SPATIAL PREDICTION OF COASTAL FLOOD-SUSCEPTIBLE AREAS IN MUSCAT GOVERNORATE USING AN ENTROPY WEIGHTED METHOD

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ABSTRACT

Flooding is one of the most commonly occurring natural hazards worldwide. Mapping and evaluation of potential flood hazards are vital parts of flood risk assessment and mitigation. This study focuses on predicting the coastal flood susceptibility area in Muscat Governorate, Sultanate of Oman. First, it is assumed that the occurrence of a hazard can be determined based on the indicators influencing it. Thus, four indicators were selected and classified into five classes based on their contribution to flood hazard probability; these include ground elevation, slope degree, soil hydrologic group, and distance from the coast. Then, the entropy weighted method was applied to calculate the weights of given indicators in influencing flood hazards. The results were finally aggregated into ArcGIS software and the produced maps were reclassified into five coastal flood susceptibility zones. The results show that the soil indicator has the highest rate of weight in Wilayats Bawshar, Muttrah, Muscat and Qurayyat. While the elevation indicator has the highest rate of flood hazard in Wilayat AlSeeb. The weight results were used then for calculation of flood hazard index which was then classified into five classes of flood hazard susceptibility zones. The results of this work will be very useful in pursuing work on assessing the potential of multiple hazard risk interactions. It is essential to include certain indicators such as land use and land cover in future work, as they play a major role in water infiltration and runoff behaviour.

Keywords: entropy weighted method, ArcGIS software, influencing indicators, precondition factors, Sultanate of Oman, trigger factors.

1 INTRODUCTION

Flooding is one of the most common natural hazards in the world. In recent years, the number of people affected by floods is more than any other type of disaster [1]. Floods can be defined as general and temporary inundations in areas that are usually dry. Flooding in coastal areas is mainly generated when sea water levels along the coast are higher than ordinary tide levels, causing inundations that may last for several days [2]. Coastal areas can be affected by floods for different reasons, such as tidal changes, storms, heavy rainfalls, or overflowing streams [3]. The EM-DAT (International Disaster Database) reported 127 floods in 2018, with 2,879 fewer deaths compared to the annual average of 5,039 in 2008–2017, and about 34 million people worldwide are relatively less affected compared to the annual average of 73 million people in the same period [4]. The development of flood susceptibility maps is therefore necessary to identify flood prone areas in order to reduce deaths and damages.

Mapping and assessing susceptibility to flooding is an important component for flood prevention and mitigation strategies [5]. Spatial prediction of coastal flood susceptibility areas requires that all influencing indicators being properly considered. These indicators, also known as causative factors [6], [7], are needed as an independent indicator contributing to the occurrence of flooding in a given area [8]. They also have a significant impact on the accuracy of produced maps [7]. The selection of influencing indicators depends on the spatial scale of the proposed study area for flood susceptibility. However, there is no specific agreement on which influencing indicators should be applied [9]. For instance, Zhao et al. [10] suggested using fewer indicators for mapping flood susceptibility on national level, as it is more difficult to gain the same accuracy of data for the entire region. On the other hand,

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Mahmoud and Gan [11] claims that with a limited number of indicators, the possibility of having some over-rated factors will increase.

In a coastal area, specific geophysical environmental factors lead to flooding. Such factors were classified into precondition factors and trigger factors based on their contribution in forming hazard. Precondition factors are stable and never change or change very little over a long period. Several precondition factors can induce flooding in coastal, including; flat and low-laying ground, land surface with low capacity for water infiltration, and coastal buffer zone. Compared to precondition factors, trigger factors are changing constantly. The principal trigger factors for coastal flood are heavy rainfalls, storm surges induced by tropical cyclones, tidal waves, and tsunamis [12], [13].

In recent years, different methods have been developed and applied in different regions to define and assess flood susceptibility areas. One of these methods is the entropy weighted which has been extensively applied in hazard and risk assessment studies to determine the weighted index of natural hazard [12], [14]–[17]. This method reflects the priority within given indicators in influencing a hazard [16]. The entropy weighted method relies on the theory of information entropy and measures the useful information provided by each indicator [12]. In flood hazard studies, entropy can be used to assess the importance of indicators in causing a hazard by measuring the information contained in the indicators. The greater the entropy of indicator, the greater the uncertainty, and the amount of useful information provided by the indicator is small. In other words, higher weights indicators have greater contributions to flood hazard than those with lower weights [16].

