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Research Article

URBAN FLOOD RESILIENCE: A MULTI-CRITERIA EVALUATION USING AHP AND TOPSIS

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Abstract
Floods are increasingly recognized as one of the most destructive natural disasters, driven by urban expansion, climate change, and unregulated development. This is particularly true in developing countries, where rapid urbanization has increased impervious surfaces, amplifying flood risks in urban areas. This study focuses on Albania, evaluating urban resilience against floods through the lens of water-related disaster data. Using a multi-criteria decision analysis (MCDA) approach, specifically the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), the research assesses flood vulnerability and resilience in rapidly urbanizing regions. Integrating AHP and TOPSIS with mixed methods introduces a novel approach, offering a comprehensive evaluation framework for flood risk management. The findings highlight critical vulnerabilities and suggest that targeted urban planning and disaster mitigation efforts can enhance resilience. Future research could incorporate climate projections and granular urban data, supporting a more adaptive flood management strategy.

Keywords: AHP, Assessment, Decision Analysis, Floods, Multi-Criteria, Topsis

INTRODUCTION

Natural disasters, such as earthquakes, floods, landslides, and hurricanes, are often perceived as uncontrollable events governed by nature. However, human activities significantly contribute to the frequency, severity, and impact of these disasters (Vargas-Hernandez et al., 2023). Several major contributors to natural disasters are poor land management, particularly in urban and agricultural areas, unplanned urban development, deforestation, inappropriate agricultural practices that degrade the land's natural capacity to absorb water, regulate temperatures, and protect against landslides, and the extraction of natural resources, including minerals, metals, and groundwater, have a direct effect on the stability of the earth's surface, (Kusuma, 2020; Suwarni, 2021; Kosova et al., 2023).

Urbanization, driven by socio-economic growth, has introduced profound challenges in managing the impacts of climate change, particularly natural disasters like floods. These water-related disasters (WRDs) account for 90% of all natural disasters, with devastating effects on urban areas, causing significant infrastructure damage, economic loss, and human displacement (EMDAT, 2019). These events, especially floods, have profound impacts on urban areas, causing extensive damage to homes, businesses, and infrastructure, and posing significant risks to the socio-economic fabric of cities (Abdullah et al., 2021; Yohanie et al., 2023; Fitriana & Waswa, 2024; Zakiyah, Boonma, & Collado, 2024).

Developing countries are more at risk and more vulnerable due to weak infrastructure, weak financial means for investment and improvement, the rapid and uncontrolled development of cities, informal constructions in cities and villages that have resulted in the destruction of infrastructure. protective against disasters and floods (Herdiani, 2021; Vikaliana, 2022). The development and mass tourism in developed countries, although it contributes to economic growth, also brings some obvious negative effects that affect the environment, society and economy such as environmental degradation, overpopulation and pressure transport infrastructure, health systems and public services of developed cities (Kosova & Sinaj, 2021; Purnomo, 2024).

The primary cause of floods in urban areas is often sudden and heavy precipitation, particularly in low-lying regions (Abootalebi et al., 2022). These floods not only disrupt daily life but also lead to long-term economic, environmental, and societal damage. The economic costs are staggering, with significant losses in infrastructure, property, and economic activity. Socially, floods cause displacement, loss of life, and adverse effects on physical and mental health. Therefore, the development of urban resilience strategies is critical in addressing these challenges (Julianto & Agnanditiya Carnarez, 2021).

The study of natural phenomena and disasters using models is an interdisciplinary approach that combines mathematical, economic, and scientific methodologies to understand, predict, and manage risks associated with these events. Mathematical models provide a framework for simulating and analyzing complex natural processes. These models can predict the occurrence, impact, and progression of natural disasters such as floods, earthquakes, and hurricanes. Economic models are created to assess the financial impacts of disasters and help guide decision-making for mitigation, recovery, and insurance purposes and to quantify the costs associated with damages and inform resource allocation for disaster preparedness and response (Kapçiu et al., 2024).

In light of these issues, this research is urgently needed to address the gaps in current urban planning frameworks. While existing models consider some aspects of resilience, they often fail to comprehensively integrate socio-economic, environmental, and infrastructural factors into a single framework (Wątróbski et al., 2019). The research aims to develop an adaptable, multi-disciplinary framework that cities can implement to increase their resilience to WRDs. The proposed research focuses on identifying vulnerable urban areas, developing a framework that integrates multiple dimensions of resilience, and ranking the alternatives (urban areas, regions, cities) from best to worst performance regarding the urban resilience. By doing so, it will contribute to the existing body of knowledge on urban resilience and provide practical solutions to reduce the impacts of WRDs. The usefulness of this research extends to policymakers, urban planners, and local governments, offering them tools to mitigate the social, economic, and environmental costs of floods (Ahmad, 2024).

