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A Combined GIS-MCDM Approach to Site Selection of Temporary Shelter: A Case Study in Dahab, Egypt

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Abstract

In this study, a model based on the Geographic Information System (GIS) and MCDM method: the Criteria Importance through Inter-Criteria Correlation (CRITIC) based type-2 neutrosophic numbers (T2NN) is used to give researchers and stakeholders a simple and reliable spatial decision-making tool. First the model focuses on determining a group of experts with experience related to the study. The selected group of experts then determines effective objectives and attributes concerning the study and estimates the relative importance of each objective and its related set of attributes using a set of linguistic variables. The T2NN-CRITIC method was used to evaluate the objectives and attribute weights and importance. Second, the spatial attribute layers were integrated with the global weights evaluated using ArcGIS Pro to rank and choose the most suitable site for the study. The proposed model was implemented through a case study to select the most suitable site for temporary shelter in case of floods in Dahab, Egypt. According to the analysis of the current study, 5.16% of the study area (17,550 Km^2) is highly suitable as a site for a temporary shelter in the event of a flood in Dahab, Egypt, (126,570 Km^2) of the study area classified as moderately suitable, (161,850 Km^2) of the study area classified as marginally suitable and, finally (34,080 Km^2) classified as not suitable. Finally, sensitivity analysis has been used to confirm the stability of the model results.

Keywords: Temporary shelter site selection; Disaster management; Geographic information system; CRITIC; T2NN.

1. Introduction

Communities must prepare for disasters, whether they are man-made or natural [1]. A disaster may have a number of damaging consequences depending on its nature, its scope, and its location, especially if it occurs in a developing country [2]. Floods are one of the natural occurrences that, if overlooked, will harm society greatly [3]. More than ever in recent decades, heavy rainfall resulting in floods has impacted Egyptian coastal areas along the Mediterranean Sea and the Red Sea, as well as arid and semi-arid areas such as Upper Egypt (e.g., Luxor, Aswan, and Assiut) and the Sinai Peninsula [4]. The increase in the intensity of rainfall rates can be disastrous, wreaking havoc on lives, infrastructures, resources, and rich cultural heritage [5]. In recent events during the period from March 12 to 14, 2020, Egypt witnessed heavy rains leading to floods that affected more than 20,000 people, according to the International Federation of Red Cross and Red Crescent Societies flood emergency plan of action report, which was published on July 14, 2020. The report clarified that only 2,258 people were assisted out of the 12,950 targets. This increases interest in disaster management activities including the site selection of temporary shelters in events of flood. A temporary shelter is defined as a location that contains a large group of affected people from a disaster and provides them with a temporary roof, meals, clothing, water supplies, healthcare, and security for a limited time [6]. In the case of providing additional resources, existing public buildings such as schools, community centers, and fitness centers can serve as temporary shelters in emergencies [7].

Recent literature has illustrated that the need for temporary shelters has increased in the last decade due to the major role that they play in disaster management [8]–[14]. In the last decade, temporary shelter selection has become a popular topic among scholars due to its significant role in assisting people during and after a disaster [11]. Key objectives and attributes for temporary shelter site selection have been established and categorized differently in previous literature [11], [15], [24]–[33], [16], [33]–[35], [17]–[23]. Objectives and attributes may differ, but basically may include accessibility (distance from roads, distance from river, distance from drainage networks), topography (Elevation, slope), land use (Bare-land, urban, green spaces), environmental considerations (distance to hazard sites, distance to exclusion zone), and safety considerations (altitude, distance to the inundation and evacuation) [30]. In this study, five main objectives and eighteen attributes are selected and used by experts for the evaluation of the presented case study. Since site selection for a temporary shelter is a complex process multi-criteria decision-making (MCDM) methods plays a major role in helping decision-makers in the selection process [36, 37]. The selection of an appropriate site for a temporary shelter is not a simple, straightforward task; it depends on a large set of dependent objectives and attributes [38]. Through the assessment and comparison of the distinguishing characteristics of the alternatives, the MCDM tool offers a suitable choice. Recently, several studies used different MCDM methods to address the problem of site selection for temporary shelters in the event of flood. Some of these methods focused on dealing with uncertainty in decision making process. For instance, a fuzzy The technique for order preference by similarity to ideal solution (TOPSIS) model has been presented to prioritize identified criteria and evaluate the candidate alternatives for emergency shelter [39]. In an intelligent multi-agent system for refugee sitting, a comparative analysis of fuzzy multi-attribute decision-making (MADM) methods has been presented [40]. Additionally, multi-objective decision-making framework integrated goal programming with fuzzy sets and the analytic hierarchy process (AHP) method to prioritize emergency shelter areas [41].

In MCDM problems where geo-referenced information is crucial, Geographic Information System (GIS) is a useful tool. The GIS framework provides the capacity for geo-referenced data computations, management, analysis, and visualization. GIS mostly transforms irrelevant, raw data into a comprehensible form when paired with expert perception. In this study, the best sites for temporary shelters in Dahab, Egypt, were chosen using a GIS and MCDM based methodologies. Thus, a special and coherent framework that can deal with challenging spatial planning issues is made possible by combining the two separate approaches of GIS and MCDM. There are several studies in the literature that use MCDM methods based on GIS to assess suitable locations [38], [42]–[44] but lack of studies in the literature discussed the site selection problem for temporary shelters using an integrated neutrosophic MCDM method in spatial environment. The Criteria Importance through Inter-Criteria Correlation (CRITIC) method was created by Diakoulaki et al. [45] to establish objective weights while simultaneously taking into account the variances and correlations among various criteria. Neutrosophic set theory was developed by Smarandache [46] to address real-world decision-making issues. The fuzzy theory is extended by neutrosophic sets. Neutrosophic numbers have proven to be a reliable area of research for locating incongruent and ambiguous data. Type-1 neutrosophic numbers (T1NN) are represented as a triplet (T, I, F), where each member of the triplet falls inside the range [0, 1]. They are referred to as membership or truth values (T), neutral values (I), and falsehood values (F), respectively. Each neutrosophic component in Type-2 neutrosophic numbers (T2NN) is divided into its truth, indeterminacy, and falsehood subparts in the form of (T_T, T_I, T_F), (I_T, I_I, I_F), and (F_T, F_I, F_F). The T2NN is an advanced form of neutrosophic methodology. It is a useful technique for addressing the incompleteness or imprecision of expert knowledge. The T2NN-CRITIC method developed by [47] is used in this study along with GIS tools to help decision-makers locate the most suitable sites for temporary shelter. The T2NN-CRITIC is used in this study due to its various advantages. First, it is possible to successfully represent how real-world preferences favor experience over expertise and vice versa. To be able to clarify the objective significance of evaluation criteria, it is possible to simultaneously evaluate their differences and correlations. Third, choosing between two built-in factors gives you more freedom to choose your preferred temporary shelter scheme.

Due to the important role of the neutrosophic set in handling uncertainty via considering truth, indeterminacy, and falsity degrees and then simulating the natural decision-making process, the main aim of this research, is to use the T2NN-CRITIC method in a raster GIS environment to select the appropriate site of temporary shelters in Dahab city, located along the south-eastern coast of the Sinai Peninsula, Egypt, to support people in the event of flooding. There is no such literature available on the systematic evaluation of suitable sites of temporary shelters in Dahab, Egypt as far as the authors' knowledge allows.

1.1 Study contributions

Given the previously mentioned points of encouragement and the discussion of the related studies that came before it, the main aims of this study are to:

- To use the T2NN-CRITIC method in a spatial environment for the first time which is divided into four main steps: Step 1: The primary goal of the study is accurately identified, and whether a single or group-based study will be conducted is also decided by the stakeholders. The selected expert/s then determines the appropriate set of objectives and attributes related to the study. Step 2: The spatial data for each attribute is gathered in a GIS environment, and a spatial analysis is then carried out to create a map layer for each attribute. Then, standardization is used to develop standardized attribute values ranging from 0 to 1. Step 3: Experts use the T2NN-CRITIC method to calculate the local and global weights of the objectives and attributes. Step 4: The resulting standardized attribute map layers from Step 2 and the global weights of the main objectives and attributes in Step 3 are then integrated and overlay operation is done to produce a final weight map using GIS tools, which is then classified to rank and select the most suitable sites. The amount of land that is available is divided into four categories based on its suitability: "highly suitable", "moderately suitable", "Marginally Suitable", and "not suitable".
- To apply GIS and MCDM to assist stakeholders locating suitable sites for temporary shelters in Dahab, Egypt in case of floods.
- To perform the sensitivity analysis to assess the persistence of the priority rating.

The innovative aspect of the current study is to combine the GIS tool and the T2NN-CRITIC approach, which have not before been used to find suitable locations for temporary shelters in case of floods in Dahab, Egypt. The study is viable as a result of the numerous suggestions made by area experts, stakeholders, and specialists from various environmental organizations, medical experts, and planning authorities.

1.2 Study structure

The remaining parts of the study are demonstrated to achieve the aims of the study and consist of the following: Section 2 briefly discusses the relative literature. Section 3 shows the fundamental methodology. In Section 4, the actual case study results and discussion for the site selection of temporary shelters in Dahab, Egypt is discussed. A sensitivity analysis is presented in Section 5. Section 6 shows the conclusion and offers suggestions for future work and the study's limitations.

2. Literature review

In the second section of this research, we will review related studies previously published and clarify basic terminologies.

2.1 GIS with MCDM

This section discusses the application of GIS in MCDM methods and its significance in real-life scenarios. The theoretical advancement and recent research on these strategies are shown in Table 1 of this section.

Table 1. Literature concerning different spatial MCDM methods and applications.

Ref.	Year	Spatial MCDM method	Area of application
[48]	2021	AHP + suitability analysis using WLC	Optimal sites for photovoltaic (PV) plants
[49]	2021	integrated index method (IIM), AHP-TOPSIS, and AHP-VIKOR	Landslide susceptibility maps (LSMs)
[50]	2021	AHP with Weighted overlay analysis (WOA)	Potential landfill site selection
[51]	2021	AHP + suitability maps	Railway design with spatial environmental considerations
[52]	2021	AHP and ANP with TOPSIS	Location selection of multi-purpose utility tunnels
[53]	2021	Fuzzy method, AHP with CA-Markov model	Forecasting drought susceptibility
[54]	2021	AHP with GIS	Drought vulnerability assessment and mapping
[55]	2021	TOPSIS with GIS	Sustainable development of territorial units
[56]	2021	F-AHP with GIS	Assessment of solar and wind farm locations
[57]	2022	AHP with GIS	Potential facility locations for park-and-ride facilities along transit corridors

[57]	2022	AHP, VIKOR, TOPSIS, WEIGHTED SUPERPOSITION, PSI, ARAS, OCRA, SMART,	Locate appropriate sites for installing photovoltaic solar farms
[58]	2022	Pythagorean fuzzy AHP, TOPSIS	Pandemic hospital site selection
[59]	2022	AHP-TOPSIS and fuzzy-GIS	Optimal off-shore wind location selection and assessment
[60]	2022	F-AHP, VIKOR and Psychometric-VIKOR	Bike-sharing station site selection
[61]	2022	OWA, MOLA module	Sustainable urban land-use optimization
[62]	2022	GIS-AHP	Site selection for radioactive waste disposal facility
[63]	2022	AHP and TOPSIS	Dam site suitability mapping
[64]	2023	AHP with WOSA	Vulnerability to water erosion and mapping potential control sites
[65]	2023	AHP with Fuzzy-VIKOR	Risk analysis, Identifying the regions with urban vulnerability to potential fire hazards
[66]	2023	AHP-GIS, interval-FAHP-GIS and ANP-GIS	Assess multi-hazard risks such as floods, muddy-water flows and landslides induced by rainstorms
[67]	2023	GIS-SMCA	Prioritize potential areas for TOD
[68]	2023	FGAHP with CRITIC	Site selection for tidal current power plant
[69]	2023	AHP – FMCDM	Traffic management, site selection of car parking
[70]	2023	GIS-AHP	Waste disposal site selection
[71]	2023	GIS-AHP	Sustainable mango production
[72]	2023	GIS-AHP	Potential sites for housing development

2.2 Neutrosophic sets with MCDM

A neutrosophic set, first introduced by Smarandache, is defined by a membership function for truth, a function for indeterminacy, and a function for falsity [73]. Recent articles on these strategies are shown in Table 2.

Table 2. Literature concerning neutrosophic sets with MCDM methods and applications.

