GIS integration with AHP and Frequency Ratio Methodologies for Landslide Susceptibility Mapping in Choman District, Iraq

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Abstract:

The geographic information system (GIS) and remote sensing techniques used in this study with a combination of both analytic hierarchy process (AHP) and frequency ratio (RF) techniques to produce accurate and reliable areas that are susceptible to landslides for Choman district in Kurdistan region of Iraq. Communities and infrastructures can be damaged severely by landslides, highlighting the significant need for accurate and reliable susceptibility map of landslides for effective disaster management and risk mitigation procedures. It is one of the few researches that used free high resolution imagery from Google Earth Pro and field trips to collect historical landslide data, using it for landslide identification and validation. Topographic, hydrologic, geological, and anthropogenic parameters were identified as the main contribution factors for landslides that used as to establish an effective susceptibility model. The research categorized Choman district into four vulnerability zones: low, medium, high, and very high susceptibility. The results highlighted that steep slope regions with proximity to geological faults and main roads are most vulnerable regions to landslides in Choman district. The research result of FR approach indicated that around 16% (137.5 km^2) of Choman district is highly susceptible to landslides and the high, medium, low susceptible areas were 42.4% (365.4 km^2), 31.7% (273.5 km^2) and 9.9% (85.3 km^2), respectively. Accuracy assessment for the created map using field surveys indicated high accuracy for both methods. Specifically, with accuracy of 0.78 for AHP and 0.9 for FR, the results indicated a strong agreement between the predicted susceptibility areas and historical landslide events, also the consistency ratio was less than 0.1 with 0.05. Value of 0.726 for AHP and 0.824 for FR of area under the curve (AUC) demonstrated a good accuracy and reliability of the techniques. The findings of the research could significantly contribute for risk mitigation strategies, infrastructure development, and policy-making.

Keywords: Analytical Hierarchy Process, Frequency Ratio, Geographic Information System, Landslide Susceptibility Assessment, Google Earth Pro, Choman District, Kurdistan Region, Disaster Management, Land-use Planning.

1. Introduction

The downward movement of rock, or earth considered as landslides which are series natural hazards. Geological, hydrological, and climatic conditions can influence these landslide events with different degrees. Landslides could make human settlements, infrastructure, and natural ecosystems face severe challenges, resulting in catastrophic consequences like loss of life, property damage, and environmental degradation. The landslides can have serous impacts, which makes the assessment and mapping of landslide susceptible area necessary to reduce its risks and enhance preparedness. Iraq's diverse geological condition, rainfall patterns, terrain slope, soil composition, and seismic activity have a huge contribution to the of landslides frequency, resulting in severe damage to structures and human life. For instance, a landslide in Karbala resulted in the death of eight people in 2022 (Al-Dhahi, Hussain et al. 2023). The Kurdistan region which is located in the north of Iraq within the Zagros series, particularly the Choman District due to its diverse mountainous formations and lithological units, is highly susceptible to landslides. Recent researches have highlighted the necessity for more detailed and region based landslide analysis and assessments to face these challenges effectively. There were 3,190 different types of landslides, such as rock falls, translational slides, and slumps in the region (Othman and Gloaguen 2013, Othman, Gloaguen et al. 2015).

The Hamilton Road, starting from Haji Omran to Soran district, is a significant economic and strategic road between Iran and Iraq borders. Every year, Kurdistan region faces huge economic losses because of landslide occurrences from the mountains during the heavy rain seasons, which frequently block the route and causing people injuries, and impacting trucks, and cars (Qadir 2016). These landslides also caused the damage of water pipes in Soran city, resulting in disruptions in the drinking water supply (Qallam 2024). Additionally, landslides caused substantial damage on roads, vehicles, and properties around Choman areas. As an example, a huge landslide in 2022 which occurred during night and heavy rainfall, buried a house full of sheep, resulting in their dramatic deaths. Furthermore, a landslide on the side roads caused damage to a car, injuring the driver and passenger in Dukan district (Kurdiu 2023). Similarly, a tragic landslide event near Darbandikhan district in southern of Sulaymaniyah province caused the deaths of two individuals and injury to a third one. The victims suffered fatal head wounds, they were mountaineers caught in the Tuni Baba gorge. The heavy rains were identified as the main cause of the landslide occurrence days (Fars 2023).