This study addresses the need of developing an adaptable, multi-disciplinary framework to assess urban resilience to floods, particularly in Albania. Using MCDA techniques, specifically AHP and TOPSIS, this research assesses flood vulnerabilities, helping urban planners and policymakers prioritize risk mitigation efforts (Ghaleno et al., 2020). This research is particularly relevant in the context of global efforts to promote sustainable urban development, as outlined by international organizations such as the United Nations. It aligns with the objectives of the UN's Sustainable Development Goals (SDGs), which focuses on making cities inclusive, safe, resilient, and sustainable (UNISDR, 2009). By developing solutions that address the specific challenges posed by WRDs, this research will play a pivotal role in advancing global efforts toward urban resilience and sustainability (Table 1).

Table 1. The number of flood and drought events, (2000–2021).

Years	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Flood	184	156	136	148	137	161	159	126	128	196	201	223
Drought	21	16	18	9	20	26	14	9	16	16	9	15

The majority of contemporary scientific investigations and written works concerning urban resilience are based on the seminal contributions of Crawford Stanley Holling, a theoretical ecologist who was the first to present the notion of "resilience" in its contemporary setting. The phrase first appeared in early 19th-century literature and described a wood's ability to support unexpected, large loads without fracturing (Holling, 1973).

One of the foundational models in assessing urban resilience is Cutter's Disaster Resilience of Place (DROP) framework model, which outlines six key indicators of urban resilience: ecological, social, economic, institutional, infrastructural, and community resilience (Cutter et al., 2008). This conceptual framework offers a holistic perspective on urban resilience, and it serves as a reference point for the development of the resilience framework in this research. Cutter's Disaster Resilience of Place (DROP) model is a well-known conceptual framework for assessing urban resilience. Ecological, social, economic, institutional, infrastructural, and community are the six primary indicators of urban resilience that are identified and examined.

Sharifi & Yamagata, (2016), after evaluating 29 resilience frameworks, identified key components designed to address environmental challenges such as river floods, droughts, and forest fires. These frameworks were adapted to the specific features of the areas under study, and the same tailored approach will be employed in this research to ensure relevance to the urban areas selected Taking into account the features of the subjects under study, these frameworks were especially created to solve environmental issues such as river floods, droughts, and summer forest fires.

Suárez et al., (2016) developed a method to classify and assess urban resilience across Spain's provincial capitals. The criteria were customized to the characteristics of each city and aligned with the available data and resilience goals. This customizable approach will inform the adaptation of the MCDA tools for the cities under investigation in this research. Suárez created a methodology for classifying and assessing urban resilience in Spain's provincial capitals. Resilience criteria were customized to the characteristics of the cities under evaluation, and the framework was adjusted to the objectives and data that were available.

Similarly, Scarelli applied a flexible framework to assess and rank the resilience of 22 Italian cities and municipalities within the Ombrone River hydrographic basin. The system emphasized socioeconomic and environmental factors, using indicators such as work accident rates, demographic density, and the ratio of job seekers to the active population. Their framework integrates ten indicators and thirty criteria, provides a robust structure for evaluating resilience in diverse urban settings (Scarelli et al., 2018).

In order to assess the urban resilience of Albanian cities and regions, comprehensive studies are urgently needed, as is the gathering of trustworthy data from national and international programs. For this purpose, mixed techniques, TOPSIS approaches, and the Analytic Hierarchy Process (AHP) are the most commonly utilized MCDA methodologies (Kosova et al., 2022; Qendraj et al., 2023).

In several studies MCDA techniques has been implemented in Albania to assess urban resilience, to select the most suitable landfill site for urban trash, to rank the effectiveness of administrative or academic services, to select the best projects among several options, etc., (Kosova et al., 2017).

Also, fuzzy AHP (Analytic Hierarchy Process) can be effectively applied to online learning to assess and prioritize different factors that contribute to its success. The fuzzy AHP approach helps handle the uncertainty and vagueness in decision-making processes, especially when human judgment is involved. (Qendraj et al., 2021; Xhafaj et al., 2024). Using MCDA evaluation techniques, Grazhdani investigates the ecological services of the Prespa Park (Al-Prespa) basin in southeast Albania. The study evaluates services from various ecosystems under various management scenarios. According to Grazhdani, (2014), this method aids in determining and ranking the importance of ecosystem services within a protected region.

