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Sensitivity Analysis of Earthquake Using the Analytic Hierarchy Process (AHP) Method: Sample of Adana

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Abstract

Turkey is a country where various disasters occur frequently due to its geological structure and position, climatic characteristics, and morphology. Earthquake, flood, and landslide are the leading ones of these disasters. Hence, devastating earthquakes encountered and flood and landslide disasters caused by global climate change have led to significant loss of life and properties. Many settlement areas in our country contain various disaster risks. Determining the factors that cause these risks in advance and implementation of disaster risk reduction policies according to vulnerability levels in cities will help to minimize the losses resulting in pre-disaster, during and post-disaster periods. In this context, the settlement areas such as Central Yumurtalık, Haylazlı, Kalemli, Ayvalık, Yeniköy, Demirtaş, Sugözü, Narlıören located in Adana province were examined within the scope of disaster-sensitive planning. In the study, the analytical hierarchy process method was used, besides, an earthquake sensitivity analysis was established with the weight ratios determined as a result of the paired comparison matrix of the parameters, and the regions with risk of disaster in the city were identified.

Keywords: *Disaster risk, risk management, analytic hierarchy process (AHP), sensitivity analysis of earthquake.*

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Analitik Hiyerarşi Süreci (AHS) Yöntemi Kullanılarak Deprem Duyarlılığının Analizi: Adana Örneği

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Öz

Türkiye coğrafi konumu, jeolojik yapısı, iklim özellikleri ve morfolojisi nedeniyle çeşitli afetlerin sıkça yaşandığı bir ülkedir. Bu afetlerin başında deprem, sel ve heyelan gelmektedir. Nitekim yaşanan yıkıcı depremler, küresel iklim değişikliği sonucu görülen sel ve heyelan felaketleri önemli can ve mal kayıplarına yol açmıştır. Ülkemizde birçok yerleşim alanı çeşitli afet risklerini barındırmaktadır. Bu risklere neden olan faktörlerin önceden belirlenmesi; kentlerde hasar görebilirlik düzeyine göre afet risklerini azaltma politikalarının uygulanmasına, afet öncesi, afet sırasında ve sonrasında oluşacak kayıpların en aza indirilmesine yardımcı olacaktır. Bu bağlamda çalışmada afet riski yüksek olan Adana kenti örneklem alanı olarak belirlenmiş, kentte bulunan Yumurtalık Merkez, Haylazlı, Kalemli, Ayvalık, Yeniköy, Demirtaş, Sugözü ve Narlıören yerleşmeleri afete duyarlı planlama bakış açısıyla incelenmiştir. Çalışmada analitik hiyerarşi süreci metodundan faydalanılmış, belirlenen parametrelerin ikili karşılaştırma matrisi sonucunda ise ağırlık oranları elde edilmiştir. Elde edilen ağırlık oranlarıyla birlikte coğrafi bilgi sistemlerinden de yararlanılarak deprem duyarlılık analizi oluşturulmuş ve kentte afet riski bulunduran bölgeler tespit edilmiştir.

Anahtar Kelimeler: *Afet riski, risk yönetimi, analitik hiyerarşi süreci (AHS), depreme duyarlılık analizi*

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Introduction

Disaster is defined as events that intensify within a certain period of time and in particular area, when a society or community is affected, where social activities are partially or completely hindered, and that occurred or are likely to occur (Twigg, 2004). According to AFAD (2014) disasters are nature, technology or man-made events that cause physical, economic and social losses for all or certain segments of society, stop or interrupt normal life and human activities, and in which the affected society's capacity to recover is insufficient. Disaster is not the event itself, but the result. In order for a natural, technology or human activities-led event to result in a disaster, it must cause losses on human settlements and interrupt normal life (Twigg, 2004; Uzunçıbuk, 2005).