These incidents emphasize the critical need to create accurate landslide prone areas, and plan accordingly to increase such risks to protect life of people and infrastructure for more sustainable environment. Effective disaster management and land-use planning, we need accurate and reliable landslide susceptibility mapping of Choman and its surroundings. Because having the risk map areas is helpful to identify areas that are prone to landslides and enables decision makers to create different strategic planning to reduce the impacts of landslides, saving properties, and protect lives of people. There are plenty of important researches that assessed and created landslide risk maps in Iraq, by using different types of approaches to improve our understanding related to the causes and impacts of landslides. In 2021, Zaki and Suleimany used the integration of GIS and AHP to identify the landslide prone areas in Wadi Hujran, north of Erbil city (Zaki and Suleimany 2021). Also in 2023, Anwar Dh. Al-Dhahi successfully used AHP and GIS to create a map of vulnerable areas to landslides for the Zurbatiya region in Wasit Governorate. This research used various parameters to create susceptible areas that have significant contribution to landslide events (Al-Dhahi, Hussain et al. 2023). Similarly, in Kurdistan region of Iraq, Kaiwan K. Fatah integrated both FR, AHP, and an ensemble FR-AHP model to create accurate map of landslide risk areas in the Akre District of the Kurdistan Region (Fatah, Mustafa et al. 2024). This research highlighted the effectiveness of different statistical model combinations together to enhance the accuracy of the landslide risk areas. Moreover, contributions of Arsalan A. Othman was pivotal related to landslides in Kurdistan region if Iraq. In 2013, Othman used remote sensing techniques to automatically extract landslides in the Kurdistan region and analysed historical landslides in detail. Then, he applied different model statistics to create map of areas susceptible to landslides in the Mawat area, highlighting the significant contribution of various techniques in landslide-prone areas. Further in his research contribution to landslides, in 2017, Othman analyzed and created landslide vulnerable map for the Qala Dize area using remote sensing and GIS applications (Othman and Gloaguen 2013, Othman, Gloaguen et al. 2015, Othman, Al-Jaff et al. 2018).

These researches together show the significant role of advanced geospatial technologies and statistical models in developing mapping landslides and risk assessment approaches in the Kurdistan region. Using different approaches like AHP, FR, and remote sensing with GIS help a lot to create reliable and accurate identification of landslides, which contribute noticeably in enhancing the disaster preparedness and mitigation strategies in the region. However, despite the high susceptibility to landslides in the Kurdistan region, there is a lack of comprehensive studies that integrate multiple methodologies to assess landslide susceptibility accurately. Existing research often lacks the integration of advanced remote sensing techniques with robust analytical methods, leaving significant gaps in understanding and preparedness (Abedini, Ghasemyan et al. 2017). Moreover, no freely available high resolution satellite imagery are available to identify historical landslides accurately, also the administrations in Choman and Kurdistan region did not collect the historical landslides and there is no a proper database to depend on. This issue makes the researchers depend on very high resolution satellite imagery to identify landslides. However, the Google Earth Pro helped the process by providing the historical imagery of entire earth with very high resolution images which are freely available (Pro 2024). This have a great contribution to create a database with reliable detail and accuracy for landslide events in the past, and solving the challenge of gaps in historical data and expensive high-resolution satellite imagery. This is one of the few researches that used Google Earth imagery as a reliable source for collecting and identifying historical landslide in Choman district.

The objective of this research is to create an accurate map of landslide vulnerable areas in Choman district by using AHP and FR techniques. The outcome of this research will be used as a source to plan accordingly to mitigate the impact of landslide events on people, infrastructures and the environment.

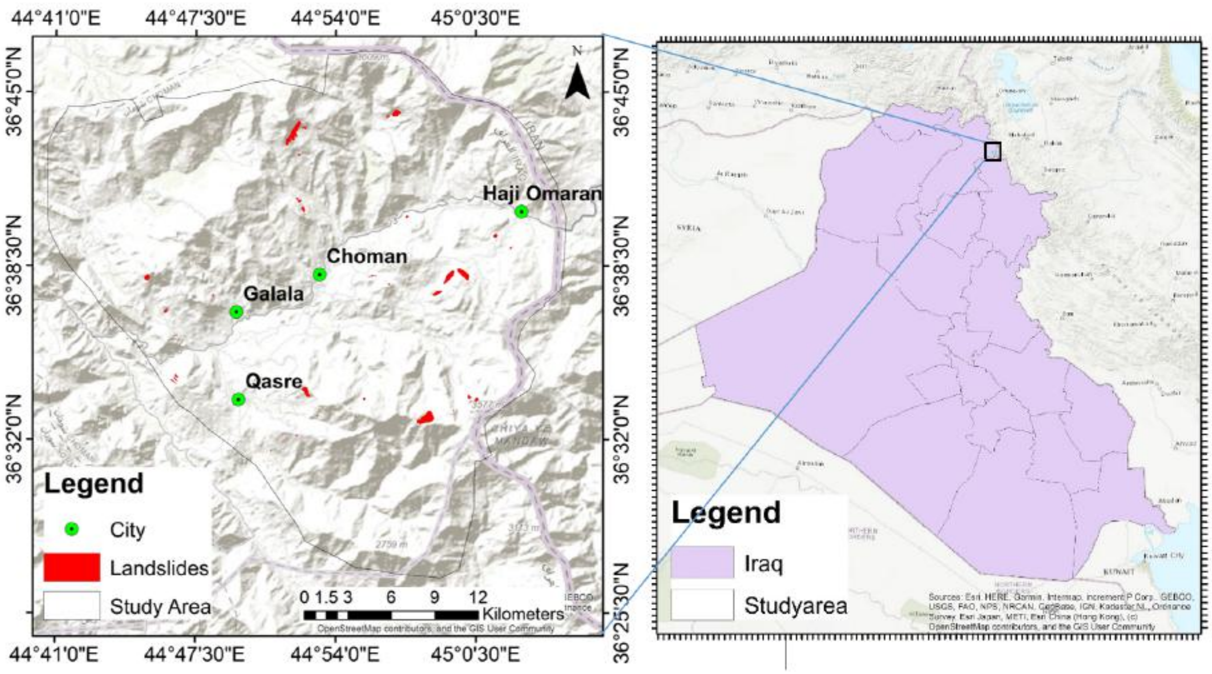

Figure 1: Study area (Choman District, Iraq).

