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CHAPTER 2

THE IMPACT OF CLIMATE CHANGE ON FLOOD AND FIRE DISASTERS: THE CASE OF MARMARIS

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INTRODUCTION

Every year, our society is impacted by new hydrological extremes that shatter records, which intensifies the argument between climate change and natural climate variability (Alfieri et al.,2015). The number of floods in Europe and worldwide has significantly increased in recent years, mainly due to people and economic assets accumulating in high-risk areas (Kreibich et al., 2015). In the last 30 years, the effects of climate change have become more apparent worldwide. The Intergovernmental Panel on Climate Change (I.P.C.C.) reported in its Fifth Assessment Report that, between 1880 and 2012, the average global land and ocean temperature increased by 0.85 °C, with the years 1983 to 2012 being the warmest in the last 800 years (Tang, 2019). As a result, the effects of climate change are now more apparent. The unusual and regular occurrence of floods, storms, droughts, and fires are a few examples of these effects. Furthermore, precipitation, sea level rise, drought, volcanic activity, hurricanes, loss of biodiversity, increased storm severity, frequent heat waves, changed rainfall patterns, reversals of ocean currents, flooding, and their extremes are among the climatic occurrences linked to global warming (Booth et al., 2012).

The impacts of climate change are observed in different fields and sectors, such as agriculture, food, energy, health, economy, and urban areas. Climate change is recognized as the most widespread problem affecting the social sphere, the natural environment, and the human system, with risks and damages to the built environment. Climate change has negative impacts on the construction sector as a result. In the context of residential buildings, these effects are as follows: energy consumption of houses in the future will increase in terms of cooling energy and cost with increasing temperatures, uncomfortable situations will arise with increasing temperatures and precipitation in indoor comfort conditions, and the adverse effects of extreme heat and precipitation anomalies on the shells of residential buildings change according to material type and location (Sarıcıoğlu et al., 2022).

For this study, climate change effects on building and urban areas are restricted to fire and flood disasters. For this reason, when examining the literature, there are several studies about these effects and consequences. In addition to long-term, gradual climate change, extreme weather events like powerful storms and flooding pose immediate threats to the construction industry. Rising average temperatures and shifting precipitation patterns threaten buildings and real estate (Alzahrani, 2015). Bello et al. (2018) provided a literature review examining the effects of flooding caused by climate change on buildings in Nigeria. After the study, they recommend that all parties involved in the built environment work together to replicate the successes of Nigeria's flood adaption strategy to climate change in order to create a sustainable built environment. Using built defenses

to prevent and lessen the impact of floods on the built environment, raising river banks and flood walls, constructing sufficient storage reservoirs and channeling the flood passage, and installing standard drainage systems on roads are the main strategies for adapting to floods (Bello et al., 2018). In a different study, Claudia (2014) said that to endure bad weather, new building techniques and materials are required for flooding, coastal erosion, subsidence, and drainage systems (Claudia, 2014).

Another effect of climate change is fire risk. According to the World Wide Fund for Nature (W.W.F.), forests are home to 300 million people worldwide and 80% of terrestrial biodiversity, so 1.6 billion people depend on them for their livelihoods. Forest fires are already threatening entire continents. Droughts and rising temperatures have led to economic and life losses and threats to animals and plants. As deforestation increases due to increasing heat and drought, there will be a danger of loss and reduction of forested areas. Under a low-emission scenario for Turkey, the whole country could experience a general increase in fires in areas dominated by Mediterranean scrub and forests. This trend is also emphasized under a medium emission scenario (C.M.C.C., 2021).

There were 8274 natural catastrophes in Turkey between 2010 and 2021 that had meteorological characteristics, according to the report written by the General Directorate of Meteorology (2022). Storms accounted for 32% of these calamities, followed by severe rain/floods (31%) and hail (17%) (Kahraman ve Polat, 2022). According to the same report, following İzmir, Muğla province in the Aegean area will have the most disasters between 2010 and 2021. This is why the natural disasters that have occurred in Marmaris are used in this study to examine the consequences of climate change using the data gathered from the literature. Climate change would affect the frequency and intensity of these disasters, according to an analysis of the Marmaris catastrophes that happened between 2015 and 2022 and caused damage and their effects. In this regard, it is thought that the study will attract attention to the influence of climate change on disasters and may be a basis for relevant people and institutions.