This study focuses on analyzing indicators that cause coastal flooding in the Governorate of Muscat, Sultanate of Oman, by which the most likely areas of flooding can be predicted. It is important to clarify that the analysis focuses only on the precondition factors that are referred to here as influencing indicators while the triggering factors were not included in this study. The next section aims to outline the area of study in detail. Then details of the method employed are given in the succeeding section. Section 4 illustrates and discusses the main finding of the study, and the concluding remarks are finally given.

2 STUDY AREA

Muscat Governorate, Oman's capital, is located in the north-eastern part of the Sultanate of Oman. The Governorate occupies a total area of 3,500 km^2 and overlooks the Sea of Oman with a coastline of 200 km in length. The Governorate consists of six Wilayats (administrative zones), only five of which overlook the Sea of Oman, including AlSeeb, Bawshar, Mutrah, Muscat and Qurayyat [18]. Thus, the assessment in this study will only apply to these Wilayats.

The coastal zone of the Sultanate of Oman overlooking the Arabian tectonic plate and the Indian Ocean where tropical storms occur makes the region more vulnerable to abnormal climatic events, cyclones and tsunami. For instance, the governorate has been affected by two powerful tropical cyclones; cyclone Gonu in June 2007, and cyclone Phet in June 2010 [19]. Moreover, the tsunami has struck Oman's coastline several times in the past, the best known of which was the tsunami of the Makran on the 28 November 1945 [20], and the 2004 Indian Ocean tsunami [21]. Furthermore, there are also a significant number of valleys that stretch across the governorate known as wadis. Such wadies lead to several floods, where floods in Oman are classified as flash floods and coastal floods [22], [23].

3 METHOD

In an effort to identify and map potential areas of susceptibility to coastal flooding in Muscat Governorate, several procedures have been taken. Starting with selecting the appropriate flood influencing indicators, followed by implementing the entropy weighted method. Finally, classifying the produced maps into five flood susceptibility zones. Fig. 1 illustrates the flowchart of the proposed methodology to identify flood susceptibility zones.

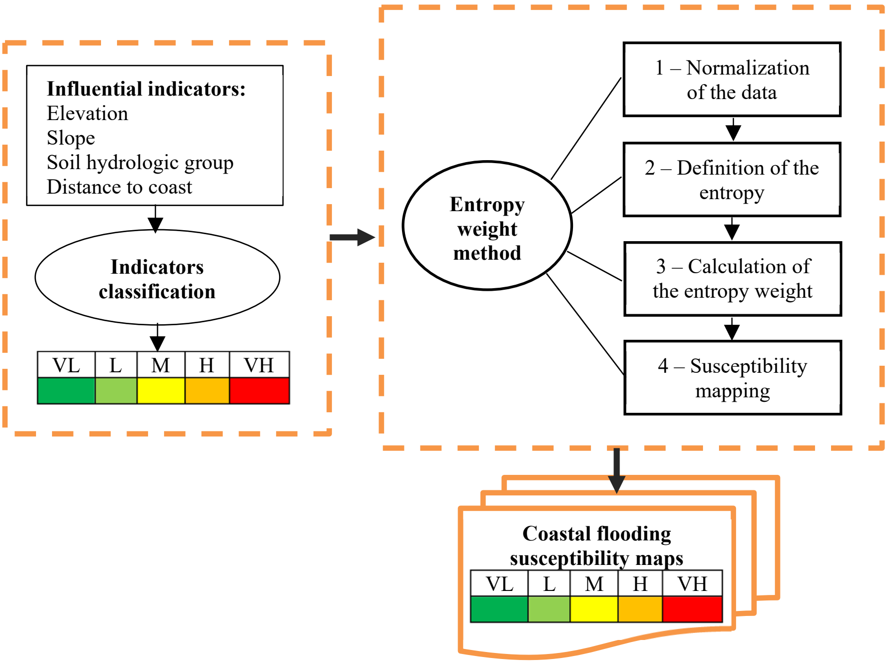


Figure 1: Flowchart showing the methodology implemented in this study.

3.1 Coastal flood influencing indicators

The most significant stage in the development of the final maps of coastal flooding susceptibility is the selection of the influencing indicators. In this study, four influencing indicators were selected to identify the potential of coastal flooding in the study area. These include: soil hydrological group, ground elevation, slope, and distance from the coast. The selection of these indicators is based on literature reviews [24], [25] and the data available for the study area. The influencing indicators of the study area were collected and compiled into spatial databases using ArcGIS software. Spatial relationships were then determined between the potential location of the flood and each of the indicators contributing to the occurrences of the flood. To simplify the evaluation process and mapping, the proposed inundation distance in land was estimated at 2,000 m. Furthermore, the influencing indicators were reclassified into classes 1 to 5, with 5 indicating a very high contribution to the probability of flood hazard and 1 indicating a very low hazard of flooding. The following paragraphs describe in detail the four selected indicators.