2. Methodology

2.1. Study Area

Choman District is located in the east of Erbil Governorate in the Kurdistan Region in Iraq, which is an ideal region to assess and analyse the impact of landslides and susceptible areas, because of its geographical and environmental condition. It's located along the Iraqi-Iranian border, and it covers 4 other sub-districts like Galala, Haji Omeran, Samilan, and Qasre, along with 166 villages, with 861.7 km^2. In the other hand, Choman is a critical region for landslide studies due to its diverse climate and geological conditions make. The district have a critical rain and snow particularly in the Halgurd-Sakran Mountain range, resulting in landslide event occurrences in the area and threatening properties and life of people every years. The Choman region is also active for its contribution in agricultural activities, which have a huge impact on erosion and slope instability of the land. Furthermore, historical and environmental significance of Choman the district, including the Halgurd-Sakran National Park and numerous archaeological sites, necessitates the process of creating the landslide vulnerable areas to save both natural and cultural resources in the region. That is why Choman district is a place that needs immediate mapping and continues assessment of landslide susceptible areas. The unique geological conditions, climatic patterns, and socioeconomic activities have a significant impact on landslides and considering these factors have role in creating an enhanced and detailed landslide susceptibility mapping and risk assessment research (Gov.org 2024).

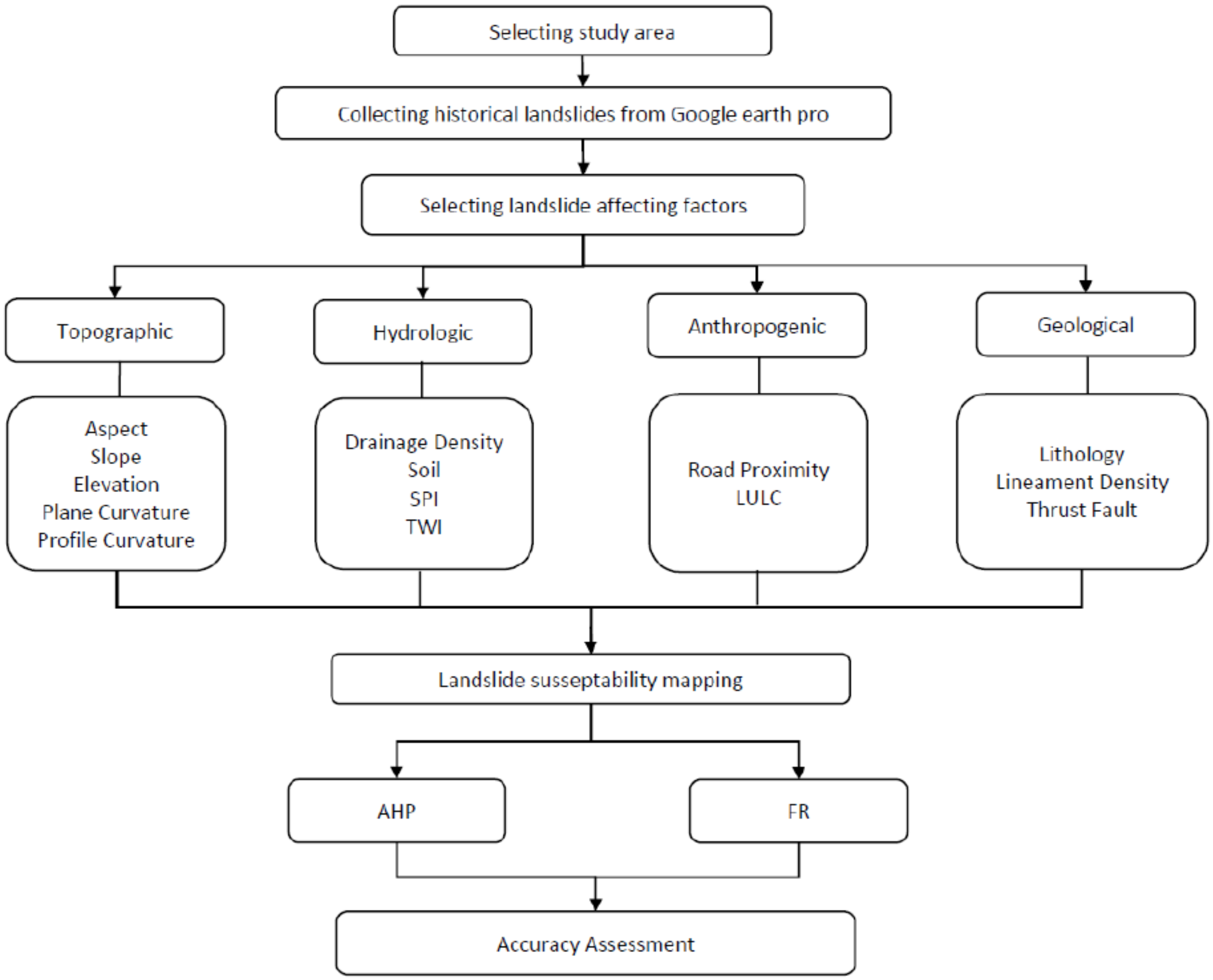

Figure 2: The flowchart of the study.