Kosova evaluates the urban resilience of Albania’s Berat city and other locations impacted by the Osum River's frequent flooding in his article. In order to assess and rank communities according to their capacity and preparedness for future floods brought on by excessive rainfall and the Osum River, all 22 criteria are selected using the MCDA/AHP technique (Kosova et al., 2020). The best landfill for urban waste can be chosen by measuring, evaluating, and ranking different options according to factors such as geology, proximity to populations, distance from roads and airports, and other infrastructure and economic factors (Kosova et al., 2018; Shkodrani et al., 2022).

Urban resilience of cities, regions, municipialities could and should also be evaluated using MCDA techniques. Using the MCDA techniques with AHP, Kosova assessed and ranked the six Durres District regions of Albania according to a standardized framework for urban resilience established by a group of specialists, literature, characteristics and problems of the regions (Kosova et al., 2022). Some important research carried out during the COVID-19 pandemic examined and analyzed the variables affecting the use of learning management systems and Google Classroom during the pandemic, offering guidance to higher education policies for improved online learning (Xhafaj et al., 2021; Iqbal, 2023).

RESEARCH METHOD

This study employs a mixed-methods research approach, integrating both qualitative and quantitative techniques to develop an urban resilience framework. Additionally, the research will utilize Multi-Criteria Decision Analysis (MCDA) methods, particularly Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), to assess and rank the most vulnerable regions of Albania.

To develop a resilience framework for the regions in Albania that frequently face WRDs. To evaluate and rank as alternatives, considering the criteria which are defined by the specialists, stakeholder, government institutions, scientific literature. To apply MCDA, AHP, and TOPSIS to provide the estimation and ranking of the alternatives based on the data provided. The study was conducted between January 2023 and September 2023. Data collection focused on urban areas in Albania, with a specific emphasis on regions identified by national flood risk assessments as being highly vulnerable to water-related disasters. These areas were selected due to their history of frequent flooding and rapid urbanisations.

The research targets urban areas prone to water-related disasters, particularly flooding, in Albania. A purposive sampling technique was employed to identify urban locations with significant flood risks, based on factors such as infrastructure quality, flood history, and local government resilience initiatives. For qualitative data, interviews with urban planners, government officials, and local disaster management experts were conducted to gather insights into flood resilience and vulnerabilities.

Literature Review, A comprehensive review of current frameworks for flood resilience and disaster management. Data Collection: Both primary and secondary data will be collected. Primary data includes surveys, interviews, and field observations, while secondary data includes geospatial data, official reports, and disaster records (CRED, EM-DAT). Gathering primary data through expert interviews and secondary data through national flood risk reports, urban planning documents, and government disaster management strategies. Document analysis, National reports on flood risk and disaster management strategies were analyzed. Semi-structured interviews with urban resilience experts to gather qualitative insights. Distributed to experts to evaluate the relative importance of resilience indicators. Geospatial Data, GIS data will be collected and analyzed to identify flood-prone areas and assess urban infrastructure vulnerability. MCDA Software: Software like SuperDecisions will be used to conduct AHP analysis, while Excel and MATLAB will be used to implement TOPSIS for ranking resilience strategies.

The following techniques will be used to analyze the data: Quantitative Analysis, Statistical techniques will be applied to analyze the relationship between flood frequency, severity, and socio-economic impacts using SPSS. AHP will be used to weigh the importance of various resilience criteria. Pairwise comparisons will be conducted, and consistency ratios will be calculated to ensure the reliability of the results. The TOPSIS method will be applied to rank potential flood resilience strategies based on their proximity to the ideal solution. This will help in determining the best solutions for each city based on the AHP-derived criteria. A resilience framework will be developed based on the AHP and TOPSIS results and tested in pilot cities through simulation exercises. Ethical Considerations, Informed consent will be sought from all participants, ensuring confidentiality. The study will adhere to ethical guidelines for research involving human subjects. Limitations, While AHP and TOPSIS provide robust decision-making tools, the results may depend on subjective judgments. To mitigate this, a diverse range of stakeholders will be involved in the decision-making process to ensure balanced perspectives. Seven indicators and twenty-six criteria make up this framework, which is used to assess 6 most vulnerable regions in Albania, regarding water-flood disasters (table 2).

Table 2. The chosen criteria to evaluate the alternatives.