Ground elevation: elevation is an important indicator in flood susceptibility, as it controls the direction of flow movement as well as the depth and extent of flooding [26]. High quality resolution digital elevation model (DEM) is essential for obtaining an accurate flood hazard zonation result. The elevation map of the study area was generated from DEM 5 m resolution image of the area using ArcGIS software. The elevation was classified into classes 1 to 5;

very high (< 10), high (10–15), moderate (15–20), low (20–25), and very low (> 25) based on [25], where 5 refers to a very high contribution to the probability of flood hazard and 1 indicates very low.

Slope angle (in degrees): Slope indicator plays a significant role in defining the rate of surface runoff velocity and infiltration, which is affecting flood susceptibility [26]. As the slope angle increases, the surface runoff increases and infiltration time decreases, leading to flooding [27]. To identify the spatial distribution of slope values across the study area, 5 m resolution DEM along with the Slope tool from Spatial Analyst extension of ArcGIS software were employed. The obtained map was reclassified into 1 to 5 classes; very high (< 3°), high (3.1–6°), moderate (6.1–9°), low (9.1–12°), and very low (> 12°) based on [28].

Hydrologic soil groups: the diversity in soil indicator plays a significant role as it controls the amount of water that can infiltrate into the ground and surface runoff. The Natural Resource Conservation Service classified soils into four hydrologic soil groups. These groups are A, B, C and D, where soils in group A have the highest infiltration rates and minimum runoff potential, and soils in group D have the slowest infiltration rates and maximum runoff potential [29]. For the purpose of this study, the hydrologic soil group of the local soil details layer was determined as proposed by Al-Rawas [22] and is shown in Table 1.

Table 1: Soil classification.

Hydrologic soil groups	Soil class
B	Calciorthids: Loamy to loamy-skeletal, deep to moderately deep soil, 0–5% slope.
A	Calciorthids-Torrifluvents-Torriorthents: Loamy sand and sandy skeletal, deep soils, moderately flooded, 0–3% slope.
B	Gypsiorthids: Loamy, loamy-skeletal and sandy-skeletal, deep to moderately deep saline soils with gypsum pan on slightly to strongly dissected alluvial terraces and pan, 0–15% slope.
B	Gypsiorthids-Rock outcrop: Loamy to loamy-skeletal, deep to shallow soils and rock outcrop, 0–35% slope.
A	Torrifluvents-Torriorthents-Torripsamments: Sandy, deep soils, on plains, 0–3% slope.
C	Torrifluvents-Torriorthents-Salorthids: Loamy, deep soils, strongly saline soils, on alluvial plains, 0–3% slope.
A	Torriorthents: very gravelly sandy and loamy deep soils moderately flooded, 0–3% slope.
A	Torriorthents: Extremely gravelly, sandy deep soils on young flooded alluvial terraces and fans, 0–5% slope.
B	Torriorthents and Calciorthids-Rock outcrop: Loamy and loamy-skeletal, shallow and moderately deep soils and rock outcrop, 0–15% slope.
A	Torriorthents-Gysiorthids: Sandy to sandy-skeletal, deep and moderately deep soils on young alluvial fans and terraces, 0–5% slope.
A	Coastal dunes and marine flats: deep Sandy soils and tidal flats, 0–10% slope.
C	Rock outcrop-Torriorthents: Mountains and strongly dissected rocky plateaus, loamy-skeletal to sandy-skeletal, shallow soils, 0–100% slope.

Distance from coastline: The distance from coast indicator plays an important role in determining the flooding area. The most affected areas during floods are those near the coasts. A recent coastline layer and multiple ring buffer tool in ArcGIS software were used to prepared five classes of distance; very high (< 30), high (300–500), moderate (500–700), low (700–1000), and very low (> 1000) based on the study in [25].

3.2 Entropy method implementation

The entropy method, as mentioned in the first section, is used to identify the importance of certain indicators in causing a hazard, where higher weight indicators lead to flood hazard more than low weight indicators. Consequently, the entropy weights for all indicators and the final susceptibility zoning maps were identified using the following steps and equations.