Ref.	**Year**	**Neutrosophic used**	**MCDM Method**	**Area of application**
[74]	2021	Bipolar Neutrosophic	TOPSIS, EDAS, WSM, VICKOR	Select optimal wind turbine
[75]	2021	Single valued Neutrosophic set	fuzzy TOPSIS	Supplier selection in the production industry
[76]	2021	Quadripartitioned single-valued neutrosophic set (QSVNS)	QSVNPDOWAA QSVNPDOWGA	Buy a smartphone

[77]	2021	Rough Neutrosophic Set	cross entropy; VIKOR	Planning of remediation for historic pedestrian bridges
[78]	2021	Single valued neutrosophic set theory	BWM, VIKOR	Evaluating the performance of IoT based supply chain
[79]	2021	Single-valued neutrosophic set (SVNS) and the interval-valued neutrosophic set (IVNS)	MCDM method based on proposed SF and AF under IVNSs	Selecting a pre-school for the first time, by the parents of a kindergarten child
[80]	2021	Neutrosophic Soft Set	TOPSIS, WSM, and WPM	The selection of LASER as surgical instrument
[81]	2022	Pythagorean neutrosophic set	PNG-based MCDM method	Best investing option for a company
[82]	2022	m-generalized q-neutrosophic sets (mGqNNs)	CoCoSomGqNN	civil engineering industry
[83]	2022	Neutrosophic sets	a novel neutrosophic MCDM	Fourth party logistics firm assessment
[84]	2022	The neutrosophic hyper-soft set	NHSS-MCDM	Optimal civil engineer for construction firm
[85]	2022	Multi-Valued Multi-Polar Neutrosophic Sets	mPIVNSWA-MCDM	associate professor selection for university
[86]	2023	Single-valued neutrosophic(SVN) -based rough sets	SVN-MCDM	Find best diagnosis for patients
[87]	2023	Trapezoidal Neutrosophic Sets	WASPAS	Risk assessment
[88]	2023	Multi-Valued Multi-Polar Neutrosophic Sets	MCDM based on MVmNSS by using TOPSIS	Optimum fuzzy soft constants
[89]	2023	Triangular neutrosophic sets	COCOSO MCDM	select best strategy in higher education
[90]	2023	Interval Valued Neutrosophic	IVN-AHP and VIKOR based MCDM method	Evaluation of universities based on student perspective
[91]	2023	Single-valued neutrosophic	CRITIC-MULTIMOORA	Warehouse manager selection
[92]	2023	Interval Valued Neutrosophic	AHP	Training assignment
[93]	2023	Single Valued Neutrosophic	TOPSIS	Interval valued neutrosophic

2.3 Site selection for temporary shelters

Site selection for temporary shelters is problematic because it depends on several contradictory criteria. In Table 3, a comparison of several temporary shelter site selection methodologies is covered.

Table 3. Literature of site selection methodologies for temporary shelters.

Ref.	Year	Methodology	Disaster Type
[11]	2021	Suitability assessment	Earthquake
[94]	2021	Multi-criteria decision analysis	Reduce human casualties during airstrike
[95]	2021	NSGA-II algorithm	Landslide
[28]	2021	P-Center Model	Flood
[96]	2022	Rapid visual screening, a geographic information system, and fuzzy analytic hierarchy process	Earthquake
[97]	2022	Index-based model	Earthquake
[98]	2022	Developed geographically weighted regression	Earthquake
[99]	2023	F-AHP	Volcano mount eruption
[42]	2023	Large Group Decision-Making (LGDM)	Earthquakes

3. Methodology

This study uses a neutrosophic-based MCDM method along with GIS tools to locate suitable sites for temporary shelters in Dahab, Egypt. The four steps of this study's framework are depicted in Figure_1. Step1: the essential aim of the study is accurately determined, and the decision of whether to conduct a single or group-based study is also made. After identifying the goal and expert(s), the selected expert(s) uses their knowledge and previous literature concerning the problem to identify appropriate objectives and associated sets of attributes. Step2: all the attributes have their spatial data collected in a GIS environment, and then a spatial analysis is conducted to create a map layer for each attribute. Standardization is then applied to prepare standardized attribute values ranging between 0 and 1 to create a common scale for allowing the map layers to be comparable. Step3: experts use the linguistic terms to evaluate both objectives and attributes. In the case of group decision-making, expert evaluations are aggregated, and then using the T2NN-CRITIC method, the local and global weights of the objectives and attributes are calculated. Step4: the resulting standardized attribute map layers from Step 2 and the global weights of the main objectives and attributes in Step 3 are then integrated using GIS tools. Overlay operation is done to produce a final weight map, which is classified to rank and select the most suitable sites. The amount of land that is available is divided into four categories based on its suitability: "highly suitable", "moderately suitable", "marginally suitable", and "not suitable". Finally, sensitivity analysis is conducted to help stakeholders explore the range of possible outcomes and identify the key drivers and risks of the selected decision.

3.1 Study area

The aim of this study is to locate suitable sites for temporary shelters in Dahab City, Egypt. As illustrated in Figure_ 2.the city of Dahab is approximately 80 kilometers (50 miles) northeast of Sharm el-Sheikh on the southernmost tip of Egypt's Sinai. Dahab is a region that is well-known around the world, particularly for its gorgeous coral reefs, uncommon marine animals, and alluring diving activities. In the south, it is likewise regarded as an emerging and developing metropolis.

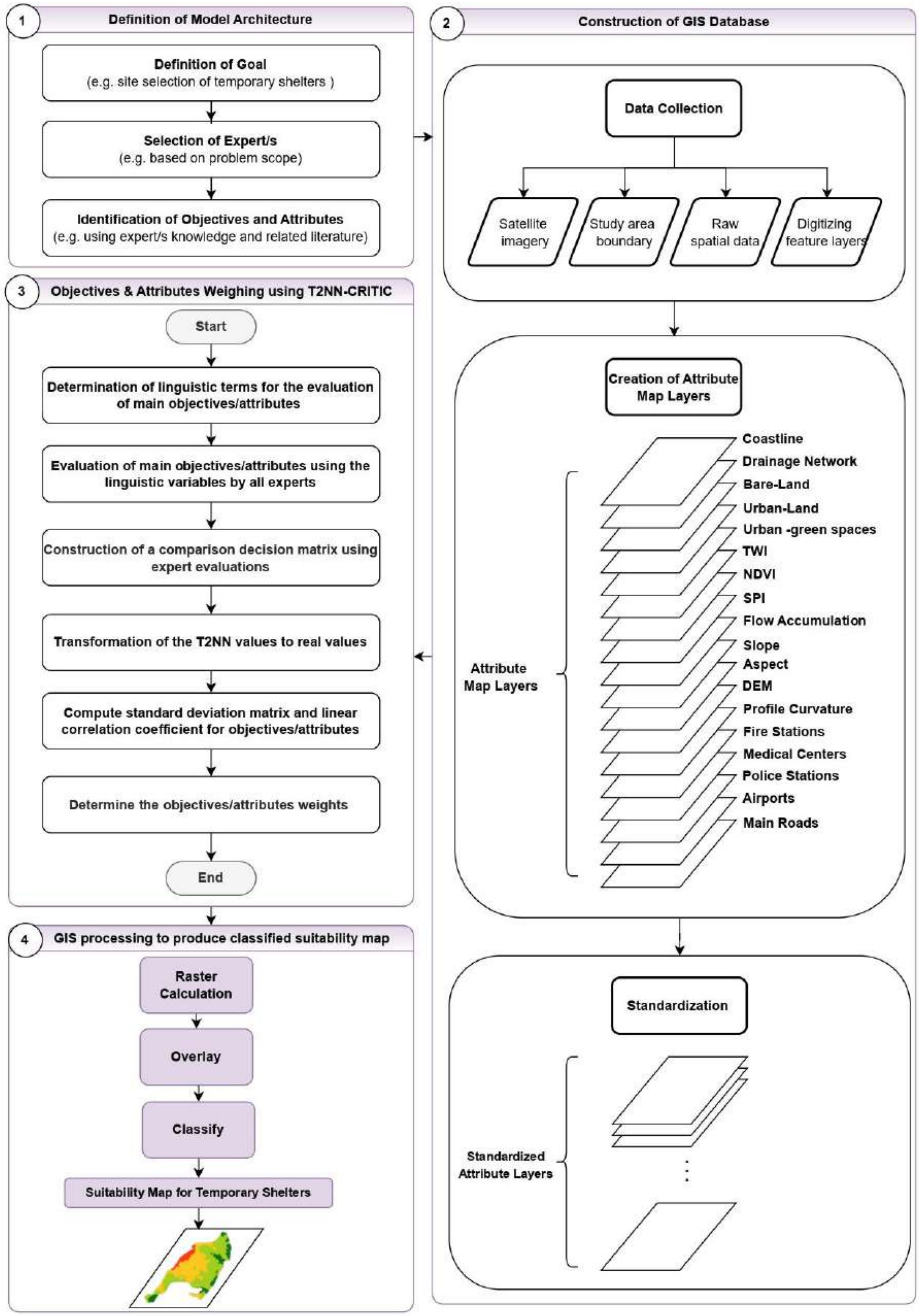

1 Definition of Model Architecture
Definition of Goal
(e.g. site selection of temporary shelters)
Selection of Expert/s
(e.g. based on problem scope)
Identification of Objectives and Attributes
(e.g. using expert/s knowledge and related literature)
2 Construction of GIS Database
Data Collection
Satellite imagery
Study area boundary
Raw spatial data
Digitizing feature layers
Creation of Attribute Map Layers
Attribute Map Layers
Coastline
Drainage Network
Bare-Land
Urban-Land
Urban -green spaces
TWI
NDVI
SPI
Flow Accumulation
Slope
Aspect
DEM
Profile Curvature
Fire Stations
Medical Centers
Police Stations
Airports
Main Roads
Standardization
Standardized Attribute Layers
3 Objectives & Attributes Weighing using T2NN-CRITIC
Start
Determination of linguistic terms for the evaluation of main objectives/attributes
Evaluation of main objectives/attributes using the linguistic variables by all experts
Construction of a comparison decision matrix using expert evaluations
Transformation of the T2NN values to real values
Compute standard deviation matrix and linear correlation coefficient for objectives/attributes
Determine the objectives/attributes weights
End
4 GIS processing to produce classified suitability map
Raster Calculation
Overlay
Classify
Suitability Map for Temporary Shelters

Figure_ 1. **The proposed spatial T2NN-CRITIC framework for suitable site selection of temporary shelters.**

Dahab City is around 1130 km2, and it is situated near the "mouth" of the Wadi Dahab Basin, a sizable hydrographic basin. Wadi Dahab Basin carries a lot of water during the flood seasons, which flows quickly through high, steeply sloping rocky ravines and feeds the outlet of the basin that encircles the city of Dahab [100]. One of the world's most dangerous natural disasters is flooding. They have a large-scale effect, especially in arid/semiarid regions, resulting in thousands of human deaths and massive economic losses. Recent frequent flash floods [101], the geographic location, the semi-arid nature of Dahab City, and its tourism and economic importance are the reasons why it is chosen as the study area [100]. The source of data used in this study was collected and processed from the Egyptian central agency for public mobilization and statistics using ArcGIS Pro 2.6 software by ESRI.

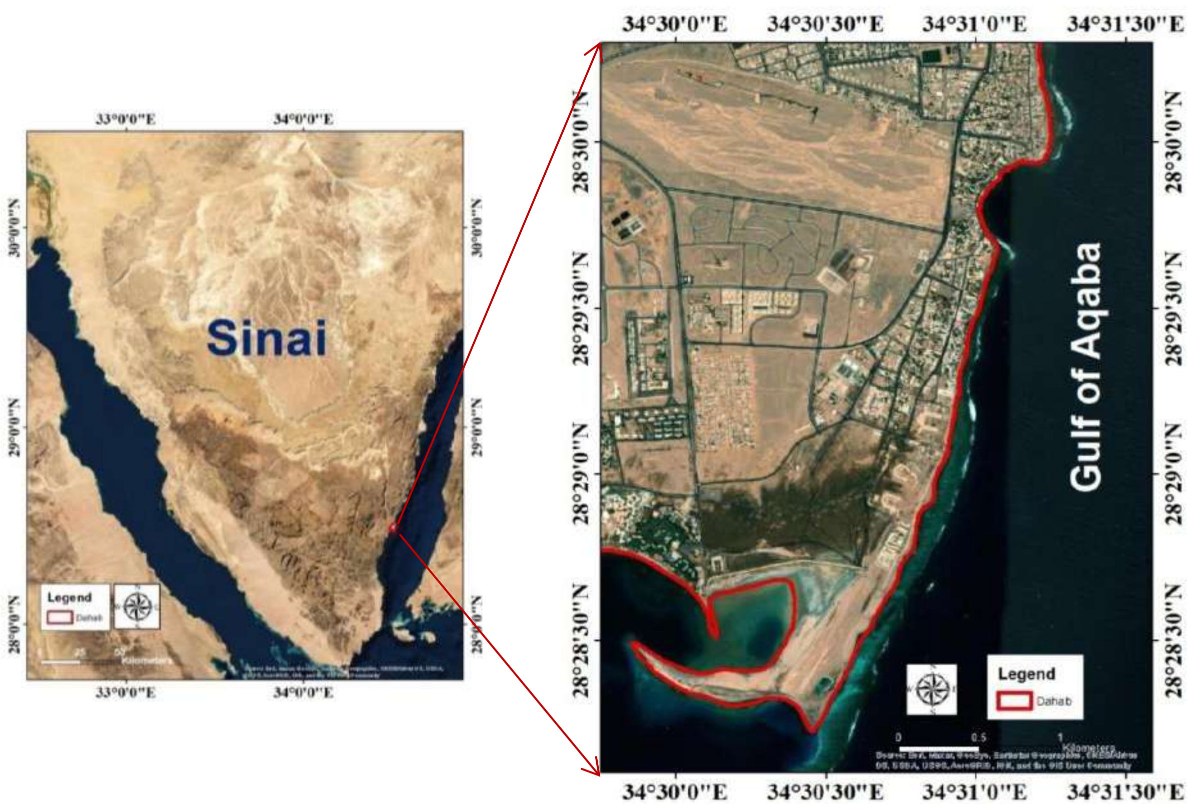


Figure_ 2. Location map of Dahab City (ESRI, 2023).