Indicators	Criteria
Infrastructure Resilience:	Quality and capacity of flood protection systems (dams, levees, flood barriers). Adequacy and maintenance of drainage and stormwater management systems. Robustness of critical infrastructure (roads, bridges, utilities) against flood damage.
Community Preparedness:	Level of public awareness and education on flood risks and preparedness measures. Existence and accessibility of evacuation plans and emergency shelters. Strength of social networks and community cohesion in disaster response. Engagement of residents in flood risk reduction initiatives.
Social and Economic Factors:	Participation in collaborative planning and decision-making processes. Socio-economic diversity and inclusiveness in disaster planning and response. The capacity of local organizations and community groups to mobilize during floods. Economic resilience, including the ability to recover livelihoods and businesses after floods.
Environmental Resilience:	Capacity to learn from past flood events and adapt strategies accordingly. Flexibility to adjust plans and actions in response to changing flood dynamics. Ecological health and biodiversity that contribute to flood regulation and mitigation. Sustainable water management practices that reduce flood risk.
Governance and Policy:	Existence and effectiveness of flood risk reduction policies and regulations. Integration of flood resilience considerations into urban and regional planning. Coordination and collaboration among government agencies, NGOs, and other stakeholders.
Emergency Response and Recovery:	Speed and efficiency of emergency response operations during floods. Availability and allocation of resources for post-flood recovery and reconstruction. Inclusiveness of recovery efforts to address the needs of vulnerable populations.
Data and Information Management:	Availability of accurate flood risk maps and vulnerability assessments. Timely collection and dissemination of flood-related data for decision-making. Use of technology and modelling tools to improve flood forecasting and risk assessment. Capacity to learn from past flood events and adapt strategies accordingly. Flexibility to adjust plans and actions in response to changing flood dynamics.

Multi-criteria decision analysis (MCDA)

Multi-criteria decision analysis (MCDA) is a mathematical method used to make decisions by considering multiple criteria or factors simultaneously. MCDA aims to identify the best option from a range of possibilities by accounting for various relevant factors. It helps decision-makers systematically evaluate and compare different choices based on multiple criteria to arrive at the most informed decision (Ozbey et al., 2022).

The multi-criteria decision-analysis process typically involves the following steps:

a) formulating evaluation criteria for the system based on its intended use and capabilities;

b) Creating alternative possibilities through experimentation or mathematical or physical models, evaluating these alternatives in terms of the criteria (calculating the values of the criterion function), and assigning weights to the criteria;

c) Substituting one option for the "optimal" (preferred) option;

d) If the final solution is deemed unacceptable, obtain further data and proceed to the next multi-criteria optimization cycle.

AHP

The Analytic Hierarchy Process (AHP) is a structured technique developed by Thomas Saaty in the 1970s to help decision-makers break down complex problems into smaller, more manageable parts. AHP is particularly useful when a decision problem requires the systematic comparison and prioritization of both qualitative and quantitative criteria (Saaty, 1990); (Saaty, 2016). The method is based on pairwise comparisons to establish the relative weights of various criteria, as shown in Table 3.

The steps involved in the AHP method are as follows: 1). Identify the decision-making problem and the relevant criteria.; 2). Organize the decision problem into a hierarchical structure, with the main goal at the top and the criteria and sub-criteria arranged below it.; 3). Perform pairwise comparisons: The decision maker evaluates the importance of each pair of criteria using a scale from 1 (equal importance) to 9 (extreme importance).; 4). Calculate weights: A mathematical method is used to determine the relative weights of each criterion based on the pairwise comparison results.; 5). Check consistency: The pairwise comparisons are checked for consistency using a mathematical formula to ensure the decision-maker's judgments are logical.; 6). Evaluate alternatives: After determining the criteria weights, the alternatives are assessed against each criterion using a scale of values. The results are combined to obtain an overall score for each alternative.

Table 3. Saaty scale for the pair wise comparison

Scale	Degree of preference	Reciprocal values
1	Equal importance	1
3	Moderate importance	1/3
5	Strong importance of one factor over another	1/5
7	Very strong importance	1/7
9	Extreme importance	1/9
2, 4, 6, 8	Values for inverse comparison	1/2, 1/4, 1/6, 1/8

Decision matrix

Let's assume n attributes/criteria, then the pairwise comparison of any attribute i with any attribute j form a square matrix $C_{n\,\mathrm{x}\,n}$ where the term $c_{\,i,j}$ denotes the comparative importance of the attribute i concerning the other attribute j.

In the comparison matrix, we have:

$$c_{i,j} = 1, for\ i = j, \text{ and } c_{i,j} = \frac{1}{c_{j,i}}, i \neq j. \tag{1}$$

$$A_{mxn} = \overbrace{\begin{pmatrix} 1 \\ 2 \\ \dots \\ \dots \\ m \end{pmatrix}}^{Attributes} \begin{bmatrix} c_{11} & c_{12} & \dots & a_{1n} \\ c_{21} & c_{22} & \dots & a_{2n} \\ \dots & \dots\dots & & \dots.. \\ \dots. & \dots. & & \dots\dots \\ c_{m1} & c_{m2} & \dots & a_{mn} \end{bmatrix} \tag{2}$$