2.2. Data Collection

The freely available historical high-resolution satellite imagery from Google Earth Pro used with trip fields to collect landslides, which is a necessary step to have detailed and accurate information related to landslides for assessing landslide susceptibility. Google Earth Pro is significant platform for researchers which have cost-effective and efficient way to gather topographical and geological data to all world by providing freely available high resolution satellite imagery, especially for remote and complex regions such as the Choman District. However, the most updated satellite imagery available from Google Earth Pro was for December 2022, and to have more historical landslide data, field surveys were conducted to collect and validate the Google Earth Pro collected data and to identify new landslides that occurred after December 2022. 60 landslides were collected in total in the study area from both satellite imagery and field data. To ensure that recent landslide events has included, and collected data from satellite imagery were accurate, this process was done to provide a strong base for mapping the reliable susceptible area to landslides (Pro 2024).

Table 1: The factors used for landslide susceptibility mapping

Category	Factor
Topographic	1. Aspect
	2. Slope
	3. Elevation
	4. Plane Curvature
	5. Profile Curvature
Hydrologic	6. Drainage Density
	7. Soil
	8. SPI (Stream Power Index)
	9. TWI (Topographic Wetness Index)
Geological	10. Lithology
	11. Lineament Density
	12. Thrust Fault
Anthropogenic	13. Road Proximity
	14. LULC (Land Use and Land Cover)

2.3. Selection of Factors

Due to the complexity and large numbers of factors that contribute landslide, prediction and mitigation of landslides become more challenging process. These factors include geological formation of the area, which is related to the type of rock and soil; geomorphological conditions which means the slope angle, aspect, and elevation of the region; and environmental variables including vegetation cover, land use, and hydrological characteristics (Table 1, Figure 3). The mixture of these factors have a significant impact of possibility and frequency of landslide events, emphasizing the need for use complex approaches that considers all factors. To create an accurate the landslide vulnerable map in the Choman District, we considered factors like topographic, hydrologic, geological, and anthropogenic, based on their critical impact on landslide occurrences as used in previous studies. We analysed each factors to understand the influence of each one on the slope stability within the region. To prioritize these factors based on their relative importance and their impact to areas with potential landslides, we used AHP and FR techniques. The flowchart of the study illustrated in Figure 2. These techniques together can be used effectively to analyse and assess the multiple factors that have impact on landslide events, leading to more accurate map of areas with risk of landslides (Shano, Raghuvanshi et al. 2020, Barman, Soren et al. 2023, Sujatha and Sudharsan 2024).

The kappa coefficient (KC) were used to assess the accuracy of the generated results by AHP and FR. The equation of KC (5) and equation of OA (4) in the matrix of kappa coefficient addresses the accuracy assessment for the landslide susceptible areas (Table 2) (Landis and Koch 1977):

User Accuracy (UA) = CR/TR (2)

Where CR equation (2) is the rows proportion that correctly identified and the TR in the equation (2) is represented by the total numbers of pixels in the same row.

Producer's accuracy (PA) = CC/TC (3)

The CC in equation (3) is the number of correctly identified pixels in each column. However the TC in the equation (3) is the accurate pixels that are identified in the column.

Overall accuracy (OA) = CD/TR (4)

The "CD" parameter in the equation (4) is the diagonal total number of pixels. However, TP is referred to the sum of all reference points.

$$\text{Kappa coefficient (KC)} = \frac{(TP*CD)-\sum(TC*TR)}{TP^2-\sum(TC*TR)} \quad (5)$$

Table 2. The classification of Kappa coefficient (Landis and Koch 1977).

No.	Kappa coefficient (KC)	Categories
1	< 0.00	Poor (P)
2	0.00-0.20	Slight (S)
3	0.21-0.40	Medium (F)
4	0.41-0.60	Good (G)
5	0.61-0.80	Very good (V.G)
6	>0.81	Excellent (E)

2.4. Analytical Methods (AHP)

The AHP (equation 6) is a commonly used technique that is based on mathematical relationship and expert judgments to assess complex problems using multiple factors, which developed by Thomas L. Saaty in the 1970s. It offers an effective approach to make decision-making process more comprehensive by considering multiple factors. Its helps to reduce complex decisions and synthesize the results using series of pairwise comparisons (Table 3). For mapping landslide risk areas, AHP is effectively used to identify the weight of different factors that have contribution and influence on landslide events. In the process of generating the objective map, hierarchical structure will be utilized to evaluate and rank the used parameters that have contribution to the landslide events, and pairwise comparisons would be used to calculate their weights based on the experts judgments. The consistency ratio (CR) is a crucial measure which commonly used in the process of evaluating the reliability of the judgments made during the pairwise comparison of criteria, which acceptable values for CR is less than 0.1 (or 10%). This approach offers an effective assessment that considers each factors based on their weight to generate a landslide prone areas, which would be an invaluable technique that can be used in the process of developing mitigation strategies and disaster management (Khatun, Hossain et al. 2023, Aparna, Abhishek et al. 2024, Liu, Ding et al. 2024).