General characteristics of disasters should be known in order to identify the negative effects of disasters, to take precautions and to develop responses. Disasters cause serious social, economic and physical damage to the natural and built-up environment (Kasapoglu and Ecevit, 2004). However, they trigger migrations and cause structural defects in order to remove the possibility of resettlement in old settlements (Ataman and Tabban, 1977). Development levels of countries and the rate of exposure to disasters show parallelism with each other. Losses of life and property resulting from disasters in countries with a high level of development are lower than in undeveloped and developing countries by the measures taken and disaster risk reduction policies implemented (Kasapoglu and Ecevit, 2004). Disasters are global events. In parallel with the developments in the world, all countries and international organizations that are neighboring or in contact with a disaster-facing country are affected by the negative consequences of this disaster (Şahin and Sipahioğlu, 2003). Damages and losses arising from disasters vary depending on factors such as the characteristics of the settlement, population density, construction durability, measures taken to prevent disasters and policies implemented. To minimize damages arising from these damages is only possible through policies for establishing an effective disaster management system and disaster risks reduction (Kasapoglu and Ecevit, 2004; Şahin and Sipahioğlu, 2003).

Disaster Management and Disaster Risk Reduction

Disaster management refers to an overall recovery process that must be undertaken by society for prevention and mitigation of disasters, timely, rapid and effective response to the events that result in disaster, creating a safer and more developed living environment for disaster-affected communities (Kadıoğlu and Özdamar, 2008). Disaster-sensitive planning approach includes the process of identifying disaster risks and introducing policies and implementation tools developed to mitigate impacts (Afet İşleri Genel Müdürlüğü, 2006; Yavuz, 2013; Yılmaz, 2008; Yiğiter, 2008). In order to be successful in disaster risk reduction policies and to minimize the negative effects of disasters within the scope of disaster-sensitive planning, disaster management processes and planning processes should be managed together.

A physical planning involving the disaster factor should consider the following objectives as a planning tool (Uzunçıbuk, 2005):

- Preventing or reducing potential disaster hazards,
- Disaster mitigation,
- Prevention of secondary disasters such as fire, explosion, landslide due to primary disaster,
- Facilitation of rapid and effective rescue and improvement after disaster.

In the planning process, disaster risk reduction consists of five main components. These components are as follow (ISMEP, 2014):

- Basic Data,
- Analysis/Synthesis,
- Progress Scenario,
- Planning Decisions,
- Implementations.

In this context, preparation of conservation plans comprising microzoning works involving assessments for each risk factor at different scales is an important tool of disaster-sensitive planning approach. Particularly in the determination of land use alternatives in urban settlements, urban geology works comprise an important basis for determining the most suitable land parcel for the settlement (Tüdeş, 2011). As is seen, planning is an important tool for disaster risk reduction (Yavuz, 2013; Yılmaz, 2008; Yiğiter, 2008).

Disaster risk reduction is defined as the development and implementation of policies, strategies, and practices to prevent, mitigate and minimize the security vulnerabilities in society and disaster risks through preparation (Twigg, 2004). Disaster risk reduction policies and strategies are based on the assumption that natural disasters alone do not cause losses and disasters.

Ensuring effective disaster management is important in disaster risk reduction. Disaster risk reduction includes activities aimed at development and implementation of policies and strategies for the development of legal, institutional, administrative and financial structure, taking measures to enact and implement the laws on space planning and housing, setting up and development of early warning systems, conducting research and development activities, improving the recovery capacity by raising public awareness of disaster hazards and risks (Taş and Erdal, 2015).

The first link to international policies of disaster risk reduction initiated by UN in 1989 after the designation of the 1990s as the International Decade for Natural Disaster Reduction. The UN prioritized disaster risk reduction policies between these dates and in 1994, held the First World Conference on Natural Disaster Reduction in Yokohama, Japan. Decisions and policies taken by states in this conference have become valid with the Yokohama Strategy Paper (UNISDR, 2015). Based on the Yokohama Strategy Paper, in 2005, the Hyogo Framework for Action was established in the Second World Conference on Natural Disaster Reduction. This action plan is a revised and updated version of the Yokohama Paper. It aims to reduce the disaster-led negativities between 2005 and 2015 (UNISDR, 2015).

Finally, in 2015, in the Third World Conference on Natural Disaster Reduction held in Sendai City of Japan, with the cooperation protocol of United Nations and Sendai; the Sendai Declaration, which is the more comprehensive and expanded version of the Hyogo Framework of Action, has been published (UNISDR, 2007).

Evaluation of Parameters for Earthquake Sensitivity

Today, many methods and parameters are used for creating sensitivity maps. The parameters used in the creation of sensitivity maps were evaluated as a result of literature review (Table 1).