Step 3. Construct the normalized decision matrix,

$$d_{i,j} = \frac{c_{i,j}}{\sum_{j=1}^{n} c_{i,j}},\ \ i = \overline{1,n};\ \ j = \overline{1,n}. \tag{3}$$

Step 4. Construct the weighted normalized matrix,

$$w_i = \sum_{j=1}^{n} \frac{d_{i,j}}{n},\ \ i = \overline{1,n} \tag{4}$$

$$W = \begin{bmatrix} w_1 \\ w_2 \\ \dots \\ \dots \\ w_n \end{bmatrix} \tag{5}$$

Step 5. Calculate eigenvectors and Row matrix $E = \frac{N^{th} rootvalue}{\sum N^{th} rootvalue}$ (6)

$$Rowmatrix = \sum_{j=1}^{n} c_{ij} * e_{j1} \quad (7)$$

Step 6. Calculate the largest Eigenvalue, the Principal Eigenvalue,

$$\lambda_{max} = \frac{Rowmatrix}{E} \quad (8)$$

Step 7. Calculate the consistency index $CI = \frac{(\lambda_{max} - n)}{n-1}$ (9)

Where n is the matrix order.

The consistent ratio $CR = \frac{CI}{RI}$ (10)

RI is called the random Consistency index. If the value of the Consistency Ratio is less than 10%, the decision matrix is consistent. If the Consistency Ratio is greater than 10%, then the process is repeated by revising the subjective pairwise comparisons of the criteria. The pairwise comparison matrix has been completed by weighing the criteria in terms of their relative importance two by two. The relative importance of each of the two criteria is expressed using index values ranging from 1 to 9. If the relative importance of A to B is n, then the relative importance of B to A is 1/n. The corresponding fractions will fill the lower-left half of the matrix.

TOPSIS

Hwang and Yoon introduced TOPSIS, a multi-criteria-based decision-making technique, in 1981. TOPSIS chooses the option that has the highest distance to the negative ideal solution and the least Euclidean distance to the ideal solution. The options are then ranked according to how close they are to the best choice. TOPSIS aids in the candidate ranking process by utilizing the weights and effects of the designated factors.

Weights serve as a guide as to how much of a given component should be taken into account (the default weight for all factors is 1). Impact indicates whether a specific factor has a good or negative effect (Hwang & Yoon, 1981). According to the TOPSIS technique, the chosen option should be the furthest from the anti-ideal solution (nadir) and the closest to the positive ideal solution (zenith). Both ideal and anti-ideal solutions-the worst possible criteria values and all best possible values—are components of an ideal solution, (Olson, 2004).

Procedure:

Starting in TOPSIS;

A decision-analyser/ maker k rates the alternatives Ai to the criteria Cj in a matrix $B^k = [f_{ij}]$ of dimensions $A_m x B_n$.

$$B_{mxn} = \begin{pmatrix} A1 \\ A2 \\ \dots \\ \dots \\ Am \end{pmatrix} \overbrace{\begin{bmatrix} f_{11} & f_{12} & \cdots f_{1n} \\ f_{21} & f_{22} & \cdots f_{2n} \\ \dots & \dots\dots & \dots.. \\ \dots. & \dots. & \dots\dots \\ f_{n1} & f_{n2} & \cdots f_{mn} \end{bmatrix}}^{C1 \quad C2 \quad \dots .; \dots \quad Cn} \quad (11)$$

where A_i represents the alternative i and Cj represents the criteria j,
for $1 = 1,2, \dots, m$ and $j = 1,2, \dots, n$, f_{ij} represents the performance rating of Ai under Cj,
for k= 1, 2,…, r the number of decision analyser/makers.

Calculating Normalized Matrix and weighted Normalize matrix. We normalize each value by making it: where m is the number of rows in the dataset and n is the number of columns. I vary along rows and j varies along the column. Normalized matrix for the above-given values will be:

$$r_{i,j} = \frac{f_{i,j}}{\sqrt{\sum_{k=1}^{m} f_{kj}^2}}, i = 1,2, \dots, m; j = 1,2, \dots, n \quad (12)$$

Quantitative values are directly input into the matrix while qualitative judgements use a linguistic scale. For that, a 1-9 scale is used for TOPSIS, like in AHP, table 4.