3.2 Panel of experts

Group decision-making is more appropriate in this study to cover all fields and aspects of the predefined goal. According to the selected study aim to identify suitable sites for temporary shelters in case of floods in Dahab, Egypt a set of experts with high experience and knowledge of the aim were selected as shown in Table 4. Since experts are people who possess both knowledge and experience in a very specialized field, our model treated all experts equally important and did not prioritize them.

Table .4. Details on the participants of the panel of experts.

Expert	Degree	Occupation	Profession	Gender
E_1	PhD	Industry	Civil Engineering	Male
E_2	PhD	Academia	Data Science	Female
E_3	M.Sc.	Industry	Urban Planning	Male
E_4	M.Sc.	Academia	Construction Technology and Management	Male
E_5	M.Sc.	Industry	Medical doctor	Female

3.3 Data Selection, Collection, and Standardization

This study's spatial and attribute data were gathered from secondary data sources. The following sentences go into further depth on the various data sources utilized for the identification of temporary shelter sites in Dahab, Egypt. United States Geological Survey (USGS) generated global digital elevation model (DEM) was used along with ArcGIS Pro 2.6 software tools to generate slope and aspect. The Land-use maps were produced using supervised classification on a Landsat-8 image collected from the United States Geological Survey (USGS) website. Both road and coastline are collected from the Egyptian national authority for remote sensing and space sciences (NARSS). Medical centers, fire stations, airports, and police department's data are collected from the Egyptian Central Agency for Public Mobilization and Statistics (CAPMAS). The remaining data are produced using different analysis tools available in ArcGIS Pro 2.6 software such as raster calculator, curvature, aspect, slope, and flow accumulation. In this study, the highest and lowest values of each attribute map layer were used to determine the standardization of each attribute map layer using a linear scale transformation method. Depending on whether the objective is to be maximized (i.e., a higher value indicates greater desire) or reduced (i.e., a lower value shows more desirability), Eq. (1) for benefit attributes and Eq. (2) for cost attributes, are used respectively. W_{ij} stands for the standardized values of the attribute that were maximized or decreased [102]. Moreover, W_{ij}^{min} is the jth attribute's lowest value, and W_{ij}^{max} is its highest value. Attributes of standardized map layers are shown in Figure_4.

$$W_{ij} = \frac{W_{ij} - W_{ij}^{min}}{W_{ij}^{max} - W_{ij}^{min}} \tag{1}$$

$$W_{ij} = \frac{W_{ij}^{max} - W_{ij}}{W_{ij}^{max} - W_{ij}^{min}} \tag{2}$$

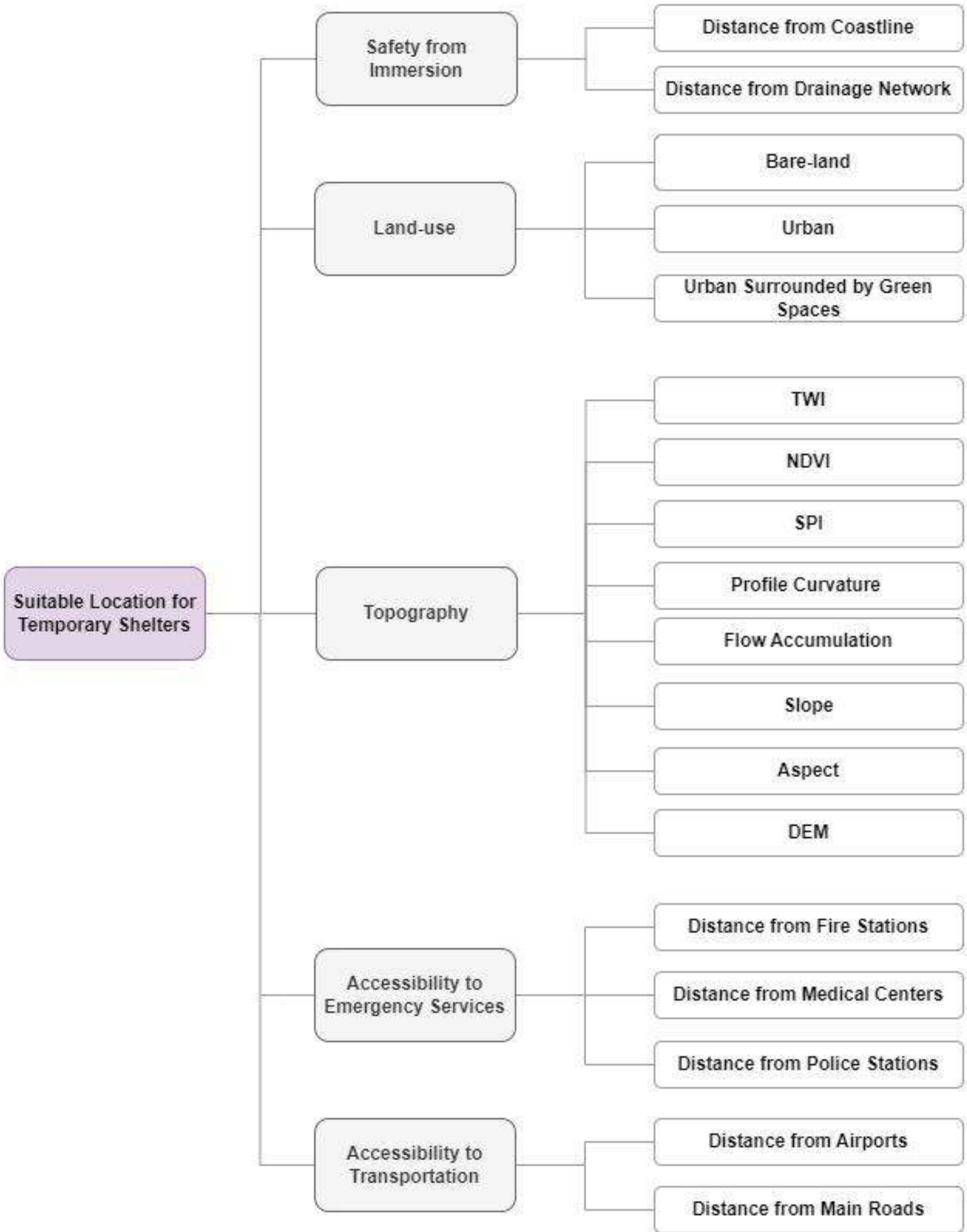


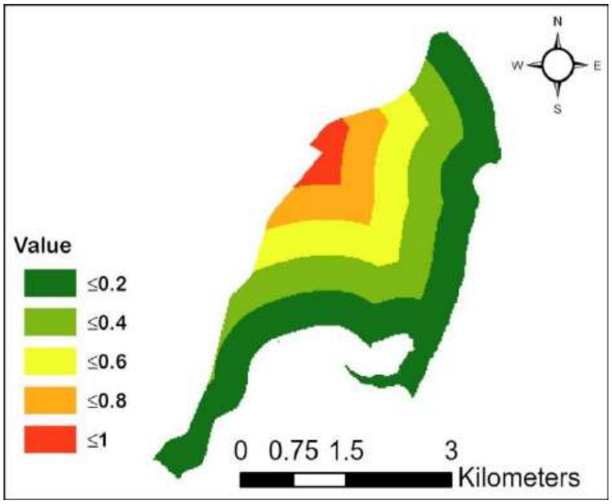
Figure_ 3. The hierarchy structure of objectives and attributes.

Table 5. Details of the evaluation objectives, attributes and spatial analysis used in this study.

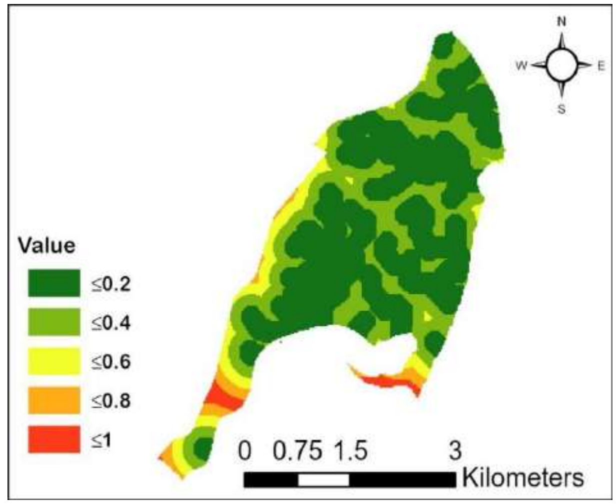
Objectives	Attributes	Description	Spatial Analysis	Standardization (Cost or Benefit)
Safety from immersion (O1)	Distance from coastline (A11)	Euclidean distance from the coastline is a significant element in flood risk; as the distance increases, the probability of flooding decreases Figure_5.1.	Euclidean distance	Minimize (Cost)
	Distance from drainage network (A12)	Together with the sub-main roadways, drainage networks are a typical method for water collection and disposal systems. Flood risk decreases as distance (network distance) from the urban drainage network increases Figure_5.2.	Euclidean distance	Minimize (Cost)
Land-use (O2)	Bare-land (A21)	The general sense described as land that is undeveloped and sits idle in one location without a building Figure_5.3.	Supervised classification + Euclidean distance	Maximize (Benefit)
	Urban-land (A22)	The broad notion shown by villages, buildings that are both commercial and residential, paved surfaces, and roadways [22], [103]–[105] Figure_5.4.		
	Urban surrounded by green spaces (A23)	Any open, public space with vegetation and preservation, such as parks, is referred to as being surrounded by green spaces in an urban area. There is a correlation between the size of these areas and a lower risk of flooding. Some locations have had basic amenities, including restrooms and access to drinking water. This kind of land use is suitable for usage as temporary shelters [106] Figure_5.5.		
Topography (O3)	TWI (A31)	Topographic wetness index (TWI) indicates the propensity for water to migrate downslope due to gravity forces and the spatial distribution of wetness conditions. TWI is crucial for controlling surface runoff since the more wet a region is, the more runoff it will produce [107] Figure_5.6.	Raster Calculator	Minimize (Cost)
	NDVI (A32)	The normalized differential vegetation index is The Landsat 8 satellite image with a resolution of 30 m was used to collect the images from which the NDVI was computed. The ratio of the red (band	Raster Calculator	Maximize (Benefit)

		4) and near infrared (band 5) readings is used to determine NDVI [106] Figure_5.7.		
	SPI (A33)	stream power index (SPI) It serves as a metaphor for the erosional force of water movement [108] Figure_5.8.	Raster Calculator	Minimize (Cost)
	Flow accumulation (A34)	Using the flow direction raster, it was estimated. In this scenario, an increase in flow accumulation should coincide with an increase in flood sensitivity [22] Figure_5.9.	Flow accumulation	Minimize (Cost)
	Slope (A35)	The slope or gradient of a surface determines how steep and incline it is, as well as what percentage of height change there is between any two points on the surface Figure_5.10.	Slope	Maximize (Benefit)
	Aspect (A36)	It affects both the soil's humidity and the direction that flooded water flows [109] 5.11.	Aspect	Minimize (Cost)
	DEM (A37)	With increasing elevation, the flood risk will decrease. Usually, the highest areas are less prone to water login and flood [30] Figure_5.12.	-	Maximize (Benefit)
	Profile Curvature (A38)	Depict the flow convergence, diversion, and slope variation as it changes direction along a contour [110] Figure_5.13.	Profile curvature	Minimize (Cost)
Accessibility to emergency services (O4)	Distance from fire stations (A41)	The distance between the temporary shelter's site and the nearest fire-station. The closer, the better for rapid response 5.14.	Euclidean distance	Maximize (Benefit)
	Distance from medical centers (A42)	The distance between the temporary shelter's site and the nearest hospital, or medical centers. The closer, the better survival rates for injured or citizens require medical care 5.15.	Euclidean distance	Maximize (Benefit)
	Distance from police stations (A43)	The distance between the temporary shelter's site and the nearest police-station. The closer, the better safety and management purposes 5.16.	Euclidean distance	Maximize (Benefit)
Accessibility to transportation (O5)	Distance from airport (A51)	The distance between the temporary shelter's site and the nearest airport, either international or local. The closer to airports, the better for evacuation purposes 5.17.	Euclidean distance	Maximize (Benefit)

