

Research Paper: Zoning of Environmental Hazards in Rural Areas of Western Iran

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ABSTRACT

Purpose: This research primarily aims to identify environmental hazards in western Iran, with a focus on flood risk in the Cultural Landscape of Hawraman.

Methods: This study is classified as scientific-applied research, employing a descriptive approach from both a natural and methodological perspective. In the zoning of the Cultural Landscape of Hawraman concerning flood hazards, 12 criteria were used, including slope, precipitation, vegetation density, river density, topographic location index (TLI), runoff, flow strength index (FSI), distance from river, land use, geology, altitude, and soil. Data analysis was conducted using the fuzzy overlap approach and the Sum operator in ArcMap software. The ROC curve in SPSS software was used to validate the obtained results.

Results: The research findings revealed that 34.46 percent of the total study area falls under high and very high-risk zones, while out of the 319 villages in the study area, 282 villages (88.4 percent of all villages) are classified as high and very high-risk zones. The ROC curve analysis confirmed that the model performed reasonably well in distinguishing flood-prone from non-flood-prone areas.

Conclusion: There has been little study done on environmental hazards in rural areas; therefore, further studies utilizing innovative methodologies and relevant criteria are necessary to identify rural areas at risk of environmental hazards. Additionally, conducting studies on smaller spatial scales would provide finer detail and greater applicability in environmental hazard zoning.

1. Introduction

T

he occurrence of different environmental hazards and disasters has significantly af-

ected the overall quality of life for the citizens (Jamini & Jamshidi, 2015: 148). Among these natural disasters flooding is one of the most common and devastating (Feng et al., 2022: 1). It causes widespread and irreversible damage to property and communication infra-

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structure (Swain et al., 2020: 1). Floods have serious repercussions in terms of social, economic, and environmental aspects through loss of human life and negative impact on communities, damage to infrastructure and infrastructural services, damage to crops and livestock, spread of diseases, and contamination of water sources (Rincón et al., 2018: 1).

Floods are a globally devastating hazard whose recorded statistics and information show that between 1998 and 2017, over 2 billion people were affected (Bullen & Miles, 2024: 1). On average, the world experience about 163 floods per year from 2001 to 2020, with an average annual economic loss of \$34.1 billion. with an annual economic loss of \$34.1 billion from 2001 to 2020. However, 2021 saw a significantly higher number of floods, causing economic losses of \$74.4 billion (Thalakkottu-kara et al., 2024: 1907).

Projections suggest that 2016 to 2035, the estimated loss on account of floods in economically strong and densely populated regions is projected to be \$597 billion (Li et al., 2019: 1). Furthermore, annual flood damage, which was around \$6 billion in 2005, is expected to rise to \$60 billion over the next few decades (Alizadeh et al., 2022: 2). This, of course, is very different from development priorities in many countries where the health, safety, and financial security of their citizens are paramount (Sydaii et al., 2014: 44).

As it is surrounded by floods like Seydaei et al. (2013: 88), almost all of the rural communities, wherein they are the center of food production and agriculture, are vulnerable to natural hazards, such as floods (Jamini et al., 2023: 119). Relating to their long association with the natural environment surrounding the fact that they live in mountainous areas coupled with dependence on agriculture and garden lands, pastures, etc.- most local communities know very well and surprisingly have an understanding of areas that flood (Bullen & Miles, 2024: 1-2). Up till now, however, very few studies have assessed the floods in rural areas and other non-urban areas (Wang et al., 2023: 1). Preparing flood risk zoning maps within emergency management is, therefore, one of the most effective and thus efficient actions that are drastically important in rural areas against flood risk (Ghansah et al., 2021: 12-13). Hence, accurate flood zoning and modeling become a prerequisite in the consideration of the multi-dimensional impacts of floods over different geographical spaces in the application of flood risk assessment, damage estimation, and sustainable planning for proper flood risk management (Notti et al., 2018: 2). Various studies have stated that the occurrence of floods,

which is one of the natural disasters, can be monitored in a better way with modern technologies (Swain et al., 2020: 2). The Geographic Information System (GIS) is widely recognized as a powerful tool for flood risk zoning (Bullen & Miles, 2024: 4; Sadeghi, 2024: 3; Sadeghi & Haseli, 2025: 3).