1. GENERAL SITUATION OF MUGLA PROVINCE AND MARMARIS

Muğla province is located in southwestern Turkey between 36˚ 17’ - 37˚ 33’ north latitude and 27˚ 13’ - 29˚ 46’ east longitude. Located on the Aegean coast, Muğla’s sea border is more than its land border. It is neighboring the provinces of Aydın, Denizli, Antalya and Burdur (Örücü and Ceylan, 1995: 2). As of 2016, there are 13 districts. These are Bodrum, Dalaman, Datça, Fethiye, Kavaklıdere, Köyceğiz, Marmaris, Menteşe (central district), Milas, Ortaca, Seydikemer, Ula and Yatağan. The location of Muğla Province on the map of Turkey is shown in **Figure 2** (Ekinci, 2016).



Figure 2. *Geographical location and borders of Muğla province (Ekinci, 2016).*

Marmaris is surrounded by Ula to the north, Balan Mountain, Karadağ and Günlük Hills to the east, Datça Peninsula and Kerme Bay to the west, and the Mediterranean Sea to the south. Adaköy, connected to the coast with a thin tongue, is located in front of the bay, and in front of it are Sedir Island, Goat Island, and Pigeon Island. The castle neighborhood is the oldest part of the city, built on a hill and extending towards the sea. The development of Marmaris has been along the coast and towards the foothills over the years. Dalaman Airport, where air transportation is made, is only one hour away. Rhodes is only 45 minutes away **(Figure 3)** (URL 2).

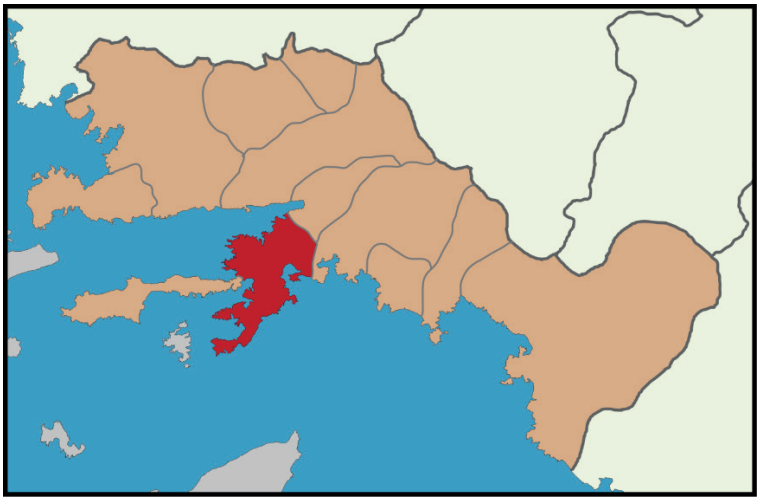


Figure 3. *Geographical location of Marmaris district in Muğla province (URL 2-3)*

1.1. Climatic and Topographical Characteristics of Marmaris District

Due to the elevation of Muğla province (646m), snowfall and frost events are more common than in Marmaris and Köyceğiz. However, especially since the early 2000s, snowfall has started to decrease frequently, which is the result of climate change (Balcıoğlu, 2021). Marmaris is the region's center with the highest rainfall (1228 mm). The direction of the mountains in Marmaris and their position relative to the sea are effective in receiving so much precipitation. The mountainous and hilly areas are close to the coast, and the settlement appears to be a lowland and closed bay. The lowland area in Beldibi, which is about 4 km inland at most, is located on the northeast side of Marmaris. The abundant rainfall in Marmaris, especially in the winter, is because the mountainous areas with elevations approaching 1000 meters meet the incoming humid air. Balaban Mountains (999 m) on the east-northeast side of the settlement and Palamut Mountain (850 m) on the south-southwest side are especially effective in meeting the humid air masses coming from the west and south and in the formation of orographic precipitation. The hills to the west, which do not exceed 300 m in height, allow the humid air coming from here to move forward. Marmaris has a corridor opening to the Mediterranean Sea with straits in the southern part, and the highest points on the Cennet Tombolo in this part do not exceed 400 meters (Balcıoğlu, 2021).