AHP = (w1*f1 + w2*f2 ... wn*fn) (6)

Where w is represent the white of the factor and the f is the used factor as a layer.

Table 3: the factors with their ranking for AHP and FR technique.

Factors	Value	Ranking	Factors	Value	Ranking
Drainage Density	<0.5	1	SPI	200000	1
	0.5-1	2		200000 - 800000	2
	1-1.5	3		800000 - 1500000	3
	1.5-2	4		1500000 - 3500000	4
	>2	5		>3500000	5
Thrust proximity	<500	5	Soil	Rough Broken and Stony land	2
	500-1000	4		Rough mountainous land	4
	1000-1500	3		Rough mountainous land,Alpine Phase	5
	1500-2000	2	lithology	Bekhma formation	3
	>2000	1		Tanjero formation	2
LULC	Bare land	2		Shalair series	2
	Tree	1		Qandil series	5
	green area	1		Naopurdan-walash series	5
	builtup	3		Red bed series	1
	snow	4	road proximity	>50	5
Plan curvature	concave	5		50-100	4
	flat	1		100-150	3
	convex	5		150-200	2
profile curvature	convex	5		>200	1
	flat	1	lineament density	>500	5
	concave	4		500-1000	4
slope	>15	1		1000-1500	3
	15-25	2		1500-2000	2
	25-35	4		>2000	1
	>35	5	Elevation	743-1000	1
aspect	flat	1		1000-1500	2
	north	4		1500-2000	3
	Northeast, east, southeast	5		2000-2500	4