Table 1. Sensitivity parameters used in the studies in the literature

INDICATORS	Antakya Study (Emre Özşahin, 2014)	Zeytinburnu (Sönmez, 2011)	Gelibolu (Pektezel, 2015)	Antakya (Emre Özşahin, 2014)	İskenderun (Değerli-yurt, 2013)	İstanbul (Tufekci, Suzen, Yalciner, and Z...	Adana (Yiğiter, 2008)	Yalova (Yavuz, 2013)	Erzincan (E. Özşahin and Eroğlu, 2019)	Ereğli (Ekinci, 2011)	Indicators Obtained within the Scope of the Study
Lithology	✓	✓	✓	✓	✓		✓	✓	✓	✓	
Liquefaction								✓			
Distance to fault line	✓	✓	✓	✓	✓		✓		✓		✓
Topography	✓		✓	✓		✓					✓
Slope	✓	✓	✓	✓	✓	✓	✓				✓
Exposure	✓									✓	✓
Relative topographic humidity	✓										
Rainfall	✓										
Distance to rivers	✓		✓	✓						✓	
Soil classification	✓						✓	✓			
Land cover and land use	✓						✓	✓		✓	✓
Groundwater depth		✓	✓	✓	✓				✓		
Largest ground acceleration				✓							
Earthquake zones rating				✓			✓				✓
Velocity of ground subsidence					✓				✓		
Distance from sea					✓	✓					
Distance to line of communica-tions								✓			
Landslide density						✓					
Elevation							✓				✓

1. Distance to Fault Lines

The most important factor affecting the magnitude of the damage in an earthquake is the distance to the fault line. The extent of damage occurred in the earthquake decreases by spreading from the epicenter of the earthquake to the environment (Sönmez, 2011). Determining the effect of the distance depending on the magnitude of the earthquake, thus, is an important factor for creating a hazard map (Erden and Karaman, 2012).

2. Liquefaction

Liquefaction is a physical process that occurs when loose water-logged sediments temporarily lose their strength and act as fluidic (Turoğlu, 2004). This situation increases the importance of the lithology factor, which is one of the most important factors increasing earthquake damage and which shows the liquefaction situation. Besides, also the fact that groundwater is near to surface increases the risk of liquefaction and this causes an increase in the ratio of destruction to occur in an earthquake (Sönmez, 2011). The fact that the constructions are located on water-logged floors is one of the determinants of the risk of damage (Turoğlu, 2004).

3. Slope

The slope status of the topography is one of the main parameters that checks and controls the formation of mass movements. In a possible earthquake, the density of sloping lands can increase the damage due to landslides (Çelebi, 1991; Sönmez, 2011). As a result of their simulation studies, Bouchon, Schultz, and Toksöz (1996), Boore, Joyner, and Fumal (1997) and Bouchon (1973) underline that the topography increases the recorded accelerations further. Pedersen, Le Brun, Hatzfeld, Campillo, and Bard (1994) point to the topography as a result of the huge acceleration increases in the peaks of the mountains. As the slope values increase, the probability of mass movements increases.

The slope shape of the topography also plays an important role in the emergence of mass movements. Concave and convex characteristics of slopes are important in terms of affecting both microclimatic conditions and soil properties. For example, the slope on the convex hillsides is higher than the concave hillsides. Therefore, due to the rapid movement of water, the soil moisture on the convex slopes is relatively low. In the analysis made with GIS software, positive values indicate convex geographical formations, negative values indicate concave geographical formations, and near-zero values indicate level areas (Moore, Grayson, and Ladson, 1991; Zevenbergen and Thorne, 1987).

4. Land Use and Land Cover

Land use and land cover characteristics are one of the most important determinant parameters in the formation of mass movements (Intarawichian and Dasananda, 2010; Kayastha, Dhital, and de Smedt, 2013; Komac, 2006; Van Westen, Rengers, and Soeters, 2003). According to this parameter, the probability of mass movements differentiates based on the land use and density of land cover. Thus, the probability of mass movements occurring in areas where the density of land use and land cover increases has been suggested to decrease, while the probability of mass movements occurring in areas where the relevant density decreases increase (Yalcin, 2008).