Step 1: Normalize the value of each indicator to calculate index weight using eqn (1)

$$y_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}}, 0 \leq y_{ij} \leq 1, \quad (1)$$

where y_{ij} is the specific gravity value for each x_{ij}. m is the number of evaluation objects.

Step 2: Define entropy for each indicator e_j using eqn (2)

$$e_j = -k \sum_{i=1}^{m} y_{ij} \ln y_{ij}, \quad (2)$$

where e_j is the entropy value. The coefficient k is determined by the sample size (number of evaluating object) m using eqn (3)

$$k = \frac{1}{\ln m}. \quad (3)$$

The information utility value for each indicator h_j is derived from eqn (4)

$$h_j = 1 - e_j. \quad (4)$$

Step 3: Calculate the entropy weight of each indicator using eqn (5)

$$w_j = \frac{h_j}{\sum_{j=1}^{n} h_j}, \quad (5)$$

where w_j is the weight of the $\acute{\imath}th$ indicators. n is the number of attribute indicators.

Step 4: Define the coastal flood susceptibility mapping using eqn (6)

$$FSI = \sum_{j=1}^{n} W_j \, Nor(F_j), \quad (6)$$

where *FSI* is a degree of flood susceptibility index, W_j stands for the weight of each indicator and $Nor(F_j)$ is the normalize rate for each flood indicator.

Step 5: For the purpose of mapping and discussion, all flood susceptibility indicator results were aggregated into ArcGIS software using union method. The produced maps were reclassified into five classes including very high, high, moderate, low and very low flood hazard potential. This classification was carried out using natural breaks (Jenks) tool [16].

4 RESULTS AND DISCUSSION

The findings of this study can be presented in two sections where, the first section defines the spatial distribution of flood influencing indicators, and the second section defines the results of implementing entropy weighted method in calculating the weights of given indicators in causing a hazard. All weight results were compiled in ArcGIS software for mapping and discussion, and the produced maps were reclassified into five flood susceptibility zones.

4.1 Coastal flood influencing indicators

It is assumed that the occurrence of a hazard can be determined based on the indicators influencing it. Four indicators were selected in this study based on published literature and limited availability of data for the study area, and they were applied to assess only five wilayats in Muscat Governorate overlooking the Oman Sea. Table 2 summarizes the spatial distribution of the influencing indicators.

Table 2: Spatial distribution of the influencing indicators.

Wilayat	Hazard class	Elevation	Slope	Distance to coastline	Soil infiltration capacity
		Area %	Area %	Area %	Area %
AlSeeb	Very high (5)	99.28	84.68	15.59	25.48
	High (4)	0.68	11.6	10.13	
	Moderate (3)	0.04	2.15	10.03	0.00
	Low (2)	0	0.76	14.99	
	Very low (1)	0	0.81	49.26	74.52
Bawshar	Very high (5)	67.41	72.53	14.50	74.16
	High (4)	14.64	17.92	9.18	
	Moderate (3)	6.98	4.50	9.24	0.00
	Low (2)	3.35	1.85	14.17	
	Very low (1)	7.63	3.21	52.91	25.84
Mutrah	Very high (5)	26.69	29.65	20.69	100
	High (4)	7.84	14.61	11.49	
	Moderate (3)	6.32	6.97	10.73	0
	Low (2)	5.83	4.57	14.97	
	Very low (1)	53.32	44.21	42.12	0
Muscat	Very high (5)	12.59	15.27	23.10	87.09
	High (4)	4.25	9.64	11.02	
	Moderate (3)	4.04	5.97	10.09	12.91
	Low (2)	3.84	5.00	14.04	
	Very low (1)	75.28	64.13	41.75	0.00
Qurayyat	Very high (5)	29.61	42.50	16.26	48.67
	High (4)	7.06	14.94	10.12	
	Moderate (3)	5.73	7.34	9.94	34.26
	Low (2)	5.44	4.57	14.67	
	Very low (1)	52.17	30.65	49.02	17.07

Wilayat AlSeeb: the extracted area between shoreline and 2,000 m distance inland is about 61.36 km^2, of which 60.75 km^2 representing 99.28% having an elevation less than 10 m and classified as very high contribution flood hazard. The slope degree map shows that 51.82 km^2 representing 84.68% having slope less than 3° and classified as very high contribution flood hazard. The distance to coast map shows that 9.56 km^2 representing 15.59% within a distance of 300 m along the Wilayat AlSeeb coast where classified as having a very high distance hazard. The soil map shows that more than 15.6 km^2 representing 25.48% of the extracted area contains a hydrological soil of group C. This area has a poor water infiltration capacity and more runoff, where it is classified as having a very high contribution to the flood hazard. 45.59 km^2 representing 74.52% of the area contains a hydrological soil of group A, where it has high infiltration capacity, less potential runoff, and classified as a very low potential hazard impact.