	Southwest, west, northwest	3		>2500	5

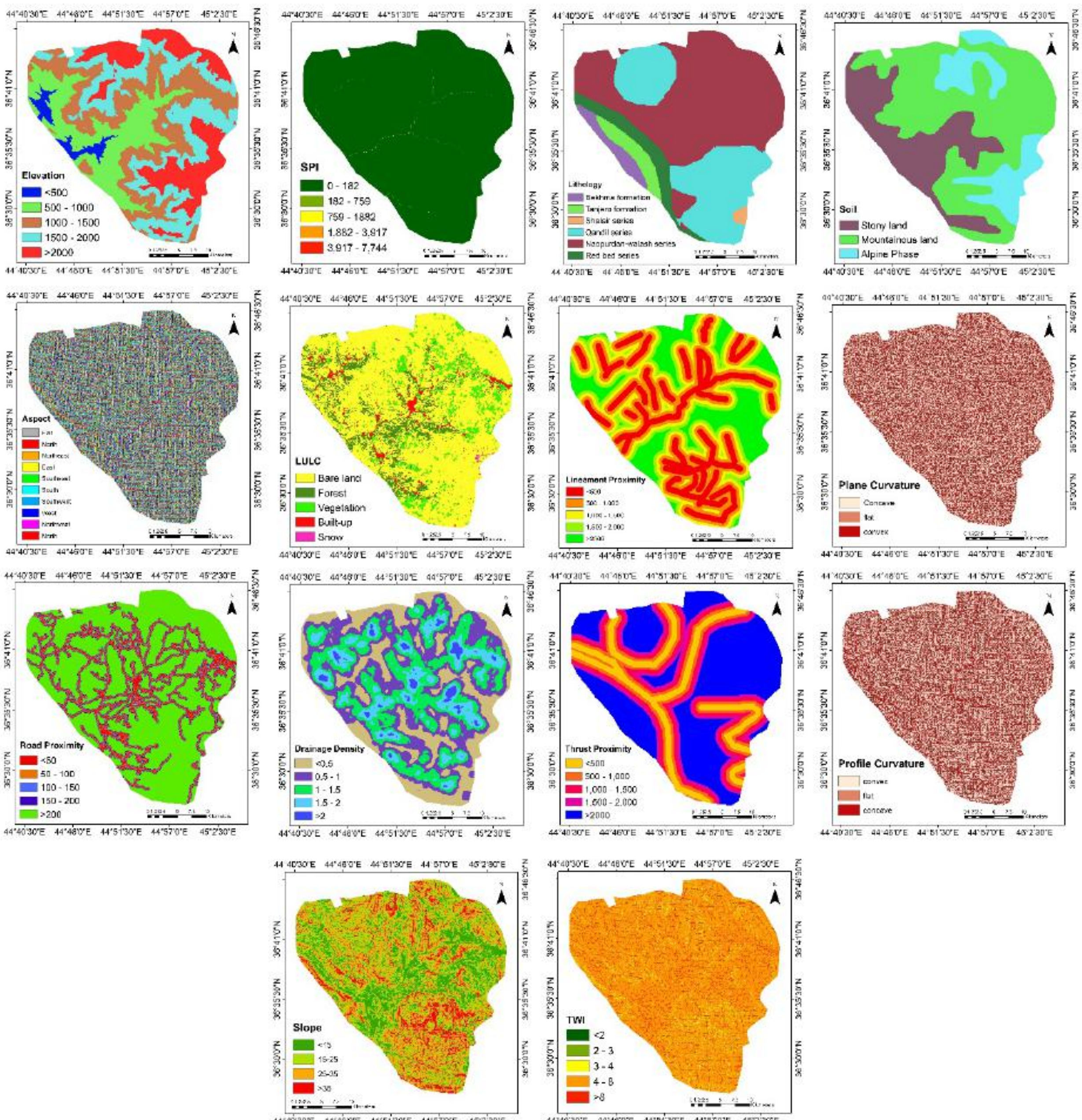

Figure 3: The factors used to map the landslide susceptibility in the Choman District.

2.5. Frequency Ratio (FR) Method:

FR used to assess the spatial relationship between the parameters with contribution to landslides and the occurrences of the events, making it as an effective empirical statistical method that commonly used in recent years with noticeable accuracy for landslide susceptibility mapping. FR technique is based on ratio calculation of landslide occurred areas to the total area of the region of interest, which would be done for each factors contributed to the landslides. Then the weight of each class will be identified by using the ratio, which is its impact of it on landslide occurrence. The reliance of FR on historical landslide data, which is a fundamental base for the assessment is the main advantage of the FR method. The FR approach is one of the commonly used method to generate accurate and detailed landslide susceptibility maps by assessing the correlation between past landslides and conditioning factors. It's one of the most accurate technique that have been used in multiple researches to estimate the probability of a landslide hazard in different types of environmental conditions. However, it's particularly effective to generate accurate maps in the study are where detailed historical data are available, which will be

Factors	S	LD	DD	LULC	SL	L	R	E	F	PL	PR	A	TWI	SPI	Sum	%W

the base for future predicting of landslide risks (Bhandari, Dhakal et al. 2024, Moragues, Lenzano et al. 2024, Oyda, Jothimani et al. 2024, Sun, Yan et al. 2024)

.

Table 4: pairwise comparison matrix: (S: slope), (LD: lineament density), (DD: drainage density), (LULC: land use land cover), (SL: soil), (L: lithology), (R: road), (E: elevation), (F: fault proximity), (PL: plain curvature), (PR: profile curvature), (A: aspect), (TWI: topographic wetness index), (SPI: stream power index).

S	1.0	2.0	1.0	2.0	2.0	2.0	0.5	3.0	3.0	3.0	3.0	4.0	4.0	4.0	34.5	10
LD		1.0	0.5	1.0	2.0	3.0	0.3	3.0	3.0	3.0	3.0	3.0	3.0	4.0	30.3	9
DD			1.0	2.0	2.0	3.0	1.0	3.0	4.0	4.0	5.0	5.0	5.0	5.0	43.0	13
LULC				1.0	1.0	1.0	0.3	2.0	3.0	3.0	4.0	4.0	4.0	4.0	29.3	9
SL					1.0	1.0	0.3	2.0	2.0	3.0	3.0	4.0	5.0	5.0	28.8	9
L						1.0	0.3	3.0	3.0	3.0	3.0	3.0	4.0	5.0	28.5	9
R							1.0	3.0	3.0	3.0	3.0	4.0	5.0	5.0	42.0	11
E								1.0	2.0	3.0	4.0	4.0	5.0	5.0	26.8	10
F									1.0	2.0	2.0	3.0	3.0	4.0	17.9	5
PL										1.0	1.0	2.0	3.0	4.0	14.1	4
PR											1.0	2.0	3.0	4.0	13.9	4
A												1.0	3.0	3.0	10.4	3
TWI													1.0	2.0	6.3	2
SPI														1.0	4.0	1

2.6. Integration of AHP and FR:

It is significant to understand the relationship between the landslide vulnerability mapping approaches. Different types of techniques such as Probabilistic, deterministic, and statistical methods have been applied in numerous ways to create and analyse susceptibility of landslide areas; each method has its own set of principles and assumptions, which can influence the results of generated result in different contexts. The reliability and effectiveness of both AHP and FR techniques have been emphasized in multiple researches in the past for various regional scales and contexts. Schicker and Moon compared bivariate and multivariate statistical approaches to create landslide risk areas, which is a purely statistical perspective and is parallel to AHP and FR techniques (Schicker and Moon 2012). Furthermore, Shahabi et al. in their research demonstrated how AHP and FR effectively can be used to generate accurate landslide susceptible areas within the central Zab basin in Iran (Shahabi, Khezri et al. 2014). These studies, among others, showed how effective the combination of different approaches such as AHP and FR are to do comparative analysis of different models and assess their usefulness in various geographical conditions (Aziz, Sarkar et al. 2024, Kebeba, Shano et al. 2024).