The Geographic Information System (GIS) is widely recognized as a powerful tool for flood risk zoning (Bullen & Miles, 2024: 4; Sadeghi, 2024: 3). Given its cultural and natural significance, UNESCO designated the Cultural Landscape of Hawraman as a World Heritage Site in 2021 (UNESCO, 2021). This region is highly mountainous, with villages constructed on steep slopes, often within high-risk flood zones. Due to the region's tourism potential, rapid village expansion has occurred, often without adequate consideration of environmental hazards.

According to the Statistical Center of Iran, there are 319 rural points in the Cultural Landscape of Hawraman, which accommodate 31,485 households and 11,483 people. The mountainous terrain, rapid rural expansion, increasing tourism, and dependence on agriculture highlight the urgent need for flood risk management to preserve this critical cultural landscape from potential disasters. Referencing the above-mentioned materials, the most important topics of this study are:

- What proportion of the Cultural Landscape of Hawraman falls within high and very high flood risk zones?
- What is the spatial distribution of high and very high flood-risk zones in the Cultural Landscape of Hawraman?
- What percentage of the rural settlements in the Cultural Landscape of Hawraman are located in high and very high-risk areas?

2. Literature Review

Natural catastrophes as earthquakes, tornadoes, floods, volcanic eruptions, and landslides pose significant challenges to both developing and developed countries. Floods are among the most frequent and destructive natural disasters (Udin et al., 2018: 1). Research indicates that floods annually affect the lives of some 20 to 300 million people worldwide and incur damage approximated at \$60 billion in economic losses (Askar et al., 2022: 1-2).

Several meteorological and geomorphological factors influence floods, which directly affect surface runoff, with the topographic, geological, and soil characteristics of the basins bringing about an effective role in the occurrence of floods (González-Arqueros et al., 2018, 685-686). Climate change and human pressure are other factors that aggravate the frequency and magnitude of severe floods. The callback of the major human-induced flood occurrence factors is the change in land use from the intensified urbanization in which forests or agricultural fields are eventually paved over to solid, impermeable city surfaces (Kyaw et al., 2024: 1). In other words, the severity of floods is conditioned on activities and interventions of traffic in natural systems, such as deforestation and improper land and water activities (Papaioannou et al., 2021: 1), high population and infrastructure density (Tan et al., 2024: 1), rapid urbanization and growing coastal populations (Thalakkottukara et al., 2024: 1907). In any case, global climate change is predicted to continue increasing flood extent and frequency based on studies conducted on flood risk (Wang et al., 2023: 1).

Flood risk analysis models and maps are fundamental for policymakers and planners in elevating both quantitative and qualitative levels of emergency management, undertaking flood related infrastructure development, and formulating emergency plans concerning floods (Tan et al., 2024: 1). One of the most enforcing strategies to manage and minimize the adverse impact brought by such floods is by identifying flood-prone areas (Askar et al., 2022: 2). Geographic information system is one of most cost-effective tools that can be employed to identify flood-prone areas. Many studies have been conducted in the current area of study, which is valuable for comparison among a fairly significant number of studies listed below.

The study by Nasrinnejad et al. (2015) used landform criteria, digital elevation model, lithology, land use, permeability, slope, precipitation, drainage network density, vegetation density, and distance from watercourse. Along with fuzzy analytic hierarchy process in a study entitled "flood potential zoning in the Baghan watershed". The study concluded that 22% of the total area was classified under high and very high risk, while 78% fell into medium, low, and very low risk categories. Ghobadi et al. (2017) used slope, geology, distance from rivers and streams, land use, as well as population density to assess and zone flood risk in the Abali region. The results indicated that about 1788 hectares of the total test area were subject to a very high risk, 5098 hectares subject to a high risk, 6190.75 hectares to medium risk and,

to 3038.75 hectares, were determined with a low risk of flooding.

In their paper, Hatami-Nejad et al. (2017) noted that flood risk zoning in Izeh County was based on geological formations, climate, aquifers, elevation, vegetation, distance from waterway networks, soil science, co-precipitation, co-evaporation, isotherms, land use, multi-criteria analysis, and GIS, which showed that the percentage share assigned to risk zones was very high with 43%, high with 16.14%, moderate with 12.46%, low with 10.91%, and very low with 8.3%. In another study by Azamirad et al. (2018), flood potential in the Kashfar River basin was evaluated using the SCS method in a GIS environment. Elevation, precipitation, land use, soil, vegetation, and slope were some of the criteria used in this study. The study revealed that 68.25% of the total area surveyed had the potential for normal flooding, while 25.5% is liable to flooding in the borderline. Supercritical potential areas constitute 25.6% for flood-risk evaluation in the said area. Results further revealed that 658 rural localities in the study area, out of which 78% fall within normal flood potential areas, while 17% and 5% occupy critical and supercritical flood potential areas, respectively. The study by Ebrahimian Ghajari & Barari Siavoshkolaei (2019) aimed at zoning and mapping runoff production potential using fuzzy GIS-MC-DA models within the Tajan River watershed. It found that, out of the total study area, less than 1% fell into the very low runoff production zone, 5.48% into the low zone, 29.09% into the medium zone, 52.4% into the high zone, and 12.52% into the very high zone.