Wilayat Bawshar: the extracted area between shoreline and 2,000 m inland in Bawshar is approximately 31.61 km^2, of which 21.21 km^2 representing 67.41% having an elevation below 10 m and classified as very high contribution flood hazard. The slope degree map indicates that 22.83 km^2 of the area representing 72.53% having slope less than 3° and rated as a very high contribution to flood hazard. On the other hand, the distance to the coast map indicates that more than 4.5 km^2 represents 14.50% within a distance of 300 m along the coast where classified as having a very high distance hazard. The soil map indicates that more than 74.61% of the extracted area representing 23.32 km^2 containing a hydrological soil group C. This area has poor potential water infiltration capacity and more runoff, which classified as having a very significant contribution to flood hazard. 8.12 km^2 covering 25.84% of the area contains a hydrological soil group A; this area has more infiltration capacity and less potential runoff where it is classified as a very low flood impact area.

Wilayat Mutrah: the extracted area between shoreline and the inland distance of 2,000 m is about 26.5 km^2, of which 7 km^2 representing 26.7% having an elevation below 10 m and classified as a very high contribution to flood hazard. The slope degree map shows that there is more than 7.8 km^2 representing 29.65% with slope less than 3° and classified as very high contribution flood hazard. The distance to the coast map indicates that over 5 km^2 represents 20.69% at a distance of 300 m along the coast were listed as having a very significant distance hazard. The soil map shows that the entire extracted area contained a hydrological soil of group C. This area has a low capacity for water infiltration and a significant surface runoff which is classified as having a very high contribution to flood.

Wilayat Muscat: the extracted area between the shoreline and 2,000 m distance inland is around 101 km^2, of which 13 km^2 representing 13% having an elevation below 10 m and classified as a very high flood hazard contribution. The slope degree map indicates that more than 15 km^2 represents 15% of the area having slope less than 3° and classified as a very high contribution to flood hazard. The distance to the coast map shows that more than 23 km^2 representing 23% within a distance of 300 m along the coast were classified as having a very high distance hazard. The soil map shows that more than 87 km^2 representing 87% of the extracted area contains a hydrological soil of group C. This area has poor water infiltration capacity, significant surface runoff and classified as having a high significant contribution to the flood hazard. More than 12 km^2 representing 13% of the area contains a hydrological soil of group B. This area has moderate surface runoff potential, and has been classified as having an average hazard impact.

Wilayat Qurayyat: the extracted area between shoreline and 2,000 m distance inland is about 146 km^2. 39 km^2 represents 30% of the area with an elevation less than 10 m and is classified as very high flood hazard contribution. The slope degree map indicates that there is more than 56 km^2 representing 42% having slope less than 3° and classified as very high contribution to flood hazard. The distance to the coast map shows that more than 24 km^2 represents 16% within a distance of 300 m along the coast of Wilayat where classified as having a very significant distance hazard. The soil map shows that more than 66 km^2 representing 48.7% of the extracted area contains a hydrological soil of group C. This area has a poor water infiltration capacity, significant surface runoff and has been classified as a highly significant contribution to flood hazard. More than 46 km^2 representing 34% of the area contains a hydrological soil of group B. This area has a moderate surface runoff potential and classified as having an average hazard impact. More than 23 km^2 covering 17% of the area containing a hydrological soil group A, has more infiltration capacity, less potential runoff and is classified as having a very low flood impact. Fig. 2(a)–(d) display the spatial distribution of the influencing indicators in each Wilayat.

