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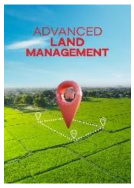

Assessment of the post-disaster assembly areas in the Merkez District of Uşak Province in Turkey

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Abstract

Natural disasters, especially earthquakes are frequent in Turkey. After the 1999 Marmara earthquake and the 2011 Van earthquake, extensive studies were carried out on what should be done before, during, and after an earthquake. In late September 2019, earthquakes in Istanbul have raised the topic of post-disaster assembly areas and temporary shelters. One of the main subjects about these areas was whether they were in good condition or not. Within the scope of this study, post-disaster assembly areas in the Merkez district of the Uşak province in Turkey, criteria for determining these areas, their sizes, and compliance conditions with the specified standards would be evaluated. Besides, the distribution of the areas would be evaluated and the maps prepared using Geographical Information Systems (GIS). This study indicates that the assembly areas in Merkez and Uşak are not sufficient, especially in the populous neighborhoods, nearly half of the neighborhoods do not have any assembly areas, and many of them have infrastructure problems. The distribution is also another problem in different neighborhoods for different reasons. The analysis made through the GIS showed that the distribution is not homogenous in terms of accessibility, all areas in the district are located in central neighborhoods.

1. Introduction

Natural disasters are frequently occurring in our country. That's why it is necessary to have plans and guidelines for what both the public and the institutions, organizations, and response teams will do. In this context, action plans and disaster response plans are evaluated as informative and guiding documents [1-5].

So, the current Earthquake Strategy and Action Plan of the Uşak province, where the study area is located, was reached through the Provincial Disaster and Emergency Directorate (AFAD). According to the 2012-2023 Uşak Earthquake Strategy and Action Plan prepared in 2012, Uşak province has not been exposed to any large earthquakes, taking into account the historical periods. In the same manner, Uşak was also not affected by the large earthquakes occurring in the surrounding provinces [6-7].

Turkey's Earthquake Regions Map, which was entered into force in 1996, was updated by AFAD in 2018 and entered into force on January 1, 2019 under the name "Earthquake Hazard Map of Turkey." In Figure 1, the Earthquake Hazard Map of Turkey was adapted and the condition of Uşak province was indicated. According to the information from Turkey's Earthquake Regions Map, Uşak province was located in the second-degree earthquake zone, except for the Eşme district. On the other hand, the Eşme district was located in the first-degree earthquake zone.

On the Earthquake Hazard Map of Turkey, more detailed data is used instead of this degree system, and the concept of an earthquake zone is no longer used. The new map is prepared with much more detailed data, taking into account the most recent earthquake source parameters, earthquake catalogs and new generation mathematical methods. Unlike the previous map, the new map shows the peak ground acceleration values rather than earthquake zones and replaces the "earthquake zone" concept [8].

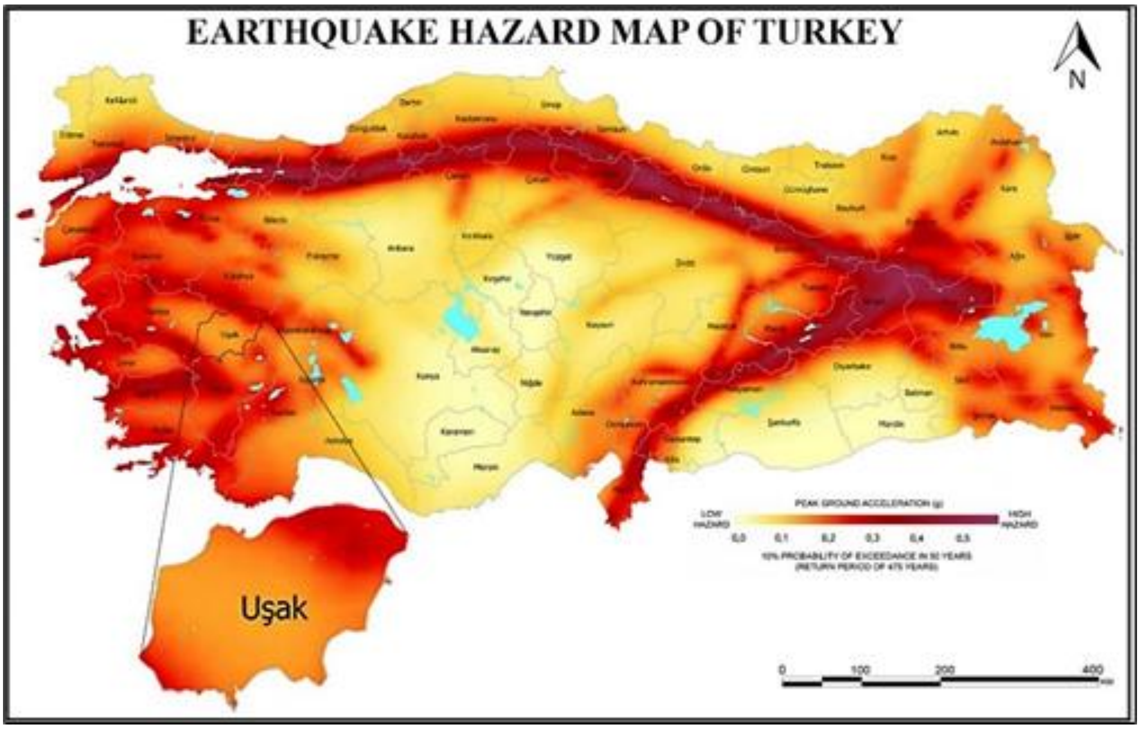

Figure 1. Earthquake Hazard Map of Turkey and the Condition of Uşak Province (Adapted from the Earthquake Hazard Map of Turkey) [8].

2. Post-Disaster Assembly Areas

The post-disaster assembly areas are also called primary evacuation areas and are defined by AFAD as follows: "Assembly areas are safe areas where people can gather by moving away from the dangerous area in the period following disasters and emergencies to prevent panic and provide a healthy exchange of information until the temporary housing centers are ready." [9-10].

The locations of the areas are determined by the relevant municipalities in each province, and AFAD indicates that seven criteria are taken into account when determining these areas. These criteria are as follows:

- Population density of the region,
- Access to the area and ease of evacuation
- Whether the area is accessible to the disabled and the elderly or not,
- Distance to secondary hazards,
- There should be availability in as many plain areas as possible.
- Availability near residential areas, not affected by structural/non-structural elements,
- Being situated near the infrastructure elements to respond to basic needs is important. The determined areas could also be accessed via e-Government.

Such criteria have been included in many national and international research and studies. For example, "The Study on A Disaster Prevention/Mitigation Basic Plan in Istanbul, including Seismic Microzonation in the Republic of Turkey" final report was prepared by the Istanbul Metropolitan Municipality (IMM) and the Japan International Cooperation Agency (JICA) in 2002 [11]. In this report, under the title of "Parks and Open Space Availability for Primary Safety Evacuation of Residents," a new urban disaster emergency evacuation system is recommended. The recommended evacuation system consists of two phases. The first one is called the "Primary Evacuation Areas" and constitutes the post-disaster assembly areas. The latter are called "Regional Evacuation Areas" and function as shelter areas and tent villages. In the report, both phases have been explained, and the criteria for their determination have been included as well. Within the Primary Evacuation Areas part of the chapter, the report also stated how much area per person there should be. According to the report, for all citizens and residents in the area, the gross minimum area should be determined as 1.5 m^2 per capita. The report also states that the evacuation area should be selected from publicly-owned lands [11-13].

In another study, which examined the factors related to the planning of post-disaster assembly areas and shelter areas, it was stated that five criteria should be considered when determining the assembly areas. In the accessibility criterion, it is emphasized that the assembly areas should be accessible to every individual easily. The connection with the road axis is determined as the second criterion by this study. In the criteria for availability and multi-functionality, some of the areas that may be recommended as assembly areas are given as an example, and some examples of active and passive green areas are presented. Within the scope of this criterion, the requirement that the area should not be smaller than 500 m^2 comes to the forefront. In the context of ownership, as indicated in the report on Istanbul as well, it is stated that publicly-owned lands should be preferred as a priority. The study includes the area sizes in the last criteria, and provides several examples from other studies, in addition to the JICA and IMM reports, which determined the minimum areas as 1.5 m^2 per capita. For example, in another study, it is stated that the area should be determined based on building blocks, and it is recommended that it should be specified as 2 m^2 minimum as well [14-16].

3. Assessment of Post-Disaster Assembly Areas in Merkez District of Uşak Province

Uşak province has six districts in total; Central district, Banaz, Eşme, Karahallı, Sivaslı and Ulubey. According to TurkStat data [17], the population of the province was 312581 in 2018. A total of 75 post-disaster assembly areas have been determined in the entire province, and the areas are 2331880.81 m^2 in total. According to the statistical information received from the Provincial Disaster and Emergency Directorate, the status of the assembly areas in Uşak is shown in Table 1-4.

In the JICA and IMM reports, the gross minimum area per capita was indicated as 1.5 m^2. The area per capita standard that would be taken into consideration in this study would be 1.5 m^2 per capita, as in the JICA and IMM reports.

Accordingly, it is possible to make a general assessment from Table 1, when we look at the area sizes determined in the districts of Uşak province. The assembly areas are above the specified m^2 standard except for the Tatar town in Sivaslı district, which has no assembly area, and the center of Banaz district. In many districts and towns, the area per capita is quite above the determined standard. However, this assessment is not adequate since it is made based on the district. In the scope of this study, assembly areas will be evaluated in the neighborhoods of the Merkez/Uşak. The population data used in the study was obtained from the TurkStat [17] address-based population registration data for 2018. The names, addresses, status of the infrastructure and superstructure, and area sizes of the assembly areas were reached through the Uşak Provincial Disaster and Emergency Directorate and via e-Government. Accordingly, the infrastructure status, which is one of the seven criteria indicated by AFAD, would be examined as well. Then, the capacities of the areas were calculated, and it was identified which assembly area could serve a population of how many during an emergency. The size of the assembly area per capita in each neighborhood was calculated. Lastly, it was indicated whether the size of the area per capita was in compliance with the standards or not.

A total of 43 determined assembly areas in 28 neighborhoods of Merkez/Uşak are listed in Table 2. As is seen from Table 2, 11 of these 28 neighborhoods do not have any assembly areas.

According to inquiries via e-Government, when you click on any area in these neighborhoods, the three assembly areas that are closest to that area are listed and shown on the map.

When we analyze the neighborhoods that have assembly areas in the context of area per capita, 9 of them are not in compliance with the standards, as is seen from Table 4 (calculations made according to the specified 1,5 m^2 standard). In this context, the Kemalöz neighborhood, which has the most population, meets the standards as its area per capita is 2.9 m^2. Cumhuriyet and Atatürk neighborhoods are the two most populated neighborhoods after Kemalöz. Both of them are below the accepted 1.5 m^2 per capita standard. The area per capita in these populous neighborhoods is quite small, and there are also less populous neighborhoods that have less than 1 m^2 assembly area per capita. Besides, some neighborhoods are well above the standard, so the assembly areas could be used by those in their immediate vicinity as well.

Another criterion to be considered when determining the area is ownership. When we look at the Central District of Uşak, all assembly areas consist of parks and picnic areas and are all public ownership. According to the information obtained from the Provincial Disaster and Emergency Directorate, all assembly areas in Uşak province are composed of public ownership areas, and no expropriation has been mentioned.

Another criterion is the infrastructure status and whether it is capable of satisfying basic needs or not. In this context, the status of the electricity, water, and sewer systems of the assembly areas was examined and is indicated in Table 3. Water infrastructure in four of the 43 assembly areas is not capable of satisfying the needs. At the same time, in all of these four parks, the sewer system is not suitable either. The only park where electricity infrastructure is not suitable is Halil Kaya Gedik Park in the Fatih neighborhood. The biggest problem, in terms of infrastructure, is the sewer system. Twenty-three of the 43 assembly areas are not capable of satisfying the sewerage related needs. In fact, sewage infrastructure is not suitable in all assembly areas in the neighborhoods of Aybey, Durak, Fevzi akmak, Işık, and slice.

Table 1. Statistical Information of the Post-Disaster Assembly Areas in the Districts of Uşak

District		**The Number of Assembly Areas**	**Assembly Area (m²)**	**Population**	**Area Per Capita (m²)**
Merkez	Merkez	43	1367350.42	252044	5.42
Banaz	Banaz	3	22150	16376	1.35
	Kızılcasöğüt Town	3	64500	1896	34.01
Eşme	Eşme	8	586470	14644	40.04
	Yeleğen Town	3	7815.39	2189	3.57
Karahallı	Karahallı	1	18570	5884	3.15
Sivaslı	Sivaslı	5	140869	7091	19,86
	Pınarbaşı Town	3	9000	1964	5.58
	Selçikler Town	2	22638	1922	11.77
	Tatar Town	-	-	1975	
Ulubey	Ulubey	4	92518	6596	14.02
Total		**75**	**2331880.81**	**312581**	

Table 2. Post-Disaster Assembly Areas in Merkez/Uşak

Neighborhood	No	Assembly Area	Neighborhood	No	Assembly Area
Atatürk	1	Şeker Park	Işık	26	Hacımlı Mehmet Park
	2	Krom Park		27	Vali Kadir Uysal Park
	3	Fevzi Çakmak Park	İslice	28	Fatih Park
	4	Akdemir Park	Kalfa		-
Aybey	5	Doğala Park	Karaağaç Köyü		-
Bozkurt	6	Çokkozlar Park	Karaağaç	29	Anıttepe Mesire Alanı
Çevre		-		30	Hilal Park
Cumhuriyet	7	Milli Egemenlik Park	Kemalöz	31	Batu Park
	8	Cumhuriyet Park		32	Yeni Garaj Park
	9	Akşemseddin Park		33	Toki Park
	10	Şirinkent Park		34	Göker Park
	11	Vural Park		35	Koru Park
	12	Faik Kökhan Park	Köme		-
Dikilitaş	13	Ilıcaksubaşı Park	Kurtuluş	36	Tiritoğlu Park
	14	Hitit Park		37	Dörtyol Park (Millet Bahçesi)
Durak	15	Aslan Park	Kuyucak		-
Elmalıdere	16	Depo Park	Mehmet Akif Ersoy	38	Akse Mesire Alanı
	17	Lamba Park		39	Çevre Park
Fatih	18	Çoban Çeşmesi Park		40	Meşe Park
	19	Yavuz Park	Muharremşah		-
	20	Alpaslan Park	Ovademirler		-
	21	Halil Kaya Gedik Park	Özdemir		-
	22	Masal Park	Sarayaltı	41	Filiz Park
Fevzi Çakmak	23	Kamer Park	Tekstil Osb		-
	24	Emre Park	Ünalan	42	Cavit Köksal Park
	25	Aysun Park		43	Karadede Park
Hacıkadem		-			
İkisaray		-			

Table 3. The Infrastructure and Superstructure Status of Post-Disaster Assembly Areas in Merkez/Uşak (✓: Available, X: Not Available)

POST-DISASTER ASSEMBLY AREAS INFRASTRUCTURE AND SUPERSTRUCTURE STATUS									
Neighborhood	No	Water	Sewer System	Electricity	Neighborhood	No	Water	Sewer System	Electricity
Atatürk	1	✓	X	✓	İkisaray				
	2	✓	X	✓	Işık	26	✓	X	✓
	3	✓	✓	✓		27	✓	X	✓
	4	✓	X	✓	İslice	28	✓	X	✓
Aybey	5	✓	X	✓	Kalfa				
Bozkurt	6	✓	✓	✓	Karaağaç Köyü				
Çevre					Karaağaç	29	✓	✓	✓
Cumhuriyet	7	✓	✓	✓		30	X	X	✓
	8	✓	X	✓	Kemalöz	31	✓	X	✓
	9	✓	✓	✓		32	✓	X	✓
	10	✓	✓	✓		33	X	X	✓
	11	✓	X	✓		34	X	X	✓
	12	✓	X	✓		35	✓	✓	✓
Dikilitaş	13	✓	✓	✓	Köme				
	14	✓	X	✓	Kurtuluş	36	✓	✓	✓
Durak	15	✓	X	✓		37	✓	✓	✓
Elmalıdere	16	X	X	✓	Kuyucak				
	17	✓	✓	✓	Mehmet Akif Ersoy	38	✓	✓	✓
Fatih	18	✓	✓	✓		39	✓	X	✓
	19	X	X	✓		40	✓	X	✓
	20	✓	✓	✓	Muharremşah				
	21	✓	X	X	Ovademirler				
	22	✓	✓	✓	Özdemir				
Fevzi Çakmak	23	✓	X	✓	Sarayaltı	41	X	X	✓
	24	✓	X	✓	Tekstil Osb				
	25	✓	X	✓	Ünalan	42	✓	X	✓
Hacıkadem						43	✓	✓	✓

Table 4. The Evaluation of Post-Disaster Assembly Areas in Merkez/Uşak [17-18]

Neighborhood	No	Area (m^2)	Capacity (Person)	Total Area	Neighborhood Population	Area Per Capita	Compliance with Standards
Atatürk	1	3564.24	2376	21301.65	20520	1.04	Non-compliant
	2	2759.45	1719				
	3	12967.93	8645				
	4	2010.03	1340				
Aybey	5	5324.77	3549	5324.77	7066	0.75	Non-compliant
Bozkurt	6	47624.93	31479	47624.93	1308	36.41	Compliant
Çevre		-			857		
Cumhuriyet	7	8471.84	5647	29322.37	30081	0.97	Non-compliant
	8	2164.89	1443				
	9	9378.18	6252				
	10	4658.39	3105				
	11	4649.07	3099				
	12	3855.56	2570				
Dikilitaş	13	250700.58	167.133	254449.6	16712	15.22	Compliant
	14	3749.02	2499				
Durak	15	1324.87	882	1324.87	4505	0.29	Non-compliant
Elmalıdere	16	9528.6	6352	20868.62	9607	2.17	Compliant
	17	11340.02	7560				
Fatih	18	17744.52	11829	114816.5	16652	6.90	Compliant
	19	13423.14	8948				
	20	44475.03	29650				
	21	27134.58	18089				
	22	12039.23	8026				
Fevzi Çakmak	23	3520.9	2347	12376.03	11399	1.09	Non-compliant
	24	3128.2	2085				
	25	5726.93	3817				
Hacıkadem		-			254		
İkisaray		-			224		
Işık	26	2082.71	1388	5700.49	4293	1.33	Non-compliant
	27	3617.78	2411				
İslice	28	2369.24	1579	2369.24	2308	1.03	Non-compliant
Kalfa		-			457		
Karaağaç Köyü		-			1887		
Karaağaç	29	369801.15	246.534	374490.88	14940	25.07	Compliant
	30	4689.73	3126				
Kemalöz	31	5008.78	3339	106099.06	36531	2.90	Compliant
	32	5350.83	3567				
	33	8672.51	5781				
	34	20776.41	13850				
	35	66290.53	44193				
Köme		-			1541		
Kurtuluş	36	3117.63	2078	4235.16	2624	1.61	Compliant
	37	1117.53	745				
Kuyucak		-			445		
Mehmet Akif Ersoy	38	348581.11	232.387	356057.12	10031	35.50	Compliant
	39	4361.94	2907				
	40	3114.07	2076				
Muharremşah		-			2082		
Ovademirler		-			1249		
Özdemir		-			633		
Sarayaltı	41	1924.58	1283	1924.58	8045	0.24	Non-compliant
Tekstil Osb.		-			17		
Ünalan	42	1228.44	818	6326.52	14012	0.45	Non-compliant
	43	5098.08	3398				

4. Examination of the Distrubution of Post-Disaster Assembly Areas With GIS

In this study, the distribution of the assembly areas in Merkez/Uşak has been examined by using the coordinates obtained from the Uşak Provincial Disaster and Emergency Directorate. The study examined the distribution of determined assembly areas in the district by using the neighborhood boundaries and satellite images. Using coordinate information, the locations of the assembly areas have been marked, and the distribution of these areas in the central neighborhoods has been shown with ArcMap 10.6. Figure 2 shows the locations and distribution of the 43 assembly areas according to the neighborhoods.