5. Geological Structure

Grain size of soil particles plays an active role in the formation of mass movements according to their sequence and species (Ekinci, 2011; Gökceoglu and Aksoy, 1996). In this respect, values of sensitivity to soils in the working area were determined according to the soil texture classes specified by Kitutu, Muwanga, Poesen, and Deckers (2009). Entisols are very low sensitivity due to their formation on alluvial materials of recent history and being located in the valley plain mostly in the working area. Alfisols, on the other hand, are of medium sensitivity resulting from being in an argillaceous or clay loam formation due to the fact that carbonates in the limestone are removed by washing away and the clay remains. Inceptisols are highly sensitive since they are formed at the initial stage of their development and mainly on the argillaceous parent material (Efe, 2010).

Material and Method

Material

The working area is located in south of Turkey, in the Eastern Mediterranean part of the Mediterranean region between 36º 46′-36º 52 ′North latitudes and 36º 42′-36º 50 East Longitudes. The working area is 178 km2 size. The working area covers Central Yumurtalik, Haylazli, Kalemli, Ayvalik, Yenikoy, Demirtas, Sugozu and Narloren settlements. As to be Karataş and Yumurtalık, there are two active fault lines in the region, which is located in the First-Degree Seismic Zone.

The exposure level of the settlements within the field of study and those living in these areas to a possible earthquake would be at high levels. Since it contains fault lines and geologically unstable formations, Yumurtalik area, where sensitivity to an earthquake is high, was preferred.

Method

In this study, sensitivity analysis was performed by using analytic hierarchy process (AHP) and Geographical Information Systems (GIS) through parameters that increase the sensitivity to the effects of the earthquake. GIS-based multi-criteria decision making processes are considered as one of the most useful methods for space planning and management (Chen, Yu, and Khan, 2010; Joerin, Thérialult, and Musy, 2001; Karnatak, Saran, Bhatia, and Roy, 2007). The framework of the study, an earthquake sensitivity map was obtained by analysing (GIS-based) the data obtained within the scope of the working area such as elevation, slope, geological structure, distance to fault and land use.

Different characteristics of the multiple criteria should be considered for the preparation of the sensitivity map. In solving complex problems involving more than one such criteria, AHP is a general measurement theory used by many researchers in recent years (Marinoni, 2004). AHP allows solving complex problems by establishing a hierarchy of objectives-criteria sub-criteria-options. In general, AHP is based on three basic principles: decomposition of the problem and creating hierarchy, creating the comparative judgement and preference matrix, synthesis of priorities (Saaty, 2008).

When using AHP to model a problem, the identification of a problem and the criteria between the hierarchical or network structure is required (Saaty, 2008). Although the Analytical Hierarchy Method is similar to the simple weighted mean, it is a more systematic method for determining criteria weights (Akdeniz and Turgutlu, 2007).

The Analytical Hierarchy Method consists of 4 basic steps. These steps are as follow:

- ***Structuring the problem hierarchy in line with the overall objective:*** The overall objective involves the division into a set of criteria and sub-criteria. Setting the overall objective represents the highest level of the hierarchy. The main criteria set out here form level 2 and sub-criteria level 3. Here, the second stage begins after the criteria are grouped (Akdeniz and Turgutlu, 2007; Duc, 2006; Pourghasemi, Pradhan, and Gokceoglu, 2012).
- ***Conducting the pairwise comparison:*** Each pair of criteria (or pairs of sub-criteria related to an upper single criterion) is evaluated according to their importance to the overall objective. In this evaluation, the criteria to

which relative dominance values are assigned between 1-9 are compared. This comparison includes expert opinions. When making this rating, the scoring between the criteria is as in the table below (Akdeniz and Turgutlu, 2007; Duc, 2006; Pourghasemi et al., 2012).

Table 2. Inter-Criteria Importance Scale (Saaty, 1990)

Importance Level	Definition
1	Equally important
3	Moderately important
5	Strongly important
7	Very strongly important
9	Absolutely important
2,4,6,8	Intermediate values

- ***Calculation of weights:*** This includes the evaluation of pairwise comparison matrices using the measurement theory. The normalized criteria in each comparison matrix are given weight values. This weight provides creating an appropriate value for each land mapping unit (Akdeniz and Turgutlu, 2007; Das, 2018; Duc, 2006).
- ***Consistency check:*** A consistency check is important in terms of consistency of dual comparisons and ensuring accuracy. Consistency Ratio (CR) is calculated to check the consistency of normalized criteria. In order to ensure consistency, the consistency ratio should be less than 0.10 (Akdeniz and Turgutlu, 2007; Das, 2018; Duc, 2006).