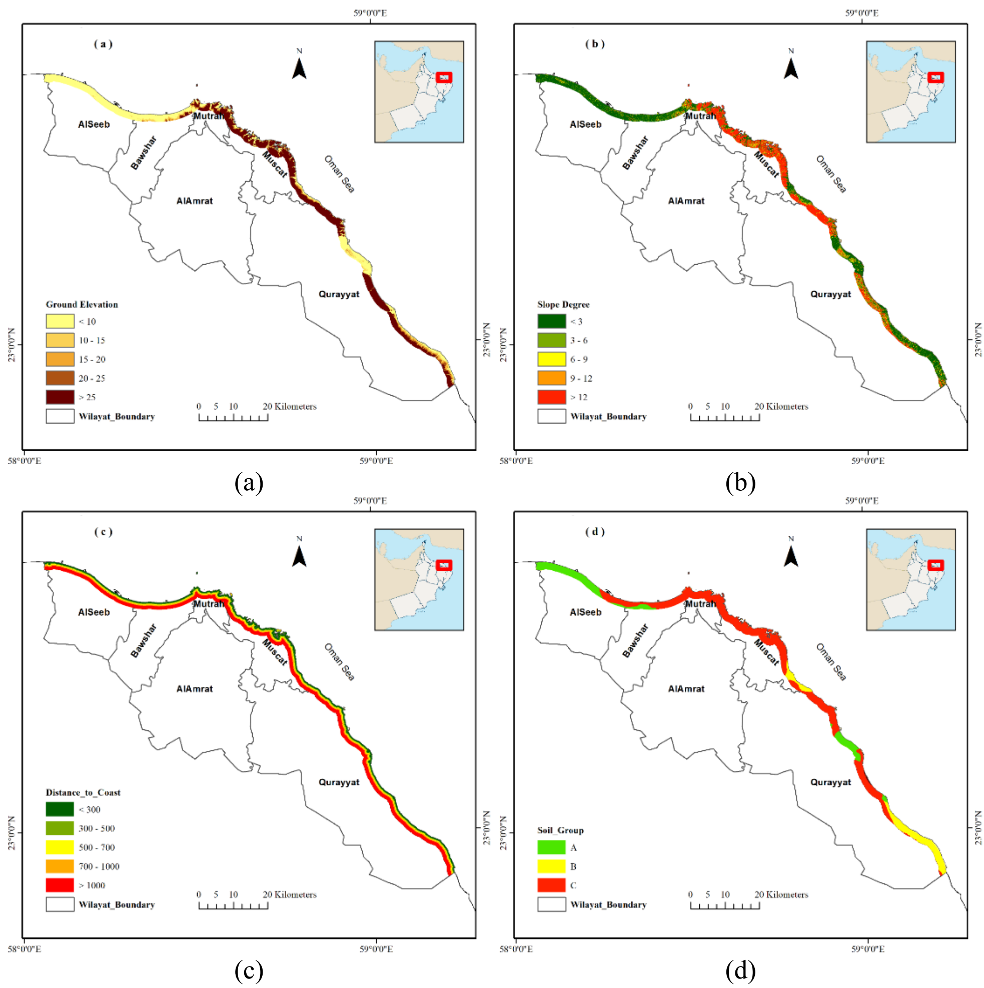


Figure 2: Spatial distribution of the influencing indicators. (a) Ground elevation; (b) Slope; (c) Distance to coast; and (d) Soil infiltration capacity.

4.2 Entropy method implementation

The entropy weighted method was applied to calculate the weights of given indicators in causing a coastal flood hazard. Indicators with higher weights have greater contributions in causing flood hazard than those with lower weights. Final results of this study indicate that the soil indicator has the highest rate of weight in Wilayats Muttrah, Muscat, Qurayyat and Bawshar. While the distance indicator from the coastline has lower values in the same Wilayats. As a consequence, soil indicator can be considered the most likely cause of flooding in those areas, while the distance indicator is the least causative. On the other hand, the elevation indicator is the most important cause of flood hazard in Wilayat AlSeeb while the distance to the coast indicator is the lowest cause.

Based on the results obtained from the entropy weights for the four indicators, the final flood susceptibility map for each Wilayat was produced and the potential flooded areas were divided into five classes of flood susceptibility; very high, high, moderate, low and very low.

Wilayat AlSeeb: about 61 km^2 of the extracted area between shoreline and 2,000 m distance inland in this Wilayat is under threat of flooding. Of this, 57.14 km^2 accounting for 93% was classified as a very high potential flood, about 3.8 km^2 representing 6% classified as a high, 0.15 km^2 classified as a medium hazard, and about 0.05 km^2 classified with low and very low flooding susceptibility. The most common cause of flooding in this area is the elevation indicator, whereas the lowest causative is the distance indicator.