2. CLIMATE CHANGE AND FIRE RISK

With climate change, increasing temperature, drought, and continuous heat waves increase the number of forest fires and areas exposed to fire (Bayazıt and Koç, 2022). Although many factors affect the start and spread of forest fires, climate and weather conditions are among the most important. The number of fires and the amount of forest area burned are significantly higher when air temperatures increase, whereas precipitation decreases and air humidity decreases. The intensity of winds also increases the speed of fire spread. For this reason, as a result of climate change, the increase in the frequency of heat waves, the rise in temperatures, and the intensified summer droughts cause the fires that have already started to be much more severe and affect large areas due to the drying of flammable materials and the decrease in the ignition temperature (Türkeş and Tolunay, 2023). According to the research done by Marmaris and İçmeler (Bayazıt and Koç, 2022), erosion and flooding were brought on by forest fires in 2021. As a result, it was determined that following the 2021 forest fires, the study area's flood extent rose by 12%.

Additionally, it was estimated that soil losses would rise by 27.28 t/ha annually. The study's findings demonstrated that forest fires kill local species and result in secondary calamities like erosion and flooding. There is a

theory that as global warming increases the frequency of severe temperature occurrences, more forest fires will occur worldwide. The study highlights the possibility of secondary disasters resulting from forest fires. As a result, it is believed that nations ought to respond to global warming as quickly as feasible (Bayazıt and Koç, 2022).

2.1. Climate Change And Flood Risk

As Turkey is located semi-arid, water resources are strategically important. Agriculture, health, and water resources need more climate indices to know how extreme climates affect their operations. The information about extremes is usually embedded in meteorological data, and only with the help of indices does the data become more visible and understandable in terms of extremes. Şensoy et al. (2019) found a decreasing trend in the number of consecutive dry days (C.D.D.), consecutive wet days (CWD), total annual precipitation (P.R.C.P.T.O.T.), R10mm and R20mm indices in Muğla, Fethiye, and Marmaris in their study with daily precipitation data covering the years 1960-2017. Daily maximum rainfall (RX1day) has an increasing trend in Marmaris (Şensoy et al., 2019).

Flooding is one of the additional consequences of climate change. An anticipated rise in the frequency of (climate-driven) risks (in the case of floods) and increased exposure in sensitive places are to blame for the predicted increase in losses. Buildings can be more structurally resilient to fluvial flood damages by elevating door and window openings, making buildings floodable, and strengthening the foundation, walls, and frame. These are common strategies that have been acknowledged in the literature. A building's material composition also plays a significant role in determining how vulnerable it is to physical flood damage. For instance, employing soil increases a building's susceptibility to floods (de Ruiter et al., 2021).

Unexpected floods in prior years have validated the forecasts for the Marmaris district. Based on an analysis of the extreme precipitation events that have occurred in recent years, a limit of more than 50 mm of precipitation in 30 minutes is observed. The significance of short-term flash floods in cities becomes evident when one considers that in 2050, 80% of the world's population will reside in urban areas. Upon analyzing the complete data set spanning several years, Marmaris emerges as one of the locations with precipitation records **(Table 1)** (Çelik et al., 2017).

Table 1. *Amounts at 30 and 1440 minutes for the heaviest rainfall recorded in recent years in some centers* **(G.D.M) (Çelik et al.,2017).**

DATE	*LOCATION*	*TIME*	*AMOUNT (mm)*	
			30'	**1440'**
18.11.2007	Bodrum	0829/0859	50.5	62.8
18.11.2007	Marmaris	1052/1122	50.1	131.2
08.09.2009	Bandırma	1135/1205	41.8	243
08.09.2009	Çatalca	1019/1049	57	205
22.09.2012	Hopa	0222/0252	42.9	340.5
20.05.2015	İzmir	1220/1250	57.3	
21.08.2015	Etimesgut	1429/1458	51.4	64.2
24.08.2015	Hopa	0732/0802	64.9	221
12.11.2015	Borçka	0616/0645	15.8	174 (290)
28.05.2016	Ünye	0238/0307	51	245
01.09.2016	Hopa	0622/0645	41	240
01.09.2016	Fındıklı	0736/0806	45.8	270
20.09.2016	Zonguldak	1949/2019	50	
21.09.2016	Beşikdüzü	0854/0924	64.3	272
08.06.2017	Gerede	1235/1305	52.4	
17.07.2017	Bayramiç	2155/2225	64.8	165
18.07.2017	Silivri	0530/0600	60.3	136
18.07.2017	Üsküdar	0527/0557	37.7	117

Flood damage needs to be minimized in places where towns or villages are already located in areas prone to flooding. Prior research has demonstrated that private houses and companies can effectively mitigate flood damage by implementing construction adaptation, mobile flood barriers, and contaminated source control (Kreibich et al., 2015).