Assembly areas that are near to the center are more densely located, and their numbers and frequency decrease as they move away from the center. The areas that are far from the center comprise the areas that are generally larger and have more use as picnic areas. Towards the center, the parks, which are smaller and have the characteristics of neighborhood parks, are located as an assembly area. Especially as you move away from the center, the number of easily accessible assembly areas is small. However, some of the assembly areas that are easily accessible and too close to the buildings have some safety concerns, such as the collapse of buildings during an emergency.

The densities of the assembly areas are shown below in Figure 3, according to their distribution and area sizes. The Kernel Density map is prepared in ArcGIS with the Kernel Density tool by using the point features of the assembly areas. "The Kernel Density tool calculates the density of features in a neighborhood around those features. It can be calculated for both point and line features. " [19].

As is seen from the kernel density map and the information so far, high-density areas are the large-sized assembly areas far from the center. Even though the number of areas is higher in the center, their sizes are not even close to the ones with the highest density areas.

Another analysis in ArcGIS has been made using the Multiple Ring Buffer tool. This tool creates multiple buffers around the input with specified distances.

So, in this study, the distances were specified as 100, 300, and 500 meters around the assembly areas. Accessibility to assembly areas by each individual is crucial during an emergency. So, the walking distance to the assembly areas should be 500 meters or less [15, 20-21-22].

In that case, Figure 4 shows that assembly areas are not sufficient, even in central neighborhoods, in terms of accessibility. The distances of 100 and 300 meters from the assembly areas could serve only a very small area in each neighborhood. Even the maximum distance of 500 meters could not serve the whole neighborhood. So, in any emergency, assembly areas are not within easy access for many individuals.

5. Conclusion

Assembly areas are of vital importance during the first 12–24 hour period after the disaster. Therefore, its role in disaster management and planning is quite large. In the event of a disaster, it is very crucial to reach the people who are exposed to the disaster in the assembly areas in the shortest time possible. Therefore, the capacity should be sufficient to serve all citizens. Although areas that are large and capable of serving many people are considered favorable, the main point is the determination of building block-scale and neighborhood-scale assembly areas that can serve each settlement.

Easily accessible assembly areas would be lifesaving during a disaster, especially by raising public awareness about the areas beforehand. There should not be any problems in terms of infrastructure and superstructure in the assembly areas, and the areas should be in good condition to respond to the vital needs of the disaster victims. All of this is very valuable in the event of a possible disaster.

In this study, the compliance with the standards of the assembly areas in Merkez/Uşak has examined, and the distribution of these areas has also evaluated by using GIS. All 43 assembly areas determined in the district are located in the central neighborhoods, and some of these areas are not sufficient, especially in the populous neighborhoods. While 11 of the 28 neighborhoods do not have any assembly area, area per capita is below the accepted standard in 9 of the 17 neighborhoods which have an assembly area. Besides, most of the assembly areas have infrastructure problems, especially in sewage infrastructure.

In respect of the distribution of areas, while there is a more homogeneous distribution in some neighborhoods, there are problems, especially in neighborhoods where single and larger areas are determined as assembly areas. So, this distribution causes trouble in terms of accessibility to assembly areas. Also, the safety concerns such as collapse of buildings should be considered besides the accessibility. In the event of a disaster, accessibility to those areas in a safe way would be as important as the sufficiency of the areas. For this reason, easy-to-access areas that can respond to smaller settlements on the building block scale and neighborhood-scale should be determined as assembly areas.

The deficiencies in the assembly areas need to be corrected, and new assembly areas need to be determined in the neighborhoods where the areas are not sufficient. With GIS, the analysis and use of spatial and non-spatial data could be achieved easily. That's why it would be very advantageous using GIS to identify deficiencies of the assembly areas and to determine the new areas.

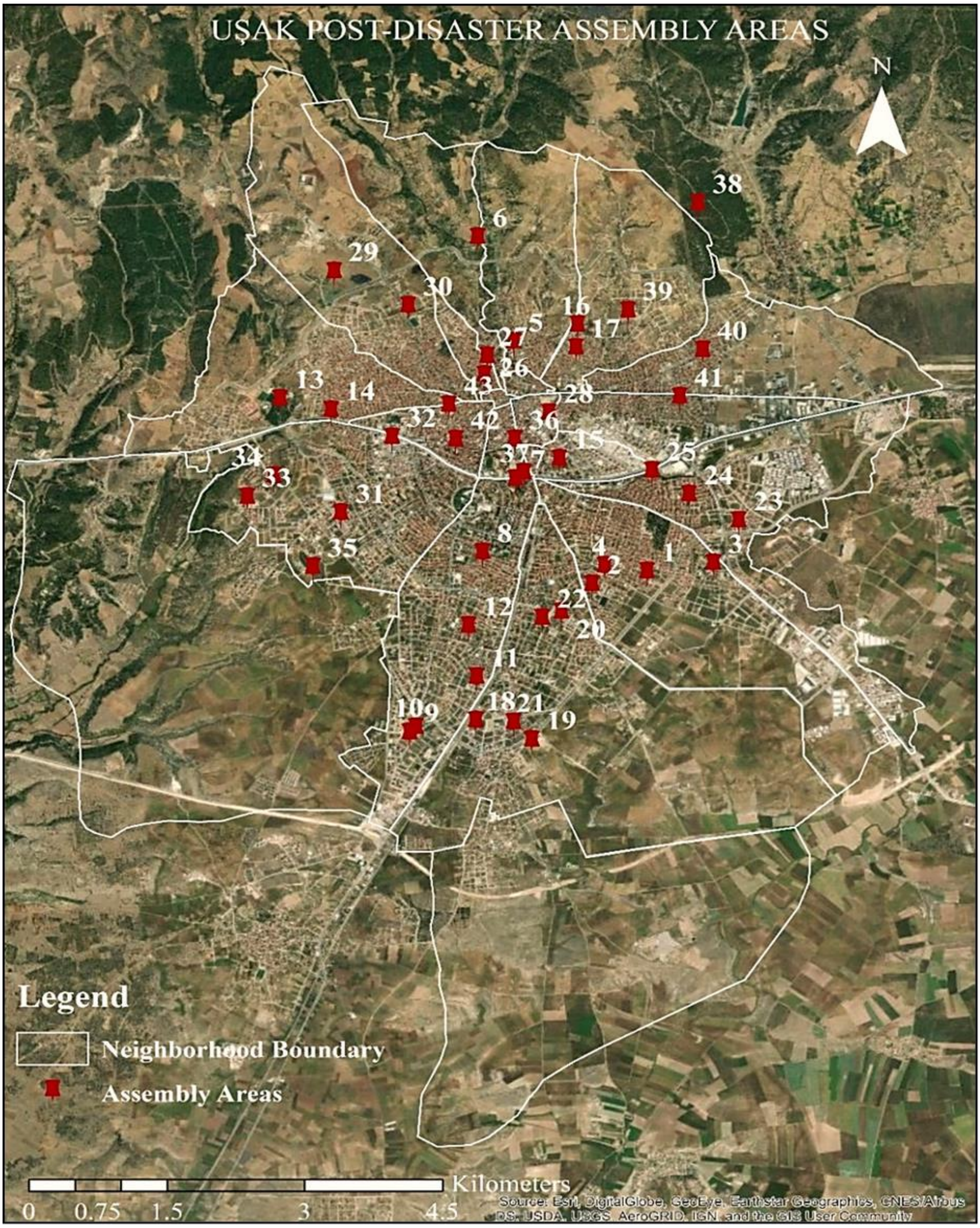

Figure 1. Distribution of the Post-Disaster Assembly Areas in Merkez/Uşak

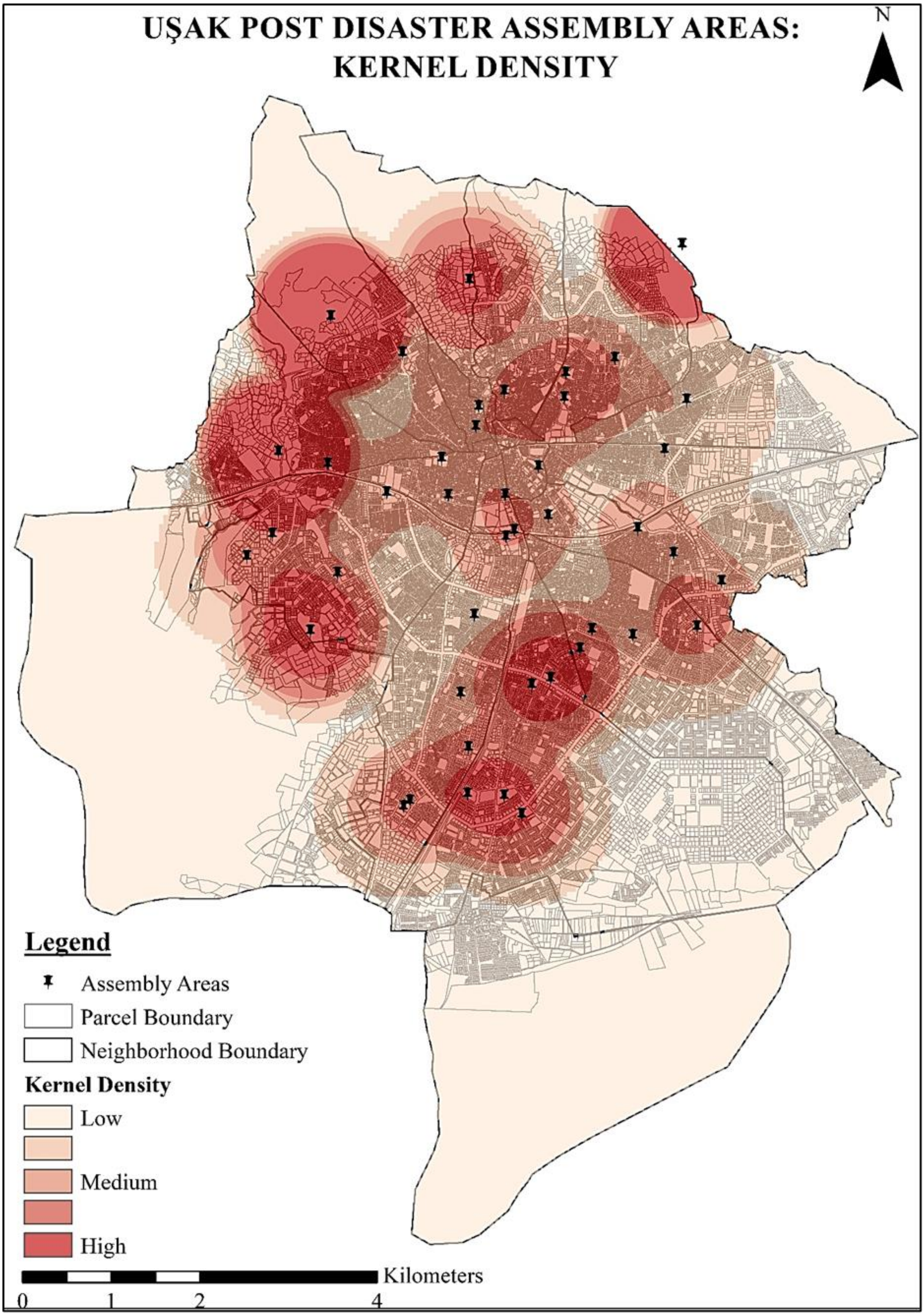

Figure 2. Merkez/Uşak Post-Disaster Assembly Areas: Kernel Density

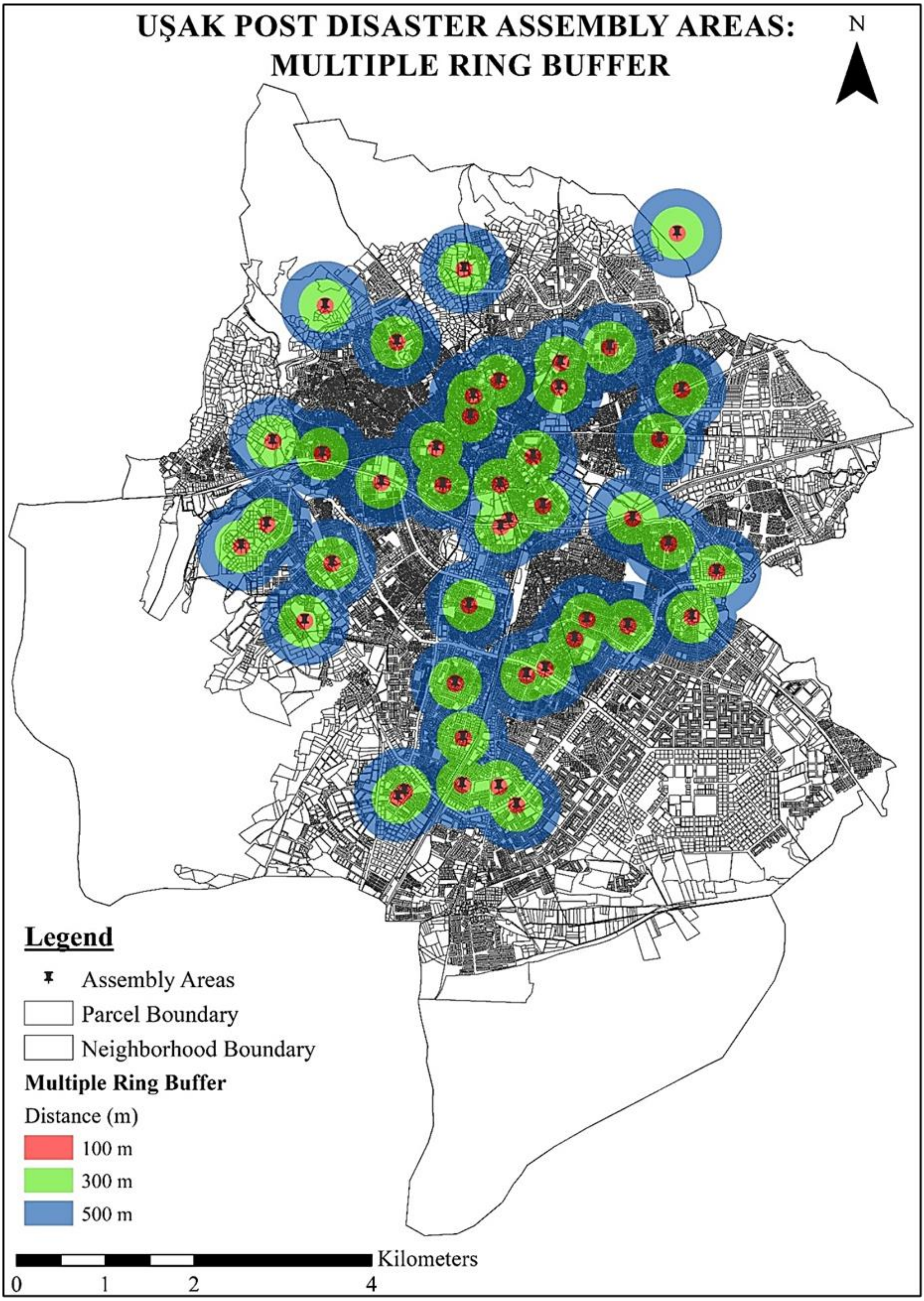

Figure 3. Merkez/Uşak Post-Disaster Assembly Areas: Multiple Ring Buffer

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Author contributions

Fatma Yüksel Doğruyol: Conceptualization, Methodology, Data curation, Software, Writing-Original draft preparation. **Fatih Taktak:** Visualization Reviewing and Editing.

Conflicts of interest:

The authors declare no conflicts of interest.

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Forest fire risk analysis using GIS; Example of Geyve

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Abstract

Forests are ecosystems that have a very important place in terms of the continuity of life on earth. Forests are subject to the danger of fire for many different reasons such as accidents, negligence and climate changes. Although it is not possible to completely prevent forest fires, predicting forest fire risk areas and taking precautions are possible. Geographical Information System (GIS) is an important support system used in the production of risk maps. In this study, the Geyve district of Sakarya province, which has a lot of forest area, was examined in terms of fire hazard. Risk values were assigned according to their fire potential with parameters. The condition with the highest probability of causing a fire was given the value "5 - Very High Risk", while the condition with the lowest probability of causing a fire was given the value "1 - Very Low Risk". The maps produced from the parameters with these risk values were predominantly overlapped and the risk map was obtained. As a result of the analyses, the forest fire risk map was produced according to the five risk factors. It was determined that 0.05% was high risk, 9.03% was risky, 38.85% was medium risk, 48.45% was low risk and 3.62% was risk-free region in the study area.

1. Introduction

Due to global climate changes and human activities, forest areas are gradually decreasing. Unpreventable forest fires are also an important factor in the reduction of forest areas. Especially in rural areas, uncontrollable fires cause loss of life and property and damage the ecological system of that region to a great extent [1].

Since Turkey is located in the Mediterranean climate zone, forests are under fire threat [2]. In the last eleven years "in between 2011 and 2021", a total of 29104 forest fires broke out in Turkey and 230,457 hectares of land were damaged (Figure 1). In 2021 huge forest fires were occurred in Turkey and a total of 139503 hectares of forest area was damaged in just one year [3].

In the fight against forest fires, it is very important to determine the high-risk areas and to take precautions before a disaster occurs in these areas. It is easy, fast and economical to get the desired information with Geographical Information Systems (GIS) technologies.

Thanks to these advantages, data can be obtained and disaster studies can be planned not only at the time of the disaster, but also for the studies that need to be done before or after the disaster [4-6].

More than one spatial criterion (aspect, slope, distance to the road, etc.) must be combined under suitable conditions for starting and spreading a fire in forest areas. GIS is very effective systems in analysing multiple spatial criteria simultaneously and drawing effective conclusions [7]. In this study, forest fire risk areas were tried to be determined in the Geyve district by using GIS.

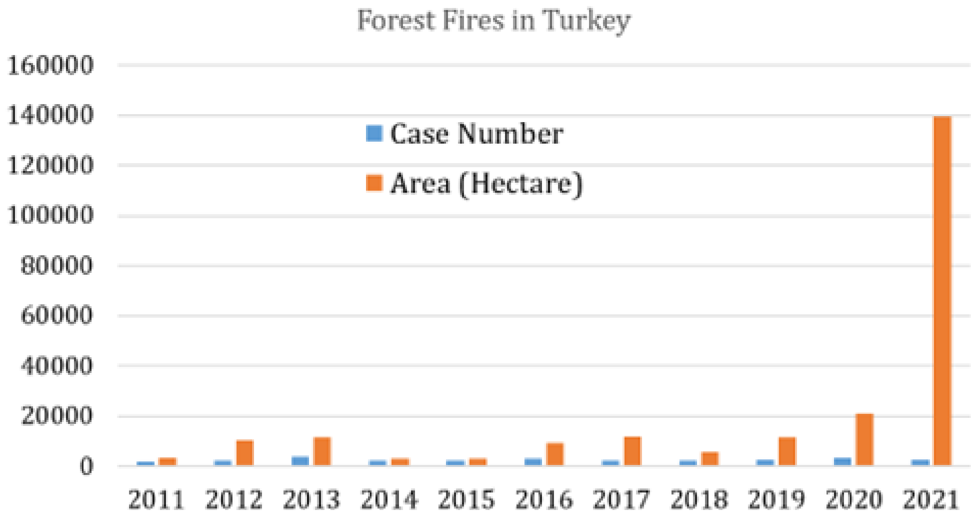

Figure 1. Number of fires and burned area by years [3]

1.1. Study Area

Geyve is a district of Sakarya province, which is located in the east of the Marmara Region. It is an important district in terms of its distance to the big cities (Figure 2). The area of the district is 780 square kilometres and its height from the sea is 74-80 meters. This height rises to 700-1500 meters in mountainous area.

Figure 2. Location map of the study area

Geyve has a rainy climate. The region receives precipitation in all months of the year, but the most common rainy months are during winter and spring. Although the climate of the region is similar to the Mediterranean climate, the reason for the precipitation in the summer months is the humid air caused by its proximity to the Black Sea [8]. Considering the geographical location of the district and its surface forms, it is seen that Geyve is located on the foothills of the Samanlı Mountains and south of the Sakarya River. The district is plateau-rich due to the presence of several plateaus, such as Soğucak and Çataltepe plateaus. Geyve's forest lands are the natural vegetation of Geyve. There are torch pine, red pine, beech and mixed-leaved tree species in the region. By nature, these trees belong to the dry forest type. This increases the likelihood of forest fires.