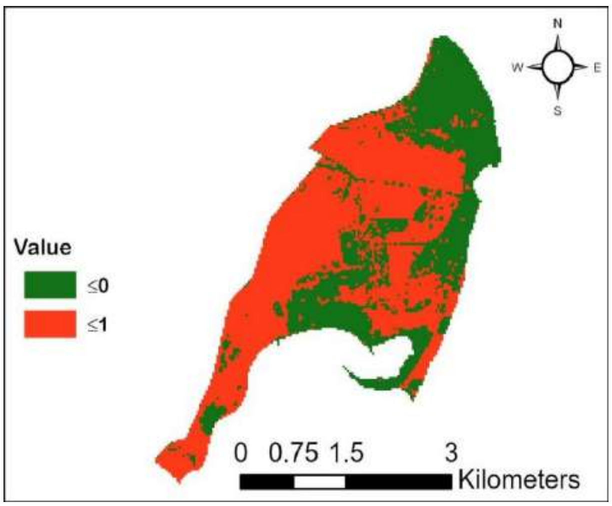
	Distance from main roads (A52)	It is important to keep temporary shelters as close as possible to major roadways in order to reduce arrival times 5.18.	Euclidean distance	Maximize (Benefit)



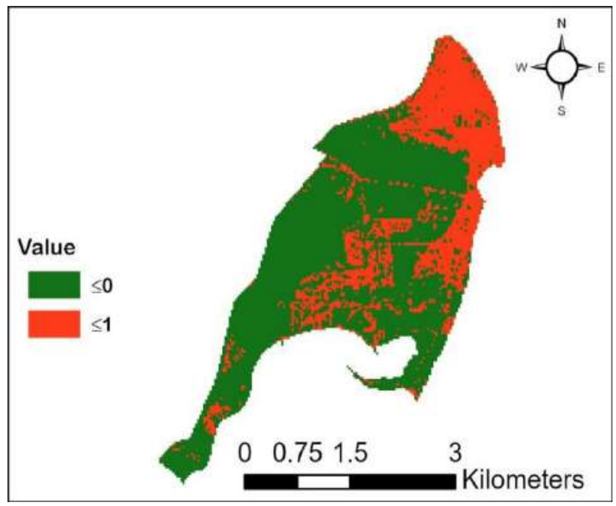
4.1 Distance from coastline.



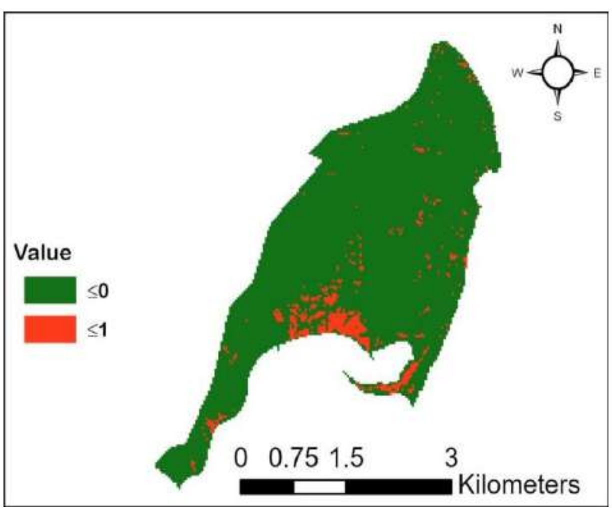
4.2 Distance from drainage network.



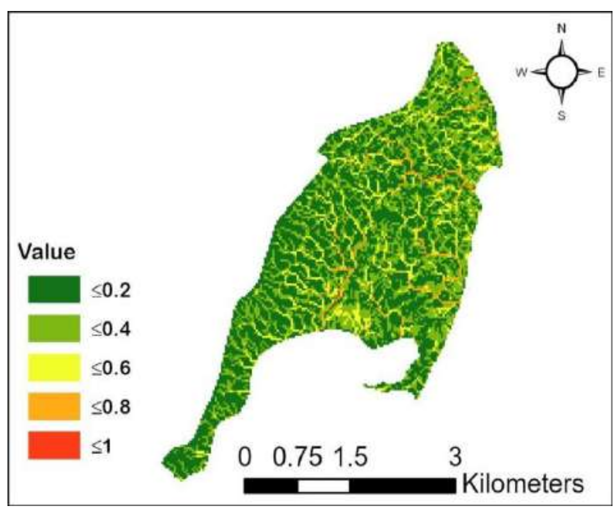
4.3 Bare-land.



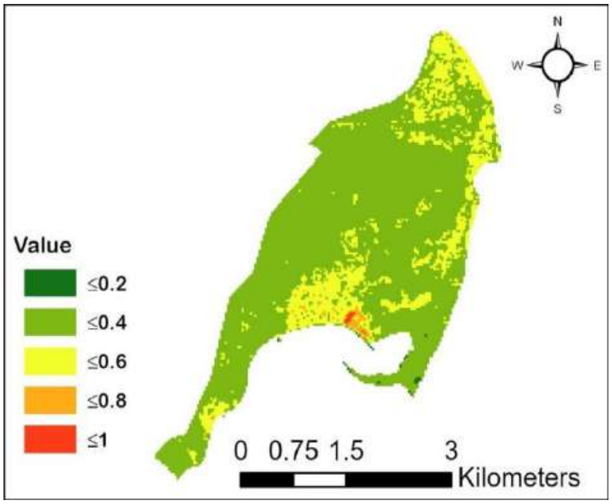
4.4 Urban-land.



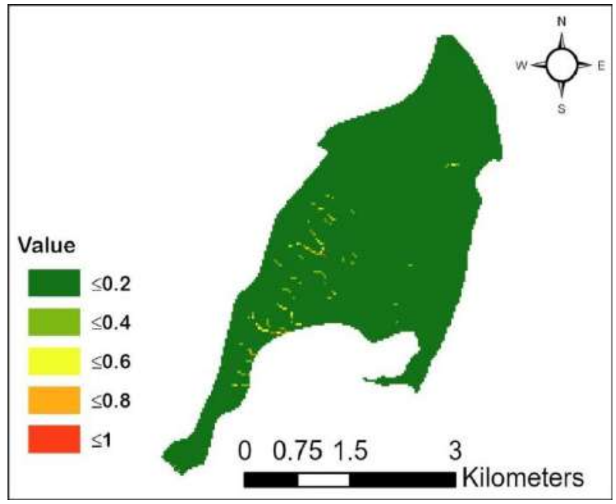
4.5 Urban surrounded by green spaces.



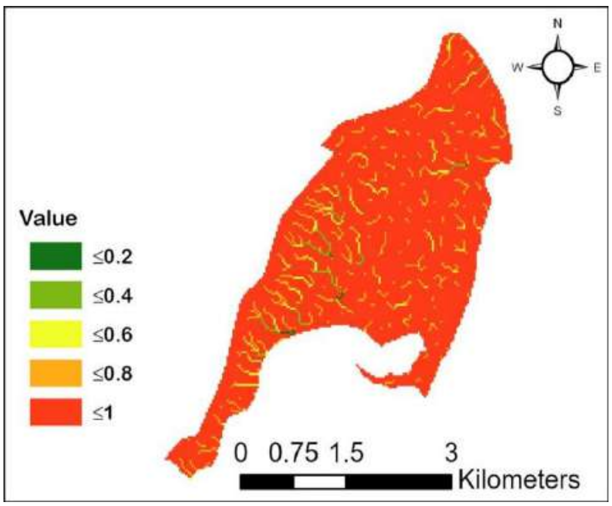
4.6 TWI.



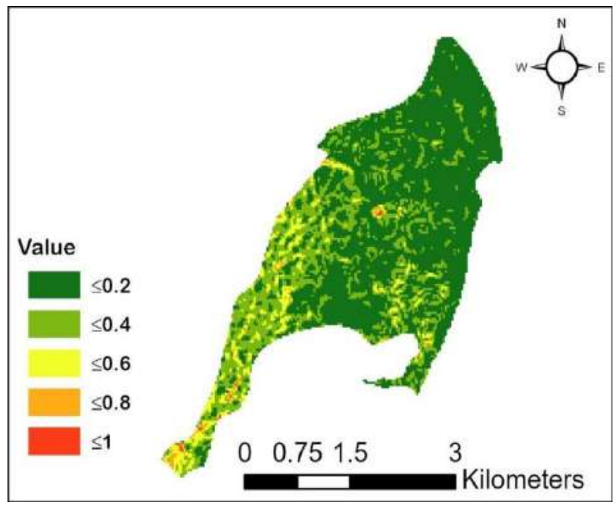
4.7 NDVI.



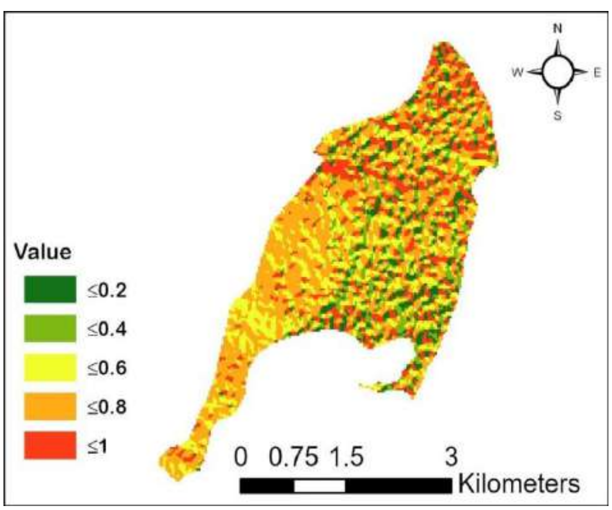
4.8 SPI.



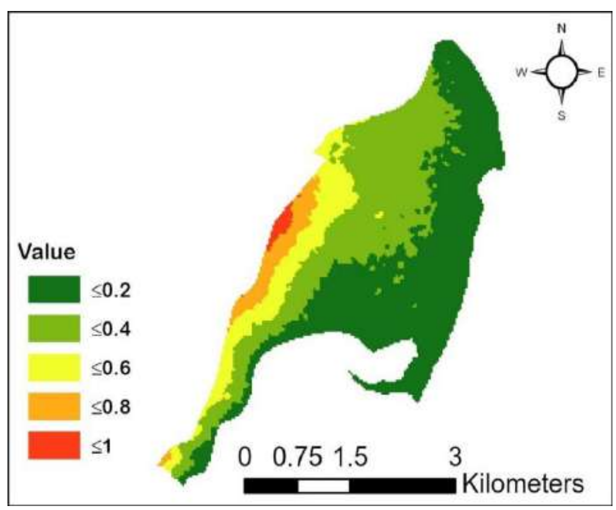
4.9 Flow accumulation.



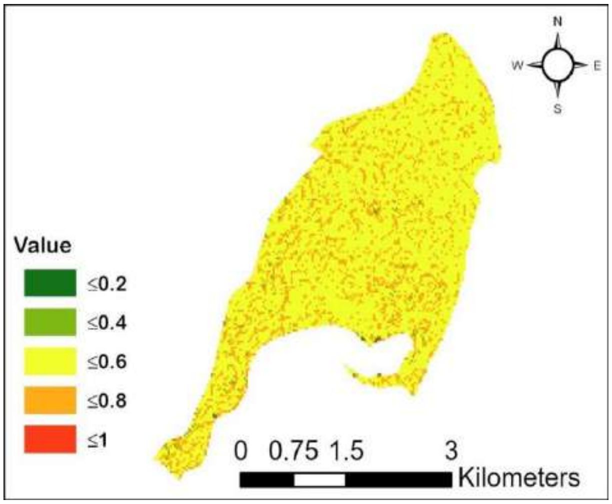
4.10 Slope.