Analysis and Findings

In this study, the analysis and high-level imaging and visualization features of Geographic Information Systems were utilized; besides, it was made use of expert opinions for determination of appropriate parameters for the field, identification of the relationship between parameters and earthquake sensitivity, and determination of their weights by AHP method. Elevation, slope, geological structure and distance to fault parameters were taken into consideration in determining earthquake sensitivity.

Elevation

When the elevation map generated over the digital terrain model (DTM) is examined, it is seen that elevation values vary between 0-300 m and are divided into five elevation classes. When the distribution of elevation values of the study area is examined, it is seen that 55% of them are 0-60 m, 27% of them are 61-120 m, 9% of them are 121-180 m, 7% of them are 181-240 m, and 2% of them are 241-300 m (Figure 1.).

When the elevation values of the area are examined, it is seen that they increase from coast to inland. Since as the elevation increases, the distance to the epicenter increases, areas with higher elevation are less sensitive. Looking at the areas with low elevation, it is seen that these areas have alluvion formation which is the geologically most unstable formation. Therefore, the most sensitive areas to liquefaction that will occur in a possible earthquake will be the areas with low elevation.

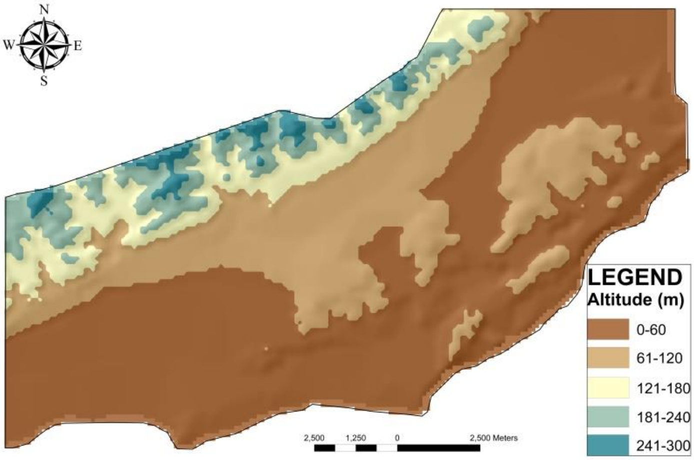

Figure 1. Elevation Analysis

Slope

In the slope map which was generated from the digital terrain model (DTM) used to form the elevation map, the field of study is divided into 7 different slope categories. The slope of the area is between 0-52%. When the slope values distribution of the field of study is examined, it is seen that 65% of them 0-5, 19% 6-10, 7% 11-15, 6% 16-20, 2.8% 21-25, 0.1% 26-30, and 0.1% 30 + (Figure 2.).

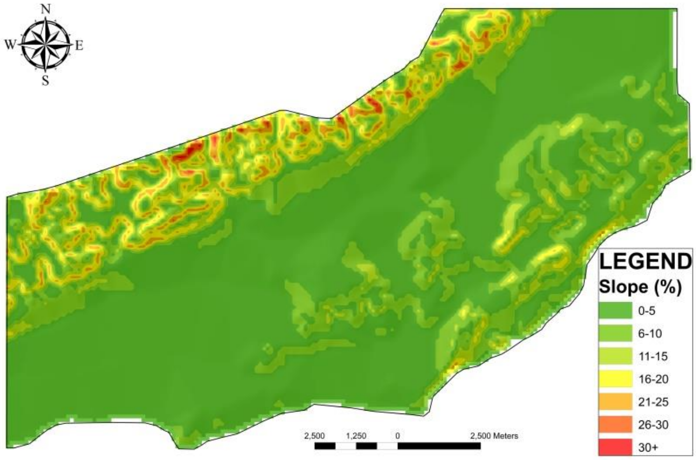

Figure 2. Slope Analysis

It is seen that as the slope increases in the area, the elevation values also increase. The places with high slope values contain the Formation M1 which is the most durable category in terms of formation and these are the areas with the lowest earthquake sensitivity. The areas with the highest liquefaction potential due to their alluvion formation are those with the lowest slope. These areas have the highest earthquake sensitivity.

