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Zoning and Flood Management in Coastal Areas (Case Study: The Coasts of Hormozgan Province)

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ABSTRACT

The dangers of floods worldwide have caused this environmental event to be called one of the major natural disasters. Today, remote sensing data with accuracy and low cost play a critical role in identifying flood-prone areas and flood zoning in coastal management. In the present study, the flooded and flood-prone areas on the coasts of Hormozgan province were investigated according to the intensity of the rainfall system in the last days of April 2024 by using the GRDH images of Sentinel-1 satellite and the Otsu thresholding method. The results revealed that the area and percentage of flooded zones on April 17 occupied the largest area (28.15 km2) of the coastal surface and the highest average rainfall was also related to the same date with an average of 35.05 mm. The greatest extent of changes in flood zones is also on the coastline and near the border of the region, which indicates the high sensitivity and susceptibility of the coastal areas to flooding in this region. According to the obtained results, about 1448.36 km2 of the surface area is affected by flood zones, and the largest area is assigned to the high risk category with an area of 669.30 km2. According to the obtained results, it is possible to manage and control floods spatially and temporally on the coasts and prevent the consequences. Therefore, in the field of coastal flood management, it is necessary to pay attention to flood control methods, a suitable model to improve water supply sources and improve water security for drinking and health purposes, as well as appropriate bioengineering methods to stabilize soil and control erosion.

1. Introduction

In the 21st century, due to climate change and global warming, the increased possibility of flood risk has provided major concerns. Flooding is one of the major natural hazards in the world that affects a large population every year [9], especially in coastal areas that are vulnerable to climate and human hazards [2,5,17]. According to the surveys, 80% of the casualties caused by floods occur within 100 km of the coast [8].

Among the management measures that can play an important role in reducing flood damage and coastal management is the preparation of a flood zoning map [11]. To prevent the occurrence of floods and to contain them, the areas that have a high potential for flooding must be identified and then the factors of flood occurrence should be investigated. Moreover, the study and implementation of flood control and management methods before its occurrence is very important [15]. Considering that the extent of flood damage depends on the geometric characteristics of the stream bed and also the adjacent lands, therefore, flood risk zoning for different return periods is important. For this purpose, it is necessary to predict damage levels caused by floods in different conditions and to justify the economic and social flood control and management programs [14].

Today, deltas and coastal areas have a significant share in the world population and the population density in these places is increasing day by day [26, 22]. However, the coasts are affected by the consequences of environmental hazards that are related to sea level fluctuations, and the risks of coastal flooding are more threatening. This problem has made it necessary to monitor the flood plains and each part of the basin has a certain potential to produce runoff and flood [10]. Flood potential zoning is a method that zones the basin based on flood potential by considering the amount of runoff production in each section. In addition to reducing the effects and consequences of floods, this method provides valuable information about the surrounding environment, floods and their effects on floodplain lands and determining river boundaries [23]. Therefore, it is very important to know the flood-prone areas to control the damages caused by it, store the runoff, and increase the underground water reserves. In this regard, it is possible to identify flood-prone areas by using advanced spatial methods and use its results in coastal management planning [1]. Due to the importance of this issue and the reduction of human and financial losses caused by floods, several studies have been conducted in this field, which can be referred to the study of Doust & Shamsnia [4], in the identification and zoning of flood-prone areas using the GIS- AHP model in Bushehr province. The obtained results showed that more than 50% of the area of the region has a medium to high flood potential risk, so these areas must be the focus of urban management planning. Tabrizi et al. [23], also investigated flood zoning for use in determining the sanctuary of the Tail River. As the results indicated, the integration of HEC_RAS model and GIS geographic system is an efficient and useful tool in identifying and zoning river floods. According to the investigations and the comparison of existing maps and uses around the Tail river, in case of a flood with a return period of 25 years, there will not be much damage to these areas. In another study, Soleimani & Mohseni [20], investigated and zoned flood risk in Mazandaran province (Babelroud watershed) using GIS software. The obtained results indicate that part of the basin is affected by the risk of flooding with a very high potential, which is mainly located downstream and leading to the sea at the outlet of the basin. Sasanpour & Mohebi [16], investigated and analyzed flood risk zoning in Taleghan watershed. According to the results, 83% of the total basin area includes safe and low risk areas. While 17% of its lands have a medium and high risk of flooding, which includes areas around the main waterway and secondary waterways with residential and agricultural uses in the basin. Therefore, the need to respect the privacy of the Taleghan River in low-lying lands with a low and medium slope, in the development of urban and rural uses in the region, to reduce the damage caused by floods, should be implemented.

According to the studies, flood zoning is one of the most important management and flood control measures in flood prone areas. However, coastal areas, which are increasingly exposed to the threat of floods due to climate change, lack comprehensive studies that deal with flood control and management in these areas. Therefore, in response to this scientific limitation, in the present study, flood zoning and management were discussed in the coasts of Hormozgan province located in the south of Iran. The southern coasts of Iran on the shores of the Oman Sea and the Persian Gulf are affected by tropical storms and waves with high intensity and height. Along the coastlines, especially in the central and eastern regions, the waves caused by these storms have led to the formation of a dominant wave, which causes the coastal areas to be flooded [10]. Due to the flood on April 17, 2024, communication routes from Khamir to Lengeh port have been blocked. In addition, the consequences of the flood have blocked the road from Bashagard city to Jask and caused damage in Minab city. Therefore, flood zoning and management using remote sensing and GIS techniques is essential in these areas. Likewise, the results of this study can help to manage and control floods in coastal areas.