Table 4. Linguistic and numeric scale for TOPSIS

Linguistic value	Numerical value
Very low	1
Low	3
Moderate	5
High	7
Very high	9

The calculation of the weighted standardized decision matrix, the weighted normalized value defined as v_{ij} is calculated using the formula:
$v_{ij} = w_j * r_{ij}$, where w_j is the weight of the $j-th$ attribute or criterion and $\sum_{j=1}^{n} w_j = 1$;
(Weights can be equal, determined by means of linear regression or the centroid method, or by means of AHP method). Determination of the ideal and anti-ideal solutions according to the formulas:

$$A^* = \{v_1^* v_2^*,..,v_n^*\} = \{\left(\max_i v_{ij} | j \in I'\right), \left(\min_i v_{ij} | j \in I''\right)\} \quad (13)$$

$$A^- = \{v_1^- v_2^-,..,v_n^-\} = \{\left(\min_i v_{ij} | j \in I'\right), \left(\max_i v_{ij} | j \in I''\right)\} \quad (14)$$

where I' is related to the benefit, and I'' to the cost criteria.

The calculation of the distance measure using n-dimensional Euclidean; the distance of each alternative from the ideal solution is expressed by the formula:

$$d_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \quad (15)$$

Similarly, the distance from the anti-ideal solutions is calculated on the basic of:

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad (16)$$

The calculation of the relative closeness to the ideal solution, the relative closeness of the alternative. A_i in relation to A^* is defined as:

$$CC_i^* = \frac{d_i^-}{d_i^* + d_i^-} \quad (17)$$

Such a formula combines the two distances, allowing the selection of a solution that offers both the greatest possible profit and, at the same time, the smallest possible loss. Ranking the order of preference, according to the TOPSIS score, i. e. higher the score, better the rank.

RESULTS AND DISCUSSION

The Republic of Albania is situated in southeastern Europe on the western coast of the Balkan Peninsula.It spans latitudes 39° 38' to 42° 39' north and longitudes 19° 16' to 21° 40' east. Covering an area of 28,748 square kilometers, Albania borders Greece to the south, North Macedonia to the east, Kosovo to the north and northeast, and Montenegro to the north and northwest. To the west, it is bounded by the Adriatic Sea and to the southwest by the Ionian Sea.

Albania's borders total 1,094 km, consisting of 657 km of land borders, 316 km of sea borders, 73 km of lake borders, and 48 km of river borders. The coastline stretches for 427 km, with 273 km along the Adriatic Sea and 154 km along the Ionian Sea. Albania's hydrographic system includes 11 main rivers with 152 branches and large streams, as well as four major lakes (Shkodra, Ohrid, Prespa, and Butrinti) and numerous reservoirs covering an area of 1,032 square kilometers.

According to existing flood modeling data, the risk of river flooding is likewise classified as high, meaning that at least one potentially hazardous and disastrous river flood is anticipated during the next ten years (Figure 1 &2). As for tsunamis, the available data classifies this hazard as medium, implying a greater than 10% chance of a potentially destructive tsunami occurring within the next fifty years (Figure 3 & 4). The risk of coastal flooding is classified as high, predicting that potentially destructive waves will flood the coast at least once in the next ten years.