Geological Structure

The field of study includes M1 (clasts and carbonates), M3 (clasts), and alluvion (quaternary) geological formations. When the ratios of geological formations in the field of study are examined, it is seen that 25% of them have formation M1; 24% of them formation M3 and 51% of them alluvion (quaternary) formation. Formation M1 consists of sandstone, mom, and limestone and it is the most resistant formation to an earthquake in the region (Figure 3.).

Formation M3 consists mainly of sandstone and it is the second formation type in terms of earthquake resistance.

Alluvion formation, on the other hand, is composed of gravel, sand and shaft material; it has the lowest earthquake resistance, and it has the highest liquefaction potential.

There are formation M1 (clasts and carbonates), M3 (clasts), and alluvion formations in the region. The most resistant formation is the formation M1, which is composed of sandstone and limestone. The second resistant formation is the formation M3 consisting of limestone. The most unstable formation is the alluvion formation consisting of gravel, sand and shaft material.

The formation with the highest earthquake sensitivity is the alluvion formation with the highest liquefaction potential.

Figure 3. Geological Structure

Distance to Fault

The working area comprises two active fault lines, Karataş and Yumurtalık, and these are in the First-Degree Seismic Zone. Distance to fault values varies between 0-2500 m. In the map of distance to fault lines, distance to fault line values are divided into 5 categories.

When the distances of the working area to the active faults are examined, it is seen that 18% of them are between 0-500 m; 19% of them 501-1000 m; 18% of them between 1001-1500 m; 17% of them 1501-2000 m and 28% of them 2001 m + (Figure 4.).

Within the area, there are two active faults parallel to each other with an average distance of 2.5 km. As it is moved away from the fault, the sensitivity decreases. The area located in the middle of these two active faults is the area with the highest sensitivity.

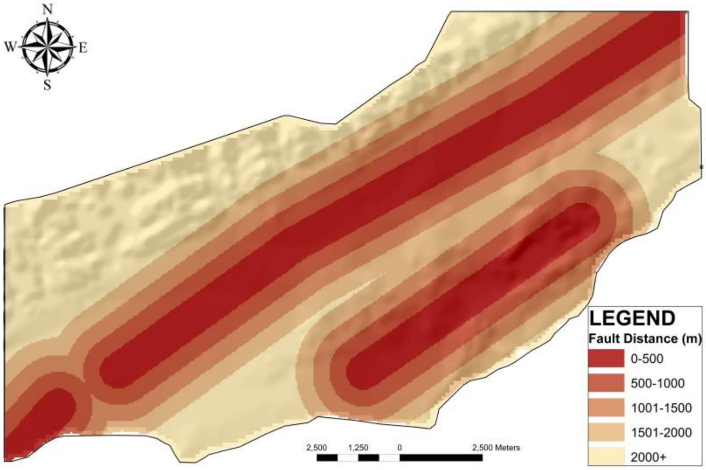

Figure 4. Distance to Fault

Land Use

The working area comprises irrigated-dry farming areas, forest, moor, pasture, urban and rural settlements (Figure 5). When the distribution of these areas is examined, it is seen that 61% of them is dry farming area; 16% of them forest; 14% of them irrigated farming area; 6% of them moor; 1% of them urban settlement; 1% of them rural settlement and 1% of them pasture area.

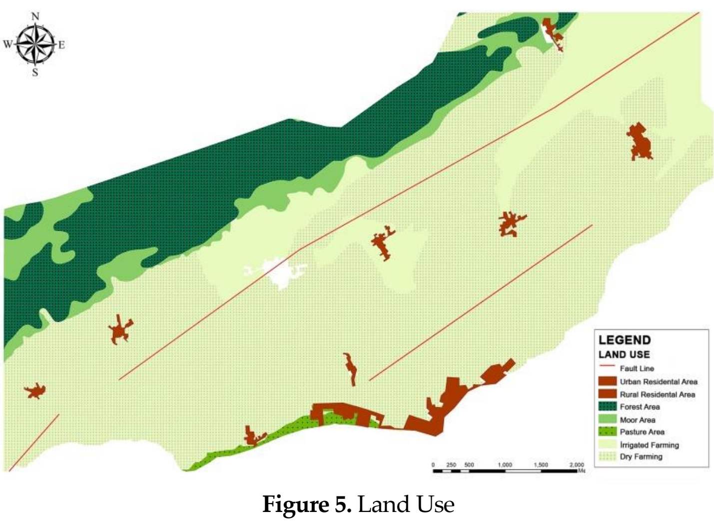

Figure 5. Land Use

Earthquake Sensitivity Analysis through AHP Method

In terms of the parameters specified for the working area and each sub-heading; how much they will take weigh in the sensitivity analysis was calculated. When the weight values for slope are examined, it is seen that the most sensitive interval is the interval of 0%-5% (Table 3).