2. Study Area

In this study, the coastal areas of Hormozgan province along the Oman Sea and Persian Gulf were investigated and analyzed. This area is located with an area of 7,124,690 ha between the northern latitude 52 ° 44 ' 26 " to 59 ° 14 ' 27 " and the eastern longitude 25 ° 24 ' 46 " to 28 ° 53 ' 55 ". In terms of climate, it has a hot desert climate and the average annual rainfall in this area is 139.4 mm. January is the rainiest month of the year (56.8 mm) and in contrast, May is the month without rain or the least rainy month in this area. This area has an average temperature of 26.8 C0, which is the hottest and coldest months of the year, respectively, August with an average temperature of 34.21 C0 and January with an average temperature of 18.44 C0 [12]. Despite the dry weather conditions of the province, no season is without rain due to the activity of monsoon low-pressure systems and their effect on Hormozgan province in the year's hot season. As expected, the highest amount of rainfall occurs in January, February and March and the lowest amount of rainfall occurs in July, August and September [21]. Figure. 1 displays th

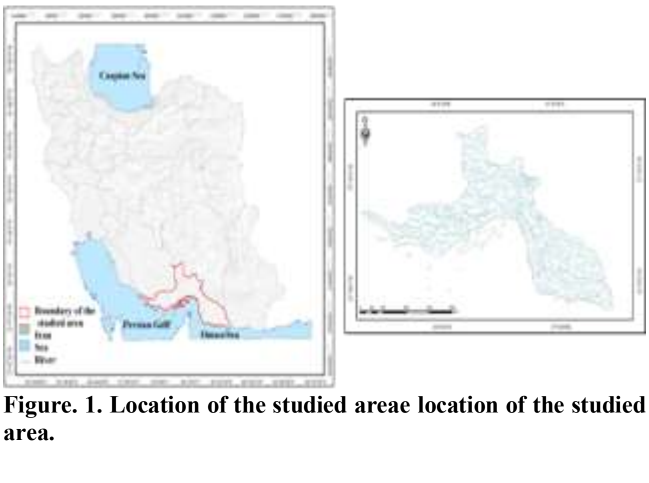

Figure. 1. Location of the studied areae location of the studied area.

3. Materials and methods

3.1 Methodology

In this study, GRDH images of Sentinel-1 satellite were used for flood zoning. The lack of need for light sources and the ability to take pictures 24 hours a day and in any weather conditions have led researchers all over the world to use these images as an efficient tool in flood investigation [25]. The Sentinel-1 satellite belongs to the European Union Space Agency (ESA) and is placed in the Earth's orbit as part of the Copernicus program. This satellite includes two sensors, A1 and B1, which provide users with radar images in a period of 6 days [24]. Therefore, in the present study, to identify and zone the flooded areas, GRDH radar images of Sentinel-1 satellite were prepared with a spatial resolution of 10 m (Table 1). In the following, using the Otsu thresholding method, the flooded areas were separated from other complications. Data related to average daily precipitation was also obtained from the power.larc.nasa.gov website. In addition, MATLAB Otsu was used for thresholding and Arc GIS 10.8 was also used to prepare maps. Figure. 2 shows the diagram of the preparation process for the flood zoning map process in the region. Flood-prone areas in the study area were identified by determining the difference in redistribution coefficient (Gamma γ0) between water and land and using Otsu's thresholding algorithm [13]. The limits of the determined threshold for the examined images can be seen in Table 1. In thresholding methods, the histogram of each image is divided into two parts according to the amount of gray composition. The greater the intensity of the grayness of the pixel (i.e. the pixels tend to be darker) indicates the blue area and vice versa, the pixels with a light gray tone (i.e. Pixels tend to white) indicate the land area (land). The most important feature of Otsu's method is the automatic thresholding of images. In this method, the threshold limit is determined based on the minimum intra-class variance and the maximum inter-class variance.

Table 1. Characteristics of radar images and threshold limits determined in the study

Row	Image date	Image mode	Image type	PASS	Polarization	Otsu's set threshold limit
1	2024/04/16	IW	GRDH	Ascending	VV	-16.11
2	2024/04/17	IW	GRDH	Ascending	VV	-16.36
3	2024/04/18	IW	GRDH	Descending	VV	-16.23