2. Material and Method

2.1. Material

In this study, to produce the forest fire risk map, slope, aspect, distance to roads and settlements, and humidity ratios of tree species were used as the parameters, which based on the previous studies [9,10]. The slope and aspect maps were obtained from 1/25,000 scaled DEM data that is available from the U.S. Geological Survey (USGS). Road and settlements data are taken from Google Earth. Tree species were obtained from the studies of the Sakarya Regional Directorate of Forestry and the humidity ratios of tree species in the region were determined by research. ArcGIS software was used to analyse the data and produce a forest fire risk map of the Geyve district produced.

2.2. Method

Some parameters, must come together under appropriate conditions for the possibility of fire in forested areas. In this study, parameters that can increase the risk of forest fire were brought together and analysed in GIS and possible results were tried to be predicted. The parameters used in the study of determining the fire risk zones were first assigned a coefficient according to the degree of importance. Considering their effects on fire, the most important parameter is forest type. The slope, aspect, road and distance from the settlement parameters, follow the forest type parameter, respectively. These five parameters were evaluated among themselves and ranked as in Table 1 according to their effects on the fire. Areas such as water, lakes, and streams are designated as non-risk areas. In order to determine the fire risk areas according to these parameters, Equation 1, [9] was used.

$$RC = 7*FT + 5*(S+A) + 3*(DR+DS) \quad (1)$$

In this equation, RC expresses the fire risk zones into five classes; high risk, risky, medium risk, low risk and no risk. FT shows forest types consisting of 3 classes. The S and A parameters, which have the same effect on the spread of the fire, show the slope and aspect analysis. The distance parameters to the road and settlement, which include the human element in the fire risk model, are also expressed with DR and DS [9,11]. First of all, risk values were assigned according to their fire potential with parameters, which are shown in Table 1. The condition with the highest probability of causing a fire was given the value "5 - Very High Risk", while the condition with the lowest probability of causing a fire was given the value "1 - Very Low Risk". The maps produced from the parameters with these risk values were predominantly overlapped and the risk map was obtained.

Table 1. Parameters and factor weights [9,10]

Parameters	Weight	Class	Factor	Risk Class
Tree Species	7	Very Dry	5	Very High
		Dry	4	High
		Medium	3	Medium
		Humid	2	Low
		Very Humid	1	Very Low
Slope	5	>35	5	Very High
		25-35	4	High
		10-25	3	Medium
		5-10	2	Low
		0-5	1	Very Low
Aspect (%)	5	South	5	Very High
		West	4	High
		East	3	Medium
		North	2	Low
		Flat	1	Very Low
Distance to Road (m)	3	0-100	5	Very High
		100-200	4	High
		200-300	3	Medium
		300-400	2	Low
		>400	1	Very Low
Distance to Settlement (m)	3	0-1000	5	Very High
		1000-2000	4	High
		2000-3000	3	Medium
		3000-4000	2	Low
		>4000	1	Very Low

2.2.1. Classification of slope and aspect parameters

Slope and aspect characteristics are important factors in the occurrence and spread of forest fires. The spread time of forest fires is shorter on sloping lands. On the aspect feature, the possibility of fire increases due to the strong sun rays on the south oriented slopes [7]. Therefore, these two factors are very valuable in fire risk maps. In the study, the slope and aspect maps were obtained from the DEM map using ArcGIS and classified (Figure 3 and Figure 4).

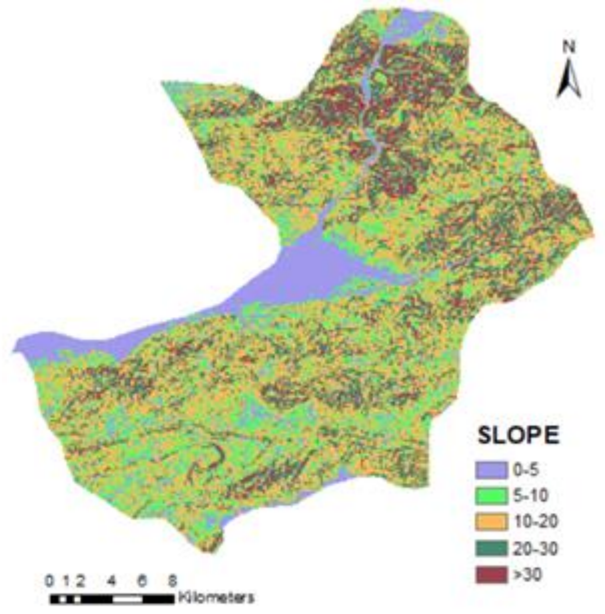

Figure 3. Slope map

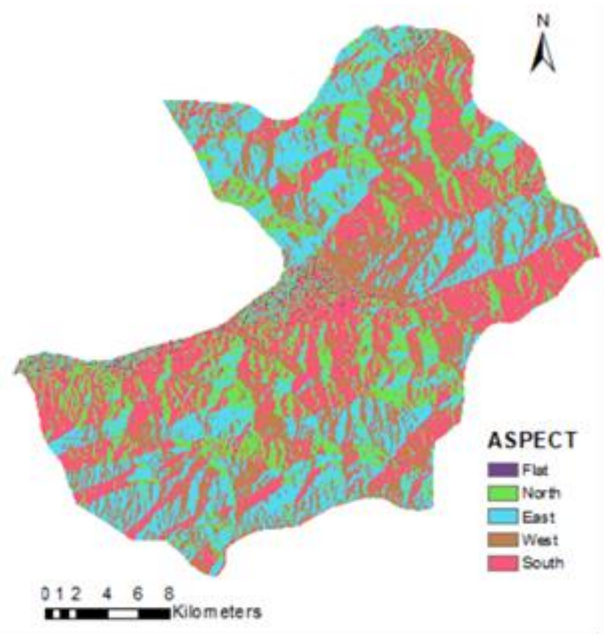

Figure 4. Aspect map

2.2.2. Classification of distance parameters to road and settlement

Distances to roads and settlements represent the human factor in fire hazard. In forest areas close to roads, the probability of fires as a result of accidents and the negligence of people is quite high. Likewise, forest fires occur frequently as a result of human activities in areas close to settlements [9-12]. Therefore, these two factors should be considered in fire risk analysis. The risk classes of the distance to the road and settlements were obtained by Euclidean distance analysis in GIS and can be seen in Figure 5 and Figure 6.

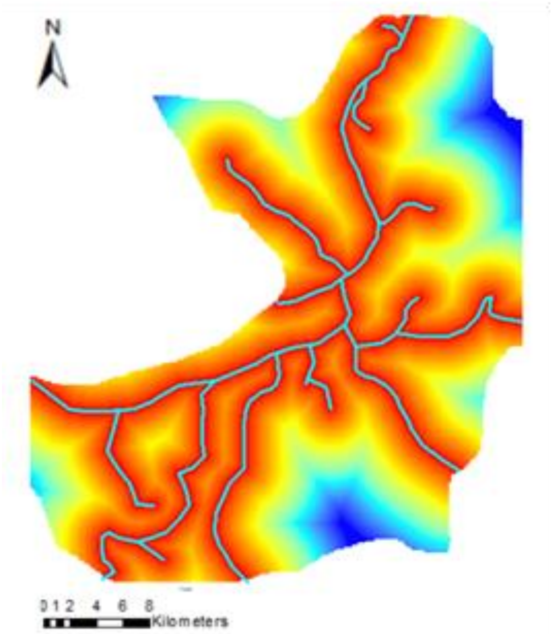

Figure 5. Distance to road

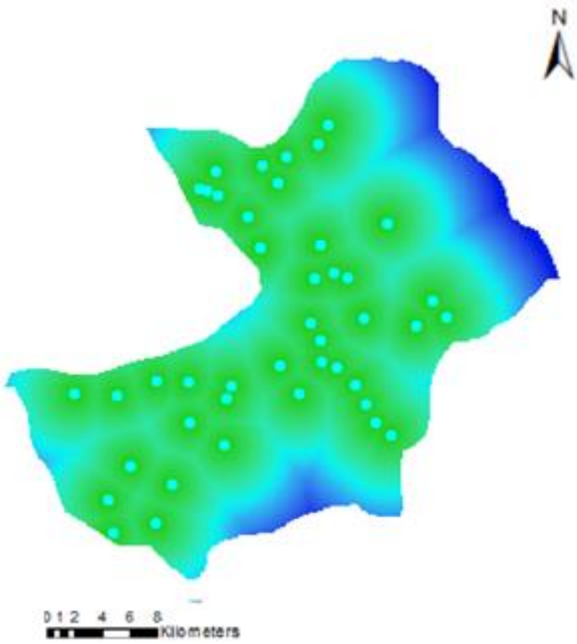

Figure 6. Distance to Settlement

2.2.3. Classification of humidity ratios of tree species

Forest areas are the natural vegetation of Geyve. There are Red Pine (Pinus brutia), Beech (Fagus), Torch Pine (Pinus nigra), Mixed-Leaved, Mixed Coniferous Leaf, Hornbeam (Carpinus) species in the region. These trees constitute the dry forest type by nature. This increases the likelihood of forest fires [8].

The flammability characteristics of tree species in forests are important for predicting the starting point of forest fires and how the fire will continue [7]. Dry tree species such as Torch Pine and Red Pine create a favourable environment for fire. For this reason, the map of tree species in the Geyve district is shown in Figure 7.

3. Results

According to the tree species in the study area, it is seen that 26.56% of the region is covered with Mixed-Leaved, 12.92% with Red Pine, 12.95% with Beech and 6.37% with Torch Pine trees. The distribution of tree species in the region is shown in Table 2 and the map of their division into risk classes is shown in Figure 8. Where the Mixed Leaf species with low flammability are seen, the probability of fire is low, while the probability of fire is high in places where Red Pine, which is a highly flammable species, is seen.

Table 2. Distribution of tree species

Tree Species	Area (%)
Open Space	% 37.16
Mixed-Leaved Trees	% 26.56
Red Pine	% 12.92
Beech	% 9.25
Torch Pine	% 6.37
Mixed Coniferous Leaf Trees	% 5.09
Hornbeam	% 2.65

Due to the slope of the land and the steep south and west slopes, it greatly increases the risk of forest fires [13]. Considering the slope levels in the field of the study, the rate for more than 30 degree high-risk areas is 7.61% (Table 3). The aspect factor, on the other hand, is 29.97% of the southern slopes, which are the areas with a high fire hazard (Table 3).

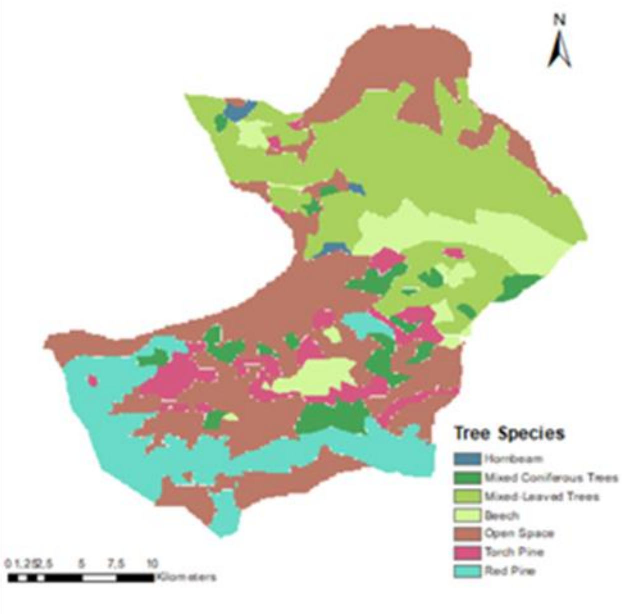

Figure 7. Tree Species map

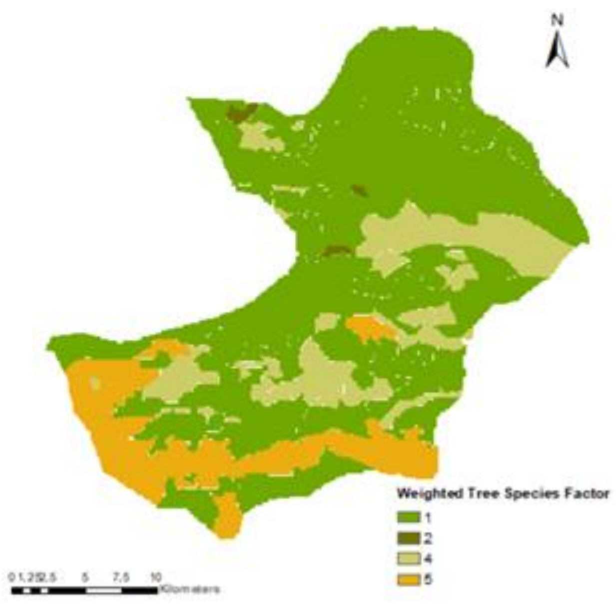

Figure 8. Weighted Tree Species Factor map

There are many main roads in the Geyve district, and Geyve has 73 neighborhoods. For this reason, the distance to the road and the settlement is important for mapping the fire risk. The area less than 400 meters from the road is 8.93% of the whole total study area. This area has the highest fire risk. The area with a distance of less than 4000 meters to the settlements covers 6.44% of the entire area.

Produced criteria maps were overlapped based on the weight of them and a forest fire risk map for Geyve was obtained. The risk map is shown in Fig.8, and the spatial distribution of fire susceptibility classes are presented in Table 4.

Table 3. Aspect and slope

Factor	Aspect	Area (%)	Slope	Area (%)
1	Flat	% 0.93	0-5	% 12.83
2	North	% 20.27	5-10	% 18.18
3	East	% 25.58	10-20	% 40.25
4	West	% 23.25	20-30	% 21.13
5	South	% 29.97	>30	% 7.61

Table 4. Spatial distribution of fire susceptibility classes

Fire Risk Region	Area (%)
High Risky Area	% 0.05
Risky Area	% 9.03
Medium Risky Area	% 38.85
Low Risky Area	% 48.45
Risk Free Area	% 3.62

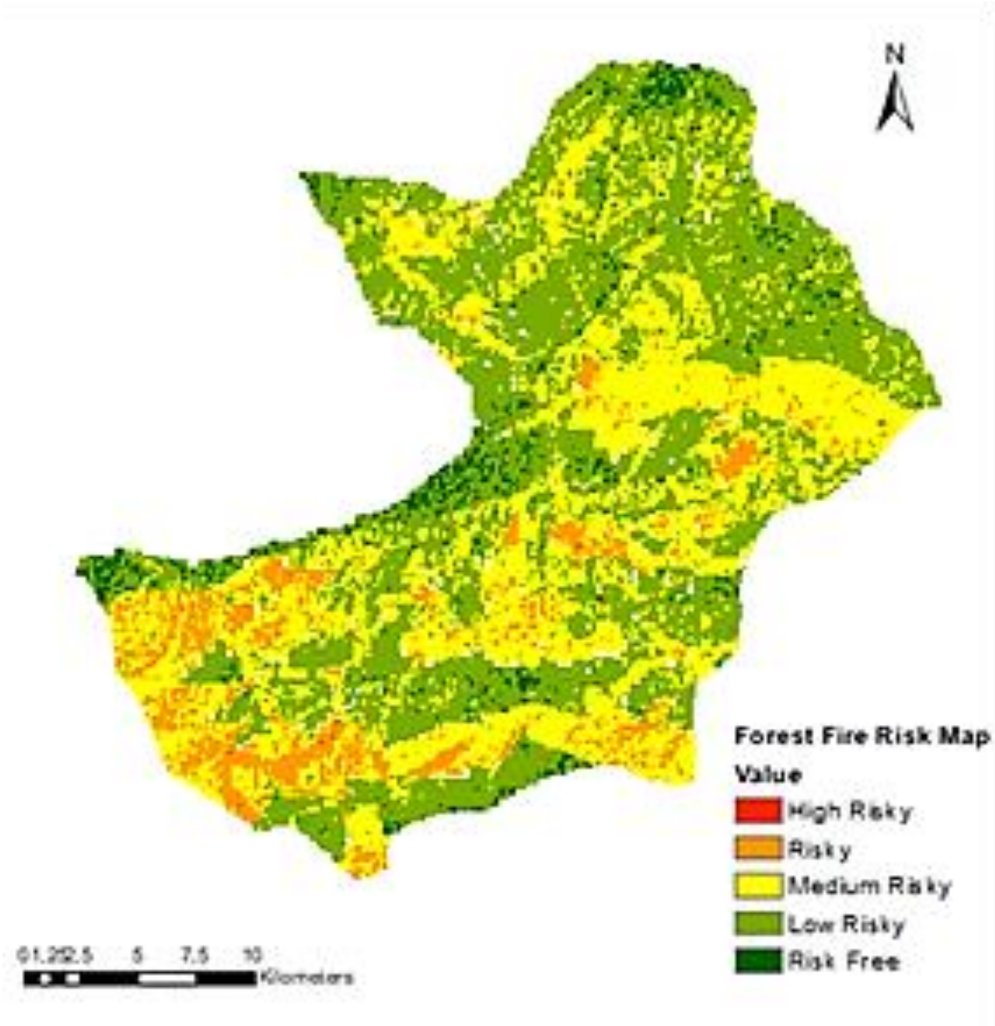

Figure 9. Fire risk map of Geyve

4. Discussion

The aim of this study is to determine the forest fire risk areas in the Geyve district of the Sakarya province. In the light of other studies, the same parameters and the same method were used in this study, but due to the different study area, the fire risk data and map preserved their subjectivity.

In the study conducted by Bingöl [14], forest fire risk areas were determined for Burdur province. They were used the same parameters in their study. As a result of the study, a forest fire risk map was obtained for the province of Burdur. According to the fire risk map, 12.3% of the area is very risky, 20.2% is risky, 20% is medium risk, 31.5% is low risk, and 16% is risk-free. In the current study, high risky and risky area is 9.08 % but it is 32.5 % in the Burdur province study. It was observed that, the rate of the risky area is getting increase in the regions to the south. As the forest fires that occurred in Turkey in 2021.

5. Conclusion

While our world is facing global warming and its effects, being prepared for these effects and their results is essential. Forest fires damage both our green areas and the species living in the forest. We must be prepared and take precautions against this type of disaster that threatens our nature. GIS technologies are very useful in analysing the factors that cause fires simultaneously and in producing effective results. In this study, the slope, aspect, plant species, distance to the road and settlement were used as the risk factors for forest fires and a Geyve district forest fire risk map was produced based on these factors. As a result of the analyses, it has been seen that the fire risk in the Geyve District changes depending on the tree species. It was observed that the fire risk is higher in the Southwest region, compared to the other regions. High risk areas cover 0.05% of the total area.

With the produced fire risk maps, knowing which areas have a fire risk and which factors cause them will make an important contribution to predicting and preventing fires.

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Author contributions

Şeydanur Güvendi: Conceptualization, Methodology, Data curation, Software, Writing-Original draft preparation.
Aziz Şişman: Visualization Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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Investigation of flood risk areas in Ünye district with Best-Worst method using geographic information systems

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Abstract

One of the main issues of land management is identifying risky areas. Floods are natural events that develop depending on the climate and topographic characteristics of the regions. The effect of human activities is also seen in flood events. In this study, flood risk areas were determined in Ünye district using Geographical Information Systems (GIS). The Best-Worst Method (BWM), one of the Multi-Criteria Decision Making Methods (MCDM), was used in the study. First of all, the criteria affecting flood formation were determined as slope, aspect, height, and land use based on previous studies. Subclasses for each criterion were determined and weighted by the BWM method. The criteria were reclassified according to the weights given to the subclasses. The flood risk map was obtained by overlaying the criteria according to these weight values. It has been observed that the settlements with low slopes are the places that will suffer the most in case of possible flooding.

1. Introduction

Natural or artificial events that cause physical, economic and social losses for the whole or specific segments of the society, stop or interrupt everyday life and human activities, and in which the coping capacity of the affected community is not sufficient, are called disasters [1]. Natural events, described as natural disasters, are generally the natural results of the cycle of reorganizing the internal balances of nature. They are called natural disasters when human societies are damaged by this cycle [2]. Turkey is a country that is always faced with natural disasters due to its geological and meteorological characteristics [3]. In recent years, flood events have emerged as one of the natural disasters that have significantly affected human life and caused loss of life and property in Turkey and worldwide. Floods are natural formations that develop depending on the region's climatic conditions and geotechnical topographic features, but the effect of human activities on floods is undeniable [4]. The most important reason for the damages caused by floods in our country is the construction in the stream beds. This situation causes the residential areas to be flooded by the rising water level after heavy rain overflows from the narrowing stream bed [5].