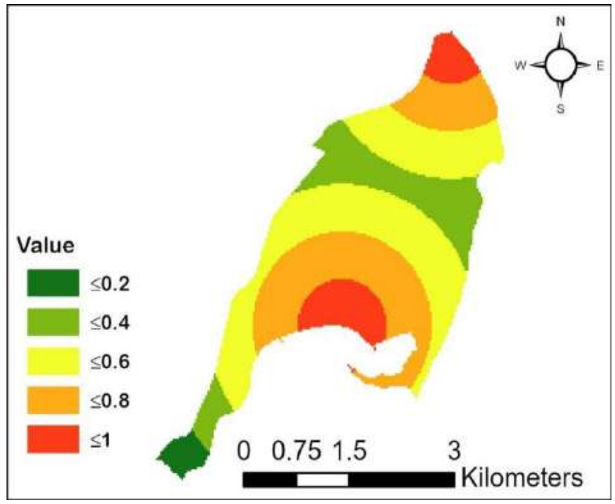
4.11 Aspect.



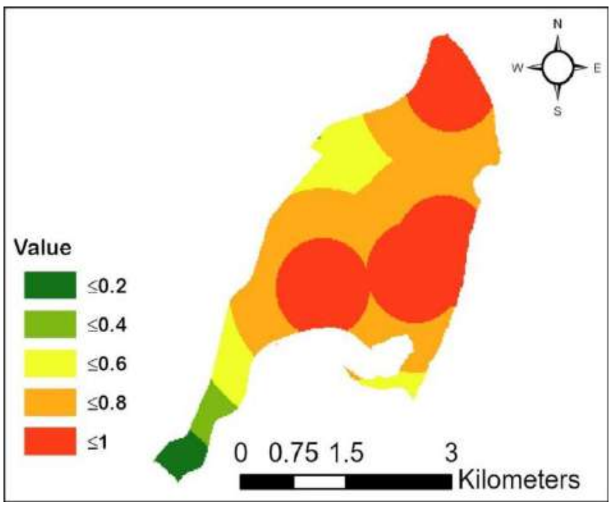
4.12 DEM.



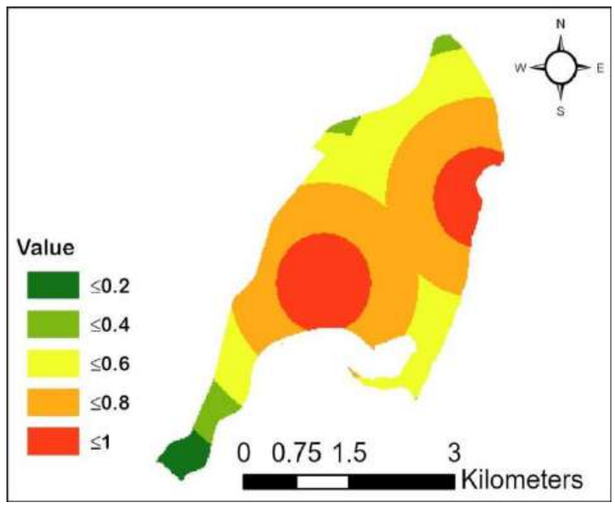
4.13 Profile curvature.



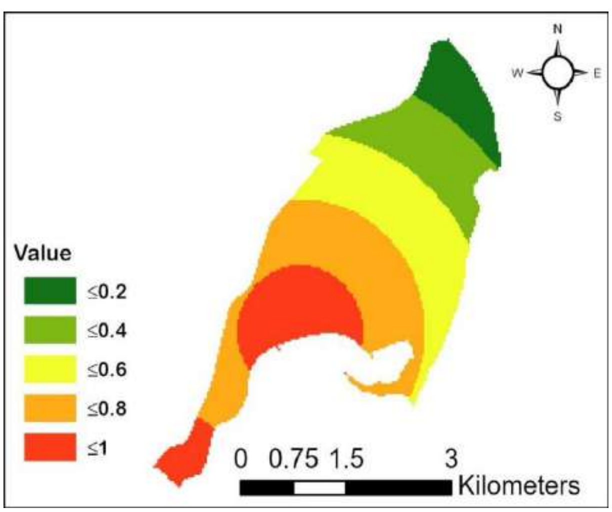
4.14 Distance from fire stations.



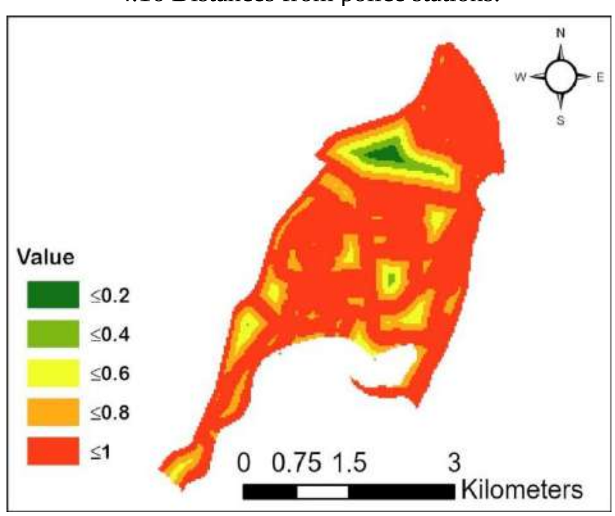
4.15 Distance from medical centers.



4.16 Distances from police stations.



4.17 Distance from airports.



4.18 Distance from main roads.

Figure_ 4. Standardized attribute map layers using ArcGIS Pro 2.6.

3.4 T2NN-CRITIC

The evaluation of potential locations for temporary shelters involves a number of complicated difficulties and contradictory factors, necessitating the use of advanced decision-making techniques. Applying the T2NN-CRITIC method is one of the options that have a strong ability to handle complex and contradictory problems with various criteria [111]. Simic et al. [111] developed the T2NN-CRITIC method in 2022. The following are its benefits: It is possible to effectively depict municipal bodies' actual preferences for favoring experience over competence and vice versa. To clarify the objective significance of evaluation criteria, differences and correlations among them might be taken into account simultaneously. Greater flexibility is provided by two built-in parameters. The process of the T2NN-CRITIC method can be described as follows:

1. Construct a problem hierarchy structure that contains identifying the main objectives and attributes.
2. Consider a set of x attributes is denoted by A = $\{A_1, A_2, \dots, A_x\}$ and a set of m objectives is represented by O = $\{O_1, O_2, \dots, O_m\}$. Let E = $\{E_1, E_2, \dots, E_t\}$ be a set of experts who offered their evaluation report for each attribute A_i(i = 1, 2... x) against their objective O_j(j = 1, 2... m). Let $s = (s_1, s_2, \dots, s_m)^T$ be the vector of weights for objective s_j and $p = (p_1, p_2, \dots, p_t)^T$ be the global weight vector for each attribute p_t(t = 1, 2... t) such that $\sum_{j=1}^{m} s_j$=1, $\sum_{t=1}^{m} p_l$=1.
3. Construct a pairwise comparison matrix for objectives/attributes by all experts to express their preferences for these objectives/attributes. The comparison decision matrix is constructed applying the linguistic terms presented in Table 6 by the experts. The expert must make the rank of objectives and attributes in the form of T2NNs (T_T, T_I, T_F), (I_T, I_I, I_F), and (F_T, F_I, F_F) as an example, if the expert will rank the first objective as the best one and give it an "Extremely high" linguistic variable, then the final evaluation value will take the following form of the T2NNs$\langle(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)\rangle$.

A_1/O_1 ... A_x/O_y

$$\tilde{R} = \begin{array}{c} E_1 \\ \vdots \\ E_t \end{array} \begin{bmatrix} \begin{bmatrix} \left(T_{T_{\tilde{R}_1}(1)}(x/y), T_{I_{\tilde{R}_1}(1)}(x/y), T_{F_{\tilde{R}_1}(1)}(x/y)\right), \\ \left(I_{T_{\tilde{R}_1}(1)}(x/y), I_{I_{R_1}(1)}(x/y), I_{F_{\tilde{R}_1}(1)}(x/y)\right), \\ \left(F_{T_{\tilde{R}_1}(1)}(x/y), F_{I_{\tilde{R}_1}(1)}(x/y), F_{F_{\tilde{R}_1}(1)}(x/y)\right) \end{bmatrix} & \cdots & \begin{bmatrix} \left(T_{T_{\tilde{R}_t}(t)}(x/y), T_{I_{\tilde{R}_t}(t)}(x/y), T_{F_{\tilde{R}_t}(t)}(x/y)\right), \\ \left(I_{T_{\tilde{R}_t}(t)}(x/y), I_{I_{\tilde{R}_t}(t)}(x/y), I_{F_{\tilde{R}_t}(t)}(x/y)\right), \\ \left(F_{T_{\tilde{R}_t}(t)}(x/y), F_{I_{\tilde{R}_t}(t)}(x/y), F_{F_{\tilde{R}_t}(t)}(x/y)\right) \end{bmatrix} \\ \vdots & \cdots & \vdots \\ \begin{bmatrix} \left(T_{T_{\tilde{R}_1}(1)}(x/y), T_{I_{\tilde{R}_1}(1)}(x/y), T_{F_{\tilde{R}_1}(1)}(x/y)\right), \\ \left(I_{T_{\tilde{R}_1}(1)}(x/y), I_{I_{\tilde{R}_1}(1)}(x/y), I_{F_{\tilde{R}_1}(1)}(x/y)\right), \\ \left(F_{T_{\tilde{R}_1}(1)}(x/y), F_{I_{\tilde{R}_1}(1)}(x/y), F_{F_{\tilde{R}_1}(1)}(x/y)\right) \end{bmatrix} & \cdots & \begin{bmatrix} \left(T_{T_{\tilde{R}_t}(t)}(x/y), T_{I_{\tilde{R}_t}(t)}(x/y), T_{F_{\tilde{R}_t}(t)}(x/y)\right), \\ \left(I_{T_{\tilde{R}_t}(t)}(x/y), I_{I_{\tilde{R}_t}(t)}(x/y), I_{F_{\tilde{R}_t}(t)}(x/y)\right), \\ \left(F_{T_{\tilde{R}_t}(t)}(x/y), F_{I_{\tilde{R}_t}(t)}(x/y), F_{F_{\tilde{R}_t}(t)}(x/y)\right) \end{bmatrix} \end{bmatrix}$$

(3)

Table 6. T2NN linguistic terms for weighing objectives, and attributes.

Linguistic terms	**Acronyms**	**Type-2 neutrosophic numbers**
Extremely low	ELW	$\langle(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.80, 0$
Low	LOW	$\langle(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0$
Medium low	MDL	$\langle(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.40, 0$
Medium	MEM	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0$
Medium high	MDH	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0$
High	HHH	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0$
Extremely high	EXH	$\langle(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0$

4. Transform the T2NNs to real values by applying the Eq. (4) [47].

$$S(\tilde{R}) = \frac{1}{12}\left\langle 8 + \left(T_{T_{\tilde{R}}}(x/y) + 2\left(T_{I_{\tilde{R}}}(x/y)\right) + T_{F_{\tilde{R}}}(x/y)\right) - \left(I_{T_{\tilde{R}}}(x/y) + 2\left(I_{I_{\tilde{R}}}(x/y)\right) + I_{F_{R}}(x/y)\right) - \left(F_{T_{\tilde{R}}}(x/y) + 2\left(F_{I_{\tilde{R}}}(x/y)\right) + F_{F_{\tilde{R}}}(x/y)\right)\right\rangle \quad (4)$$

5. Compute the standardized decision matrix for objectives/attributes according to Eq. (5) and Eq. (6).

For advantage objectives/attributes:

$$x/y_{ij}^{*} = \frac{x/y_{ij} - \min(x/y_{ij})}{\max(x/y_{ij}) - \min(x/y_{ij})} \quad i = 1, 2...x \text{ and } j = 1, 2...y. \quad (5)$$

For disadvantage objectives/attributes:

$$x/y_{ij}^{*} = 1 - \frac{x/y_{ij} - \min(x/y_{ij})}{\max(x/y_{ij}) - \min(x/y_{ij})} \quad i = 1, 2...x \text{ and } j = 1, 2...y. \quad (6)$$

6. Computation of the values of the matrix's standard deviation and linear correlation per column. Then, identify the amount of information for the objectives/attributes by applying the Eq. (7).

$$q_j = \sigma_j \cdot \sum_{v=1}^{m}(1 - r_{jv}) \quad (7)$$

where σ_j is the standard deviation of the objectives/attributes, and r_{jv} is the linear correlation coefficient for the objectives/attributes.

7. Determine the objectives/attributes weights by applying the Eq. (8).

$$w_j = \frac{q_j}{\sum_{v=1}^{m} q_v} \tag{8}$$

3.5 GIS processing

According to the proposed framework in Figure_.1. Step number 4 focus on the use of GIS tools to `produce the final suitability map as follow:

1. Integration operation is conducted using Eq. (9) to combine each attribute map layer with its global weight. Let L= $\{l_1, l_2, \dots, l_d\}$ denote set of attribute map layers, p = $(p_1, p_2, \dots, p_t)^T$ be the global weight vector for each attribute, and w = $(w_1, w_2, \dots, w_b)^T$ be the weight vector for integrated attribute map layer w_b:

$$w_b = l_d * p_t \tag{9}$$

where b = 1, …, d.