3. METHOD AND CASE STUDY

The study used reports, theses, and news articles from the literature review to gather data on the catastrophes in Marmaris between 2015 and 2021. The data was then broken down into categories such as flood and fire. Muğla Province has 15 Disaster-Prone Areas Decision taken by the Council of Ministers. As seen in **Table 2**, these disasters are mainly landslides and rock falls, but floods, floods, tsunamis and earthquakes are also experienced in the region.

Table 2. *List of Rockfall and Landslide Disaster-Prone Areas of Muğla Province (AFAD, 2021).*

	PROVINCE	COUNTY	VILLAGE	DISTRICT	TYPE OF DISASTER	DATE OF REPORT
1	MUĞLA	YATAĞAN	BAĞYAKA	CENTRAL	LANDSLIDE	25.02.1999
2	MUĞLA	KAVAKLIDERE	ÇAYBOYU		LANDSLIDE	14.06.2019
3	MUĞLA	KAVAKLIDERE	MENTEŞE		LANDSLIDE	14.06.2019
4	MUĞLA	SEYDİKEMER	ÇATAK		LANDSLIDE	10.12.2018
5	MUĞLA	CENTRAL	CENTRAL		ROCK FALL	
6	MUĞLA	ULA	GÖKOVA	KOZLUKUYU	ROCK FALL	23.10.2018
7	MUĞLA	BODRUM	GÜNDOĞAN	YUKARI	ROCK FALL	25.07.2018
8	MUĞLA	ORTACA	GÖKBEL	KIZILCAPINAR	LANDSLIDE	12.02.2012
9	MUĞLA	FETHİYE	BAĞLIAĞAÇ		LANDSLIDE	03.04.2012
10	MUĞLA	FETHİYE	DEREKÖY		LANDSLIDE	05.12.2011
11	MUĞLA	MİLAS		ÖREN DISTRICT	ROCK FALL	10.02.2015
12	MUĞLA	DALAMAN		ÇÖĞMEN DISTRICT	LANDSLIDE	20.04.2015
13	MUĞLA	SEYDİKEMER	ARSAKÖY		LANDSLIDE	11.03.2019
14	MUĞLA	CENTRAL	KUZLUK		LANDSLIDE	25.02.1981
15	MUĞLA	KÖYCEĞİZ	YAYLA	YAYLA AMB	LANDSLIDE	13.05.2014 / 14.08.2017

3.1. Flood and Fire Disasters in Marmaris

On February 3, 2015, a landslide occurred in Marmaris due to the torrential rains that have continued intermittently for a week in the district. As a result of the landslides in two regions, the highways were closed to traffic, and no vehicles passed by during the incident, preventing any possible injury or loss of life. On February 24, 2015, flood and landslide disasters occurred in Marmaris due to torrential rains for two consecutive days. After the downpour, floods occurred in Hisarönü and Karacasöğüt neighborhoods. In Karacasöğüt, many vegetable and strawberry greenhouses were damaged, while houses and summer residences were flooded. In the Bayır locality of the neighborhood, the retaining wall of a house garden collapsed. In addition, agricultural lands and gardens of houses were flooded due to floods in the Değirmenyanı locality of Hisarönü. At the same time, highways were closed to traffic due to falling rocks and soil (Figure 4) (Ersoy, 2015). Finally, on January 10, 2022, a landslide occurred on the Marmaris İçmeler road due to rain, and falling rocks and soil pieces caused the road to be closed to traffic for 45 minutes. According to the data announced by Meteorology, 60.4 kilograms of rain fell in the district in the last 24 hours (Hürriyet, 2022).



Figure 4. *A view of a landslide in Marmaris (Ersoy, 2015).*

The statistics of fire disasters in Marmaris district covering the years 2018-2021 are shown in **Figure 5.** House fires have the largest share with 16%, followed by open area fires with 15% (AFAD, 2021).