The findings also indicated that among the 441 villages in the basin, 87 were located in areas with very high runoff production potential. The study by Mohammadi et al. (2020), entitled Detection and Zoning of Flood Susceptibility in Fanoj County in Sistan and Baluchestan Province, further elaborated that 12 parameters were used for flood zoning purposes: elevation, normalized vegetation difference index, slope, topographic moisture index, direction of slope, curvature, flow power index, lithology, drainage density, distance to the river, soil type, and rainfall. The research conducted by Swain et al. (2020) on flood risk zoning in the Bihar region, India, utilized five criteria: hydrological, human, morphometric, permeability, and land cover changes. The study revealed that approximately 3000 square kilometers (40.36%) fell into high to very high-risk areas, while about 1000 square kilometers (12%) were classified as very low flood sensitivity.

In a study using eight criteria - slope, distance from the river, elevation, geology, land use, precipitation, drainage density, and cover, using fuzzy logic, [Saeedi & Asiaei \(2021\)](#) showed that about 38.8% of the total area was found to fall under high and very high-risk areas, 11.3% in medium-risk areas, and 49.9% in low-risk and very low-risk areas for flooding in Sabzevar County. The findings also indicated that the main concentration of population areas in Sabzevar city is in the low-risk zone, while most of the villages are located in the medium-low and very low risk zones.

[Askar et al. \(2022\)](#) studied flood-susceptible zoning in the Sulaymaniyah Province of Iraq, using various algorithms and considering slope, elevation, slope direction, plan curvature, distance from rivers, land cover, geology, topographic wetness index (TWI), stream power index (SPI), rainfall, and NDVI. They also conducted comparative analyses of results from multiple algorithms.

Lastly, [Cherian et al. \(2024\)](#) carried out flood hazard mapping in Ernakulam, India, using boundary maps, along with elevation, channel network, and land use/land cover data, within a QGIS environment.

Based on the reviewed literature, it is evident that various criteria have been applied for flood hazard zoning across different geographical regions. However, few studies have focused on identifying rural settlements at risk of flooding. The global significance of the Cultural Landscape of Hawraman, its vulnerable rural settlements, and the need for crisis management mapping in this newly designated global heritage region, combined with the limited attention given to rural areas in previ-

ous studies, underscore the novelty and importance of the present research.

3. Methodology

World Heritage sites need to have outstanding universal value and one or more of the ten criteria for listing. By the end of 2004, World Heritage sites had been selected based on six cultural and four natural criteria. Out of these 10 criteria considered by UNESCO, the Cultural Landscape of Hawraman met two criteria:

- Criterion (iii): A unique example of the evolution and continuity of traditional semi-nomadic agricultural way of life for several thousand years,
- Criterion (v): an outstanding example of human interaction with and adaptation to the surrounding environment, and therefore, the Cultural Landscape of Hawraman was inscribed in the World Heritage List by UNESCO in 2021 ([UNESCO, 2021](#)). The people of this region have a spiritual bond and relationship with their land, which they mainly depend upon for agriculture. Due to the attractions of both the natural and man-made environment, the Cultural Landscape of Hawraman has increasingly welcomed tourists in recent years. The mountains in the region pose a great threat to rural living through floods and other environmental hazards.

This study falls under the category of scientific and applied research in terms of purpose and is descriptive in nature and methodology. It aims to zone flood risk across the Cultural Landscape of Hawraman using spatial data and GIS-based analysis. A total of 12 flood-influencing criteria were identified through an extensive literature review:

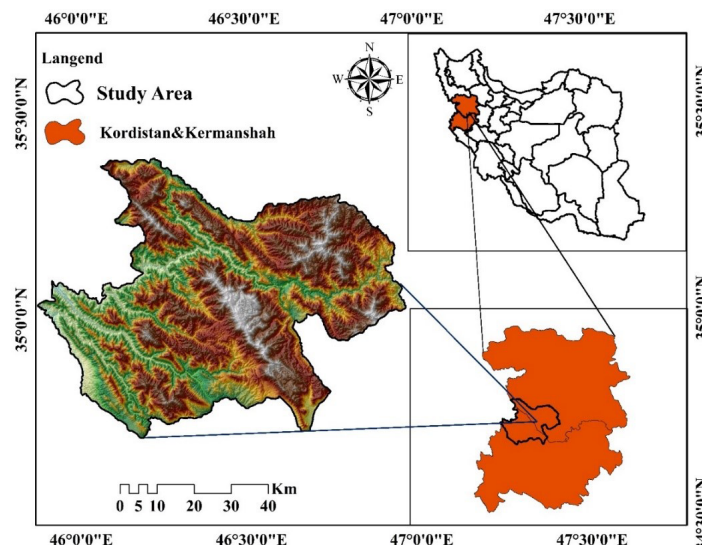


Figure 1. Geographical location of the study area in western Iran

slope, precipitation, vegetation dispersion, river density, topographic location index, runoff, flow strength index, distance from river, land use, geology, elevation, and soil. It should be noted that the required basic spatial data have been prepared from the UNESCO website and other available sites and resources (Table 1).

In order to identify existing flood points on the study area, Sentinel-1 radar images were employed, whereas the weighting of zones and criteria affecting flooding was conducted by a panel of fifteen experts and researchers. The above-mentioned processes were executed in Arc Map software. Finally, the fuzzy overlay method and Sum operator were applied for flood risk zoning of the study area. Under this framework, the study area was classified into five risk zones, and based on the zoning assessment of flood risk, the settlement status of 319 villages around the Cultural Landscape of Hawraman was investigated. The ROC curve in SPSS software was em-

ployed to check the accuracy of the results obtained from flood zoning using the Sum operator.

4. Findings

The study offered maps depicting 12 flood-risk-elevating factors pertinent to the main objective of the study, accompanied by explanations of each layer. Research pertaining to the flood risk zoning map based on geological factors, land use, distance, and river density in the Cultural Landscape of Hawraman as shown in Figure 2 and detailed in Table 2.

- Geological factors: class II geological formations—primarily composed of limestone and shale were found to dominate the study area. A total of 109 villages are located within this geological class, making it the most extensive in terms of settlement

Table 1. Factors affecting flood risk and their extraction method

Factors	How to Extract	Factor	How to extract
Geology	Existing Databases	Slope	Arc Map software
Land use	Sentinel Satellite Product in GEE	Elevation	SRTM satellite product in GEE
Distance from river	Arc Map Software	Stream Strength Index (SPI)	Arc Map software
Soil	Existing Databases	Topographic Position Index (TPI)	Arc Map software
Runoff	GEE System	Non-Differential Vegetation Index (NDVI)	Arc Map software
River density	Arc Map Software	Rainfall	Arc Map software



Table 2. Details of classes of factors affecting flooding (geological factors, land use, distance from the river, and river density)

Geology	Number of villages	Area (km ²)	Land use	Number of villages	Area (km ²)
II	109	1287.95	Agri	5	160.19
IX	1	3.28	Forest	21	407.14
V	45	1149.85	Shurb Land	0	66.34
VI	96	902.09	Grass Land	140	3259.11
VII	14	289.45	Bilt Up	92	15.48
IV	54	561.94	Barren Land	61	230.47
-	-	-	Permanent Water	0	5.71
Sum	319	4195	Sum	319	4144.4
Distance from river	Number of villages	Area (km ²)	River Density	Number of villages	Area (km ²)
0 - 100	131	351.68	0 - 0.22	24	730.43
100 - 200	54	337.94	0.22 - 0.36	57	1031.82
200 - 300	32	323.02	0.36 - 0.50	88	1009.97
300 - 400	15	309.16	0.50 - 0.65	94	860.58
>400	87	2822.73	0.65 - 1	59	511.69
Sum	319	4144.53	Sum	319	4144.53



- Land use: The grassland class occupies the largest area as the largest number of villages (140 villages) also exist in this major class.
- Distance from River: Spatial analysis revealed that the most extensive area falls under the class of more than 400 meters (>400 m) from riverbeds, covering approximately 2822.73 square kilometers. However, the highest concentration of villages—a total of 131—is found within 0–100 meters from the rivers, highlighting the

exposure of many rural communities to potential flood hazards.