Combining and integration the strength of both AHP and FR techniques, we can get a comprehensive approach to assess the landslide inventory mapping. AHP uses expert judgment and pairwise comparisons, which is based on hierarchical structure with weights for each factor. On the other hand, the FR method relies on empirical data to assign weights to each factor class based on the observed frequency of landslide occurrences. However, even though the AHP techniques is simpler to use, but FR is more effective and promising for achieving greater accuracy for complex cases. This integration ensures that we generate a reliable result of landslide vulnerable areas considering both expert judgment and historical data, which making the integration a comprehensive tool to use for mitigation strategies and disaster preparedness (Das, Sarkar et al. 2022, Gopinath, Jesiya et al. 2023).

3. Results

The landslide inventory map was developed using high-resolution Google Earth Pro imagery and validated through field surveys. This map indicates the spatial distribution of landslide occurrences in the Choman District, highlighting areas where landslides have been historically recorded. The use of satellite imagery allowed for the identification of landslide features, while field surveys provided ground truth data to ensure the accuracy of the mapped landslides. The result showed that as much as 0.36% of Choman District area faced landslides in the past accounting for some 3.1 km^2. The largest landslide covered 0.6 km^2 in the south east of the study area. The final landslide susceptibility map, integrating the results from AHP and FR, is presented in Figure 4. This map categorized the Choman District into zones of low, medium, high, and very high susceptibility. The integration of AHP and FR methodologies ensured a comprehensive assessment, balancing expert judgment with empirical data to produce a robust susceptibility model. The result of FR showed that nearly 16% of Choman District is highly vulnerable to landslides, with the majority of these places being from the top peak of mountains and the areas near to roads and rivers (Table 3). The validation process involved comparing the landslide susceptibility map with historical landslide occurrences and conducting field verification. The collected 60 landslides were divided to training and test points with 70% and 30%, respectively.

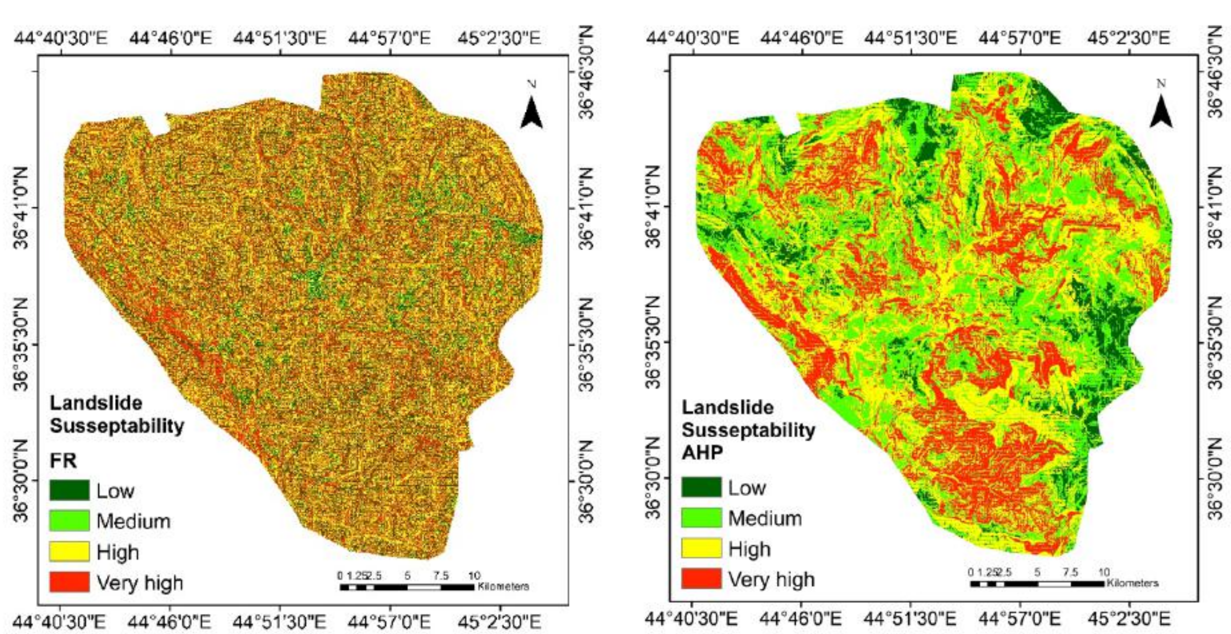

Figure 4: Result of landslide susceptibility using FR and AHP techniques in GIS.

