known introduced approach such as “multiple criteria decision-making (MCDM)” and it also enhances the reliability & capability of decision modeling. Moreover, risks & uncertainties are inevitable substances in the nature, which appears in terms of climatic changes, soil erosions, contamination of water, risk of flooding etc. There occurs a significant impact on the ecosystem by these variables which need to be addressed in decision making processes. The governing systems must have the realization and assessment of the involved risks. There is a requirement of reaction to those risks by initiating efficient strategies. In the present study, multi-criteria decision-making approach has been used for assessing the prioritization of the environmental impacts of flood risks in Odisha (India). The optimized weight values of the environmental criteria affected by flooding were determined by using the BWM method. Subsequently, with the use of SWARA method, it was found that based on the criteria the most important environmental impacts of flooding in Odisha were: environmental losses, environmental damages, and pattern of flooding due to environment. While, on the basis of ranking on the prioritization of sub-criteria, the environmental impacts of flooding were found as criticality in the survival and restoration of habitats, followed by damages in commercial sectors, environmental pollutions, damages of properties, level of flood, generation of debris due to floods, damages in agricultural sectors, creation of new type of flooding, susceptibility of landslides in the affected areas, and changing of flood outside the affected areas, respectively. The results of the present study can be utilized by the governing systems as well as the local authorities as supporting information for an effective sustainable management of flood risks. In the same way, the methodology used in the present study can have applications to other flood prone areas having related & similar attributes.

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