Efforts to minimize the loss of life and property in a possible flood and to reduce the negative effects of the flood can be carried out with risk management in flood areas. In risk management studies; hazards and risks are determined, risk scenarios are prepared, protection and mitigation measures are selected, the results are presented with up-to-date maps and graphics, the usability of the resources and opportunities are determined, decisions about the most appropriate options and priorities for disaster protection and disaster response are eliminated and implemented. The knowledge gained is of great importance in determining the floods, performing risk analysis, and planning before and after the disaster. Generating and organizing knowledge requires time-consuming work. Therefore, Flood risk analysis is a complex issue that concerns many occupational groups [5].

With its query and analysis capabilities Geographical Information Systems (GIS) provides is an important decision support for the decision makers. GIS has been one of the leading sources used in the determination of possible risk areas in disaster and emergencies in recent years. There are many studies in our country in which flood risk analysis is made by using GIS [4-9].

In this study; Cevizdere stream, which has experienced flood events in the past and a major flood event in 2018, was investigated. The parameters affecting the flood were determined based on previous studies, and the weights of these parameters were calculated with the Best-Worst Method (BWM). By using the analysis capabilities of GIS, flood risk areas were tried to be determined. In this study, flood risk areas were tried to be determined by using fewer parameters than the parameters used in the studies conducted by Beden [4] and Ocak and Bahadır [7] in the same area, and the weights were determined by BWM, and the results were compared.

2. Material and Method

The analysis was carried out using the Multi-Criteria Decision Making Method (MCDM), and a flood risk map was created. MCDM Methods are the process of evaluating a finite number of options for selection, ranking, classification, prioritization or elimination by using a large number of criteria that are generally weighted, contradictory and do not use the same unit of measure, and some even take qualitative values [10]. The purpose of using MCDM methods is to keep the decision-making mechanism under control in cases where the number of alternatives and criteria is high and to obtain the decision result as easily and quickly as possible [11]. BWM, one of the MCDM methods, was used in this study. BWM is one of the multi-criteria decision-making methods based on pairwise comparisons. In the BWM method, not all criteria related to the decision problem are compared in pairs [12]. The decision maker determines the Best and Worst criteria, and pairwise comparisons are made between each of these two criteria and all other criteria. The most important feature of the method is that it requires fewer comparison data and obtains more consistent results than some MCDM methods.

The BWM is a relatively new weighting method using pairwise comparisons to calculate criteria weights. Transportation, communication, energy, investment, manufacturing, supply chain management, aviation industry, education, performance evaluation, healthcare, finance, technology, and tourism are just a few examples of real-world challenges where the BWM has been used [12-19].

The steps of BWM can then be used to compute the weights of the criteria as follows [12].

Step 1. Identify a set of decision criteria. In this step, the decision-maker identifies n criteria that will be used to make a decision.
Step 2. Determine the most important “best” and the least important “worst” criteria.
Step 3. Assign a preference to the best criterion between 1 and 9, compared to the other criteria.
Step 4. Compared to the criteria, assign a preference to the least important criterion between 1 and 9.
Step 5. Find the optimal weights for the criteria.

This study investigated flood risk analysis based on four main criteria; elevation, slope, aspect, and land use. These criteria were determined based on previous studies in the literature as mentioned above. In the study, it was aimed to determine flood risk areas with a small number of parameters. To assess the risk areas in terms of flood, first of all, the necessary data were obtained from the relevant sources. Digital Elevation Model (DEM) with 25m resolution was used as altitude data obtained from USGS EarthExplorer. The slope and aspect characteristics of the study area were produced by performing slope and aspect analyzes with ArcGIS software using the Digital Elevation Model. Slope and aspect maps of the study area were produced. A relief map was obtained with the "Hillshade" analysis in the "3D Analyst" module to be used in the created maps. CORINE 2018 data was used as the land use data of the study area. Stream data of the study area were obtained from topographic Map. After producing all data, the land use data in vector structure was converted into the raster data structure. While transforming the land use data to a raster structure, the cell size was adjusted to be the same as the elevation data. The criteria and sub-criteria cultivated in flood risk were determined, and the weight values for these criteria were calculated using BWM. The criteria and weight values used in the study are given in Table 1.

Slope, aspect, elevation and land use in flood risk analysis were reclassified according to the weight values given to subclasses with the "reclassify" function of the "Spatial Analyst" tool group, a module of ArcGIS software, and made ready for analysis. A model was created with the "Model Builder" module to perform the analysis.

The weight values in the flood analysis for the reclassified slope, aspect, elevation and land use criteria were determined as percentages, and the "weighted overlay" function of the "Spatial Analyst" tool group was overlapped according to these values and the Flood Risk Map was created.

Table 1. Criteria, subclasses and weight values that are effective in determining flood risk areas

Criteria	Weight
Slope	
0-5	0.55
5-15	0.27
15-25	0.10
25+	0.08
Aspect	
Straight	0.28
North	0.17
Northeast	0.13
East	0.07
Southeast	0.06
South	0.04
South West	0.05
West	0.08
Northwest	0.12
Elevation	
0-20	0.59
20-100	0.20
100-200	0.13
200+	0.08
Land Use	
Farming areas	0.25
Industrial areas	0.15
Residential areas	0.18
Hazelnut gardens	0.06
Forests	0.03
Plant exchange areas	0.10
Roads	0.12
Open Spaces	0.11

Table 2. Weight percentages of analysis criteria

Criteria	Weight values (%)
Slope	0.30
Aspect	0.05
Land Use	0.25
Elevation	0.40

2.1. Location and features of the study area

The study area is Ünye district, which is located within the provincial borders of Ordu city. Ünye located in the Central Black Sea division of the Black Sea Region, in the west of Ordu Province. It borders with Fatsa in the east, Terme, İkizce and Çaybaşı in the west, Akkuş and Kumru in the south. The Black Sea coast is located on the northern side of the district. Its area is about 565 km^2 (Figure 1). There are 85 neighbourhoods within the boundaries of the district. According to the latest data, its population is 130,692 [20]. Ünye is under the influence of the Black Sea climate due to its location. Since it receives precipitation in all seasons, the number of cloudy days and annual precipitation are high. Humidity is high due to its low altitude compared to its surroundings and its close distance to the sea. The yearly average temperature is 14.4 °C and the average annual precipitation is 1183 mm [21].

2.2. Criteria Affecting Flood Risk

2.2.1. Slope

One of the most essential criteria effective in flood risk is the slope. Due to the low water holding capacity of the soil in areas with a high slope, the amount of water flowing into the flow is higher. For this reason, places with less slope are more risky areas in terms of flooding (Figure 2).

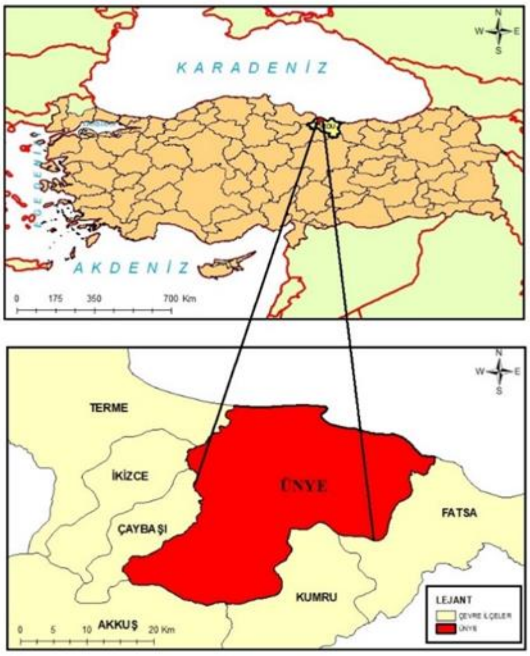

Figure 1. Study area

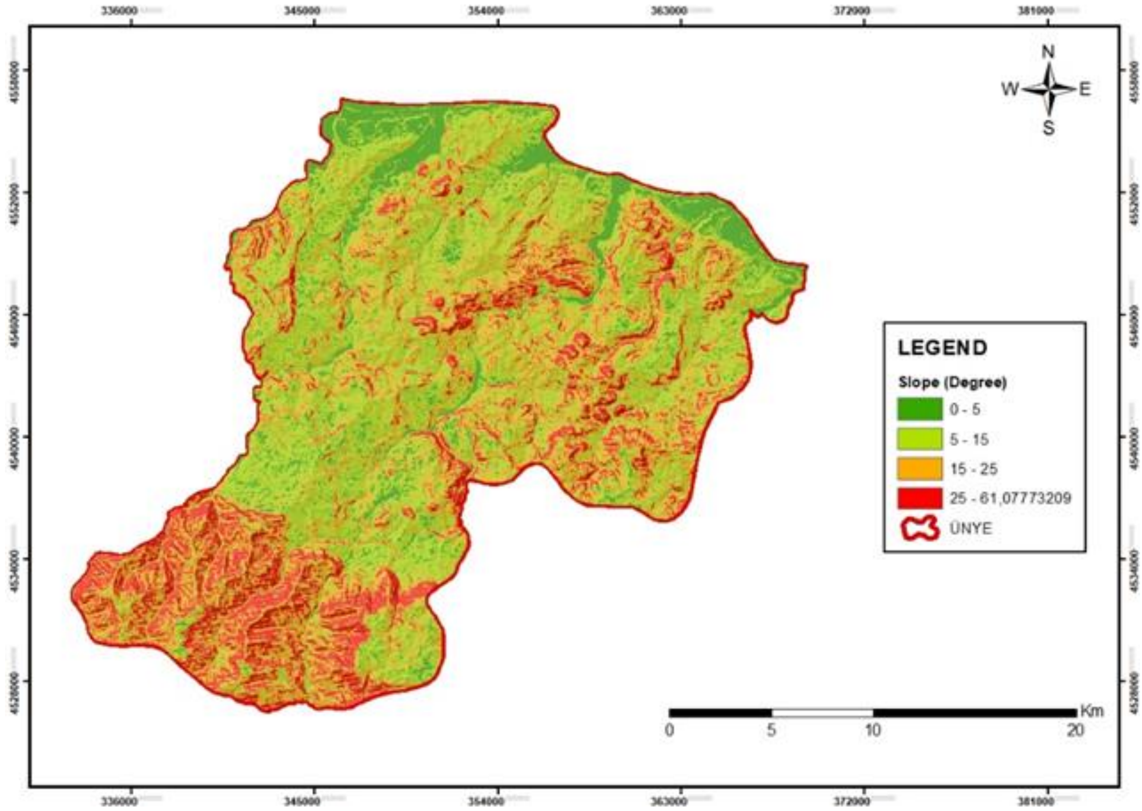

Figure 2. Slope map

While creating the slope classes of the study area, the classifications in the study by Özcan [5] were taken into account. Four slope classes were designed for the study area. Areas with a slope of 0°-5° were determined as the areas with the highest risk in terms of flood risk and the highest weight value was assigned to these areas.

2.2.2. Aspect

Another criterion that is effective in flood risk is aspect. Flat and near-flat areas are areas where precipitation and water can accumulate. These areas are the most risky areas in terms of flood risk. The saturation of soils on north-facing slopes causes surface waters to flow rapidly and increases the risk of flooding [7].

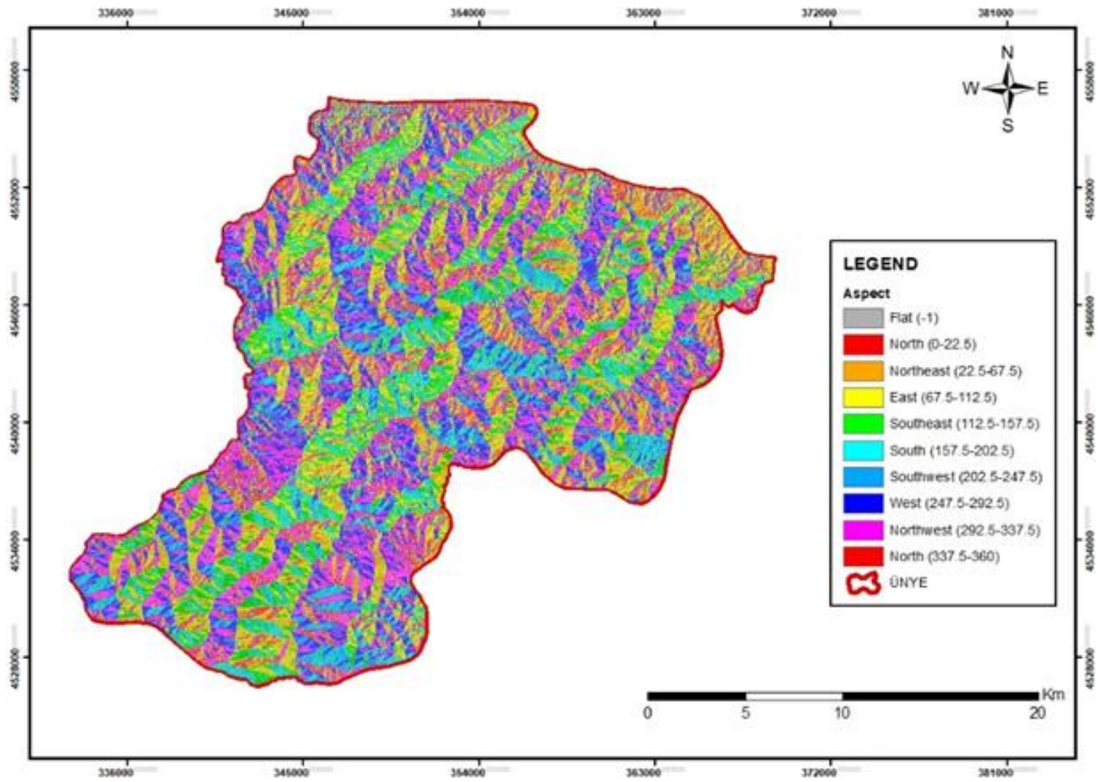

Figure 3. Aspect map

In the study area, 4 classes were created for aspect and flat areas were determined as the areas with the highest risk. Areas facing north have also been identified as high-risk areas (Figure 3).

2.2.3. Elevation

Another important criterion in the formation of a flood is the altitude. As the altitude increases, the precipitation falling on the basin also increases. In areas with high elevation, water passes to the surface flow faster and increases the risk of flooding in lower elevations (Figure 4).

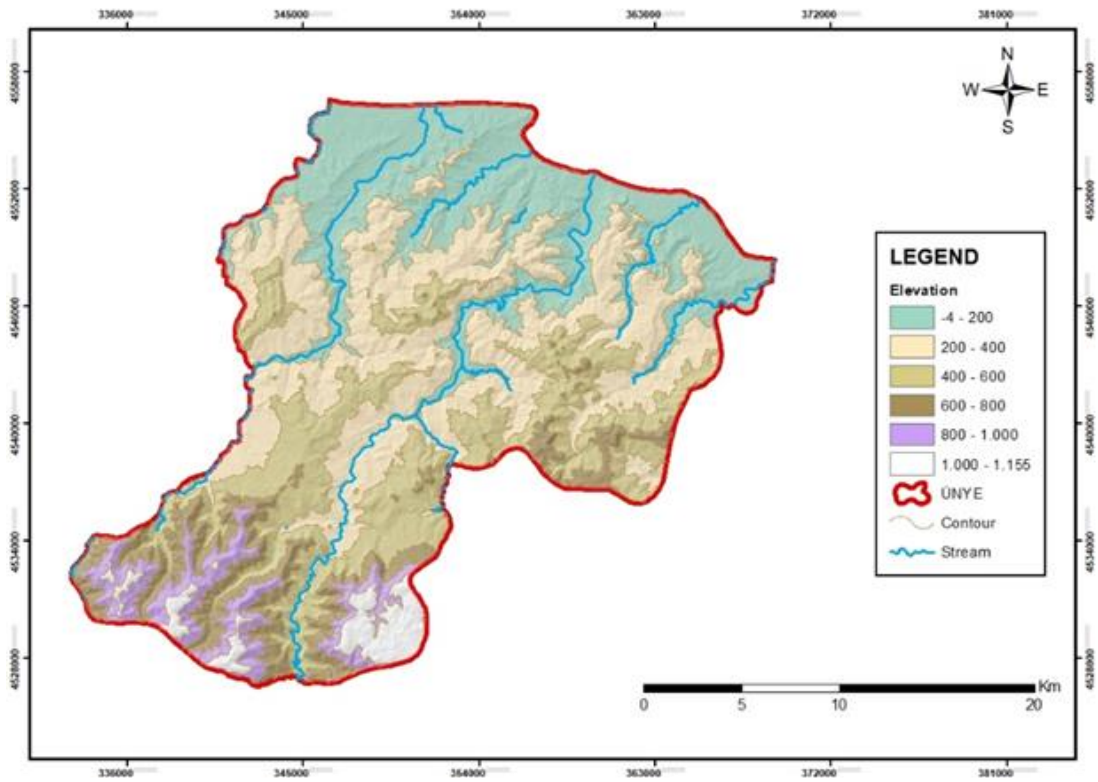

Figure 4. Elevation map

While creating the altitude classes in the study area, the classes used by Ocak and Bahadır [7] were considered. The altitude between 0 and 20 m has been determined as the most risky area in terms of flooding and the highest weight value has been assigned to these areas.

2.2.4. Land Use

In this study, land use was chosen as the fourth criterion effective in flood formation. Due to the moist soils in agricultural areas, residential areas and industrial areas, rain water quickly passes to the surface flow. Therefore, these areas increase the risk of flooding. Since hazelnut orchards are areas that require plenty of precipitation, they absorb water easily, reduce the flow of surface waters, and reduce the risk of flooding. Forest areas also reduce the risk of flooding.

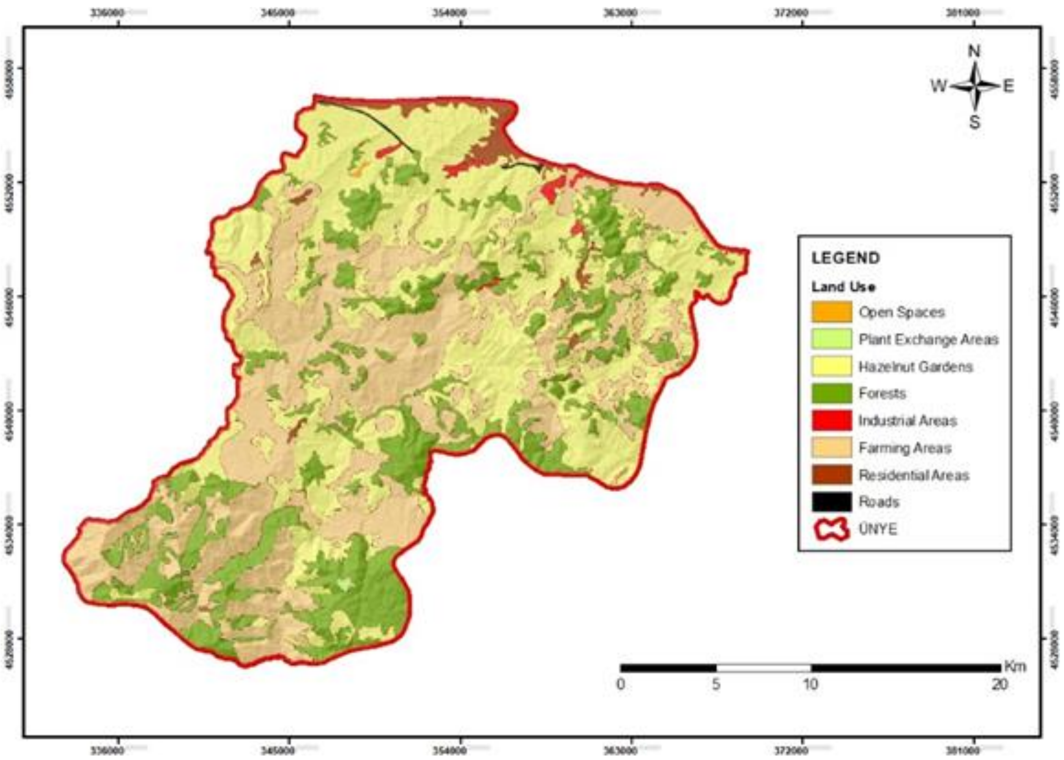

Figure 5. Land use map

The land use status of the study area is divided into 9 classes. Agricultural areas were determined as the areas with the highest risk, and these areas were given the highest value (Figure 5).