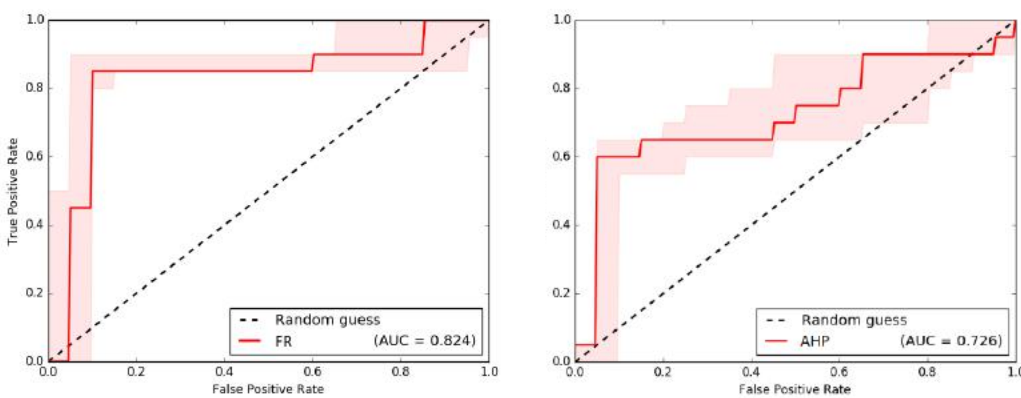

Figure 5: The area under curve value for FR and AHP techniques.

The number of landslides which were located in the very high susceptibility class of landslides were divided by the total number of all landslides in the Choman District to find the accuracy of the AHP and FR. The results of kappa coefficient showed that the accuracy of AHP was 0.78; however, the accuracy of FR was higher with 0.9, indicating the effectiveness and accuracy of FR technique. Also the area under the curve (AUC) value was determined for both techniques, the values were 0.726 for AHP and 0.824 FR (Figure 5). The results indicated that both techniques generated good results of landslide vulnerable areas, especially FR method which its accuracy is promising and more reliable than AHP technique. This validation highlights the effectiveness of both approaches to generate landslide susceptible areas and used for disaster management and land-use planning in the Choman District.

Table 5: The landslide susceptibility areas and percentages in the Choman District.

Landslide index	FR		AHP	
	Area Km2	%	Area km2	%
Low	85.3	9.9	90.1	10.5
Medium	273.5	31.7	276.2	32.2
High	365.4	42.4	370.3	43
Very high	137.5	16	121.1	14.3

4. Discussions

The results showed that the areas that are high susceptible to landslides are those which have steep slopes and near to geological faults in Choman district. During rainy seasons the landslides triggered due to the instability conditions of the area. This factors highlight the significant of considering slope and fault proximity for risk mitigation strategies and disaster management procedures to reduce the landslide events in the region. The outcome of this research supports the previous studies that have been done in the area, which slope conditions and lithological formations considered as significant factors contributing to landslide hazards. The AHP method is subjective, which depends on expert judgment, which could lead to bias in the assigned weights of each used factors, which is a limitation of this technique.

On the other hand, future contributions could use advanced techniques like machine learning and deep learning approaches to enhance assessment procedure and develop more accurate map of landslide vulnerable areas. The maps created by this research serve significant insights for policymakers and planners in the Choman District. It can be used as a valuable guide for natural resource and disaster management in the area along with better land-use decision makings to avoid high-risk areas in the future. Categorizing the region into different level of landslide susceptibility, offers a critical help to prioritize high susceptible areas for detailed investigation, infrastructure development, and developing immediate mitigation strategies for these areas. This procedures can significantly ensure the safety of people and properties, also reducing the possible damages from landslide.

5. Conclusion

The GIS and remote sensing technologies effectively used in this research with both AHP and RF techniques to generate accurate landslide susceptibility map for Choman district in Kurdistan region of Iraq. The results categorized the Choman region into four risk levels, low, medium high, and very high susceptible area of landslides. 14 factors from different categories were considered to create landslide vulnerable areas. 60 landslides were collected using google earth pro and field trips, and the study found that approximately 16% (137.5 km^2) of the Choman districts is highly susceptible to landslide hazards, resulting in high risk to the local population, specifically during rainfall seasons (Figure 4, Table 5). Also the results of FR approach showed that 42.4% (365.4 km2), 31.7% (273.5 km2) and 9.9% (85.3 km2) in Choman district were located in high, medium, low susceptible areas, respectively. The outcome indicated that steep slope and regions near geological faults and roads are prone to landslide events. The result of this research offers invaluable insights about the factors that significantly contribute in landslide events, and emphasizing the necessity of considering these factors in disaster reduction strategies. Additionally, the result indicated that AHP is more user friendly, however, despite its complexities FR is proved to be more accurate technique to generate the landslide susceptible areas.

Furthermore, the map can offer a significant help for early warning systems and could be used as a consideration for infrastructure planning projects by policymakers, ensuring the location of new constructions in safer areas and reducing the risks caused by landslide. Communities and infrastructures in Choman district which is a highly susceptible region to landslides could be protected by doing continues researches and investment in landslide susceptibility assessment. By developing our understanding of factors that contribute in landslides and enhancing the integrated approaches to generate accurate map of those places prone to landslides, we can reduce the risks of landslide events and prepare more effectively to reduce the impacts of natural hazards and safe people and resources to have more sustainable environment.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Kaifi Chomani: Conceptualization, Methodology, Data Curation, Validation, Resources, Software, Formal Analysis, Investigation, Writing—Original Draft, Visualization. Shaki Pshdari: Methodology and review.

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