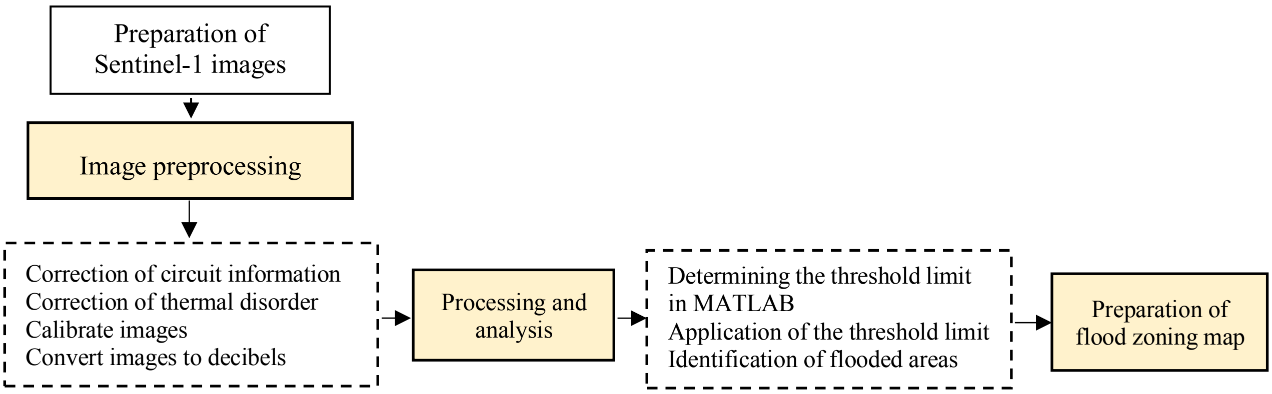

Figure 2. Diagram of the process of preparing flood zoning map in the studied area

4. Results and Discussion

4.1 Investigating flood areas and rainfall in the region

The obtained results indicate that the area and percentage of the flooded areas on April 16 occupied the largest area of the coast (28.15 km2) and the highest average rainfall was also related to the same date with an average of 35.05 mm. Table 2 displays the area and percentage of flooded areas and the amount of precipitation per day. According to the investigations, on the 16th to 18th of April 2024, the coasts of Hormozgan province were affected by a powerful rainfall system that caused torrential rain, lightning, momentary gusts and sometimes hail. In this region, Lavan, Jask, and Sardasht Bashagard synoptic weather stations have received the most rainfall from this system with total rainfall of 123.2, 121.1, and 120.5 mm, respectively. Thus, the rain gauge stations recorded more than 70 mm of rain during this rainfall system from 16 to 18 April (Figure 3). Further, to identify and zone flood areas, the map of flood areas on April 16 and 17 is shown in Figures 4 and 5, respectively. It is worth mentioning that April 18 was not included in this study due to the lack of significant changes and the limited extent of the flooded areas. As the results show, the greatest extent of changes in floodplains is on the coastline and near the border of the region, which indicates the high sensitivity and susceptibility of coastal areas to flooding in this region (floodplains with dark gray spots in the figure). It is given that increasing darkness of pixels indicates flooded areas).

Table 2. The area and percentage of flooded areas and the amount of precipitation per day

Row	Image date	Flooded area		Average rainfall (mm)
		Area (Km2)	Percentage (%)	
1	2024/04/16	22.56	3.16	23.13
2	2024/04/17	28.15	4	35.05
3	2024/04/18	18.46	2.57	21.08

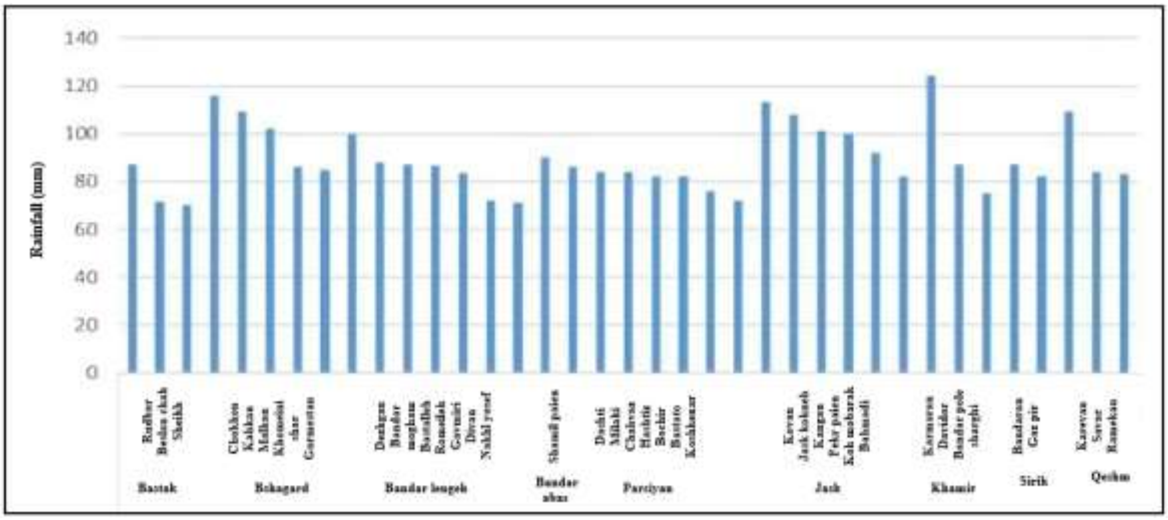

Figure 3. The graph of total rainfall of rain gauge stations in the studied area (April 16 to 18, 2024)