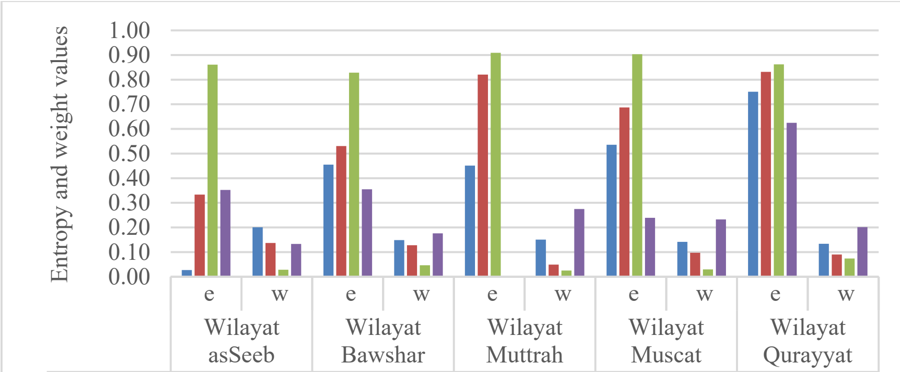
Wilayat Bawshar: about 30 km^2 covering 94% of the extracted area of Wilayat Bawshar is under threat of coastal flooding. Of this, about 24 km^2 accounting for 76% was classified as a very high potential flood hazard, 0.6 km^2 representing 2% classified as a high, 3 km^2 representing 10% classified as a medium hazard, and about 1.7 km^2 representing 5% classified as a low and very low susceptibility hazard for flooding. The soil indicator is the most common cause of flooding in this area, whereas distance indicator is the least causative.

Wilayat Muttrah: around 21 km^2 comprising 79% of the extracted area between shoreline and 2,000 m inland in Wilayat Muttrah is under threat of flooding. Of this, 9 km^2 accounting for 34% is classified as a very high potential hazard, 7 km^2 representing 27% classified as a high, 2.45 km^2 representing 9% classified as a medium hazard, and about 2 km^2 representing 9% of flooding classified as a low and very low susceptibility. In this area, the soil indicator is the most common cause of flooding, whereas the least causative is the distance indicator.

Wilayat Muscat: about 53.5 km^2 representing 76% of the extracted area between shoreline and 2,000 m distance inland in this Wilayat is threatened with flooding. Of this, 41 km^2 accounting for 30% is classified as very high potential hazard, 5 km^2 representing 27% classified as high, 4.45 km^2 representing 9% classified as medium, and about 1.8 km^2 classified as low and 1.2 km^2 classified very low susceptibility hazard flood. The soil indicator in this Wilayat is the most common cause of flooding, whereas the least causative is the distance indicator.

Wilayat Qurayyat: about 128.5 km^2 representing 88% of the extracted area between shoreline and 2,000 m distance inland in Wilayat Qurayyat is under threat of flooding. Of this, 47 km^2 accounting for 32% is classified as a very high potential flood hazard, 21.5 km^2 representing 15% classified as a high, 3.79 km^2 representing 3% classified as a medium hazard, and about 3.9 km^2 classified as a low and 2.45 km^2 classified very low susceptibility flooding hazard. The soil indicator in this area is the most common cause of flooding, while the distance is the least causative indicator.

The entropy and weight values for the influence's indicators in each Wilayat are summarized in Fig. 3, whereas Fig. 4 displays the potential coastal flood susceptible areas in Muscat Governorate.



	e	w	e	w	e	w	e	w	e	w
	Wilayat asSeeb		Wilayat Bawshar		Wilayat Muttrah		Wilayat Muscat		Wilayat Qurayyat	
Elevation	0.03	0.20	0.46	0.15	0.45	0.15	0.54	0.14	0.75	0.13
Slope	0.33	0.14	0.53	0.13	0.82	0.05	0.69	0.10	0.83	0.09
Distance	0.86	0.03	0.83	0.05	0.91	0.03	0.90	0.03	0.86	0.07
Soil	0.35	0.13	0.36	0.18	0.00	0.27	0.24	0.23	0.63	0.20

Figure 3: The entropy (e) and weight (w) indicator values in each Wilayat.