3. Results

In this study, the areas that will be affected in the event of a possible flood in Ünye district have been tried to be determined using few criteria. For this purpose, slope, aspect, elevation and land use criteria in terms of flood risk are discussed. Maps belonging to these criteria were produced. Each criterion was divided into subclasses and weighted using BWM and reclassified according to these values and a flood risk map was produced (Figure 6). In the flood risk map, the flood risk is classified in five groups as "Very High", "High", "Medium", "Low" and "No Risk".

4. Discussion

According to the flood risk map created, it is seen that the 55.7 km^2 area in Ünye district is a very high-risk area in terms of flood risk. These areas correspond to a small part of the entire study area. However, since they are the areas above the residential areas, it is seen that they are the p1laces that are most likely to be damaged in the event of a flood. A total of 90.8 km^2 of the study area poses a high risk of flooding. It is understood that these two areas are the areas remaining in the coastal areas. 293.3 km^2 of the study area is medium risk, 108 km^2 is low risk and 16.1 km^2 is risk-free (Table 3). It is seen that the risk of flooding decreases as you go to higher elevations in the study area. The fact that the areas where Tabakhane Stream, Cevizdere and Curi Stream are located in the district are densely populated also poses a risk in terms of flooding. The presence of agricultural lands and hazelnut orchards in the area where Cevizdere is located causes severe property losses in case of a possible flood.

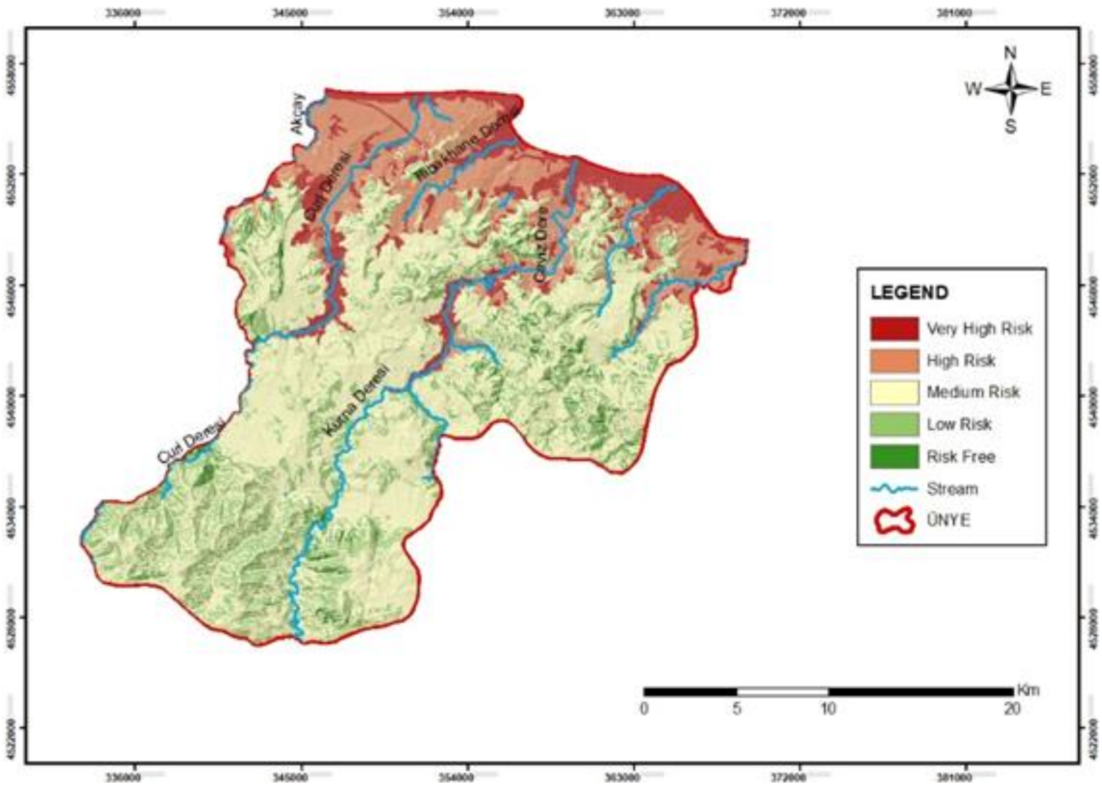

Figure 6. Flood risk map

Table 3. Created flood map risk classes, areas and rates

Risk Groups	Area (km^2)	Ratio
Very High	55.7	9.9
High	90.8	16.1
Middle	293.3	52.0
Little	108.0	19.1
Risk free	16.1	2.9

The risk classes presented in (Table 3) are compared with the Ocak and Bahadır [7] study, while the Very High and High risk groups constitute 26% of the total area in the current study, this ratio remains at 8.5 % in the other study. Areas in the medium risk group accounted for 52% of the total area in the current study, while this rate was 29.5% in the other study. It is thought that this situation is due to the reflection of the number of criteria in the current study on the result obtained, and that few criteria show more areas as risky.

5. Conclusion

In recent years, GIS has been an effective tool in studies on flood risk, as in many other fields. In this study, the flood risk in Ünye district was analyzed using GIS.

Elevation, slope, aspect and land use were used as the risk factors in the current study. Compared with the previous studies that used more criteria in the same region, it was observed that, the results are not close to each other in very high and high risk areas, but the results are close to each other in total medium and low risk areas. In addition to increasing the number of effective criteria in the analysis, it is predicted that using data with higher resolution will provide more precise results. It is anticipated that conducting more detailed and comparative studies in the region, which is at risk in terms of flooding due to the streams and topographic structure it contains, will be beneficial in terms of reducing the risk. According to the results, measures should be taken to minimize the risk, and early warning systems should be developed. Since the damages caused by the flood may be more, especially in the residential areas where the population is dense, necessary planning should be made in terms of risk in these areas. The results of this and similar studies should also be considered when planning for construction in places where the risk is high. The people living in the region should be informed about the possible floods and the social and economic damages they will cause.

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Author contributions

Nilay Yıldız*:* Conceptualization, Methodology, Data curation, Software, Writing-Original draft preparation. **Aziz Şişman**: Visualization Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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Importance analysis of the criteria affecting the house selection with the analytical hierarchy process

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Abstract
Houses meet the housing needs of people. At the same time, it draws attention as a means of status, social acceptance and investment. Therefore, housing is important for individuals and families. The house selection should be deal with as a multi-criteria decision problem for containing many criteria and effecting factors. In order to obtain an objective result in determining the importance of criteria in house selection, multiple decision maker analysis is needed. For these purposes, a total of 20 sub-criteria in 3 basic groups were examined for criterion selection in this study. Then, the importance levels of these criteria were determined using the Analytical Hierarchy Process. While determining the degree of importance, answers were taken from 15 decision makers (the student of Geomatics Engineering) and pairwise comparison matrices were created. The weights of the criteria were obtained with the Analytical Hierarchy Process and the importance levels of the criteria were determined as a result of the study. Also, the importance of criteria analyzed.

1. Introduction

The real estate is independent and permanent rights that give the owner the right to use it as they wish, registered on different pages in the independent sections registered in the title deed and condominium, excluding the prohibitions developed in favor of the citizens [1]. Housing is the living space where people continue their lives and generations by meeting to need for shelter. Houses have undergone many changes in social, cultural, economic, technological and legal terms over time [2]. A large number of financial resources are needed for buying or renting a house. The wishes, economic reasons, social factors etc. are also effective in the house selection. House selection has turned into a multi criteria decision making problem with the increase in housing options and evaluation criteria. For these reasons, it is necessary to make the right choice by expressing the criteria according to which the house is evaluated as much as possible numerically. Multi criteria decision making methods can be used to find the best solution by evaluating many criteria that are effective in the house selection [3].

Each house has its own unique feature in terms of its location. Therefore, a house cannot be exactly the same, but when expressed as a value, another one with the same value can be found like real estate. Another issue to consider is the subjective values that buyers use when house selection [4]. The buyers have their own preferences. Some may want a good physical environment, an area close to parks and green spaces, while the other may want an area close to the school. These preferences of the buyers are effective in the house selection [5-6].

When the studies on house and real state selection in the literature are examined, it is seen that, a few methods have been used. Analytical Hierarchy Process (AHP) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) methods from multi criteria decision making methods, regression analysis and hedonic methods as statistical methods, fuzzy logic and artificial neural network methods as modern methods are used frequently. [1,2, 7-10].

In this study, the importance levels of the criteria taken into account in the house selection were analyzed using the AHP method for the answers received from undergraduate students of geomatics engineering. The pairwise comparison matrices in AHP method were created for the criteria affecting the house selection and their weights were determined.

2. Material and Method

It is important to examine house criteria mathematically for finding the right choice. In the house selection, it must be to evaluate many criteria together. For this reason, in the solution requires a multi-criteria decision-making process. Multi-criteria decision making process evaluates many criteria together and assigns values to options. The AHP method, which is one of the multi-criteria decision-making methods, was used to determine the importance levels of the criteria considered in the house selection in this study. The answers of the creation of pairwise comparison matrices were collected from undergraduate students of geomatics engineering were taken as data. The reason of selection these students is that real estate appraisal is a geomatics engineering study area, taken real estate appraisal course and not have work experiences.

2.1. Analytic Hierarchy Process (AHP) Method

The analytical hierarchy process was first introduced by Myers and Alpert in 1968 and developed by Saaty in 1977. AHP is a method that can be used in solving multi criteria decision making problems [3].

The problem with the AHP method developed for complex decision problems involving more than one criterion; It is modeled in a hierarchical system at the level of main purpose, criteria, sub-criteria and options. The hierarchy consists of at least three levels. Accordingly, at the top of the hierarchy (Figure 1), there is the general purpose of the problem, and below the goal, there are criteria and alternative, respectively [11-15].

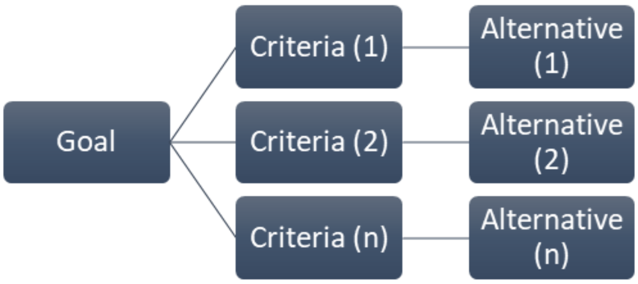

Figure 1. AHP Workflow

The application steps of the AHP method are as follows under 5 headings [2,3,11,13,16-23]:

1) Determination of decision criteria: Criteria and alternatives of the problem are determined.

2) Creation of the pairwise comparison matrix: After determining a decision criteria of problem, the pairwise comparison matrix of the criteria $A_{n,n}$ is created. Here, n is the criteria number. The criteria are compared among themselves using the pairwise comparison scale given in Table 1.

3) Obtain the single judgement: This step is applied if there is more than one decision maker. If the analysis is to be done with a single decision maker, this step should be skipped. One of the important issues of decision analysis is to obtain a single judgement by combining the evaluations of the decision makers in the group. In the analytic hierarchy process, the geometric mean of the matrices is taken to consolidate the judgements of the decision makers. The final value is obtained by taking the power of the decision makers' evaluations according to their importance.

4) Calculation of weights: A pairwise comparison matrix is created (Equation 1) and each value is divided by the column total to which it belongs (Equation 2). The sum of the values in each column of the resulting normalized matrix should be "1,00". The weight vector W is obtained by averaging the values in each row of the normalized matrix (Equation 3).

5) Checking the consistency: The consistency ratio (CR) is calculated for each pairwise comparison matrix. The upper limit for the consistency rate recommended by Saaty is "0,10". If the calculated consistency ratio is greater than "0,10" the pairwise comparison is must be re-evaluated. The basis of the consistency ratio is based on the comparison of the number of criteria with a coefficient called the baseline value (λ) (Equation 4-5). After calculating the basic value (λ) coefficient, the CR is calculated (Equation 6). Random consistency index (RI) are given in Table 2. Comparisons are said to be consistent if "CR≤0,10". The CR is close to zero, the more consistent

the comparison results will be. In case of "CR>0,10" the results obtained are inconsistent and should be reconsidered.

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & 1 & a_{23} & \dots & a_{2n} \\ a_{31} & a_{32} & 1 & \dots & a_{3n} \\ \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & a_{n3} & \dots & 1 \end{bmatrix} \quad (1)$$

$$b_{ij} \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (2)$$

$$w_i \frac{\sum_{j=1}^{n} b_{ij}}{n} \quad (3)$$

$$[d_i] = [a_{ij}] \ x \ [w_i] \quad (4)$$

$$\lambda = \frac{\sum_{i=1}^{n} {d_i}/{w_i}}{n} \quad (5)$$

$$CR = \frac{\lambda - n}{RI(n-1)} \quad (6)$$

Table 1. Comparison Scale in AHP

Intensity of importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong Importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another, it dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation

NOTE: 2, 4, 6, 8 can be used to express intermediate values

Table 2. Random Consistency Index Values

(n)	1	2	3	4	5	6	7	8	9	10	11	12
(RI)	-	-	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,48

2.2. Material

In the house selection, the buyer wishes should be taken into account. For this reason, previous studies were examined and information was collected about the criteria used in the house selection. In the Alkan and Durukan [3] using AHP and TOPSIS methods, the criteria of price, usage area, age, floor, number of rooms, number of sun facades/landscape, heating system and distance to the city center were examined. In the Tabar [24] using artificial neural networks and fuzzy logic method, the criteria of apartment area, number of rooms, building age, floor of the apartment, heating type, number of bathrooms and balcony were examined. In the Bozdağ and Ertunç [25] using the AHP method, it was stated that the main criteria and sub-criteria should be determined. E.g; The distance to work and work area, which belongs to the location and is specified as a sub-criterion, can be in different ways by people.

As a result, when the studies in the literature are examined, it is seen that various criteria are preferred in the house selection [16,26-30]. Frequently preferred criteria for selection are given in Table 3.

At the end of the literature review, it was decided to determine the basic criteria and the sub-criteria related to these criteria. General features of the building were selected as basic criteria and it was divided into 3 groups as detailed features, spatial features and environmental features. Then, 20 criteria affecting the house selection were selected as sub-criteria. These criteria are: number of rooms, building area, balcony, en-suite bathroom, floor location, building age, heating system, elevator, proximity to city center, proximity to educational institution, proximity to health center, proximity to main road, proximity to worship areas, proximity to parks and gardens, proximity to the workplace, building parking, public transport stop, bening on the site, neighborhood, facade/landscape.

Table 3. Frequently Used Criteria in the Literature [2]

Criteria Name	Criteria Name
Building Price	Proximity to city center
Proximity to Public Transport	Number of Sunny Facades
Neighborhood	Building Area
Car park	Number of Rooms
Playground	Sound and Heat Insulation
Green Area	Dues and Expenses
Proximity to School	Bank Loan Eligibility
Proximity to Hospital	Building Age
Proximity to Social Areas	Floor location
New/Pre-owned Condition	Total Floor in the Building
Heating system	Security

The criteria are grouped as given in Table 4. The grouped criteria were analyzed by preparing pairwise comparison matrix.

Table 4. Criteria Used in the Study

Building General Features	Sub-Criteria
1) Building Detail Features	1) Number of Rooms 2) Building Area 3) Balcony Condition 4) En-suite Bathroom 5) Floor location 6) Building Age 7) Heating system 8) Elevator
2) Building Spatial Features	1) Proximity to City Center 2) Proximity to Educational Institution 3) Proximity to Health Center 4) Proximity to Main Road 5) Proximity to Worship Areas 6) Proximity to Parks and Gardens 7) Proximity to the Workplace
3) Building Environmental Features	1) Building Parking 2) Public Transport Stop 3) Being on the Site 4) Neighborhood 5) Building Facade / Landscape

3. Results

The paired comparison matrix was created for the 3 main criteria and sub-criteria related to them in the house selection. In the study, the answers of 15 undergraduate students were used. The steps of the AHP method were applied to the data obtained as a result of the evaluation of the decision makers.

The paired comparison matrix and consolidated matrix for Building Detail Features, Building Spatial Features, Building Environmental Features and Building General Features are in Table 5-8.

The consolidated matrix, obtained by taking the geometric mean of the answers, were analyzed according to the AHP method and the criterion weights were found. The weight values and CR of the analysis of the building detail features, building spatial features, building environmental features and building general features are given in Table 9-12.

Table 5. Building Detail Features - Binary Comparison Matrix

C	1	2	3	4	5	6	7	8
1	**1**	0,42	1,91	4,37	0,76	0,30	0,49	1,88
2	2,36	**1**	2,33	4,97	1,42	0,54	0,55	2,84
3	0,52	0,43	**1**	2,89	0,49	0,25	0,35	2,06
4	0,23	0,2	0,35	**1**	0,2	0,23	0,23	0,34
5	1,31	0,71	2,06	4,89	**1**	0,41	0,55	2,54
6	3,35	1,86	3,97	4,27	2,47	**1**	1,19	3,53
7	2,06	1,83	2,86	4,31	1,82	0,84	**1**	3,00
8	0,53	0,35	0,49	2,94	0,39	0,28	0,33	**1**

Building Detail Features

Weighted geometric mean of participants

Consolidated Matrix

15 = k number of participants

8 = n number of criteria

1	1	2	3	4	5	6	7	8
1	**1**	1/9	9	9	1/9	1/7	6	6
2	9	**1**	9	9	6	7	9	9
3	1/9	1/9	**1**	1/5	1/9	1/9	1/9	1/5
4	1/9	1/9	5	**1**	1/9	1/9	1/9	1/7
5	9	1/6	9	9	**1**	5	9	9
6	7	1/7	9	9	1/5	**1**	9	9
7	1/6	1/9	9	9	1/9	1/9	**1**	9
8	1/6	1/9	5	7	1/9	1/9	1/9	**1**

2	1	2	3	4	5	6	7	8
1	**1**	1/5	7	7	3	3	5	3
2	5	**1**	7	7	5	3	3	3
3	1/7	1/7	**1**	3	1/3	1/3	1	1
4	1/7	1/7	1/3	**1**	1/3	1/3	1/3	1/3
5	1/3	1/5	3	3	**1**	1/3	1	1
6	1/3	1/3	3	3	3	**1**	3	1
7	1/5	1/3	1	3	1	1/3	**1**	1
8	1/3	1/3	1	3	1	1	1	**1**

3	1	2	3	4	5	6	7	8
1	**1**	1/7	6	6	1/6	1/7	1/8	6
2	7	**1**	8	8	1/6	1/7	1/7	9
3	1/6	1/8	**1**	3	1/9	1/9	1/9	8
4	1/6	1/8	1/3	**1**	1/9	1/9	1/9	1/3
5	6	6	9	9	**1**	1/4	1/6	5
6	7	7	9	9	4	**1**	1/7	9
7	8	7	9	9	6	7	**1**	9
8	1/6	1/9	1/8	3	1/5	1/9	1/9	**1**

4	1	2	3	4	5	6	7	8
1	**1**	1/5	7	6	1/3	1/7	3	4
2	5	**1**	3	5	2	1/3	4	2
3	1/7	1/3	**1**	7	1/3	1/3	2	4
4	1/6	1/5	1/7	**1**	1/4	1/5	1/4	1/2
5	3	1/2	3	4	**1**	1/5	1/4	3
6	7	3	3	5	5	**1**	5	5
7	1/3	1/4	1/2	4	4	1/5	**1**	1/2
8	1/4	1/2	1/4	2	1/3	1/5	2	**1**