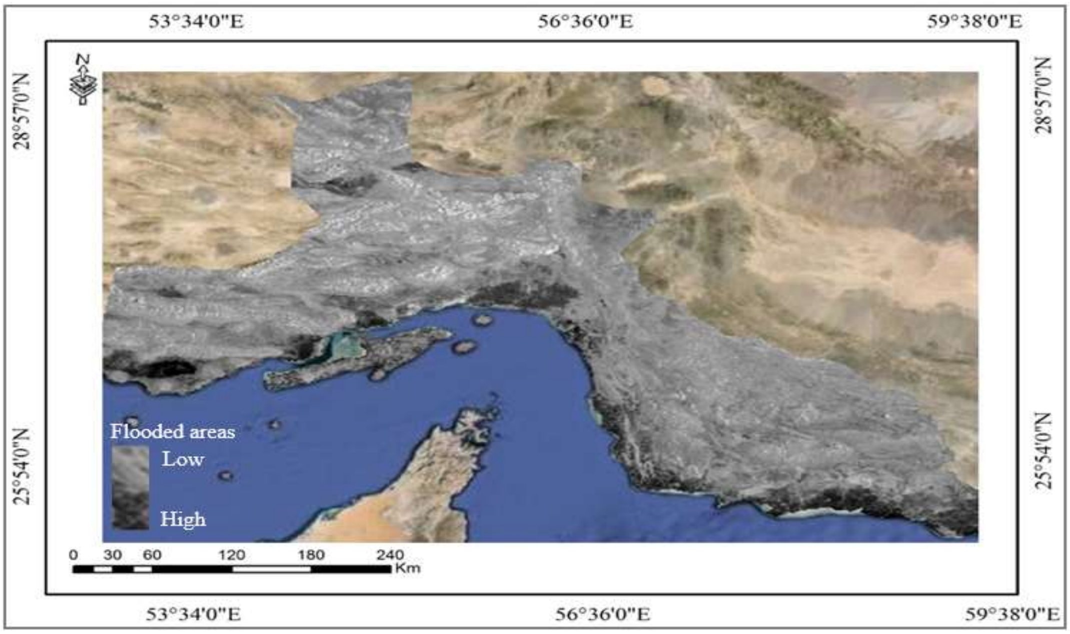

Figure 4. Map of flooded areas on April 16, 2024

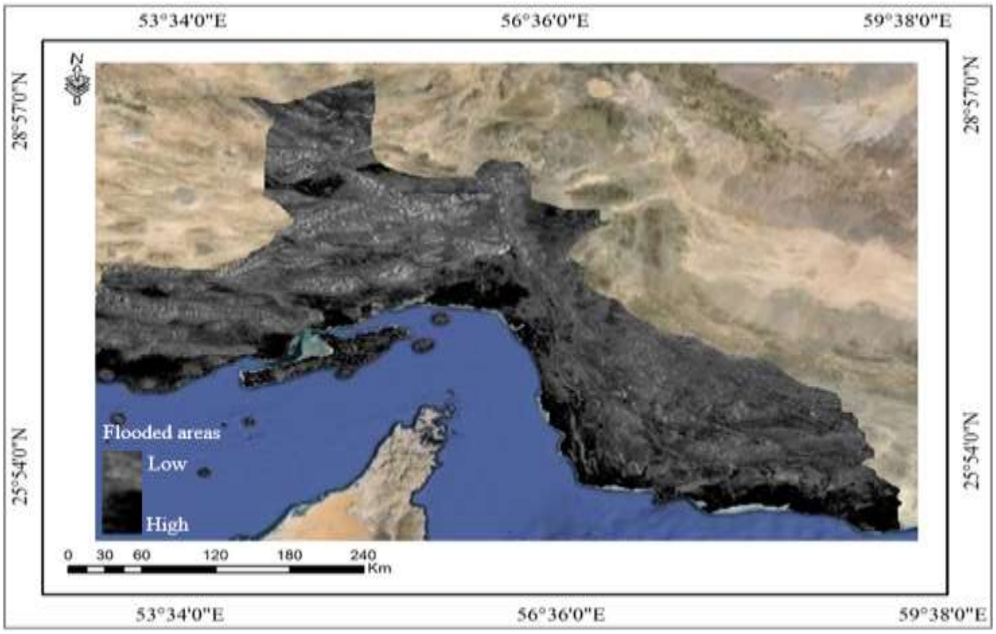

Figure 5. Map of flooded areas on April 17, 2024

4.2 Flood zoning in the area

In this study, after examining the flooded areas and the amount of rainfall that occurred in the region, the flood zoning was carried out by the spatial criteria such as the infrastructure and facilities of the region, population centers (cities and villages), communication network (main roads, railway transportation lines, airports), and rainfall distribution (maximum and average rainfall) were discussed during the studied days (Figures 6 to 10).

The map of the maximum rainfall on April 16-18, 2024, indicates that the maximum amount of rainfall was less than 20 mm in the southeast of the province, while the amount of rainfall was more than 55 mm in the eastern and western regions of the province (especially Bashagard and Persians) is considerable. Likewise, most rainfalls are related to Bashagard and Bandar-e Lengeh cities with more than 200 mm, and Bandar Abbas, Rodan and Haji Abad cities were also affected by more than 55 mm rain.

Further, due to the concentration of marine infrastructure and facilities along the coastline, the abundance of population centers, especially villages in the coastal area, and the network of roads and airports, flood zoning was analyzed in the province. As the results illustrate, 1,448.36 km^2 of the area is made up of floodplains, the largest area of which is the floodplain with an area of 669.30 km^2 (46.21 percent) along the coasts. (Table 3 and Figure 11). Since most of the cities, including Khamir, Minab, and Haji Abad, and some coastal villages are located in lowland areas and the flood plains of rivers, the occurrence of floods and river inundations in these areas is the most threatening factor.