2. Using GIS tools overlay operation is computed to aggregate all attribute map layers and to calculate final weight by applying the Eq. (10). Let f be the final overlay attribute weight map layer:

$$f = \sum_{b=1}^{d} w_b \tag{10}$$

where b = 1, …, d.

3. Rank sites based on their final overlaid value divided into four categories based on their suitability: "highly suitable", "moderately suitable", "Marginally Suitable", and "not suitable". Stakeholders can then take a suitable decision.

4. To evaluate the longevity of the priority rating and to ascertain the effectiveness of the suggested model, a sensitivity analysis of the results is carried out. Eight different sensitivity scenarios tested the rank of objectives.

4. Results and discussions

In this section, the analysis of the findings applying the framework is presented. This study used GIS tools and T2NN-CRITIC method to assess the suitability of sites for temporary shelters in Dahab, Egypt in case of floods.

The T2NN-CRITIC method was used to develop the weights for the objectives and attributes, which were based on the views expressed in the interviews by the experts. In this regard, the main objectives were assessed by all experts using linguistic variables as presented in Table 7. The chosen set of objectives' correlation coefficients is calculated to determine the evaluation scores for each objective as exhibited in

Table 8. Table A.1-A.12 (Appendix A) presents the evaluation of attributes related to each main objective by all experts and the normalized decision matrix for attributes related to each main objective.

Table 7. Evaluation of main objectives using linguistic variables by all experts

Experts	Main Objectives				
	O_1	O_2	O_3	O_4	O_5
E_1	HHH	MDL	ELW	MEM	LOW
E_2	ELW	MEM	LOW	MDH	MDL
E_3	MDL	MDH	ELW	MEM	MEM
E_4	LOW	MDL	LOW	LOW	LOW
E_5	ELW	MEM	MDH	MEM	MDL

Using the CRITIC method the relative weight of each objective is calculated. Table 8 shows the correlation coefficient of the relationship between the main objectives and final weights. In Figure_5, we can note that "safety from immersion” is the highest objective in weight with a score of 0.332 followed by topography with a score of 0.205.

Table 8. Correlation coefficient of the relationship among the main objectives and final weights.

Obj.	O_1	O_2	O_3	O_4	O_5	q_j	w_j
O_1	1.000	-0.286	-0.431	0.102	-0.357	2.093	0.332
O_2	-0.286	1.000	0.662	0.426	0.993	0.915	0.145
O_3	-0.431	0.662	1.000	0.094	0.687	1.291	0.205
O_4	0.102	0.426	0.094	1.000	0.480	1.070	0.170
O_5	-0.357	0.993	0.687	0.480	1.000	0.938	0.149

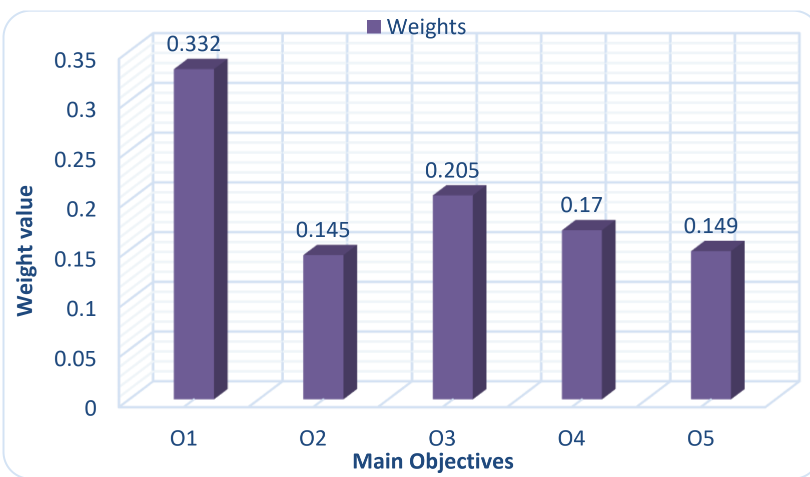


Figure_5. Final weights of main objectives.

Through Tables 9-18, all attributes for each main objective are evaluated by all experts using T2NN linguistic variables. The main objective attributes' correlation coefficients are also calculated to determine the evaluation scores for each attribute.

Table 9. Evaluation of safety from immersion attributes using linguistic variables by all experts.

Experts	Safety from immersion attributes	
	A_{11}	A_{12}
E_1	HHH	MDL
E_2	ELW	MEM
E_3	MDL	MDH
E_4	MDH	MDL
E_5	ELW	ELW

Table 10. Correlation coefficient of the relationship among safety from immersion attributes and final weights.

	A_{11}	A_{12}	q_j	w_j
A_{11}	1.000	0.097	0.415	0.555
A_{12}	0.097	1.000	0.333	0.445

Table 11. Evaluation of land-use attributes using linguistic variables by all experts.

Experts	Land-use attributes		
	A_{21}	A_{22}	A_{23}
E_1	MDL	ELW	MEM
E_2	MEM	EXH	MDH
E_3	MDH	ELW	MEM
E_4	MDL	LOW	HHH
E_5	MEM	MDH	MEM

Table 12. Correlation coefficient of the relationship among land-use attributes and final weights.

	A_{21}	A_{22}	A_{23}	q_j	w_j
A_{21}	1.000	0.578	-0.526	0.808	0.309
A_{22}	0.578	1.000	-0.131	0.641	0.245
A_{23}	-0.526	-0.131	1.000	1.165	0.446

Table 13. Evaluation of topography attributes using linguistic variables by all experts.

Experts	Topography attributes							
	A_{31}	A_{32}	A_{33}	A_{34}	A_{35}	A_{36}	A_{37}	A_{38}
E_1	HHH	MEM	ELW	MDL	MEM	ELW	MDL	LOW
E_2	ELW	MDH	EXH	MEM	MDH	LOW	MEM	MDL
E_3	MDL	MEM	ELW	MDH	MEM	ELW	MDH	MEM
E_4	LOW	LOW	LOW	MDL	HHH	LOW	ELW	LOW
E_5	ELW	MEM	MDH	MEM	MEM	MDH	MEM	MDL

Table 14. Correlation coefficient of the relationship among topography attributes and final weights.

	A_{31}	A_{32}	A_{33}	A_{34}	A_{35}	A_{36}	A_{37}	A_{38}	q_j	w_j
A_{31}	1.000	0.102	-0.696	-0.286	-0.371	-0.431	-0.036	-0.357	3.820	0.192
A_{32}	0.102	1.000	0.638	0.426	-0.594	0.094	0.769	0.480	1.877	0.095
A_{33}	-0.696	0.638	1.000	0.578	-0.131	0.392	0.606	0.664	2.042	0.103
A_{34}	-0.286	0.426	0.578	1.000	-0.526	0.662	0.879	0.993	1.773	0.089

A_{35}	-0.371	-0.594	-0.131	-0.526	1.000	-0.578	-0.784	-0.524	4.609	0.232
A_{36}	-0.431	0.094	0.392	0.662	-0.578	1.000	0.573	0.687	2.420	0.122
A_{37}	-0.036	0.769	0.606	0.879	-0.784	0.573	1.000	0.894	1.537	0.077
A_{38}	-0.357	0.480	0.664	0.993	-0.524	0.687	0.894	1.000	1.778	0.090

Table 15. Evaluation of accessibility to emergency services attributes using linguistic variables by all experts.

Experts	Accessibility to emergency services attributes		
	A_{41}	A_{42}	A_{43}
E_1	MEM	ELW	LOW
E_2	MEM	EXH	MDH
E_3	MDH	HHH	MEM
E_4	MDL	LOW	HHH
E_5	MEM	MDH	EXH

Table 16. Correlation coefficient of the relationship among accessibility to emergency services attributes and final weights.

	A_{41}	A_{42}	A_{43}	q_j	w_j
A_{41}	1.000	0.572	-0.346	0.628	0.337
A_{42}	0.572	1.000	0.370	0.473	0.254
A_{43}	-0.346	0.370	1.000	0.761	0.409

Table 17. Evaluation of accessibility to transportation attributes using linguistic variables by all experts.

Experts	Accessibility to transportation attributes	
	A_{51}	A_{52}
E_1	HHH	MDL
E_2	EXH	MEM
E_3	MDL	ELW
E_4	MDH	MDL
E_5	MEM	ELW

Table 18. Correlation coefficient of the relationship among accessibility to transportation attributes and final weights.

	A_{51}	A_{52}	q_j	w_j
A_{51}	1.000	0.952	0.019	0.472
A_{52}	0.952	1.000	0.021	0.528

In Table.19, A_{11} (i.e., Distance from coastline) is the attribute with the highest weight value of 0.184 followed by A_{12} (i.e., Distance from drainage network) with global weight of 0.148. The attribute with the least weight value is A_{37} (i.e., DEM) with a global weight of 0.016.

Table 19. Global weights of main objectives and their attributes.

Main Objectives	Weights of main objectives	Attributes	Local weight of Attributes	Rank	Global weight of Attributes	Rank global weights
Safety from Immersion O_1	0.332	A_{11}	0.555	1	0.184	1
		A_{12}	0.445	2	0.148	2
Land-use O_2	0.145	A_{21}	0.309	2	0.045	9
		A_{22}	0.245	3	0.036	12
		A_{23}	0.446	1	0.065	6
Topography O_3	0.205	A_{31}	0.192	2	0.039	11
		A_{32}	0.095	5	0.019	15
		A_{33}	0.103	4	0.021	14
		A_{34}	0.089	7	0.018	17
		A_{35}	0.232	1	0.048	8
		A_{36}	0.122	3	0.025	13
		A_{37}	0.077	8	0.016	18
		A_{38}	0.090	6	0.018	16
Accessibility to Emergency Services O_4	0.170	A_{41}	0.337	2	0.057	7
		A_{42}	0.254	3	0.043	10
		A_{43}	0.409	1	0.070	5
Accessibility to Transportation O_5	0.149	A_{51}	0.472	2	0.070	4
		A_{52}	0.528	1	0.079	3

In Figure_6 ArcGIS Pro 2.6 Model Builder all attribute map layers are integrated with each attribute's global weigh and all the integrated attribute map layers are overlaid using an overlay operation.

The final overlaid attribute map layer is classified into the 4 main classes found in Table 20. The final site suitability map is shown in Figure_7 classified into 4 main classes, the first class value ranges between 0 and 25% and represents sites that are not suitable for temporary shelters. The second class ranges between 25% and 50% and represents marginally suitable sites for the selected problem. The third class ranges between 50% and 75% and represents moderately suitable sites. Finally, the fourth class ranges between 75% and 100% and indicates highly desired sites for temporary shelters in case of flood in Dahab, Egypt.

Table 20. Suitability classes.

Category	Value Range	Interpretation	Color Scheme
Not Suitable	0 % - 25%	Absolute ineligibility for concession	
Marginally Suitable	25% - 50%	An inconvenient or somewhat acceptable	
Moderately Suitable	50% - 75%	Suitable in the majority	

Highly Suitable	75% - 100%	Perfectly acceptable for concession	


Weight of Distance from coastline
Distance from coastline
map1
Weight of Distance from main roads
Distance from main roads
map18
Weight of Slpoe
Slope
map10
Weight of Aspect
Aspect
map11
Weight of DEM
DEM
map12
Weight of Profile Curvature
Profile Curvature
map13
Weight of Distance from fire stations
Distance from fire stations
map14
Weight of Distance from police stations
Distance from police stations
map15
Weight of Distance from medical centers
Distance from medical centers
map16
Weight of Distance from airport
Distance from airport
map17
Weight of Distance from drainage network
Distance from drainage network
map2
Weight of Bare - land
Bare -land
map3
Weight of Urban - land
Urban -land
map4
Weight of Urban surrounded by green spaces
Urban surrounded by green spaces
map5
Weight of TWI
TWI
map6
Weight of NDVI
NDVI
map7
Weight of SPI
SPI
map8
Weight of Flow accumulation
Flow accumulation
map9
Overlay
Integerated Outpu
Rescale by Function
Standardized Output
Reclassify
Classified Output

Figure_6. Model Builder for classified suitability map.

The selection of temporary shelters is one of the main issues in the disaster management process. Although Egyptian authorities have been trying to enhance planning in case of floods, still, according to late reports, the effects of floods on people and properties are high and require further action. For these reasons, MCDM methods integrated with GIS tools are considered an important tool for improving the quality and success of the disaster management process, including temporary shelter selection in case of floods. The research community and authorities looking for the best locations for temporary shelters in case of floods will benefit greatly from this study, which is the first of its kind to be conducted in Dahab, Egypt. The study's findings will aid in better disaster planning and management in the future.