- River Density: While the river density class 0.22–0.36 covers the largest land area (1031.82 km²), the 0.50–0.65 class hosts the greatest number of villages (94). This suggests that villages tend to cluster in regions with moderate-to-high river network density, which may increase vulnerability during heavy rainfall and runoff events.

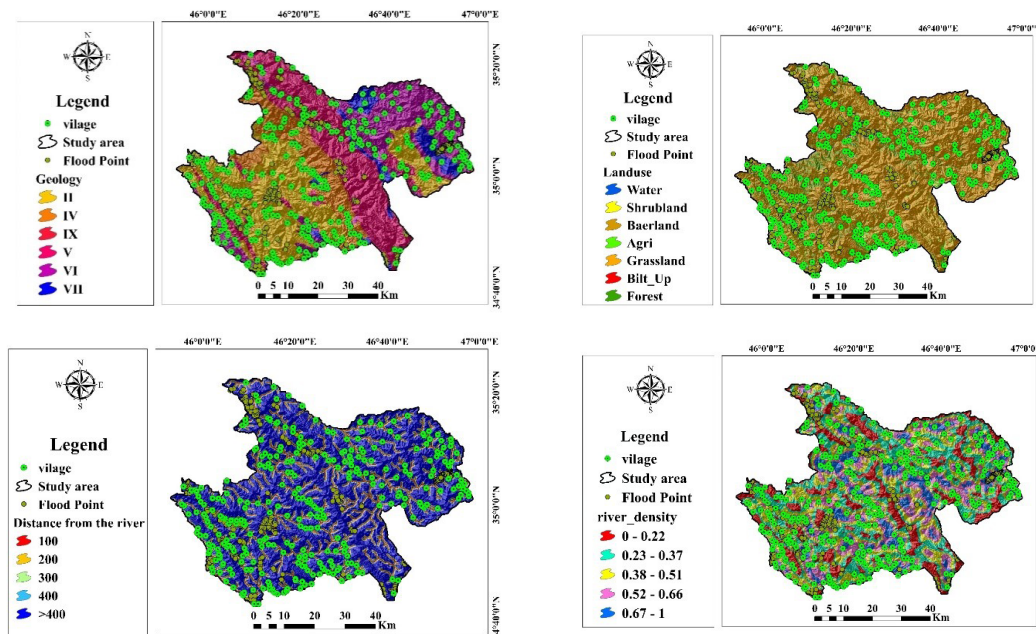


Figure 2. Geological maps, land use, distance from the river, and river density



As seen in Figures 3 and 3A-3B, the research into the flood-risk zoning map shows that the majority of the study area lies in the slope class of between 12.7 to 22 degrees, and the 0-12.6 degrees slope class hosts a substantial portion of the rural points, 151 rural points. From the findings regarding the altitude factor, most of the area of the cultural landscape of Huraman is found in the altitude class of 1529 meters to 1887 meters, while 120 of the villages are found in the 1139-1529 meters altitude class. In relation to precipitation, it can be said that the results show that 1174.96 square kilometers of the cultural landscape of Huraman are located in the precipitation class of 507-606 mm, and most of the rural points, 117 rural points, are also located in this class. The soil factor study shows that the Rock Outcrops/Entisols class is the dominant cover of the study area, and this class serves most of the villages (257 villages).

These results demonstrate that in terms of stream power index (SPI) factors, it is the class 0-3990, which covers the largest area (4077.25 square kilometers) and has the maximum number of rural points (299 villages). In the meantime, with respect to the TPI factor, class -18 to 18 covers the most area, while class -57 to -18 shows the maximum rural points. In terms of NDVI, it has been revealed that class 34/ To 40/. Covers the most area and class 21/ To 29/. Count the most rural points. Lastly, with respect to the runoff factor, the studies reveal that the 0 to 0.01 class has the maximum area, while the 0.0294 to 0.0411 class accommodates the largest number of rural areas.