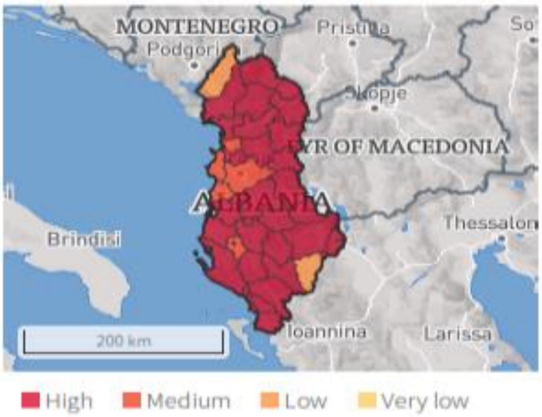

Figure 1. Urban flood risk level

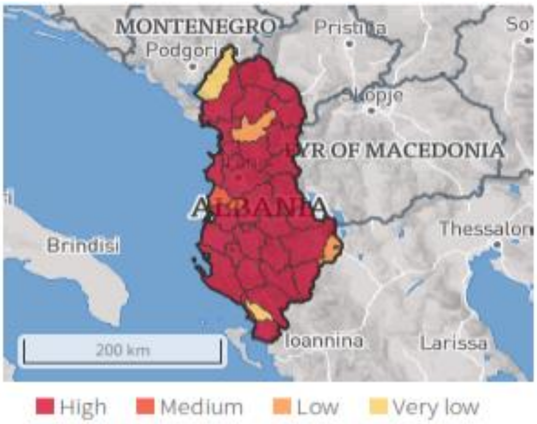

Figure 2. River flood risk level

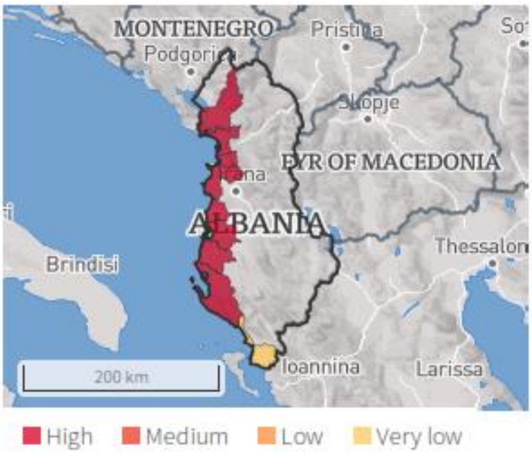

Figure 3. Coastal flood risk level

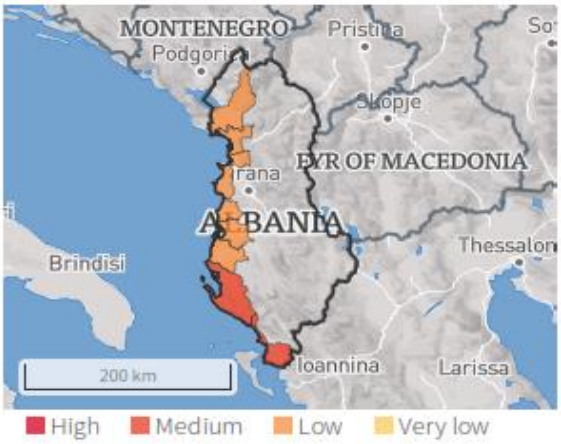

Figure 4. Tsunami risk level

The most vulnerable regions from floods in Albania, are presented in the map, figure 6. These are the alternatives under study, which are to be measured by a group of specialists, stakeholders, state institutions representatives. The evaluation will show the vulnerability or strength of each alternative, and the ranking will show the region/alternative with the best/worst performance, regarding flood related disaster resilience, figure 3.

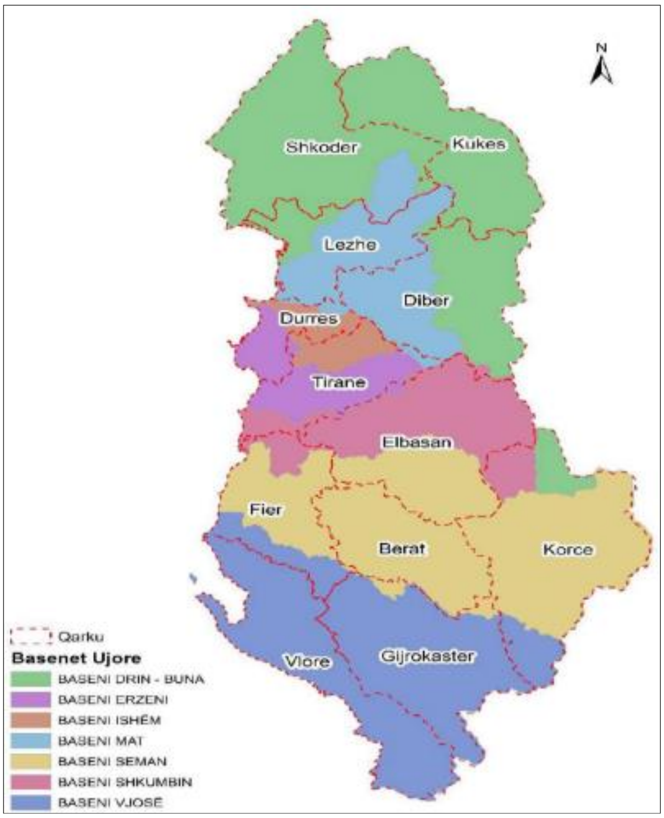

Figure 5. The water basins in Albania

The regions under study are:
1) Drin-Buna water basin, centered in Shkodër;
2) Mat water basin, based in Lezha;
3) Ishem water basin, based in Durrës;
4) Erzen water basin, based in Tirana;
5) Shkumbin water basin, centered in Elbasan;
6) Seman water basin, based in Fier;
7) Vjosa water basin, centered in Vlora;

Using the AHP pairwise comparison, the criteria weights are produced and, with the criteria values put on each alternative, the results are shown in table 5-7.

Table 5. The assessment and ranking of regions, according to criteria evaluations.

Normalized Decision Matrix						
0.05	0.05	0.05	0.06	0.04	0.03	0.03
0.06	0.05	0.05	0.06	0.05	0.04	0.04
0.07	0.06	0.06	0.05	0.05	0.04	0.04
0.07	0.06	0.06	0.06	0.06	0.05	0.05
0.08	0.05	0.04	0.06	0.04	0.05	0.06
0.09	0.06	0.05	0.05	0.05	0.04	0.05
0.07	0.07	0.06	0.05	0.05	0.05	0.06

Table 6. Vectors and distances.