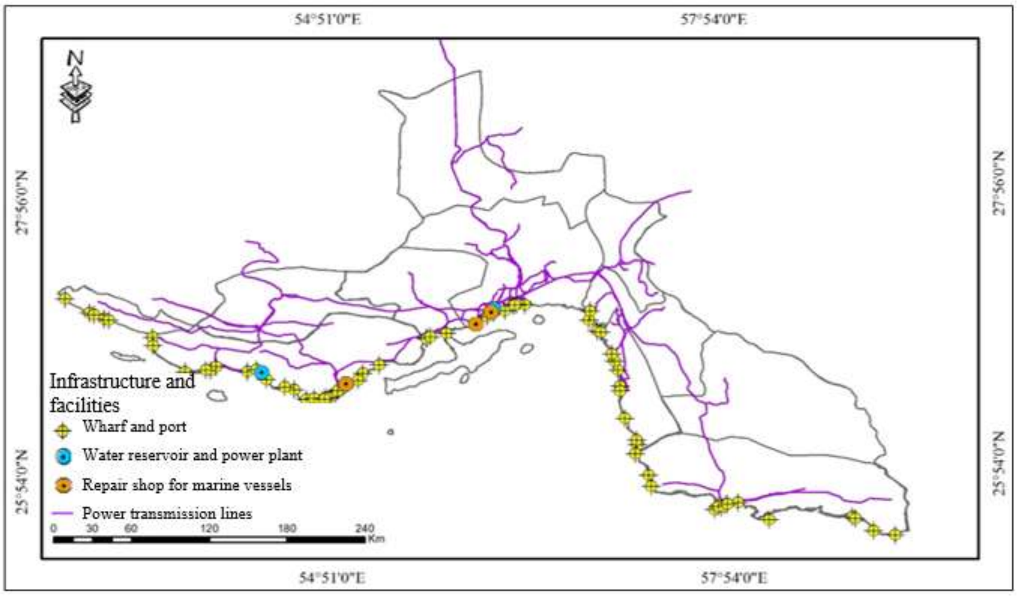

Figure 6. Map of infrastructure and facilities of the area

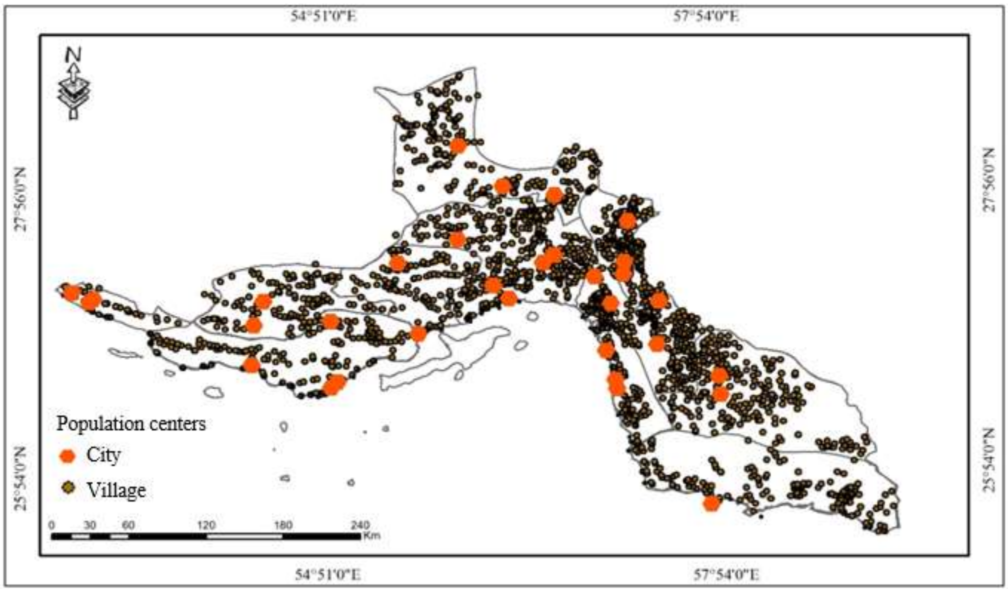

Figure 7. Map of population centers of the area

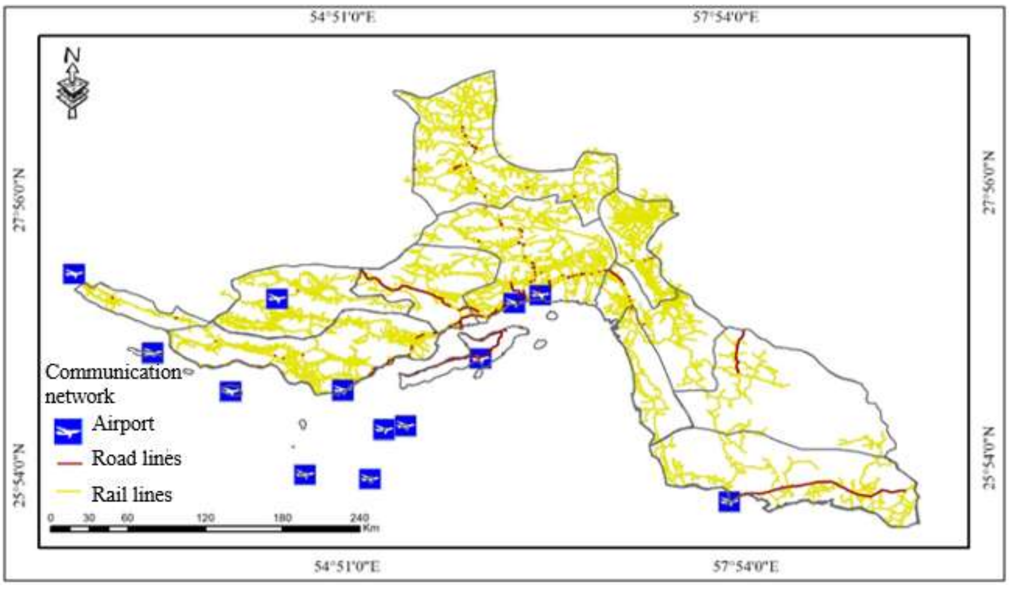

Figure 8. Map of the communication network of the area

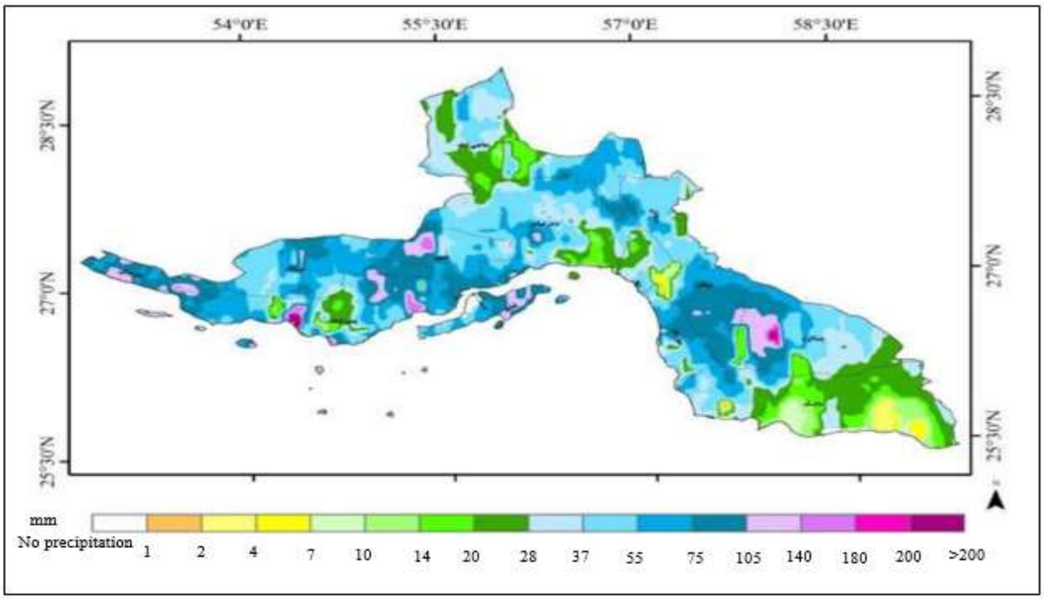