This paper seeks to provide an adequate method for locating and classifying suitable sites of temporary shelters in case of floods. The results show that "safety from immersion" is the most important objective, with a weight of 0.332. Second in rank comes the "topography" objective with a score of 0.205. The "Accessibility to emergency services" comes third in rank with a score of 0.17. The least two objectives in ranks are the "Accessibility to transportation" with a score of 0.149 and the "Land-use" objective with a score of 0.145. According to the results of the study 5.16% of the study area (17,550 Km^2) is highly suitable as a site for a temporary shelter in the event of a flood in Dahab, Egypt, (126,570 Km^2) of the study area classified as moderately suitable, (161,850 Km^2) of the study area classified as marginally suitable and, finally (34,080 Km^2) classified as not suitable.

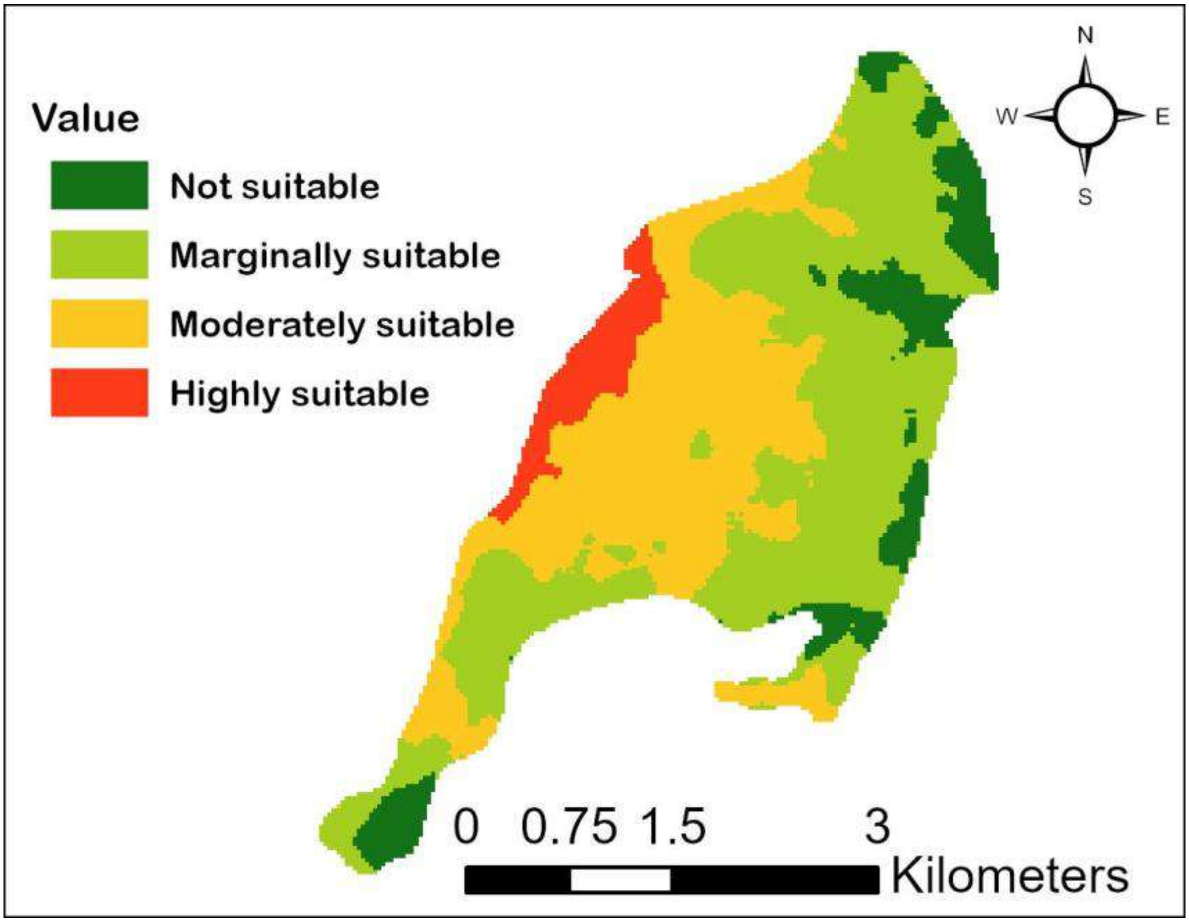


Figure_7. Site suitability for temporary shelters in case of flood in Dahab, Egypt.

5. Sensitivity analysis

In this section, the sensitivity analysis of the results is conducted to assess the persistence of the priority rating and it can be an efficient way to determine the proposed approach's efficiency. The rank of objectives was subjected to a sensitivity analysis. Eight different sensitivity scenarios were evaluated as found in Table 21. The obtained objective weights are taken into account in Scenario 1. Scenario 2 has equal weights for each objective. In Scenario 3, the O_1 objective's weight is raised by 20%. In Scenario 4, the O_2 objective has a 20% higher weight. In Scenario 5, the O_3 objective's weight is raised by 20%. In Scenario 6, the O_4 objective's weight is increased by 20%. In Scenario 7, the O_5 objective has a 20% higher weight. In Scenario 8, the weight of the O_1 and O_3 objectives—which actually have the highest weight of the five objectives used—is increased by 10%. Figure_8 shows the resulting suitability maps for each sensitivity scenario. As seen in the figure, adjusting the ranking of the attributes has a direct influence on the weights of the objectives.

Table 21. Sensitivity analysis objective weight scenarios.

Scenarios	O1	O2	O3	O4	O5
Scenario 1	-	-	-	-	-
Scenario 2	20%	20%	20%	20%	20%
Scenario 3	+20%				
Scenario 4		+20%			
Scenario 5			+20%		
Scenario 6				+20%	
Scenario 7					+20%
Scenario 8	+10%		+10%		

The findings of the sensitivity analysis indicate that scenarios 6 and 7 propose the most change in the percentage of suitability classes for site selection of temporary shelters, as found in figures from Figure_8, the results are either stable or slightly changing throughout weight differences in the remaining scenarios.

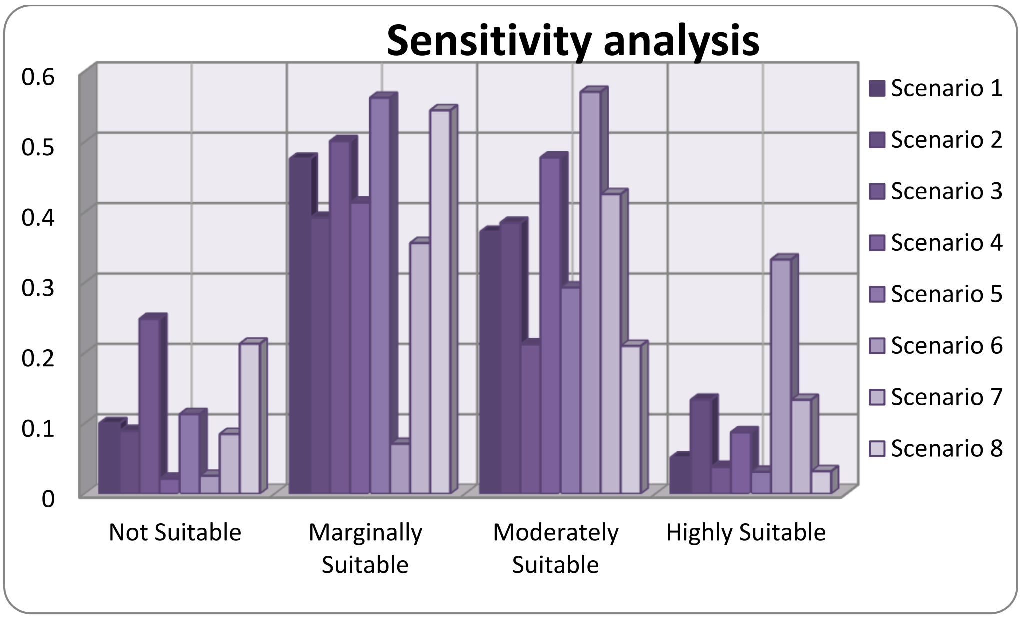
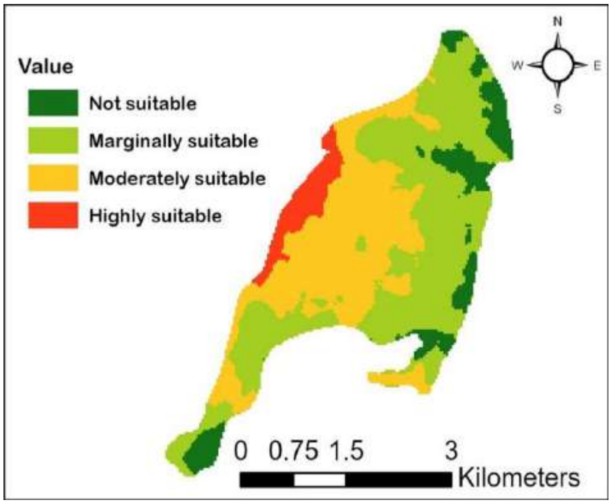
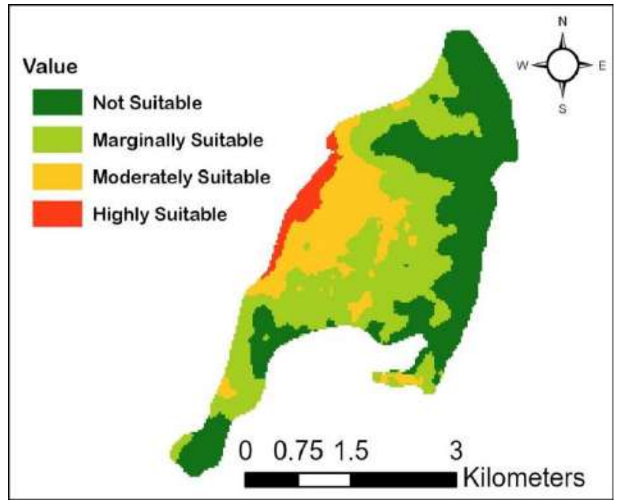


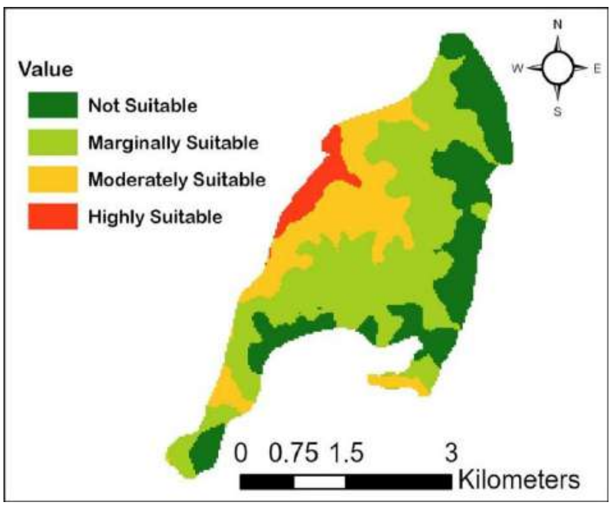
Figure_8. Suitability classes for sensitivity scenarios.



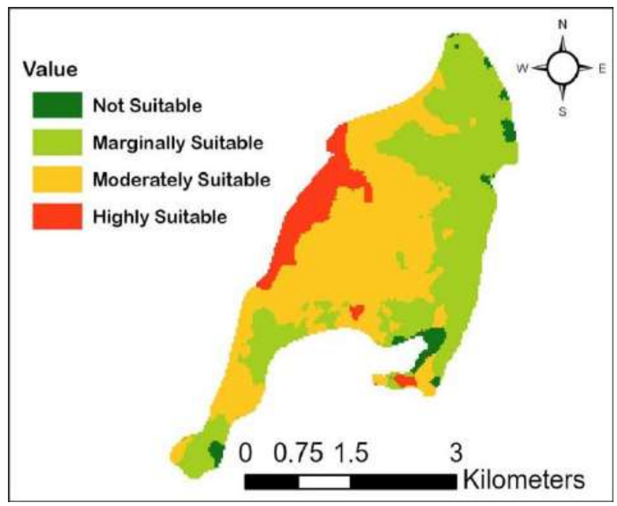
9.1 SA-Scenario 1.