5	1	2	3	4	5	6	7	8
1	**1**	1/3	3	5	1/4	1/3	1/4	2
2	3	**1**	1/3	3	1/4	1/3	1/4	4
3	1/3	3	**1**	4	1/4	1/4	1/4	1/3
4	1/5	1/3	1/4	**1**	1/4	1/4	1/4	1/4
5	4	4	4	4	**1**	1/3	1/4	1/3
6	3	3	4	4	3	**1**	1/4	4
7	4	4	4	4	4	4	**1**	3
8	1/2	1/4	3	4	3	1/4	1/3	**1**

6	1	2	3	4	5	6	7	8
1	**1**	3	1/5	2	5	1/7	1/6	1/4
2	1/3	**1**	1/5	5	5	1/6	1/6	1/5
3	5	5	**1**	6	4	1/7	1/7	4
4	1/2	1/5	1/6	**1**	1/5	1/5	1/5	1/5
5	1/5	1/5	1/4	5	**1**	1/5	1/5	5
6	7	6	7	5	5	**1**	5	5
7	6	6	7	5	5	1/5	**1**	5
8	4	5	1/4	5	1/5	1/5	1/5	**1**

7	1	2	3	4	5	6	7	8
1	**1**	1/6	6	6	6	6	1/5	4
2	6	**1**	3	3	6	5	1/4	5
3	1/6	1/3	**1**	5	4	3	1/5	4
4	1/6	1/3	1/5	**1**	1/4	1/4	1/4	1/4
5	1/6	1/6	1/4	4	**1**	1/5	1/4	4
6	1/6	1/5	1/3	4	5	**1**	1/4	4
7	5	4	5	4	4	4	**1**	4
8	1/4	1/5	1/4	4	1/4	1/4	1/4	**1**

8	1	2	3	4	5	6	7	8
1	**1**	2	1/3	9	2	1/5	1/7	2
2	1/2	**1**	1/4	9	3	1/4	1/5	2
3	3	4	**1**	3	4	1/5	1/4	2
4	1/9	1/9	1/3	**1**	1/5	1/5	1/5	1/5
5	1/2	1/3	1/4	5	**1**	1/4	1/4	3
6	5	4	5	5	4	**1**	1/5	5
7	7	5	4	5	4	5	**1**	7
8	1/2	1/2	1/2	5	1/3	1/5	1/7	**1**

9	1	2	3	4	5	6	7	8
1	**1**	7	5	5	5	1/3	1/5	5
2	1/7	**1**	5	3	5	1/7	1/5	3
3	1/5	1/5	**1**	5	1/5	1/5	1/5	5
4	1/5	1/3	1/5	**1**	1/7	1/7	1/7	1/7
5	1/5	1/5	5	7	**1**	1/7	5	3
6	3	7	5	7	7	**1**	1/3	3
7	5	5	5	7	1/5	3	**1**	3
8	1/5	1/3	1/5	7	1/3	1/3	1/3	**1**

10	1	2	3	4	5	6	7	8
1	**1**	1/7	5	8	1/7	1/7	1/9	1/8
2	7	**1**	7	8	1/9	1/8	1/9	6
3	1/5	1/7	**1**	8	1/9	1/9	1/8	5
4	1/8	1/8	1/8	**1**	1/9	1/8	1/9	1/4
5	7	9	9	9	**1**	1/9	1/8	5
6	7	8	9	8	9	**1**	6	9
7	9	9	8	9	8	1/6	**1**	9
8	8	1/6	1/5	4	1/5	1/9	1/9	**1**

11	1	2	3	4	5	6	7	8
1	**1**	1/3	1/3	1	1/3	1/5	3	1/3
2	3	**1**	3	5	1	1/3	3	1
3	3	1/3	**1**	3	1/3	1/3	5	1
4	1	1/5	1/3	**1**	1/5	1/5	1	1/3
5	3	1	3	5	**1**	1	3	1
6	5	3	3	5	1	**1**	5	3
7	1/3	1/3	1/5	1	1/3	1/5	**1**	1/3
8	3	1	1	3	1	1/3	3	**1**

12	1	2	3	4	5	6	7	8
1	**1**	1/9	1/5	7	7	1/5	1/9	7
2	9	**1**	9	9	9	9	1/9	9
3	5	1/9	**1**	5	5	1/5	1/9	5
4	1/7	1/9	1/5	**1**	1/3	5	1/9	1/5
5	1/7	1/9	1/5	3	**1**	3	1/9	3
6	5	1/9	5	1/5	1/3	**1**	1/9	1/5
7	9	9	9	9	9	9	**1**	9
8	1/7	1/9	1/5	5	1/3	5	1/9	**1**

13	1	2	3	4	5	6	7	8
1	**1**	1/3	1/3	1	1/3	1/5	3	1/3
2	3	**1**	3	5	1	1/3	3	1
3	3	1/3	**1**	3	1/3	1/3	5	1
4	1	1/5	1/3	**1**	1/5	1/5	1	1/3
5	3	1	3	5	**1**	1	3	1
6	5	3	3	5	1	**1**	5	3
7	1/3	1/3	1/5	1	1/3	1/5	**1**	1/3
8	3	1	1	3	1	1/3	3	**1**

14	1	2	3	4	5	6	7	8
1	**1**	1/3	3	4	1/3	1/2	1/5	3
2	3	**1**	1/2	5	1/2	1/2	1/2	2
3	1/3	2	**1**	3	1/2	1/2	1/3	2
4	1/4	1/5	1/3	**1**	1/3	1/3	1/3	2
5	3	2	2	3	**1**	1/2	1/2	2
6	2	2	2	3	2	**1**	1/2	3
7	5	2	3	3	2	2	**1**	4
8	1/3	1/2	1/2	1/2	1/2	1/3	1/4	**1**

15	1	2	3	4	5	6	7	8
1	**1**	3	3	3	1/3	1/7	1/3	5
2	1/3	**1**	3	1	1/3	1/7	1/3	5
3	1/3	1/3	**1**	1/3	1/7	1/7	1/7	3
4	1/3	1	3	**1**	1/4	1/7	1/5	3
5	3	3	7	4	**1**	1/5	1/3	5
6	7	7	7	7	5	**1**	4	7
7	3	3	7	5	3	1/4	**1**	8
8	1/5	1/5	1/3	1/3	1/5	1/7	1/8	**1**

Table 6. Building Spatial Features - Binary Comparison Matrix

C	1	2	3	4	5	6	7
1	**1**	1,78	0,99	1,6	4,4	2,51	0,88
2	0,56	**1**	0,72	1,35	4,01	1,5	0,79
3	1,01	1,4	**1**	1,9	3,24	1,48	0,91
4	0,62	0,74	0,53	**1**	3,16	1,18	0,75
5	0,23	0,25	0,31	0,32	**1**	0,36	0,21
6	0,4	0,67	0,68	0,85	2,76	**1**	0,3
7	1,14	1,26	1,1	1,34	4,76	3,3	**1**

Building Spatial Features

Weighted geometric mean of participants

Consolidated Matrix

15 = k number of participants

7 = n number of criteria

1	1	2	3	4	5	6	7
1	**1**	7	7	1/7	3	3	5
2	1/7	**1**	1/8	1/8	3	3	3
3	1/7	8	**1**	1/4	7	3	3
4	7	8	4	**1**	5	5	5
5	1/3	1/3	1/7	1/5	**1**	5	1/4
6	1/3	1/3	1/3	1/5	1/5	**1**	1/4
7	1/5	1/3	1/3	1/5	4	4	**1**

2	1	2	3	4	5	6	7
1	**1**	3	3	1/3	3	1/3	3
2	1/3	**1**	1	1	1	1	1
3	1/3	1	**1**	1	1	1/3	1/3
4	3	1	1	**1**	5	5	5
5	1/3	1	1	1/5	**1**	1	1
6	3	1	3	1/5	1	**1**	1
7	1/3	1	3	1/5	1	1	**1**

3	1	2	3	4	5	6	7
1	**1**	8	1/8	1/7	8	8	1/7
2	1/8	**1**	1/9	1/7	8	5	1/5
3	8	9	**1**	8	9	9	8
4	7	7	1/8	**1**	9	8	8
5	1/8	1/8	1/9	1/9	**1**	1/9	1/9
6	1/8	1/5	1/9	1/8	9	**1**	1/7
7	7	5	1/8	1/8	9	7	**1**

4	1	2	3	4	5	6	7
1	**1**	4	2	2	9	6	3
2	1/4	**1**	1/4	1/3	9	1/2	2
3	1/2	4	**1**	2	9	1/2	3
4	1/2	3	1/2	**1**	9	1/2	4
5	1/9	1/9	1/9	1/9	**1**	1/9	1/9
6	1/6	2	2	2	9	**1**	3
7	1/3	1/2	1/3	1/4	9	1/3	**1**

5	1	2	3	4	5	6	7
1	**1**	2	1/4	3	3	4	1/3
2	1/2	**1**	1/4	2	3	2	1/4
3	4	4	**1**	4	1/3	3	3
4	1/3	1/2	1/4	**1**	2	2	1/4
5	1/3	1/3	3	1/2	**1**	1/2	1/4
6	1/4	1/2	1/3	1/2	2	**1**	1/4
7	3	4	1/3	4	4	4	**1**

6	1	2	3	4	5	6	7
1	**1**	3	3	3	3	3	3
2	1/3	**1**	1/3	4	4	4	4
3	1/3	3	**1**	5	5	5	5
4	1/3	1/4	1/5	**1**	7	1/6	1/6
5	1/3	1/4	1/5	1/7	**1**	1/6	1/6
6	1/3	1/4	1/5	6	6	**1**	1/6
7	1/3	1/4	1/5	6	6	6	**1**

7	1	2	3	4	5	6	7
1	**1**	8	7	5	5	5	1
2	1/8	**1**	1/4	1/4	5	1/5	1/8
3	1/7	4	**1**	1/5	4	1/4	1/8
4	1/5	4	5	**1**	6	6	8
5	1/5	1/5	1/4	1/6	**1**	1/6	1/8
6	1/5	5	4	1/6	6	**1**	1/8
7	1	8	8	1/8	8	8	**1**

8	1	2	3	4	5	6	7
1	**1**	2	1/5	1/5	3	3	1/5
2	1/2	**1**	1/5	4	2	2	1/5
3	5	5	**1**	4	3	4	5
4	5	1/4	1/4	**1**	4	3	1/5
5	1/3	1/2	1/3	1/4	**1**	1/4	1/4
6	1/3	1/2	1/4	1/3	4	**1**	1/5
7	5	5	1/5	5	4	5	**1**

9	1	2	3	4	5	6	7
1	**1**	5	5	5	5	5	1/7
2	1/5	**1**	7	7	5	3	7
3	1/5	1/7	**1**	3	5	5	1/7
4	1/5	1/7	1/3	**1**	1/5	1/5	1/7
5	1/5	1/5	1/5	5	**1**	5	1/3
6	1/5	1/3	1/5	5	1/5	**1**	1/7
7	7	1/7	7	7	3	7	**1**

10	1	2	3	4	5	6	7
1	**1**	1/8	1/8	7	9	8	1/7
2	8	**1**	7	7	9	7	1/4
3	8	1/7	**1**	5	6	7	1/6
4	1/7	1/7	1/5	**1**	7	8	1/8
5	1/9	1/9	1/6	1/7	**1**	1/7	1/9
6	1/8	1/7	1/7	1/8	7	**1**	1/9
7	7	4	6	8	9	9	**1**

11	1	2	3	4	5	6	7
1	**1**	3	3	3	5	1	1
2	1/3	**1**	3	3	5	1	1
3	1/3	1/3	**1**	3	5	1/3	1/3
4	1/3	1/3	1/3	**1**	1/3	1/5	1/5
5	1/5	1/5	1/5	3	**1**	1/5	1/5
6	1	1	3	5	5	**1**	3
7	1	1	3	5	5	1/3	**1**

12	1	2	3	4	5	6	7
1	**1**	1/7	1/9	5	5	1/7	7
2	7	**1**	1/9	7	7	7	7
3	9	9	**1**	9	9	9	9
4	1/5	1/7	1/9	**1**	5	1/7	1/5
5	1/5	1/7	1/9	1/5	**1**	1/7	1/7
6	7	1/7	1/9	7	7	**1**	1/7
7	1/7	1/7	1/9	5	7	7	**1**

13	1	2	3	4	5	6	7
1	**1**	1/3	1/3	3	3	2	1/2
2	3	**1**	2	3	3	1/2	1/2
3	3	1/2	**1**	2	3	1/2	1/3
4	1/3	1/3	1/2	**1**	2	1/3	1/3
5	1/3	1/3	1/3	1/2	**1**	1/3	1/3
6	1/2	2	2	3	3	**1**	1/3
7	2	2	3	3	3	3	**1**

14	1	2	3	4	5	6	7
1	**1**	1/3	1/3	3	3	2	1/2
2	3	**1**	2	3	3	1/2	1/2
3	3	1/2	**1**	2	3	1/2	1/3
4	1/3	1/3	1/2	**1**	2	1/3	1/3
5	1/3	1/3	1/3	1/2	**1**	1/3	1/3
6	1/2	2	2	3	3	**1**	1/3
7	2	2	3	3	3	3	**1**

15	1	2	3	4	5	6	7
1	**1**	3	7	2	5	5	3
2	1/3	**1**	7	1/5	3	1/2	1/3
3	1/7	1/7	**1**	1/7	1/3	1/5	1/7
4	1/2	5	7	**1**	5	4	3
5	1/5	1/3	3	1/5	**1**	1/2	1/7
6	1/5	2	5	1/4	2	**1**	1/5
7	1/3	3	7	1/3	7	5	**1**

Table 7. Building Environmental Features - Binary Comparison Matrix

Building Environmental Features

Weighted geometric mean of participants

Consolidated Matrix

15 = k number of participants

5 = n number of criteria

C	1	2	3	4	5
1	**1**	0,62	0,6	0,23	0,3
2	1,6	**1**	1,28	0,59	0,49
3	1,67	0,78	**1**	0,47	0,66
4	4,3	1,71	2,13	**1**	2,12
5	3,29	2,03	1,52	0,47	**1**

1	1	2	3	4	5
1	**1**	7	7	1/7	1/5
2	1/7	**1**	1/5	5	5
3	1/7	5	**1**	3	5
4	7	1/5	1/3	**1**	5
5	5	1/5	1/5	1/5	**1**

2	1	2	3	4	5
1	**1**	3	1/3	1/3	1/5
2	1/3	**1**	1/3	1/3	1/5
3	3	3	**1**	1/5	1/5
4	3	3	5	**1**	1/3
5	5	5	5	3	**1**

3	1	2	3	4	5
1	**1**	1/7	1/8	1/9	1/8
2	7	**1**	1/7	1/9	1/6
3	8	7	**1**	1/7	8
4	9	9	7	**1**	9
5	8	6	1/8	1/9	**1**

4	1	2	3	4	5
1	**1**	1/5	5	1/7	1/4
2	5	**1**	8	1/4	5
3	1/5	1/8	**1**	1/6	1/7
4	7	4	6	**1**	7
5	4	1/5	7	1/7	**1**

5	1	2	3	4	5
1	**1**	1/3	1/4	1/3	1/4
2	3	**1**	3	3	3
3	4	1/3	**1**	1/3	1/3
4	3	1/3	3	**1**	3
5	4	1/3	3	1/3	**1**

6	1	2	3	4	5
1	**1**	3	1/4	1/6	1/5
2	1/3	**1**	1/5	1/5	1/5
3	4	5	**1**	1/5	5
4	6	5	5	**1**	5
5	5	5	1/5	1/5	**1**

7	1	2	3	4	5
1	**1**	5	1/4	1/5	1/4
2	1/5	**1**	1/4	1/4	1/4
3	4	4	**1**	5	1/4
4	5	4	1/5	**1**	1/5
5	4	4	4	5	**1**

8	1	2	3	4	5
1	**1**	1/4	1/4	1/3	1/4
2	4	**1**	5	1/3	1/4
3	4	1/5	**1**	1/3	1/4
4	3	3	3	**1**	1/4
5	4	4	4	4	**1**

9	1	2	3	4	5
1	**1**	9	3	5	3
2	1/9	**1**	3	1/3	1/3
3	1/3	1/3	**1**	3	1/5
4	1/5	3	1/3	**1**	5
5	1/3	3	5	1/5	**1**

10	1	2	3	4	5
1	**1**	1/7	1/6	1/8	1/9
2	7	**1**	7	5	4
3	6	1/7	**1**	5	6
4	8	1/5	1/5	**1**	7
5	9	1/4	1/6	1/7	**1**

11	1	2	3	4	5
1	**1**	1/3	1	1/5	1/7
2	3	**1**	3	1/3	1/7
3	1	1/3	**1**	1/3	1/7
4	5	3	3	**1**	1/5
5	7	7	7	5	**1**

12	1	2	3	4	5
1	**1**	1/5	7	1/9	7
2	5	**1**	1/7	1/7	1/9
3	1/7	7	**1**	1/9	7
4	9	7	9	**1**	9
5	1/7	9	1/7	1/9	**1**

13	1	2	3	4	5
1	**1**	1/5	1/3	1/5	1/5
2	5	**1**	5	3	1/3
3	3	1/5	**1**	1/5	1/5
4	5	1/3	5	**1**	4
5	5	3	5	1/4	**1**

14	1	2	3	4	5
1	**1**	1/5	1/3	1/5	1/5
2	5	**1**	5	3	1/3
3	3	1/5	**1**	1/5	1/5
4	5	1/3	5	**1**	4
5	5	3	5	1/4	**1**

15	1	2	3	4	5
1	**1**	1/3	1/5	1/5	1/3
2	3	**1**	3	1/5	1/3
3	5	1/3	**1**	1/3	1/3
4	5	5	3	**1**	1
5	3	3	3	1	**1**

Table 8. Building General Features - Binary Comparison Matrix

Building General Features

Weighted geometric mean of participants

Consolidated Matrix

15 = k number of participants

3 = n number of criteria

C	1	2	3
1	**1**	0,31	0,49
2	3,22	**1**	3,64
3	2,02	0,27	**1**

1	1	2	3
1	**1**	1/5	1/5
2	5	**1**	5
3	5	1/5	**1**

2	1	2	3
1	**1**	1/5	3
2	5	**1**	3
3	1/3	1/3	**1**

3	1	2	3
1	**1**	1/8	1/7
2	8	**1**	5
3	7	1/5	**1**

4	1	2	3
1	**1**	1/3	1/2
2	3	**1**	3
3	2	1/3	**1**

5	1	2	3
1	**1**	3	1/2
2	1/3	**1**	1/3
3	2	3	**1**

6	1	2	3
1	**1**	1/3	1/3
2	3	**1**	4
3	3	1/4	**1**

7	1	2	3
1	**1**	1/5	4
2	5	**1**	5
3	1/4	1/5	**1**

8	1	2	3
1	**1**	1/5	1/5
2	5	**1**	5
3	5	1/5	**1**

9	1	2	3
1	**1**	1/5	1/5
2	5	**1**	5
3	5	1/5	**1**

10	1	2	3
1	**1**	1/7	1/7
2	7	**1**	7
3	7	1/7	**1**

11	1	2	3
1	**1**	1/3	2
2	3	**1**	3
3	1/2	1/3	**1**

12	1	2	3
1	**1**	1/5	1/7
2	5	**1**	7
3	7	1/7	**1**

13	1	2	3
1	**1**	1/4	1/3
2	4	**1**	4
3	3	1/4	**1**

14	1	2	3
1	**1**	1/4	1/3
2	4	**1**	4
3	3	1/4	**1**

15	1	2	3
1	**1**	3	5
2	1/3	**1**	3
3	1/5	1/3	**1**

Table 9. AHP Result of Building Detail Features

Criteria	Weights	+/-
Number of Rooms	10,00 %	2,55 %
Building Area	15,92 %	3,52 %
Balcony Condition	7,29 %	2,12 %
En-suite Bathroom	3,19 %	1,29 %
Floor location	12,57 %	2,01 %
Building Age	25,03 %	6,23 %
Heating system	20,13 %	4,23 %
Elevator	5,87 %	1,67 %
		CR = 0,0252

As a result of the analysis of building detail features, the CR value was found to be 0,0252 and a consistent result was obtained. When the weights were examined, building age was found to be the most important criterion with 25,03%.