Best answer vector	0.09	0.07	0.06	0.06	0.06	0.05	0.06
Choices distance from best vector	0.06	0.05	0.03	0.02	0.03	0.03	0.02
Worst answer vector:	0.05	0.05	0.04	0.05	0.04	0.03	0.03
Choices distance from worst vector:	0.02	0.02	0.04	0.05	0.04	0.05	0.05
Closeness vector from each choice:	0.21	0.32	0.59	0.66	0.56	0.66	0.73

Table 7. ranking the Alternatives

Ranking From Best to Worst Performance		
1	VLORA	0.73
2	FIER	0.66
3	TIRANA	0.66
4	DURRES	0.59
5	ELBASAN	0.56
6	LEZHA	0.32
7	SHKODER	0.21

The TOPSIS analysis of urban resilience for the six regions provides a ranking from best to worst performance, indicating the relative capacity of these regions to withstand and recover from water-related disasters:

1. Vlora (0.73): Vlora ranks highest, showing the strongest resilience performance. This could imply better infrastructure, effective governance, and stronger socio-economic factors that contribute to its ability to manage and mitigate WRD risks. 2. Fier (0.66) and Tirana (0.66): Both regions show equal resilience scores, suggesting similar levels of preparedness and capacity to respond to disasters. These regions likely have moderate infrastructure and socio-economic conditions that provide them a balance of resilience but still require improvement compared to Vlora. 3. Durres (0.59): Durres scores lower, indicating that while it has some resilience measures in place, it faces vulnerabilities that might affect its response to WRDs. Its ranking may be influenced by infrastructure deficiencies or socio-economic challenges. 4. Elbasan (0.56): Slightly below Durres, Elbasan shows weaknesses in its resilience framework. The score suggests that improvements in environmental management and disaster preparedness could enhance its overall resilience. 5. Lezha (0.32): This region's lower score reflects significant vulnerabilities in urban resilience, such as poor infrastructure or lack of effective planning against WRDs. It may face greater risk due to inadequate flood prevention or emergency response mechanisms. 6. Shkoder (0.21): Ranking last, Shkoder has the weakest resilience. The region likely suffers from major gaps in preparedness, infrastructure, and socio-economic conditions, making it highly susceptible to water-related disasters.

The results identify where intervention and resources should be focused, with regions like Shkoder and Lezha requiring urgent attention, while Vlora, Fier, and Tirana are better positioned but still not immune to vulnerabilities. In an effort to assess and prioritize the areas most vulnerable to water-related disasters in Albania, this article aims to identify the regions most at risk from river floods and torrential rains, especially during the autumn and winter seasons. Many specialized organizations, local and state governments, research projects and published articles have provided important data on these vulnerable areas. Before implementing the best strategy for each region, it is essential to identify the areas most at risk of water disasters. Urban planners and policymakers can greatly benefit from assessing a wide range of factors, including social cohesion, governance, environmental sustainability and infrastructural resilience.

A national strategy will create the necessary conditions for budget allocation, risk-sensitive development and national coordination. It will not only ensure effective pre- and post-disaster actions, but will also set clear mandates for responsible agencies. Empowered communities will be able to identify risks more quickly and provide accurate information to relevant government institutions. Strengthening public structures, especially hospitals and schools, guarantees the continuity of services during and after disasters. Investments in these structures not only minimize the risk of direct losses, but also accelerate the recovery process.

With the increasing frequency and severity of water disasters as a result of climate change, the development of resilient cities is crucial. To improve urban resilience, stakeholders must advance investments that prevent risks while promoting equitable and sustainable development. Collaboration and knowledge sharing are key to strengthening cities' capacities to respond and adapt to water disasters.

CONCLUSION

In conclusion, we hope that new research and initiatives will provide a deeper analysis and more reliable conclusions to improve the limitations of this article. Despite the successful implementation and integration of MCDM techniques to assess and rank urban resilience to water-related disasters (WRD), several limitations should be noted. First, the accuracy and reliability of any scientific research depend heavily on the availability, quantity, and quality of data. Institutions must provide comprehensive historical data relevant to the issues being studied. Ensuring that this data is accessible to the broader academic and scientific community will support collaborative research and projects.

Second, while MCDA/MCDM techniques are valuable for structuring decision-making processes, they can introduce subjectivity due to the reliance on decision-makers' judgments when assigning weights to various criteria. However, the impact of this subjectivity is minimized when data is sufficient, and the criteria selected are crucial to the study, thereby enhancing the reliability of the results. Future research is recommended given the importance of addressing the challenges posed by WRD in all countries, including Albania.

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AUTHOR CONTRIBUTIONS

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CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

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