Table 3. Slope Criteria Weights

CRITERIA (%)	(1) (0-5)	(2) (5-10)	(3) (10-15)	(4) (15-20)	(5) (20-25)	(6) (25-30)	(7) (31+)	WEIGHT
(1) (0-5)	1	3	3	5	7	7	8	0.393
(2) (5-10)	1/3	1	3	3	5	6	7	0.243
(3) (10-15)	1/3	1/3	1	2	3	5	7	0.147
(4) (15-20)	1/5	1/3	1/2	1	2	3	5	0.093
(5) (20-25)	1/7	1/5	1/3	1/2	1	3	3	0.061
(6) (25-30)	1/7	1/6	1/5	1/3	1/3	1	3	0.039
(7) (30+)	1/8	1/7	1/7	1/5	1/3	1/3	1	0.024
CONSISTENCY RATIO (CR): 0.052								

When the sub-weight values of elevation parameter are examined, it is seen that the most sensitive interval is the interval of 0 – 60 m (Table 4).

Table 4. Elevation Criteria Weights

CRITERIA (M)	(1) (0-60)	(2) (61-120)	(3) (121-180)	(4) (181-240)	(5) (240-300)	WEIGHT
1) (0-60)	1	3	3	5	7	0.458
(2) (61-120)	1/3	1	3	3	5	0.256
(3) (121-180)	1/3	1/3	1	3	5	0.162
(4) (181-240)	1/5	1/3	1/3	1	3	0.083
(5) (240-300)	1/7	1/5	1/5	1/3	1	0.041
CONSISTENCY RATIO (CR): 0.062						

When the sub-weight values of geological structure parameter are examined, it is seen that the most sensitive sub-parameter is the alluvion formation (Table 5).

Table 5. Geological Structure Criteria Weights

CRITERIA	(1) M1	(2) M3	(3) ALLUVION	WEIGHT
(1) M1 FORMATION	1	1/3	1/9	0.066
(2) M3 FORMATION	3	1	1/7	0.149
(3) ALLUVION FORMATION	9	7	1	0.785
CONSISTENCY RATIO (CR): 0.084				

When the sub-weight values of distance to fault line parameter are examined, it is seen that the most sensitive interval is the interval of 0-500 m (Table 6).

Table 6. Distance to Fault Criteria Weights

CRITERIA (M)	(1) (0-500)	(2) (501-1000)	(3) (1001-1500)	(4) (1501-2000)	(5) (2001+)	WEIGHT
(1) (0-500)	1	3	5	7	8	0.532
(2) (501-1000)	1/3	1	2	4	5	0.229
(3) (1001-1500)	1/5	1/2	1	2	3	0.123
(4) (1501-2000)	1/7	1/4	1/2	1	2	0.070
(5) (2001+)	1/8	1/5	1/3	1/2	1	0.046
CONSISTENCY RATIO (CR): 0.017						

Considering the percentage importance of the weight of the factors as a result of scoring between criteria, it is seen that 49.9% distance to fault, 36.3% geological structure, 8.8% slope and 5.0% elevation. As a result of this, it is seen that the priority factor in terms of earthquake sensitivity is the factor of distance to fault (Table 7).

Table 7. Earthquake Sensitivity Criteria Weights

CRITERIA	(1) SLOPE (%)	(2) ELEVATION (M)	(3) GEOLOGY	(4) DISTANCE TO FAULT (M)	WEIG HT
(1) SLOPE (%)	1	3	1/7	1/6	0.088
(2) ELEVATION (M)	1/3	1	1/6	1/7	0.050
(3) GEOLOGY	7	6	1	1/2	0.363
(4) DISTANCE TO FAULT (M)	6	7	2	1	0.499
CONSISTENCY RATIO (CR): 0.081					

The working area is located within the First-Degree Seismic Zone and it consists of two active fault lines: Yumurtalık and Karataş. When making the earthquake sensitivity analysis, the factors of slope, elevation, geology and distance to fault were used. These factors were determined by evaluating the characteristics of the area and taking expert opinion.