Table 10. AHP Result of Building Spatial Features

Criteria	Weights	+/-
Proximity to City Center	20,36 %	3,03%
Proximity to Educational Institution	14,53 %	2,01 %
Proximity to Health Center	18,16 %	3,37 %
Proximity to Main Road	12,04 %	1,98 %
Proximity to Worship Areas	4,19 %	0,72 %
Proximity to Parks and Gardens	9,55 %	1,96 %
Proximity to the Workplace	21,17 %	4,89 %
CR = 0,0121		

As a result of the analysis of building spatial features, the CR value was found to be 0,0121 and a consistent result was obtained. When the weights were examined, proximity to the workplace was found to be the most important criterion with 21,17%.

Table 11. AHP Result of Building Environmental Features

Criteria	Weights	+/-
Building Parking	8,51 %	0,92 %
Public Transport Stop	16,10 %	3,65 %
Being on the Site	14,71 %	1,67 %
Neighborhood	36,16 %	9,20 %
Building Facade / Landscape	24,53 %	5,79 %
		CR = 0,0174

As a result of the analysis of building environmental features, the CR value was found to be 0,0174 and a consistent result was obtained. When the weights were examined, neighborhood was found to be the most important criterion with 36,16%.

Table 12. AHP Result of Building General Features

Criteria	Weights	+/-
Building Detail Features	14,75 %	4,03 %
Building Spatial Features	62,61 %	17,09 %
Building Environmental Features	22,64 %	6,18 %
		CR = 0,0797

Also, the analysis of building general features, the CR value was found to be 0,0797 and a consistent result was obtained. When the weights were examined, building spatial features was found to be the most important criterion with 62,61%. Building environmental features are 22.64% and building detail features are 14.75% rate was found to be significant.

4. Discussion

The AHP weights were proportioned as a percentage and the importance of 20 criteria in house selection was determined for discussing the sub-criteria. The importance weights of the criteria of house selection are given in Table 13.

Table 13. Criteria Weights in Housing Selection

No	Criteria	Weights
1	Proximity to the Workplace	13,25 %
2	Proximity to City Center	12,75 %
3	Proximity to Health Center	11,37 %
4	Proximity to Educational Institution	9,10 %
5	Neighborhood	8,19 %
6	Proximity to Main Road	7,54 %
7	Proximity to Parks and Gardens	5,98 %
8	Building Facade / Landscape	5,55 %
9	Building Age	3,69 %
10	Public Transport Stop	3,64 %
11	Being on the Site	3,33 %
12	Heating system	2,97 %
13	Proximity to Worship Areas	2,63 %
14	Building Area	2,35 %
15	Building Parking	1,93 %
16	Floor location	1,85 %
17	Number of Rooms	1,48 %
18	Balcony Condition	1,08 %
19	Elevator	0,87 %
20	En-suite Bathroom	0,47 %

When the importance weights of 20 criteria were examined, it was found that proximity to the workplace was the most important criterion with 13,25%. Proximity to the city center by 12.75%, to health centers by 11.37%, to educational institutions by 9.10%, to the neighborhood 8.19%, to the main road by 7.54%, to parks and gardens by 5%, 98%, Building Facade / View 5.55%, building age 3.69%, public transport stops 3.64%, being in the complex 3.33%, heating system 2.97%, proximity to places of worship 2.63%, flat size 2.35%, building parking 1.93%, 1.85% on which floor it is located, 1.48% number of rooms, 1.08% balcony status, 0.87% elevator and en-suite bathroom 0.47% rate was found to be significant.

In the study, the criteria were analyzed in groups, unlike the studies of Alkan and Durduran [3] and Tabar [24] (2020). The study shows similar characteristics with the study of Bozdağ and Ertunç [25], in which the criteria are grouped and analyzed. However, the use of a large number of decision makers in the study is the most important part that distinguishes the study from other studies.

5. Conclusion

In this study, 20 criteria affecting the house selection were examined in 3 different groups. These criteria were analyzed by the AHP method, which is one of the multi criteria decision making. Relative importance levels were obtained by creating pairwise comparison matrix of the criteria. The use of more than one decision maker or different decision makers in the analysis caused the CR value to be low and the consistency ratio to increase. Since subjective results will be obtained in analyzes made with a single decision maker, the study has generally reached an objective result. The study can be made more effective by increasing or decreasing the decision makers and criteria, or decision makers with different characteristics and used.

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Author contributions

Aslan Cihat Başara: Conceptualization, Methodology, Software, Data Supply, Data Curation, Analyze, Writing-Original Draft Preparation, Validation, Visualization. **Yasemin Sisman:** Data Supply, Writing-Original Draft Preparation, Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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Three-dimensional cadastre-from two-dimensional plan to three-dimensional digital model

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Abstract

The three-dimensional (3D) cadastre first came to the agenda in 2001 with a workshop organized by the International Federation of Surveyors (FIG). In the past two decades, many scientific meetings, academic studies and pilot projects have been carried out on 3D cadastre. At the same time, there have been significant developments in 3D data collection techniques, data modelling, 3D visualization, policy and institutional structures. In this study, the effects of these developments on cadastre are evaluated. In addition to the literature review, to make a comparison and evaluation, the questionnaire results conducted by the FIG 3D Cadastres Working Group in 2010, 2014 and 2018 were examined. As a result of the examination, it is seen that the demand for 3D cadastre data has increased with the need for planning and sustainable management of cities. This increasing demand has expanded the use of digital 3D models to represent cadastral data. Legal and organisational structure of Turkey is advantageous for 3D cadastre. Data modelling and pilot projects for 3D cadastral were carried out in Turkey in recent years. Although technological advances offer significant opportunities, the applicability and sustainability of 3D cadastre projects requires the creation of a workflow that supports the use of international standards and digital models beyond pilot projects.

1. Introduction

The significant increase in the world population in the last two centuries has led to intensification of land use, especially in urban areas. This increasing trend in population has changed the relationship between land and people over time, increasing the importance of land ownership [1]. Accordingly, a system to clearly and unambiguously record ownership of land was required. Although various names (land registration, land recording, land administration, etc.) are used to describe this system, today this system is generally called cadastre [2-4]. Cadastre forms the basis of land management by recording the geometric (boundaries) and legal (rights, restrictions and responsibilities) information of real estates. Until today, a standard cadastre has not been developed due to differences in legal structure, technical and economic opportunities [5]. Various classifications and definitions have been made for cadastre, taking into account criteria such as priority purposes, types of recorded rights, techniques used in data collection [6].

Although the right of property is applied to a space from legal point of view, the boundaries of the right of property are traditionally represented on cadastral maps by using two-dimensional (2D) parcels. However, as a result of the increasing use of the vertical dimension of the land in especially cities, since the beginning of the 2000s, due to the increasing population, the need for the cadastre to refer to a space instead of a plane when representing the property boundaries has come to the fore, and the concept of three-dimensional (3D) cadastre has emerged [7-9]. Difficulties in registration and representation of different types of land uses (limited real rights such as right of superficies, right of easement) and 3D objects (such as individual units and utilities) affecting below and above the land surface have further increased the interest in 3D cadastre [10]. The first examination of 3D cadastre within the scope of a postgraduate study was with the doctoral thesis completed in Delft Technical University in 2004 [11]. However, the issue of 3D cadastre was addressed at the international level for the first time in a workshop organized by the International Federation of Surveyors (FIG) in Delft, Netherlands in 2001. After this workshop, it was decided to establish a working group called 3D Cadastres in partnership with the third (Spatial Information Management) and the seventh (Cadastre and Land Management) commissions of FIG. However, until 2010 the 3D Cadastres group had no activity other than special sessions held at the annual FIG working week meetings. At the 24th FIG congress held in Sydney in 2010, it was decided to reconstitute the 3D Cadastres working group and a website [12] was created to include studies and developments in this field [13]. The organized and planned activities of the 3D Cadastres working group since 2010 are shown in Table 1.

Table 1. Organized and planned activities of the FIG 3D Cadastres working group

Year	Activity Explanation
2010	Creation of the FIG 3D Cadastres website. Sending the first 3D Cadastres questionnaire to the participants.
2011	Second 3D Cadastres Workshop (16-18 November, Delft, Netherlands).
2011- 2013	Organizing 3D Cadastres sessions at FIG Working Weeks. Marrakech, Morocco, 18-22 May 2011, Rome, Italy, 6-10 May 2012, Abuja, Nigeria, 6 - 10 May 2013.
2012	Third 3D Cadastres Workshop (October 25-26, Shenzhen, China).
2013	Publication of the 3D Cadastres special issue of Computers, Environment and Urban Systems.
2014	Presentation of four-year results and 3D Cadastres session at the 25th FIG Congress (June 16-21, Kuala Lumpur, Malaysia).
2014	Sending the second 3D Cadastres questionnaire to the participants. Fourth 3D Cadastres Workshop (9-11 November, Dubai, United Arab Emirates).
2015- 2017	Organizing 3D Cadastres sessions at FIG Working Weeks. Sofia, Bulgaria, 17-21 May 2015, Christchurch, New Zealand, 2-6 May 2016, Helsinki, Finland, 29 May - 2 June 2017.
2016	Fifth 3D Cadastres Workshop (18-20 October 2016, Athens, Greece).
2018	Publishing the book named Best Practices 3D Cadastres by FIG.
2018	Sixth 3D Cadastres Workshop (2-4 October 2018, Delft, Netherlands).
2018	Publication of the 3D Cadastres special issue of the ISPRS International Journal of Geo-Information.
2018	Sending the third 3D Cadastres questionnaire to the participants.
2020	Publication of the 3D Cadastres special issue of Land Use Policy journal.
2021	Seventh Workshop on 3D Cadastres (October 12-14, 2021, New York, USA).
2021	Eighth 3D Cadastres Workshop (24 June 2021, Amsterdam, Netherlands).
2023	Ninth 3D Cadastres Workshop (11-13 October 2023, Gavle, Sweden).

According to Table 1, 3 questionnaires have been carried out in 2010, 2014 and 2018 with the participation of country representatives, 8 workshops have been organized, 1 book and 3 special issues in 3 international journals has been published, apart from the special sessions held at the FIG congresses and annual meetings on 3D cadastre research. The 2010 questionnaire of the FIG 3D Cadastres working group was evaluated in [14], the 2014 questionnaire was evaluated in [15], and the 2018 questionnaire was evaluated in [16] separately. However, there is a need for studies in which all questionnaires are handled together in order to evaluate the development of 3D cadastre in a more reliable way. In this study, in order to evaluate the development of 3D cadastre and make a comparison, besides the literature review, the results of the questionnaires conducted by the FIG 3D Cadastres Working Group in 2010, 2014 and 2018 are examined. As a result of this examination, the main trends and development areas for 3D cadastre were determined and the studies of different countries in these areas were compared. The material and method used in the study are introduced in the second section. The findings based on the 3D Cadastres working group questionnaires and literature reviews are presented in the third section. Finally, the study ends with the conclusion section.

2. Method

In this study, the method of examining the questionnaires prepared by the FIG 3D Cadastres working group and answered by the researchers of the participating countries was adopted to determine the development in the field of 3D cadastre. The basic trends and development areas for 3D cadastre were determined by examining the questionnaires of the years 2010, 2014 and 2018, which were used as materials. Then, the studies of different countries in these determined areas were compared.

The main purpose of the questionnaires, which have been carried out every four years since 2010, is to reveal the current status of the work in the field of 3D cadastre around the world, the plans for the next four years and the progress made compared to the previous four years. In this way, it is aimed to increase cooperation by sharing the knowledge and experience of different countries. The basic structure of all three questionnaires is almost the same. Chapter titles and question numbers in chapters have been retained to facilitate comparison. However, in the questionnaires prepared for 2014 and 2018, some questions were simplified and made more understandable and new questions were added at the end of the relevant section. In Table 2, the main sections of the 2018 questionnaire of the FIG 3D Cadastres working group and the contents of these sections are given.

In the FIG 3D Cadastres working group, which has participants from 42 countries in total, the 2010 questionnaire was answered by the participants of 36 countries, the 2014 questionnaire was answered by the participants of 33 countries, and the 2018 questionnaire was answered by the participants of 29 countries. The number of countries responding to all three questionnaires is 23. The names of these countries alphabetically are Argentina, Australia (Queensland and Victoria States), Canada (Quebec Province), China, Croatia, Finland, Germany, Greece, Hungary, India, Israel, Kenya, Malaysia, Netherlands, Nigeria, Poland, South Korea, Southern Cyprus, Spain, Sweden, Switzerland, Trinidan and Tobago, Turkey.

Table 2. FIG 3D cadastres working group 2018 questionnaire chapter and its contents [17-18]

Number	Title	# of question	Content
1	3D Parcels	23	Legal base, 3D Geometric Structures, ISO 19152:2012 (LADM) Compliance
2	Utilities	9	Independent Registration, Rights Used, Intersecting Parcels
3	3D Representation of Individual Units	14	Building and Individual Unit Registration, Definition of Boundaries, Common Use Areas, Land Share
4	3D Coordinate	8	Absolute and Relative Heights, Representation in Database
5	Representation of the Third Dimension	8	Using Elevation Model, Storing Elevation Model in Database
6	4th Dimension (Time)	10	Time-Changing Boundaries, Timeshare
7	3D Right, Restriction, Responsibility	14	Land Registration System, Integration of 2D and 3D Registration
8	Database	15	LADM Schema, 3D Geometric Structures, Validity
9	3D Survey Plans	26	3D Representation, Content of Survey Plans, Regulations, 3D Survey Methods
10	Web Based 3D Representation	9	3D Data Formats, Cartographic Rules
11	Statistics	11	Smallest/Biggest Parcel Sizes, Permissible Limits
12	Progresses	7	Goals in Previous questionnaires, Progress, Challenges

3. Results

This section first presents the findings from a review of the FIG 3D Cadastres working group questionnaires. Then, under the subtitles determined by this review, the findings of the development in the 3D cadastre studies are discussed. At the end of each subtitle, the situation in Turkey is also evaluated to provide an opportunity for comparison.

3.1. 3D Cadastre Questionnaires

The evolution of the FIG 3D Cadastre questionnaire design is illustrated in Figure 1. The first 3D cadastral questionnaire designed and sent to country representatives in 2010 consists of 9 sections. The second 3D cadastral questionnaire of 2014 was updated by adding 3 new sections. These sections are respectively web-based 3D representation, statistics and developments. Another change in the 2014 questionnaire was the first use of the term Land Administration Domain Model (LADM) in some of the questions in sections 1 and 8. With this approach, it is aimed to adopt the terminology offered by LADM, which was accepted as an ISO standard in 2012, in questionnaires and to facilitate comparisons between questionnaires. The third 3D cadastral questionnaire design change in 2018 consisted of 24 new questions added to the questionnaire. The final questionnaire was prepared by adding new questions to sections 1 (6 questions), 4 (2 questions), 5 (2 questions), 6 (4 questions), 7 (1 question), 9 (7 questions) and 12 (2 questions). New questions added are about registration of 3D usage rights at sea, monitoring temporal changes, institutions responsible for registration and mapping, use and recording of height information, legal resources in 3D representation, accuracy, pilot studies and legal barriers to a fully 3D cadastre. Since the new sections added to the 2014 questionnaire and the new questions added to the 2018 questionnaire were determined as a result of the answers given to the previous questionnaires and workshops on different dates, they are important in terms of showing the development and trends in the 3D cadastre research.

It is observed that there has been a decrease in the number of countries answering the questionnaires over time. The number of countries responding to the 2010, 2014 and 2018 questionnaires was 36, 33 and 29, respectively. While the studies in the field of 3D cadastre increases, the decrease in the number of countries participating in the questionnaire can be interpreted as no progress or change in the new questionnaire period for the countries that responded to the previous questionnaire. Austria, Bahrain, United Kingdom, France, Indonesia, Italy, Kazakhstan, Nepal and Russia, which participated in the 2010 questionnaire, did not participate in the next two questionnaires. Brazil, Denmark, Macedonia and Norway, which participated in both the 2010 and 2014 questionnaires, did not respond to the 2018 questionnaire. The number of countries that answered all three questionnaires is 23.

The main difficulty in making an evaluation by comparing the three questionnaires conducted in 2010, 2014 and 2018 with each other is that the number of sections and questions of the questionnaires is not the same, as explained in this section. In addition, when the answers given by the countries to the questionnaires are examined, it is seen that short answers (such as yes, no, none) were given to many questions, and many fields were left blank. Especially in the first 3D cadastral questionnaire in 2010, there was no integrity in the answers given to the questionnaire questions due to the inability to create a common terminology and the differences between countries in the use of terms such as cadastre, land administration, registration and recording. However, the 8th section, which is common to all three questionnaires, and the 12th section added to the questionnaires since 2014 (12.4: the three most important obstacles for 3D cadastre and 12.5: pilot studies) are suitable for comparison in terms of containing more detailed explanations. The main findings that can be reached from the responses of the countries for the 2010 questionnaire are that there are studies on 3D digital database design in Sweden and Italy, and that volumetric parcels can be created and registered in Australia and Canada. In addition, it is stated that case studies have been carried out for 3D registration of utilities and complex buildings in the Netherlands, Sweden and Norway.

The first finding of the 2014 3D cadastral questionnaire is that in the answers given to the questions in the third part of the questionnaire, case studies were conducted for the 3D registration of individual units in Australia and China. It has been tried to examine whether LADM, which was accepted as an ISO standard in 2012, has an effect on the 3D cadastre, with the answers given to the 8th section of the 2014 questionnaire. Accordingly, only 5 of the 29 participants who answered the relevant question stated that there are partial studies on LADM in their countries (Australia, Czech Republic, China, Croatia and Greece). When the answers given to the questions of the 10th section, which is one of the new sections of the 2014 questionnaire, are examined, it is seen that digital data models such as CityGML (City Geography Markup Language), KML (Keyhole Markup Language), PDF (Portable Document Format), LandXML (Land eXtensible Markup Language) and 3D data sharing studies are mentioned in Germany, Brazil, China, Croatia, Spain, Sweden, Switzerland and Canada. In the 12th section of the 2014 questionnaire, the participants are asked questions about the progress in the past four years, expectations for the next four years, and what are the three most important obstacles to the development of 3D cadastre. Responding to these questions, the participants stated that their main expectation is the creation of a digital database. The obstacles stated for the development of 3D cadastre vary. The most common ones are lack of legal regulation, lack of digital data, lack of institutional policy, lack of academic studies, lack of economic resources and the need for experienced personnel.

When the answers given by the countries to the 2018 3D Cadastre questionnaires are evaluated, it is seen that Germany, Czech Republic, Finland, Croatia, Netherlands, Malaysia, Portugal and Singapore reported modelling studies compatible with LADM, unlike the 2014 questionnaire. In addition, it was stated that pilot projects are planned or ongoing in the Netherlands, Israel, Switzerland, Sweden, Hungary, Malaysia, Singapore, Slovenia and Turkey. However, details on these pilot projects were not given. It is stated that the main obstacles to the development of 3D cadastre are mainly legal and institutional issues (10 of 19 participants).

As a result, when the development in the FIG 3D Cadastre questionnaire design and the responses of the participating countries to the questionnaires are evaluated together, it is seen that the most active field of activity in the development of 3D cadastre is the use of data models in the cadastre. In addition, it is noteworthy that pilot studies were expressed in the 2018 questionnaire. The resolution of legal and institutional issues is gaining weight as the main challenge for real 3D cadastre development. These topics, obtained from the examination of the questionnaires, need to be examined in more detail to reveal their effects on 3D cadastre research. These topics are covered in the following subtitles of this section.