Figure 9. Map of maximum rainfall from April 16 to 18, 2024

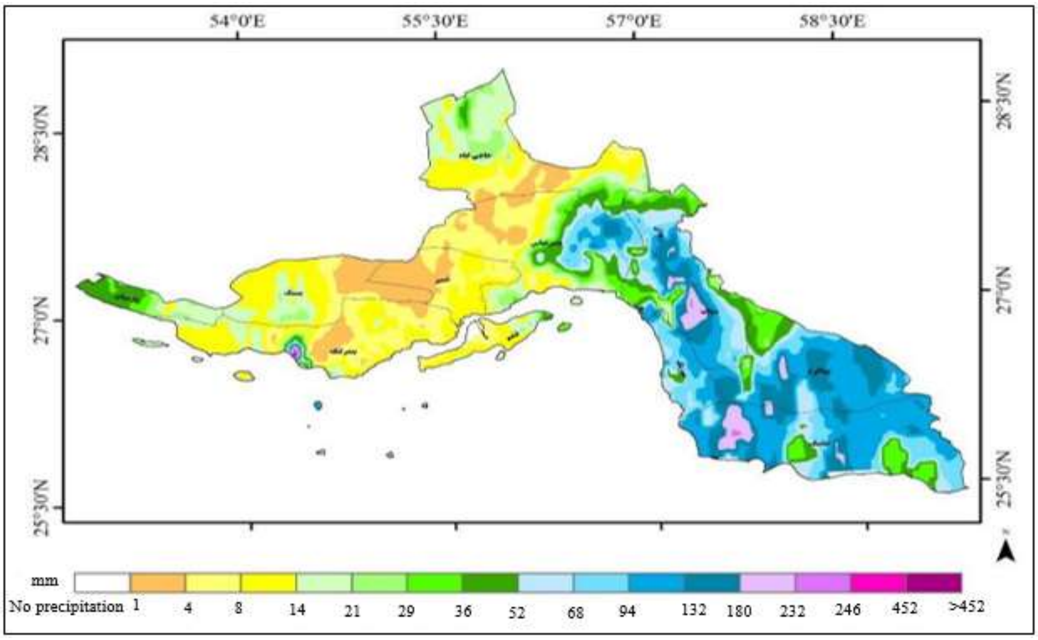

Figure 10. Map of average rainfall from April 16 to 18, 2024

Table 3. Area and percentage of flood zones in the studied area

Row	Classes	Area (Km^2)	Percentage (%)
1	Low	113.62	7.84
2	Medium	664	45.84
3	High	669.30	46.21
Sum		1448.36	100