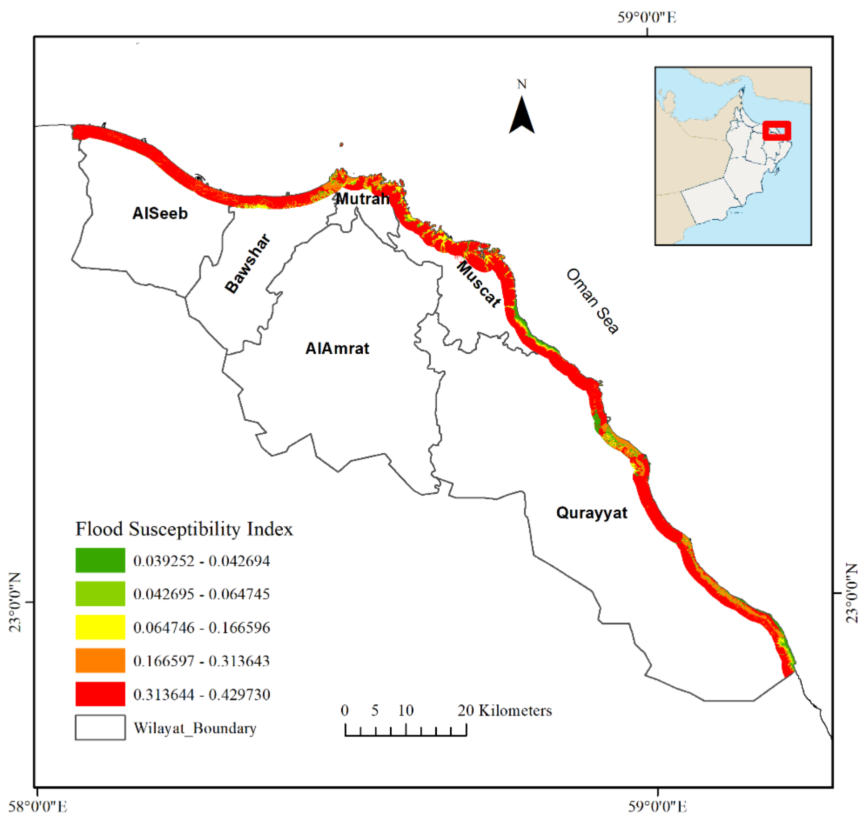


Figure 4: Coastal flood susceptibility map.

Overall, flood susceptibility maps for the Governorate of Muscat have been developed using an entropy weight method and classified into five zones with very low, low, moderate, high, and very high potential flood hazard. The aim of using entropy weight method is to examine different influencing indicators together, which indicate the degree of impact of each indicator on floods in a given area. The greater the entropy value is, the greater the influence of the indicator in causing a hazard. In other words, indicator with higher weight of entropy has greater contribution to flood hazard than those with lower weight. Four influencing indicators, including ground elevation, slope degree, distance from the coast and soil type were examined in this study. Low elevation of less than 10 m and slope of less than 3° are the most causative indicators for inundation in Wilayat AlSeeb. Whereas, the soil type (Group C hydrologic soil) is the main causative indicator for flood in Wilayat Bawshar, Wilayat Muttrah, Wilayat Muscat, and Wilayat Qurayyat.

The approach used in this study is common and can be extended to different regions in the country. However, certain spatial indicators such as land use and land cover (urban areas, agriculture areas, road network, and so on) are required to improve the accuracy of coastal flood potential in future work, as they can play a significant role in water infiltration and runoff behavior. It should also be noted that there are a significant number of Wadies that extend across the governorate. Considering such an aspect (distance from Wadies) in future research is important, as these areas are most affected by flood hazards as being the main pathways for flood discharge.

As the purpose of this study was only to analyze the preconditioning factors that influence coastal flood susceptibility, triggering factors such as rainfall, maximum wind speed, and maximum tide level data were not included. Analyzing triggering factors is important in measuring the frequency and magnitude of a potential flood and thus, to gain a general overview of the potential flood hazards in the future.

5 CONCLUSION

Susceptibility mapping of coastal flood is an essential step in the planning for flood risk management and mitigation methods. Therefore, highly accurate and reliable flood susceptibility maps are important. In this study, flood prone areas for Muscat Governorate were recognized using the entropy-weight method which is useful in determining the weights of each indicator in causing flood. Digital spatial layers of ground elevation, slope degree, distance from the coast and soil type were considered as influencing flood indicators. The potential flooded areas produced were classified into five classes of flood susceptibility; very high, high, moderate, low and very low.

According to the results of flood susceptibility maps, most parts of Wilayat AlSeeb are located in zones of very high and high susceptibility, covering 99% of the extracted area from the shoreline to 2,000 m inland. Low elevation of less than 10 m and slope of less than 3° were the key factors in the very high susceptibility zones. On the other hand, the results showed that about 78%, 61%, 57% and 47% of the extracted area representing Wilayat Bawshar, Muttrah, Muscat, and Qurayyat, respectively, are located in very high and high zones of susceptibility to potential flood hazard. Group C hydrologic soil is the main causative factor for flood in these areas.

The results of this study can be a useful resource for helping local and national government agencies to mitigate the risk of flood and controlling planning purposes. However, certain indicators such as land use and land cover are essential to include in future work as they play a major role in water infiltration and runoff behaviour.

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