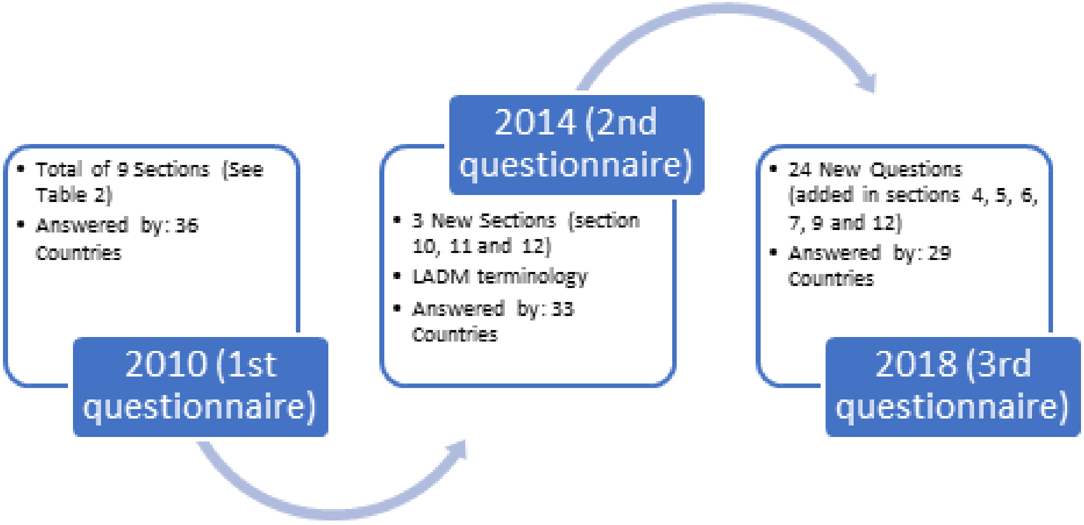

Figure 1. Development of 3D cadastre questionnaire

3.2. Use of Data Models in Cadastre

According to the questionnaire studies examined, one of the most important developments in the field of 3D cadastre is the widespread use of data models for 3D modelling of cadastral data. In particular, LADM, which was accepted as an ISO standard in 2012, has been shown as the main reference in the development of the country's 3D cadastral data model by the participants of some countries responding to the questionnaire. Some of the countries where these studies that base on LADM have been published are Australia [19], Czech Republic [20], Israel [21], Korea [22], Malaysia [23], Poland [24], Serbia [25] and Greece [26]. The evolution of LADM, a conceptual model aimed at standardizing data in the field of land administration, is given in Figure 2. LADM was first announced as the 'Cadastral Domain Model' after the 22nd FIG congress held in the United States of America in 2002 [27]. With this name, the work continued until 2008. In 2008, the first step towards becoming an ISO standard was taken with FIG's application to ISO under the name of 'Land Administration Domain Model' (NWIP-New Work Item Proposal). LADM was adopted as the draft standard (CD-Committee Draft) in 2009. The current version (v1) of LADM was adopted in 2012 and received the standard number (ISO 19152: 2012). FIG's application for revision of LADM was accepted by ISO TC (Technical Committee) 211 in May 2018. The revision process, which will take four years, is planned to result in the adoption of the new version (v2) of LADM in 2022. Besides FIG, revision of LADM is also supported by international organizations and institutions such as World Bank, Open Geospatial Consortium (OGC), United Nations Global Geospatial Information Management (UN-GGIM) and Global Land Tool Network (GLTN). The second version of LADM is aimed to include new modules (Information Models) for real estate valuation, spatial planning, indoor representation and modelling of sea boundaries. While the current version of LADM supports 3D cadastre, the new version is planned to include detailed 3D spatial profiles (predefined data structures) for different spatial data types. In addition to third dimension, geometry, topology and time profiles will be included in the new version of LADM to model the fourth (time) dimension [28].

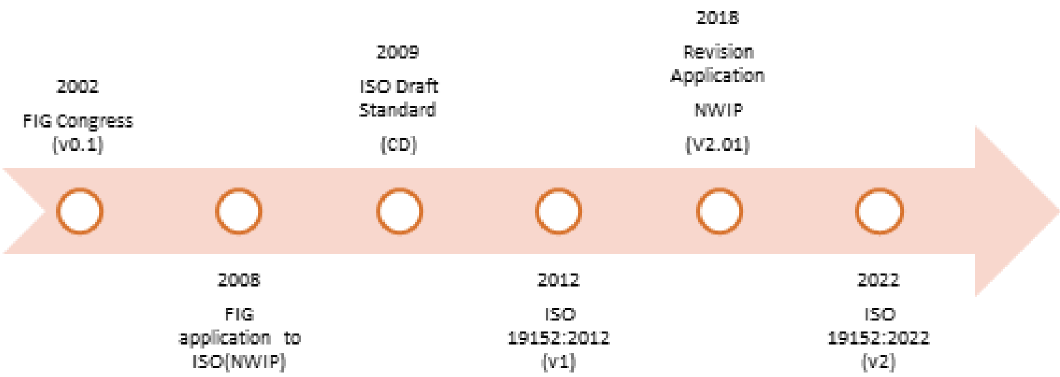

Figure 2. Development of ISO LADM 19152

In addition to LADM, which is a conceptual model, spatial data models are also preferred for the 3D digital representation of cadastral data. The most common of these digital models are BIM (Building Information Modelling) and CityGML models. These models are particularly advantageous for the 3D representation of individual units in buildings and associated rights. Studies were carried out for the 3D representation of individual units in the cadastre using BIM or GML (Geography Markup Language) based data models in Australia [29-30], China [31], India [32], the Netherlands [33], Sweden [34] and Greece [35]. Especially BIM models has been widely used in the 3D design, modelling, construction and renovation processes of buildings in the fields of architecture, engineering and construction by replacing traditional CAD (Computer Aided Design) models in recent years [36]. Similarly, CityGML, which is a common information model for the representation of 3D city objects, defines classes and relations of objects, taking into account their geometric, topological and semantic properties, unlike other vector data structures. CityGML is implemented with the GML application scheme published by OGC and ISO TC 211 (International Organization for Standardization- Technical Committee- Geographic information/ Geomatics). 3D models produced with CityGML find a wide range of application area from urban planning to disaster management, from cadastre to tourism [37]. In addition, IndoorGML, which is an OGC standard and developed for network analysis in indoor spaces, offers opportunities to model indoor spaces and their boundaries in 3D cadastre, thanks to the topological and semantic structure and relations it contains. There are studies in which IndoorGML is used alone or in combination with LADM [38-40]. Besides, LandInfra, as a new OGC standard implemented with GML (InfraGML), has a potential for 3D cadastre. LandInfra has been developed to cover objects both above and below the land surface and can represent administrative boundaries, parcels, easements and individual units [41].

Studies on modelling cadastral data in Turkey according to international standards were first initiated in 2006 with the Turkish National Geographic Information Systems (TUCBS in Turkish) project. Within the scope of this project, 10 geographical data themes, including Land Registry-Cadastre and Building data themes, were developed by the Ministry of Environment, Urbanization and Climate Change (MoEUCG) General Directorate of Geographical Information Systems (GDGIS) in 2012. Land Registry-Cadastre [42] and Building [43] data themes were developed based on ISO 19152 LADM and INSPIRE (Infrastructure for Spatial Information in the European Community) Cadastral Parcel data theme [44]. GDGIS updated 12 of the total 32 national geographic data themes (coordinate reference systems, administrative units, geographical place names, cadastre, building, address, elevation, orthoimage, transportation networks, hydrography, geology, land cover) in 2018. The remaining 20 geographic data themes are planned to be updated within a schedule [45].

3.3. Pilot Projects

In the questionnaires examined, the participants of 9 countries stated that there are pilot projects completed or ongoing in their countries for 3D cadastre. Three of these countries are Australia, the Netherlands and Sweden. The common feature in the pilot projects of these countries is that the aim of the project was determined as a 3D digital representation of the individual units in the buildings. The survey plans of the selected buildings in the pilot study area in Queensland, Australia, and the drawings of the individual units in these buildings were digitized and digital 3D models were produced in the KML format compatible with the LADM conceptual scheme. These 3D models are then presented on the web with 2D cadastral parcels. A test study was also carried out to determine how useful and understandable the produced models and web-based presentation are for users and citizens from different disciplines [46]. In the last 3D cadastre project carried out in the Netherlands, it is aimed to determine whether BIM models can be used in the legal process of creating individual units. In order to produce the 3D models, the 2D boundaries of the buildings shown on the cadastral maps and the drawings of the individual units attached to the notary deeds were taken as reference. The produced models were visualized in 3D in GIS and web environment together with 2D cadastral parcels [33]. In the pilot project in Sweden, 3D digital models based on IFC (Industry Foundation Classes) produced with reference to the legal documents (property formation dossiers) and maps (cadastral index map) used for the establishment of property rights in the individual units were used to represent the legal and physical space of the individual units in the buildings [47]. In addition to these three current pilot projects included in the questionnaire in 2018, 3D representation of independent sections in China [48], production of 3D cadastral parcels in Poland [49] and web-based display and querying of 3D cadastral objects in Russia [50] were aimed. In addition to pilot projects related for directly 3D cadastre, some other 3D cadastre studies encountered in the literature review are supported under project titles such as Smart Cities and Digital Twins. In these studies, it is aimed to create an infrastructure for sustainable city design, management and planning by integrating digital 3D property information with data such as noise, energy, air pollution, mobility and temperature [52-55]. This situation can be considered as an indication that the demand for 3D cadastral data has increased so much that it cannot be limited to legal purposes only. From this point of view, it is seen that there is a need to consider future 3D cadastral researches and projects from a broader perspective.

A project called 3D City Models and Cadastre was announced by the General Directorate of Land Registry and Cadastre (GDLRC) in February 2018 in Turkey. In the announcement, it is stated that the pilot studies of the project, which started in Ankara, are planned to last for four years. The main purpose of the project is to create 3D models of the individual units and to associate these models with the title information of the individual units. While the project was continuing, it was stated in the announcement made by GDLRC that floor models were started to be created within the scope of the project and the integration studies of the produced models with the Land Registry and Cadastre Information System (LRCIS) continued [56]. The stages of the GDLRC 3D Cadastre project are given in Table 3 [57]. In 2019, GDLRC shared a test demonstration showing how the individual units and related information will be presented with the project. In Figure 3, a screenshot taken from this demonstration of the project in the testing phase is given. When Figure 3 is examined, it is seen that the 3D building model, the floor plans of the individual units in the building and the legal information of the selected individual units can be presented together.

Table 3. Stages of GDLRC 3D cadastre project

Stages	Activity
Geodetic Studies	Establishment, marking and measurement of ground control points
Photogrammetric Studies	Aerial image acquisition with digital aerial cameras
Data Processing/Generation	Processing of GPS/GNSS-IMU (Inertial Measurement Unit) data, digital surface/terrain model generation, point cloud and orthophoto generation
3D Modeling	Generating 3D floor and building models
Data Control and Improvement	Verifying and optimizing the position and geometry of 3D models
Model texture	Overlaying 3D building models using oblique and vertical aerial images
Individual Units Modeling	3D modeling of individual units from architectural projects
Data attribution	Associating the produced 3D models with GDLRC legal data

HGM-Atlas and HGM-Sphere applications, which were opened for use by the General Directorate of Maps (GDM, HGM in Turkish) on January 24, 2019, are important in terms of creating an infrastructure for the presentation of models produced for 3D cadastre. GDM has developed these applications in order to meet the map needs of citizens and public institutions on the internet with national means, to eliminate foreign dependency and to provide a basis for digital transformation. Şirin [57] showed that 3D models with different data structures developed for cadastre can be presented with HGM-Atlas and HGM-Sphere applications. In this way, it will be possible to prevent the payment of fees paid to applications abroad in the presentation of cadastral data to users and the collection of personal data through foreign applications.

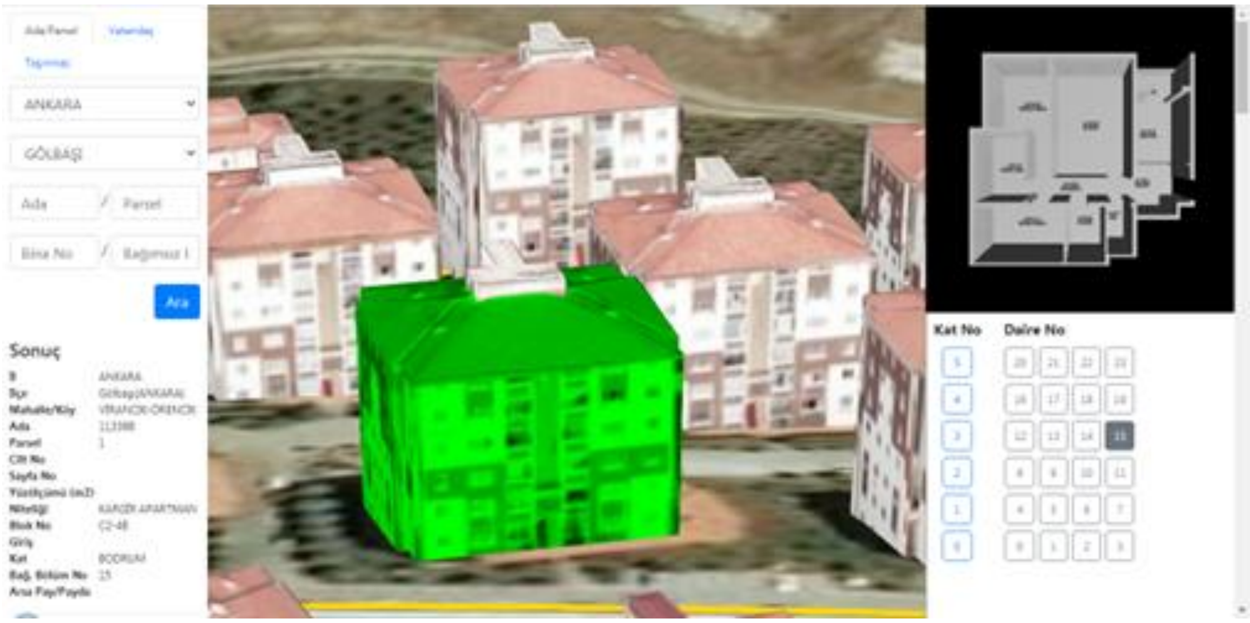

Figure 3. TKGM 3D cadastre project test data [58]

3.4. Legal and Institutional Issues

Considering the examined 3D cadastre questionnaires and related literature, it is seen that the least discussed topics in 3D cadastre projects and research are legal and institutional issues [59]. As a result, both pilot projects and academic studies are mainly focused on solving technical problems. Legal bases form the basis of the cadastre. If legal definitions of 3D real estate objects do not exist, measuring and registering them will be meaningless. When the questionnaires are evaluated, it is seen that some countries have made legal arrangements or the legal infrastructures of the countries allow the creation of 3D real estate units. For example, in Scandinavian countries such as Sweden [60] and Norway [16], legal arrangements have been made to improve the process of registering individual units. In the Netherlands, there have been regulations for adding 3D digital data belonging to utilities and buildings with complex use cases to notary deeds [51]. In addition, in some states of Australia [61] and Canada [62], it is legally possible to create volume-constrained property units. These property units are called volumetric parcels in Australia and air-space parcels in Canada. Although there are laws regulating the use of the vertical dimension of the land in each country, a generally accepted 3D property definition does not seem possible since the legal and institutional structures of the countries are unique to them. The inability to develop a common terminology in legal matters is another challenge. Even researchers from the same country can use different words to express the same concepts. This makes it difficult to compare legal studies.

Cadastre systems only make sense if they exist within an institutional structure. For this reason, the institutional dimension of the 3D cadastre includes the duties and responsibilities of the public registration and mapping institutions. In addition, the success and sustainability of the developed projects requires the creation of a workflow between the stakeholders who produce and use 3D digital data. It is to ensure that the authorities, responsibilities and standards are determined and implemented as a state policy in the production, updating and sharing of data that will provide this workflow. As in the legal structure, there is no partnership in the institutional structures of the countries when it comes to cadastre. In some countries, such as Austria and Romania, registration and cadastral mapping are the responsibility of different institutions. In some countries, cadastre may be carried out under the responsibility of local governments (such as Sweden and Norway), while in others (such as Turkey and the Czech Republic) it is the responsibility of the central government. While the cadastral institutions of some countries are only responsible for mapping property boundaries, in others it is the duty of these institutions to produce value maps (such as Germany) and produce country maps (such as the Netherlands) [63-64]. This situation causes the meaning of the word cadastre to differ from country to country. In the e-mail sent by the FIG 3D Cadastres working group management to the researchers of the participating countries in June 2020, it was requested to evaluate the use of the expression 3D Land Administration instead of 3D Cadastres and their opinions on this subject were requested. As the reason for the name change, it was stated that the land administration should be better known by different countries and that the compliance with ISO 19152 LADM, which is based on the activities of the working group, is ensured. A decision on the name change is planned before the adoption of the planned LADM update in 2022.

When the legal and institutional structure in Turkey is evaluated, it can be said that there is an advantageous structure for the development of 3D cadastre. The boundaries of the property right on the land, which are guaranteed by the Constitution, are defined in the Civil Code and the land and individual units are registered in accordance with the relevant laws. The same institution (GDLRC) is responsible for the registration process and the production of cadastral maps. Both GDLRC and GDGIS, which is responsible for updating geographic data themes, operate under the same ministry (MoEUCG). In addition, there have been recent developments in which strategies have been adopted as state policy in determining the cadastral data content according to international standards and sharing them for different purposes of use. On November 7, 2019, a Presidential Decree was published in order to establish the target and strategy for the national spatial data infrastructure, to ensure inter-institutional coordination, and to update the geographic data themes to be prepared in accordance with national or international standards. A total of 32 geographic data themes are listed in the decree, and there are also cadastre and building data themes [65]. Shortly after the publication of the presidential decree, the National Smart Cities Strategy and Action Plan, covering the period between 2020 and 2023, was published in the Official Gazette and entered into force on 24.12.2019. Among the activities in the action plan are the reference architecture model to be developed and the integration with the national spatial data infrastructure [66]. These developments show that cadastral data will be integrated with other data and will be used more frequently for sustainable urban management and planning in the future.

4. Conclusion

The inadequacy of existing cadastral systems in registering and representing some situations that arise in the modern world, with the effect of developing technology, has led to the 3D cadastre research being on the agenda for the last two decades. In this study, the effects of developments in 3D cadastre research and projects on cadastre were evaluated. In order to make a comparison and evaluation, besides the literature review, the results of the questionnaires conducted by the FIG 3D Cadastres Working Group in 2010, 2014 and 2018 were examined. The reasons such as the fact that the number of sections and questions of the questionnaires belonging to different years are not the same, that the questionnaire participants generally give short answers to the questions and questions that are left blank make it difficult to compare the questionnaires. However, with the new sections and questions added to the questionnaires since 2014, the participants are asked to explain the pilot projects in their countries and the obstacles for the 3D cadastre. When these new sections and the questions that are common and frequently answered in all three questionnaires are examined, it is seen that the most significant effect of the progress on the cadastre is the use of ISO 19152 LADM in the 3D modelling and representation of the cadastral data. In the 2014 questionnaire, only 5 of the respondents stated that their country's cadastral data models are partially compatible with ISO 19152 LADM, while in the 2018 questionnaire, 12 participant countries stated that their cadastral data models are compatible with ISO 19152 LADM. Updates of data models produced in Turkey based on ISO 19152 LADM are carried out under the responsibility of GDGIS. In addition, the adoption of digital transformation as a state policy with the Presidential Decree on Geographic Information Systems and the National Smart Cities Strategy and Action Plan published in the Official Gazette in the last months of 2019 supports the use of digital models in the cadastre. In addition to ISO 19152 LADM, although various studies on the use of IFC and GML-based data models for 3D cadastre are found in the literature, it is seen that this situation is not reflected in the questionnaires. It is necessary to address this issue in the next questionnaire period, and to determine the place of common standards and data models in 3D cadastre applications by developing new questions or improving existing questions. As a result of the examination of the questionnaires, it has been determined that pilot projects for 3D cadastre have been carried out or are ongoing in countries including Turkey (Netherlands, Israel, Switzerland, Sweden, Hungary, Malaysia, Singapore, Slovenia and Turkey). Within the scope of these projects, 3D data collection, modelling and display studies were carried out. Legal and institutional issues emerge as the least discussed issues in 3D cadastre research. In the 2018 questionnaire, respondents are asked about the three most important obstacles to 3D cadastre development in their country. Of the 19 respondents who answered this question, 10 stated legal and institutional issues among these barriers. The legal and institutional structure in Turkey is advantageous for 3D cadastre. Although technological advances offer important opportunities, the viability and sustainability of 3D cadastre projects requires the creation of a workflow that supports the use of international standards and digital models beyond pilot projects.

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Author contributions

Fatih Döner: Conceptualization, Methodology, Data curation, Writing-Original draft preparation, Validation. **Cemal Bıyık:** Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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