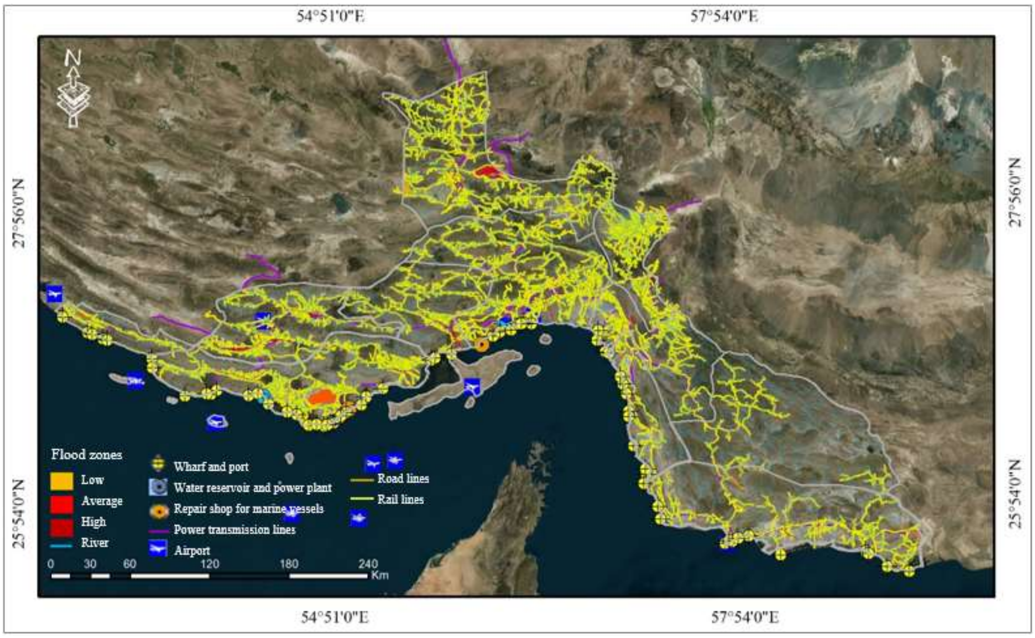

Figure 11. Flood zoning map in the studied area

The damages caused by floods worldwide have caused this environmental event to be referred to as one of the most important natural disasters. Today, along with the advancement of technology, humans can identify flood-prone areas and zoning these areas at risk [24].

In the present study, the flooded and flood-prone areas on the coasts of Hormozgan province were investigated according to the intensity of the rainfall system in the last days of April 2024 by using the GRDH images of Sentinel-1 satellite and the Otsu thresholding method.

As the results reveal, the greatest extent of changes in flood zones is in the coastline and near the border of the region, which indicates the high sensitivity and susceptibility of coastal areas to floods in this area. Therefore, controlling and managing floods in the province plays an important role in the safety of citizens, security of investment, and stability of infrastructure.

The results of studies by Carreno Conde and De Mata Munoz [3] and Gasparovic & Klobucar [6], also confirm the results obtained in this research. Their findings showed that the coastal areas are more affected by the dangers of floods due to their high sensitivity and vulnerability, as well as in the passage of the main rivers to the sea.

Likewise, according to land use planning studies of Hormozgan province [21], coastal areas are very sensitive in terms of environmental capacity and are considered as special biological areas. Therefore, in the future planning process, pay attention to the zoning of these lands in terms of the distance from the sea, determine the area of coastal, post-coastal and pre-coastal areas and functional areas.

According to the results, about 1448.36 km^2 of the area is affected by flood zones, the largest area is allocated to the high-risk category with an area of 669.30 km^2. The obtained results indicate high accuracy and its application in predicting the occurrence of floods. In this regard, Ghahreman & Zangeneh Asadi [7], also stated that radar images are a highly accurate and reliable tool in determining flooded areas, especially for quick investigations and close to the time of the flood phenomenon. In addition, the study of Sobhani & Danehkar [19], showed that remote sensing techniques are useful tools in examinations and evaluation of coastal areas.

5. Conclusion

The results obtained in this research indicate the use of new methods in a short period of time and with high accuracy, so these results can be used for accurate flood zoning and efficient planning in the future. According to the results, it is possible to manage and control floods spatially and temporally on the coasts and prevent the consequences. Therefore, in the field of coastal flood management, it is necessary to pay attention to flood control methods, a suitable model to improve water supply sources and improve water security for drinking and health purposes, as well as appropriate bioengineering methods to stabilize soil and control erosion. Likewise, it is suggested that in addition to flood zoning, flood forecasting should also be conducted in future studies. Based on this, it is possible to manage and control flooding spatially and temporally on the coasts and prevent its consequences. The repetition of floods in the country and in the coastal areas of Hormozgan province reminds us of the necessity for zoning and forecasting against flood risks. In addition, these hazards emphasize the need to improve infrastructure and apply management strategies to control floods in the area.

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6. References

[1] Ahmadi, Y., Bazrafshan, O., Salajeghe, A., Holisaz, A., & Azareh, A., (2021). Identifying the Factors Affecting Urban Flood Vulnerability in Bandar Abbas with Emphasis on Urban Runoff Management. Urban Economics and Planning, 2(3), 236-246.

[2] Barbaro, G., Bombino, G., Foti, G., Barillà, G. C., Puntorieri, P., & Mancuso, P., (2022). Possible increases in floodable areas due to climate change: The case study of Calabria (Italy). Water, 14 (14), 2240.