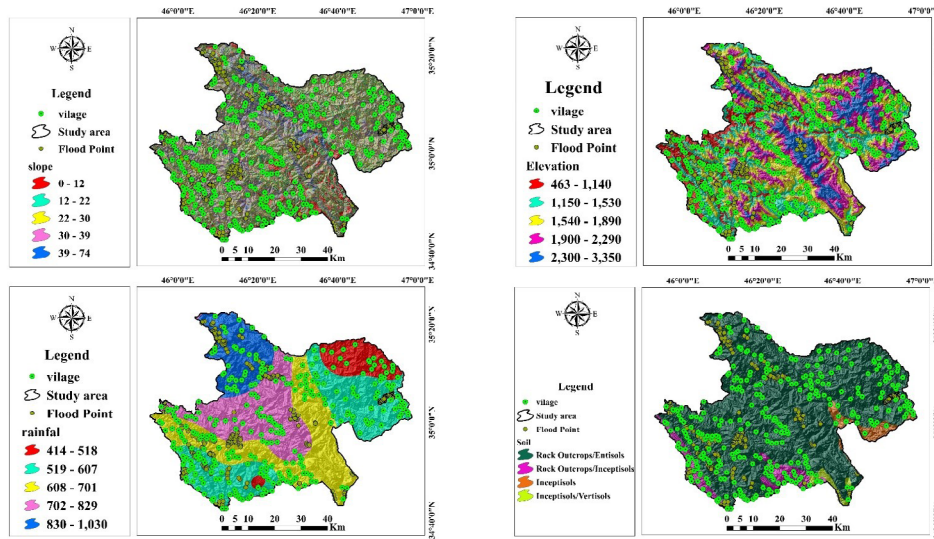


Figure 3. Slope, elevation, precipitation, and soil maps



Table 3. Details of classes of factors affecting flooding (slope, elevation, precipitation, and soil factors)

Slope	Number of villages	Area (km ²)	Elevation	Number of villages	Area (km ²)
0 – 12.6	151	684.38	463 – 1139	110	537.60
12.7 – 22	117	1125.37	1139 – 1529	120	1021.76
22.1 – 30.6	32	1048.44	1529 – 1887	85	1187.15
30.7 – 40	19	926.66	1887 – 2285	4	950.75
40.1 – 74.9	0	355.51	2285 – 3350	0	453.92
Sum	319	4140.36	Sum	319	4151.18
Rainfall	Number of villages	Area (km ²)	Soil	Number of villages	Area (km ²)
414 – 517	25	347.34	Rock Outcrops /Entisols	257	3687.73
517 – 606	117	1174.96	Rock Outcrops/Inceptisols	47	262.75
606 – 701	83	1101.56	Inceptisols	9	126.78
701 – 828	57	959.23	Inceptisols /Vertisols	6	58.72
828 – 1028	37	561.46	-	-	-
Sum	319	4144.55	Sum	319	4135.98

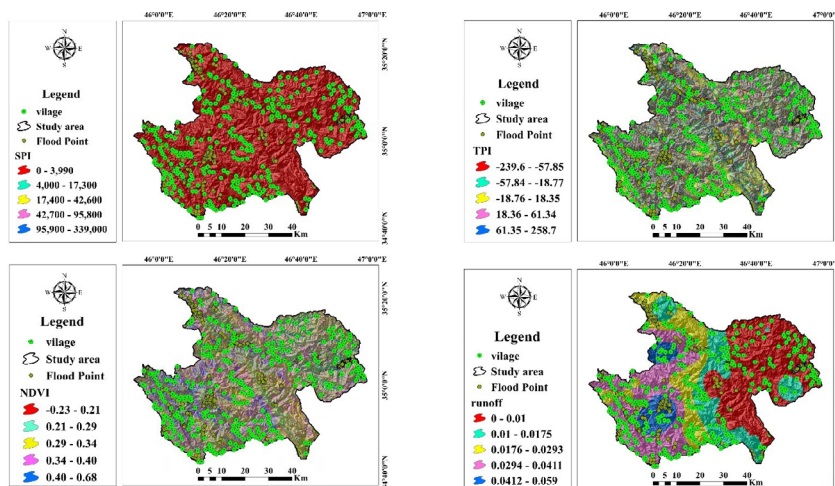


Figure 4. SPI, TPI, NDVI, and runoff



Table 4. Details of classes of factors affecting flood occurrence (SPI, TPI, NDVI, and runoff factors)

SPI	Number of villages	Area (km ²)	TPI	Number of villages	Area (km ²)
0 - 3990	299	4077.25	-239 - -57	95	440.52
3990 - 17291	12	49.90	-57 - -18	136	1008.13
17291 - 42564	8	10.90	-18 - 18	81	1339.23
42564 - 95769	0	2.29	18 - 61	7	931.06
95769 - 339183	0	0.29	61 - 258	0	432.08
Sum	319	4140.63	Sum	319	4151.02
NDVI	Number of villages	Area (km ²)	Runoff	Number of villages	Area (km ²)
-0.23 - 0.21	96	117.12	0 - 0.01	85	1452.96
0.21 - 0.29	117	838.08	0.01 - 0.0175	50	665.60
0.29 - 0.34	61	1187.17	0.0176 - 0.0293	50	665.58
0.34 - 0.40	27	1355.91	0.0294 - 0.0411	106	1040.72
0.40 - 0.68	18	518.20	0.0412 - 0.059	28	319.67
Sum	319	4016.48	Sum	319	4144.53