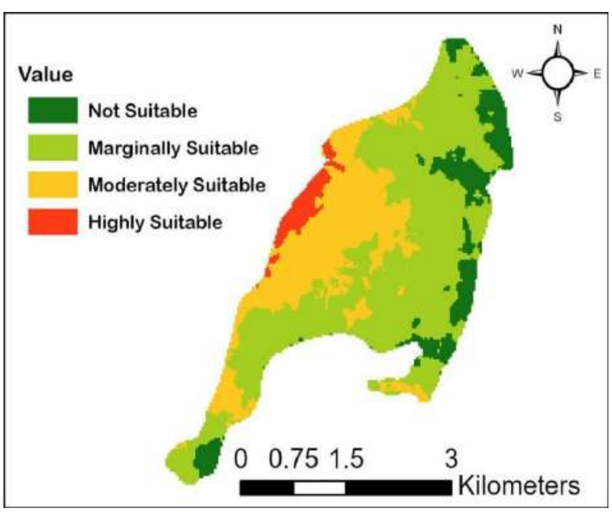
9.2 SA-Scenario 2.



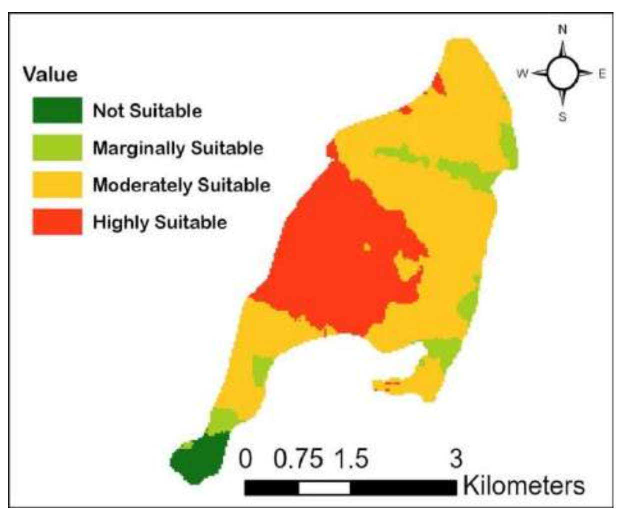
9.3 SA-Scenario 3.



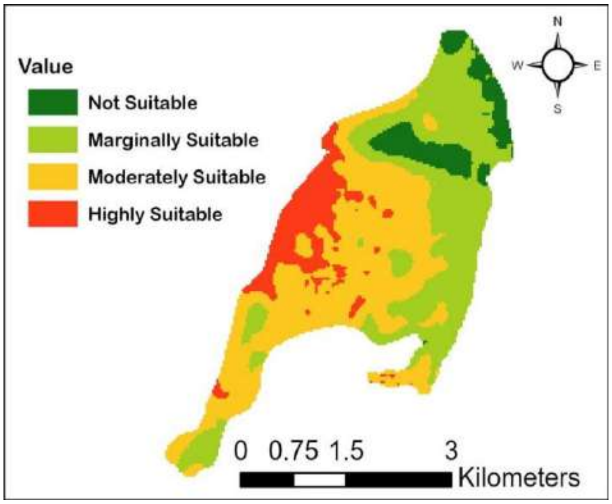
9.4 SA-Scenario 4.



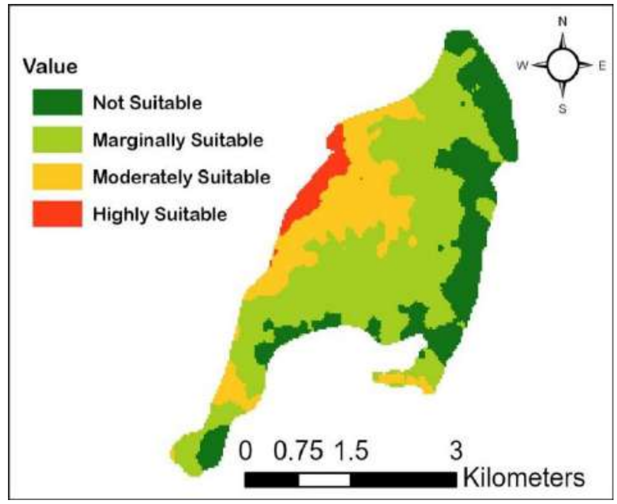
9.5 SA-Scenario 5.



9.6 SA-Scenario 6.



9.7 SA-Scenario 7.



9.8 SA-Scenario 8.

Figure_9. Sensitivity analysis scenarios of main objectives.

6. Conclusions

The study's goal is to identify potential locations in Dahab, Egypt, for emergency flood shelters. The first and most important step in the proper planning and management of disasters includes assessing suitable sites for temporary shelters. For the purpose of finding suitable sites for temporary shelters, a combination of GIS and MCDM techniques has been used, taking into account objectives such as land use, topography, and accessibility to emergency services and safety from immersion. The study includes eighteen significant attributes that were chosen from the literature and considered by the experts. The evaluation attributes were given varying degrees of importance using the T2NN-CRITIC method. The GIS approach created the final four suitability classes of "highly suitable", "moderately suitable", "marginally suitable", and "not suitable" by preparing a spatial dimension of the decision objectives and elaborating on them. The study reveals that 5.16% of the study area (17,550 Km^2) is highly suitable as a site for a temporary shelter in the event of a flood in Dahab, Egypt, (126,570 Km^2) of the study area is classified as moderately suitable, (161,850 Km^2) of the study area classified as marginally suitable and, finally (34,080 Km^2) classified as not suitable. The five objectives' sensitivity analyses were completed. There were eight different sensitivity scenarios tested. The first scenario objective weights each objective is equally weighted. In Scenario 2 the weight of the O_1 objective is increased by 20% in Scenario 3. The O_2 objective has a 20% higher weight in Scenario 4. The weight of the O_3 objective is increased by 20% in Scenario 5.The O_4 objective's weight is raised by 20% in Scenario 6. The O_5 objective has a 20% higher weight in Scenario 7. The weight of the O_1 and O_3 objectives, which are actually the two with the highest weights out of the five used, is increased by 10% in Scenario 8. Sensitivity analysis concluded that the output of suitable land is sensitive to changes in the weights of the objectives. The study limitation centered about a certain amount of the study was done using data that is freely accessible from various trustworthy sources, but these data are less updated and accurate than privately accessible data. With the help of the ground measurement data, the outcomes can be further enhanced. However, by combining the developed methodology with MCDM ideas, open-source GIS tools, and presumptions, the study is making it easier to replicate improved results. In the future, we plan to use different MCDM methods to solve the problem to compare the accuracy of the results also use various MCDM methods with GIS to solve other disaster management problems to facilitate the complex dependencies between objectives and attributes.

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Appendix A

Table A.1. Evaluation of main objectives using T2NNs by all experts.

Experts	Main objectives	
	O_1	O_2
E_1	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.
E_2	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.
E_3	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.
E_4	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.
E_5	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.
Experts	O_3	O_4
E_1	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.
E_2	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.
E_3	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.
E_4	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.
E_5	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.
Experts	O_5	
E_1	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)⟩	
E_2	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.40, 0.60)⟩	
E_3	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0.45)⟩	
E_4	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)⟩	
E_5	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.40, 0.60)⟩	

Table A.2. Normalized decision matrix based on main objectives by all experts.

Experts	Main objectives				
	O_1	O_2	O_3	O_4	O_5
E_1	1.000	0.000	0.000	0.730	0.000
E_2	0.000	0.468	0.149	1.000	0.562
E_3	0.383	1.000	0.717	0.668	1.000
E_4	0.122	0.000	0.149	0.000	0.000
E_5	0.000	0.468	1.000	0.668	0.562
Standard deviation	0.421	0.415	0.432	0.369	0.427

Table A.3. Evaluation of safety from immersion attributes using T2NNs by all experts.

Experts	safety from immersion attributes	
	A_{11}	A_{12}
E_1	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.
E_2	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.
E_3	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.
E_4	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.
E_5	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.

Table A.4. Normalized decision matrix based on safety from immersion attributes by all experts.

Experts	Safety from immersion attributes	
	A_{11}	A_{12}
E_1	1.000	0.468
E_2	0.000	0.717
E_3	0.383	1.000
E_4	0.817	0.468
E_5	0.000	0.000
Standard deviation	0.460	0.369

Table A.5. Evaluation of land-use attribute using T2NNs by all experts.

Experts	Land-use attributes	
	A_{21}	A_{22}
E_1	$\langle(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.$	$\langle(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.$
E_2	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.$	$\langle(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.$
E_3	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.$	$\langle(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.$
E_4	$\langle(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.$	$\langle(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.$
E_5	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.$	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.$

Experts	A_{23}
E_1	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0.45)\rangle$
E_2	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)\rangle$
E_3	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0.45)\rangle$
E_4	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)\rangle$
E_5	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0.45)\rangle$

Table A.6. Normalized decision matrix based on land-use attributes by all experts.

Experts	Land-use attributes		
	A_{21}	A_{22}	A_{23}
E_1	0.000	0.000	0.105
E_2	0.468	1.000	0.559
E_3	1.000	0.488	0.000
E_4	0.000	0.101	1.000
E_5	0.468	0.680	0.000
Standard deviation	0.415	0.413	0.439

Table A.7. Evaluation of topography attributes using T2NNs by all experts.

Experts	Topography attributes	
	A_{31}	A_{32}
E_1	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.$	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.$
E_2	$\langle(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.$	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.$
E_3	$\langle(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.$	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.$
E_4	$\langle(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.$	$\langle(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.$
E_5	$\langle(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.$	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.$

Experts	A_{33}	A_{34}
E_1	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.
E_2	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.
E_3	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.
E_4	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.
E_5	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.
Experts	A_{35}	A_{36}
E_1	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.
E_2	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.
E_3	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.
E_4	⟨(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.
E_5	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.
Experts	A_{37}	A_{38}
E_1	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.
E_2	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.
E_3	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.
E_4	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.
E_5	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.

Table A.8. Normalized decision matrix based on topography attributes by all experts.

Experts	Topography attributes							
	A_{31}	A_{32}	A_{33}	A_{34}	A_{35}	A_{36}	A_{37}	A_{38}
E_1	1.000	0.730	0.000	0.000	0.105	0.000	0.468	0.000
E_2	0.000	1.000	1.000	0.468	0.559	0.149	0.717	0.562
E_3	0.383	0.668	0.488	1.000	0.000	0.717	1.000	1.000
E_4	0.122	0.000	0.101	0.000	1.000	0.149	0.000	0.000
E_5	0.000	0.668	0.680	0.468	0.000	1.000	0.717	0.562
Standard deviation	0.421	0.369	0.413	0.415	0.439	0.432	0.375	0.427

Table A.9. Evaluation of accessibility to emergency services attributes using T2NNs by all experts.

Experts	Accessibility to emergency services attributes	
	A_{41}	C_{42}
E_1	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.	⟨(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.
E_2	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.	⟨(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.
E_3	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.	⟨(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.
E_4	⟨(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.
E_5	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.
Experts	A_{43}	
E_1	⟨(0.35, 0.35, 0.10); (0.50, 0.75, 0.80); (0.50, 0.75, 0.65)⟩	
E_2	⟨(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.25, 0.15)⟩	
E_3	⟨(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.30, 0.45)⟩	

E_4	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.15, 0.15)\rangle$
E_5	$\langle(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.05, 0.05)\rangle$

Table A.10. Normalized decision matrix based on accessibility to emergency services attributes by all experts.

Experts	Accessibility to emergency services attributes		
	A_{41}	A_{42}	A_{43}
E_1	0.468	0.000	0.000
E_2	0.468	1.000	0.644
E_3	1.000	0.832	0.430
E_4	0.000	0.101	0.813
E_5	0.468	0.680	1.000
Standard deviation	0.354	0.447	0.385

Table A.11. Evaluation of accessibility to transportation attributes using T2NNs by all experts.

Experts	Accessibility to transportation attributes	
	A_{51}	A_{52}
E_1	$\langle(0.70, 0.75, 0.80); (0.15, 0.15, 0.25); (0.10, 0.$	$\langle(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.$
E_2	$\langle(0.95, 0.90, 0.95); (0.10, 0.10, 0.05); (0.05, 0.$	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.$
E_3	$\langle(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.$	$\langle(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.$
E_4	$\langle(0.60, 0.45, 0.50); (0.20, 0.15, 0.25); (0.10, 0.$	$\langle(0.40, 0.30, 0.35); (0.50, 0.45, 0.60); (0.45, 0.$
E_5	$\langle(0.50, 0.45, 0.50); (0.40, 0.35, 0.50); (0.35, 0.$	$\langle(0.20, 0.20, 0.10); (0.65, 0.80, 0.85); (0.45, 0.$

Table A.12. Normalized decision matrix based on accessibility to transportation attributes by all experts.

Experts	Accessibility to transportation attributes	
	A_{51}	A_{52}
E_1	0.754	0.653
E_2	1.000	1.000
E_3	0.000	0.000
E_4	0.531	0.653
E_5	0.248	0.000
Standard deviation	0.396	0.444

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