[3] Carreno Conde, F., & De Mata Munoz, M., (2019). Flood monitoring based on the study of Sentinel-1 SAR images: The Ebro River case study. Water, 11(12), 2454.

[4] Doust, A. M., Shamsnia, S. A., & Shabani, M., (2023). Spatial Analysis of Water Areas Potential for Small Water Supply Projects in the Southeast of Bushehr Province. Management, 3(4), 48-59.

[5] Garzon, J. L., Ferreira, Ó., Reis, M. T., Ferreira, A., Fortes, C. J. E. M., & Zózimo, A. C. (2023). Conceptual and quantitative categorization of wave-induced flooding impacts for pedestrians and assets in urban beaches. Scientific reports, 13(1), 7251.

[6] Gasparovic, M., & Klobucar, D., (2021). Mapping floods in lowland forest using sentinel-1 and sentinel-2 data and an object-based approach. Forests, 12(5), 553.

[7] Ghahraman, K., & Zanganeh Asadi, M., (2022). Determination of flood-prone areas using Sentinel-1 Radar images (Case study: Flood on March 2019, Kashkan River, Lorestan Province). Journal of Spatial Analysis Environmental hazarts, 9(3), 103-118.

[8] Hu, P., Zhang, Q., Shi, P., Chen, B., & Fang, J., (2018). Flood-induced mortality across the globe: Spatiotemporal pattern and influencing factors. Science of the Total Environment, 643, 171-182.

[9] Jafarzadegan, K., Moradkhani, H., Pappenberger, F., Moftakhari, H., Bates, P., Abbaszadeh, P., & Duan, Q., (2023). Recent advances and new frontiers in riverine and coastal flood modeling. Reviews of Geophysics, 61(2), e2022RG000788.

[10] Karimi, P., Safaval, P. A., Behzadi, S., Azizi, Z., Zarkash, M. M. K., & Kalashami, H. K., (2022). Flood Risk Zoning using Geographical Information System Case Study: Khorramabad Flood in April 2019. Acta hydrotechnica, 35(63), 89-100.

[11] Kautsary, J., & Rahman, B., (2024). Evaluation of Zoning Regulations in Coastal Areas for Disaster Risk Reduction of Climate Change. In IOP Conference Series: Earth and Environmental Science, 1321 (1), 012004. IOP Publishing.

[12] National Meteorological Organization., (2023). Annual climate report.

[13] Otsu, N. (1979). A threshold selection method from gray-level histograms. IEEE transactions on systems, man, and cybernetics, 9 (1), 62-66.

[14] Pornaby Darzi, S., Vafakhah, M., & Rajabi, M. R., (2021). Flood hazard zoning using HEC-RAS Hydraulic Model and ArcGIS (Case Study: CheshmehKileh River in Tonekabon County). Journal of Natural Environmental Hazards, 10(28), 15-28.

[15] Rezaee, Z., & Vahidnia, M. H., (2022). Offering flood prevention solutions using remote sensing and approaches integrating fuzzy logic and agent-based modeling. Scientific-Research Quarterly of Geographical Data (SEPEHR), 31(121), 111-125.

[16] Sasanpour, F., & Mohebbi, F., (2021). Flood risk analysis and zoning-Case study: Taleghan Watershed.

[17] Sobhani, P. & Danehkar, A., (2023). Assessment of environmental hazards and vulnerability of Hara protected area using DPSIR model. Environmental Hazards Management, 10 (3), 215-232.

[18] Sobhani, P., & Danehkar, A., (2023). Natural features and management areas of Khamir and Gheshm mangrove forests. Iran Nature, 8(4), 97-112.

[19] Sobhani, P. & Danehkar, A., (2024). Sea level changes and its impacts on Hormozgan Province mangrove forests (Case of study: Hara protected area). Journal of Oceanography, 15 (57), 115-126.

[20] Solaimani, K., & Mohseni, B., (2023). Evaluation of effective criteria on flood risk based on network analysis process and GIS in Vazroud basin of Mazandaran province. Iranian journal of Ecohydrology, 10(1), 61-75.

[21] Land use planning of Hormozgan province., (2018). Management and Planning Organization of Hormozgan Province, 1-77.

[22] Sun, H., Zhang, X., Ruan, X., Jiang, H., & Shou, W., (2024). Mapping Compound Flooding Risks for Urban Resilience in Coastal Zones: A Comprehensive Methodological Review. Remote Sensing, 16 (2), 350.[23] Tabrizi, R., Rahmati, S. H., Seyed Mohammad Shirazi, R. H., & Shahbazi Bilehsavar, M., (2023). Zoning of the 25-Year Flood for Use in Determining the Boundaries of the River's Bed and Boundaries (Til River as Case Study). Journal of Water and Soil Resources Conservation, 12(3), 111-127.

[24] Tanim, A. H., McRae, C. B., Tavakol-Davani, H., & Goharian, E., (2022). Flood detection in urban areas using satellite imagery and machine learning. Water, 14(7), 1140.

[25] Uddin, K., Matin, M., & Meyer, F., (2019). Operational flood mapping using multi-temporal sentinel-1 SAR images: a case study from Bangladesh. Remote Sensing, 11, 1581.

[26] Van de Sande, B., Lansen, J., & Hoyng, C., (2012). Sensitivity of coastal flood risk assessments to digital elevation models. Water, 4(3), 568-579