When creating base layers for flood risk zoning within the Cultural Landscape of Hawraman, the weights of the 12 factors were computed using expert and researcher opinions (see Figure 5). The findings reveal that the three important factors: slope, precipitation, and vegetation dispersion index have weights that are fairly proportional (0.111, 0.107, and 0.098, correspondingly), while the last three factors, SPI, elevation, and soil, have low weights (0.061, 0.063, and 0.068, respectively).

The final flood risk map for the Cultural Landscape of Hawraman was generated using the fuzzy overlay method and the Sum operator, fulfilling the main objective of this research (Figure 6 and Table 5). As mentioned earlier, study areas have been divided into 5 classes. On first glance, if we divide the Cultural Landscape of Hawraman into two halves, the western half of the region might be more prone to flooding than the eastern half. Under these conditions, the rural settlements in western parts of the region will be more prone to flooding as well. A more detailed examination of the final map

further proves that in all the flood points of the Cultural Landscape of Hawraman, 261 points (which correspond to 69.23 percent of the flood points) locate in higher and even higher risk zones. This shows the capability of the zoning and its importance in increasing the validity of the findings. Analyzing currently the state of the 319 villages that were visited, the result indicates that there is no one village classified into the very low risk category, and about 2.51 percent such villages (i.e., 8 villages) were classified into the low risk category, 9.09 percent into the medium risk category (which refers to about 29 villages), 19.12 percent of the villages (which refers to 61 villages) are in the high risk category, and the remaining 69.28 percent of mostly rural points (which corresponds to about 221 villages) in the very high risk category. The results indicate that 11.79 percent of the entire area of the Cultural Landscape of Hawraman is classified as very low risk, while 24.29, 29.46, 19.34, and 15.12 percent are in the lower, medium, higher, and very high risk zones, respectively.

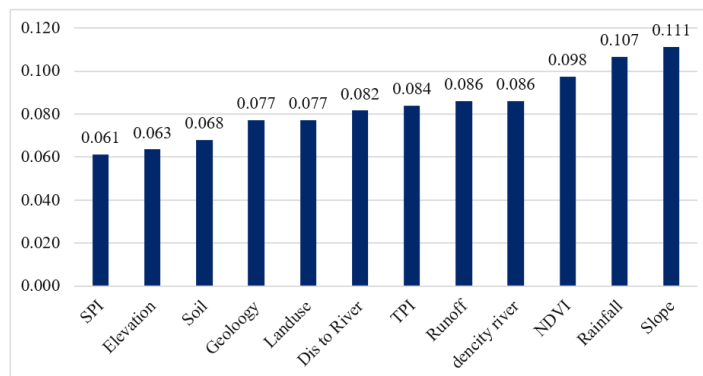


Figure 5. Weight assigned to factors affecting flood occurrence



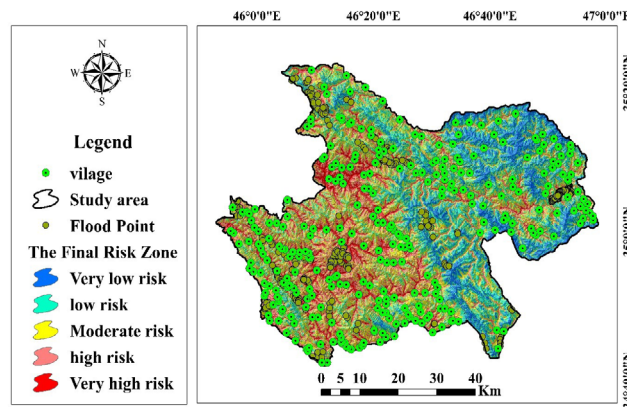


Figure 6. Zoning of the Cultural Landscape of Hawraman in the face of flood risk



Table 5. Final flood hazard zoning details using the Sum operator

Final zone	Flood Point		Village Point		Area (Km2)	
	frequency	Percentage	frequency	Percentage	frequency	Percentage
V L R	10	2.65	0	0	486.91	11.79
L R	41	10.88	8	2.51	1003.19	24.29
M R	65	17.24	29	9.09	1216.80	29.46
H R	79	20.95	61	19.12	798.66	19.34
V H R	182	48.28	221	69.28	624.23	15.12
Sum	377	100	319	100	4129.79	100