It is seen that the areas sensitive to the earthquake are close to the fault lines and unstable in terms of a geological formation; while the regions, which are remote from fault lines and have a resistant formation in terms of geology, have a low level of earthquake sensitivity. This result shows that the earthquake sensitivity decreases as the distance from the fault line in the area increases (Figure 6).

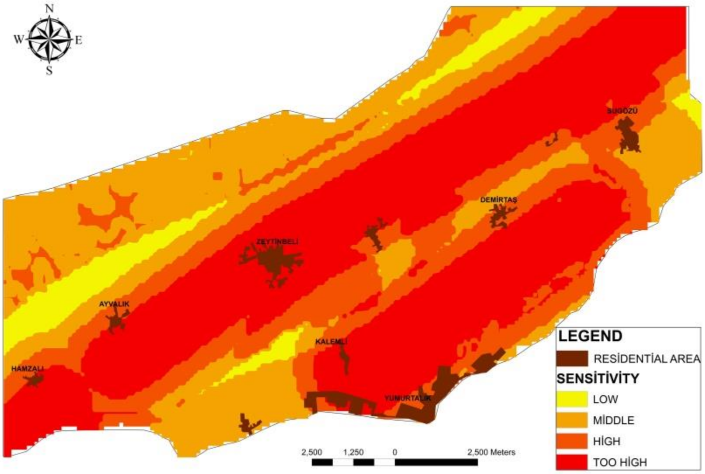

Figure 6. Earthquake Sensitivity Analysis

Considering the settlement areas within the working area boundaries, it is seen that earthquake sensitivity of the settlements of Hamzalı, Ayvalık, Demirtaş, Kalemli, and Yeniköy is very high. When the macroform of the Central Yumurtalık is examined, it is seen that its sensitivity is mainly high. Settlements are areas with high sensitivities and their vulnerability levels are also high.

Conclusion

Disasters are nature, man, and technology-led events that cause social, economic and environmental losses. Efforts to reduce losses and negativities during impact and after disasters form the basis of the concept of disaster management. Geographical information systems are important for disaster risk reduction and disaster-sensitive planning approach. Disaster-sensitive planning approach includes planning processes of various types and scales that develop policies to reduce disaster risks.

Various risk and sensitivity maps generated by geographical information systems are important in developing disaster-sensitive planning approaches and reducing the impact of disaster risks on cities. Various decision-making methods are used to generate these maps. In this study, the analytical hierarchy method, one of the multi-criteria decision-making methods, has been used. Integrated use of Geographical Information Systems and AHP increases the strong visual perception by generating maps that will provide input to the planning, thus, it strengthens the decision support methodology (Marinoni, 2004). In determining the use of urban areas and sustainable urban planning, to be able to create land use that is free from geological risks and provides maximum benefit is only possible if on-site exploration and analysis of urban geology criteria is a decisive basis in the decision-making process. Especially before the planning process starts in disaster areas, natural structure and geological analyzes covering the city and its environments should be prepared with the contribution of related disciplines and these analyzes should be included in the disaster-sensitive planning process. Only in this way can the consciousness and perspective be provided which ensures an environment and disaster-sensitive planning approach, and it can be based on rational foundations.

While generating earthquake hazard maps, after determining the parameters affecting the earthquake by the AHP method, sensitivity analysis control enhances dominance and control over the selected parameters. In this study, for the maps related to parameters affecting the earthquake sensitivity generated in GIS and AHP environment, sensitivities of weights determined as input data were tested and they were evaluated numerically and visually. In order to test the earthquake sensitivity, five parameters (elevation, slope, geological structure, distance to fault and land use). were determined based on expert opinion and local government database. First of all, the current situation of the area within the framework of these parameters is presented and sensitivity analysis was completed in line with the weights determined by taking expert opinion. The significance of these parameters in terms of sensitivity is as follows respectively: distance to fault, geological structure, slope and elevation.

The working area is located within the First-Degree Seismic Zone and comprises Karataş and Yumurtalık, two active fault lines. When the settlements in the working area are examined, it is seen that their vulnerability level is high and they are earthquake sensitive areas. In this region where there are also settlements, before an earthquake, determination of earthquake hazard and risks in the existing constructions, performing microzoning works, development of strategic and spatial plans have importance to minimize damage in case of a possible disaster.

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