Validation of flood risk zoning in the Cultural Landscape of Hawraman

The ROC curve was employed in checking the accuracy of the final flood risk zoning map in the Cultural Landscape of Hawraman (Figure 7 and Table 6). The results show that the shape of the ROC curve (blue color) is tending towards the upper corner and the left side, in-

dicating its high power in detecting flood occurrence in the Cultural Landscape of Hawraman. The results of the AUC index (area under the curve) with a value of 0.852 also show that the model performed well in distinguishing flood-prone versus non-flood-prone areas. On the whole, the results indicate good performance of flood zoning in the Cultural Landscape of Hawraman.

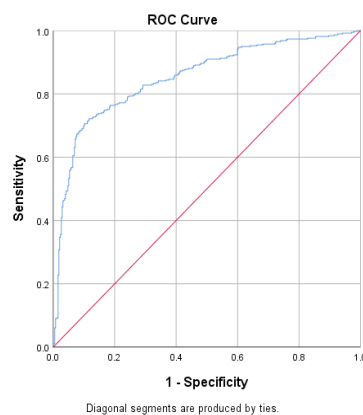


Figure 7. Overview of the ROC curve



Table 6. AUC details for flood risk zoning using the Sum operator

Area Under the Curve				
Test Result Variable(s): sum				
Area	Std. Error ^a	Asymptotic Sig. ^b	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.852	.014	.000	.824	.880

The test result variable(s): The sum has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5



5. Discussion

The Cultural Landscape of Hawraman is a prime example of a rural region profoundly shaped by both its natural environmental conditions due to its geographical location and the relationship of its people with the environment over generations. Basically, in the case of this area, the impact will be the scenic nature and abundant water resources positive for people’s livelihood or, on the other hand, the environmental hazard events like floods and landslides, which become adversities. The mountainous nature of this Cultural Landscape of Hawraman, therefore, becomes a world-class registered space propitious to floods and other environmental hazards.

Floods tend to create a lot of multidimensional challenges to the natural environment and human settlement in the Cultural Landscape of Hawraman. The application of GIS in flood risk zoning is, therefore, justified in providing a perspective to identify the rural settlements in this context for crisis management. The study results revealed that more than one-third of the area in the Cultural Landscape of Hawraman lies between high and very high-risk zones during flooding. This result aligns with previous research conducted by Nasrinnejad et al. (2015), Ghobadi et al. (2017), Azamirad et al. (2018), Swain et al. (2020), and Saeedi & Asiaei (2021), which also indicated that 20-40% of the study area falls within high-risk and very high-risk zones.

An analysis of 319 villages in the region showed that 88.4 villages are located within these high to very high-risk flood zones, underscoring the vulnerability of rural settlements to flooding. These findings call attention to the urgent need for targeted flood-risk management strategies. Rural development planners and the residents of the Cultural Landscape of Hawraman must recognize

the profound interrelationship between communities and their environment, as these dynamics play a pivotal role in flood vulnerability.

Given the global recognition of the area by UNESCO and its significant geographical and cultural importance, it is imperative to implement effective flood-risk management measures. The following recommendations are proposed to mitigate flood risks and protect both the environment and rural communities:

1. Disseminate flood-risk zoning maps to local communities to raise awareness of vulnerable areas.
2. Develop and implement an enhanced rainstorm forecasting model, with the Government Meteorological Organization providing timely alerts to at-risk communities.
3. Enforce restrictions on construction activities, especially within flood-prone zones, to prevent the development of vulnerable infrastructure.
4. Prohibit human settlements in flood-risk zones to reduce exposure to disaster.
5. Equip villages with modern flood warning technologies to provide early warnings of impending floods.
6. Establish relief centers in villages identified as being at high and very high flood risk, ensuring swift response in case of emergencies.
7. Ensure that new buildings adhere to technical and engineering principles designed to withstand flood conditions.

8. Set up emergency food and sanitary warehousing to support communities during floods.

9. Construct diversion barriers to redirect floodwaters away from populated areas.

10. Prevent the encroachment of grazing lands and forests by villagers, ensuring the natural environment is preserved and flood risks are minimized.

By implementing these measures, it is possible to improve the resilience of the Cultural Landscape of Hawraman to flood hazards and enhance the safety and well-being of its inhabitants.

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Conflict of Interest

The authors declared no conflicts of interest.

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