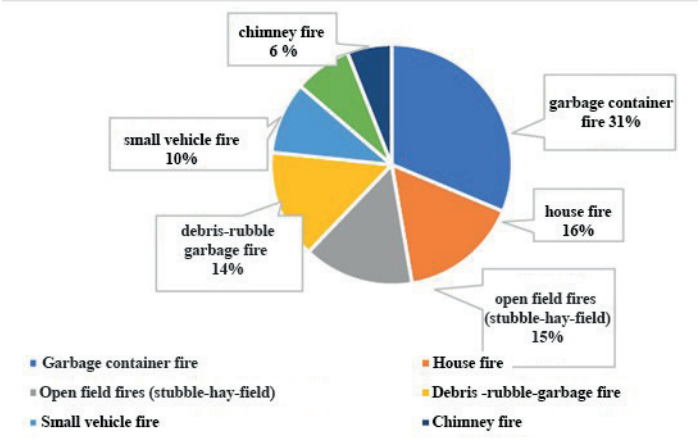


Figure 5. *Distribution of fires occurring in Marmaris District (2018-2021) (AFAD, 2021).*

The forest fire, which began on July 29, 2021, in the Armutalan neighborhood, spread quickly due to wind and was contained after nine days, burning 13,600 hectares in total. A single person perished in the fire, and it destroyed a warehouse, 27 homes, a car, a facility that produced olive oil, and 16 roofs. Neighborhoods were damaged by the flood that resulted from the fire (Sözcü, 2022).

Regarding the flood and flood risk in Marmaris, the locations and dates of floods mentioned in AFAD's IRAP (2021) report are shown in **Table 3** Accordingly, there was no loss of life in the floods experienced, but considering that there is a flood risk in the places where the disaster occurred, they are places that should be taken into consideration for future disasters.

Table 3. *Places subject to flooding in Marmaris district of Muğla province (AFAD, 2021)*

Flood Date	Starting Date	Flood Place	River_Arm	Loss of life	Reference
2003	19.01.2003	Mugla Marmaris	Sümbül River	0	DSİ
2004	22.12.2004	Mugla Marmaris	Berber, Kara, Haci Osman Sinan Rivers	0	DSİ
2006	12.03.2006	Mugla Marmaris	Sinan River	0	DSİ
2015	23.10.2015	Mugla Marmaris	-	0	AFAD
2017	08.03.2017	Mugla Marmaris	-	-	-
2017	09.03.2017	Mugla Marmaris	Degirmen	-	-

DISCUSSION AND CONCLUSION

The results show that the severe risks of climate change and increasing risk rates over time affect all countries, especially developing countries. As a result, climate change has clear impacts on agriculture, water resources, forests, coastal areas, health, ecosystems, cities and infrastructure systems, built environments, and energy. The percentage of anthropogenic impact in these changes stands as an inevitable fact. In order to avoid the impacts mentioned above and the consequences, governments, managers, collaborators, and politicians must work with scientists to develop and implement mitigation strategies.

The study's analysis of the disasters that have struck the Marmaris district revealed that their incidence and severity have increased recently. This recent shift serves as a warning about impending climate change-related tragedies. The study includes a distinct discussion of the steps that should be taken to avert these tragedies.

The Marmaris district was determined to be at extremely high risk of flooding in the A.F.A.D. (2021) disaster risk reduction study, which prioritizes areas at risk of flooding. A.F.A.D. (2021) incorporated the locations in **Table 4** susceptible to flooding into their risk mitigation plan. **Table 4** indicates that

the primary cause of risk in the dangerous neighborhoods is their unsuitable land structure, with previous floods in some neighborhoods or their location as district and provincial centers on alluvium contributing to risk.

Table 4. *Flood risk locations in Marmaris mentioned in AFAD IRAP report (AFAD, 2021)*

CITY	COUNTY	DISTRICT	CASE ANALYZE	FLOOD RISK
Muğla	Marmaris	Bayir District	risky due to its land structure	TO BE
Muğla	Marmaris	Bozburun District	risky due to its land structure	TO BE
Muğla	Marmaris	Camli District	risky since it is within the scope of the rivers listed in Table 1 of the Technical Specifications.	TO BE
Muğla	Marmaris	Cetibeli District	risky due to its land structure	TO BE
Muğla	Marmaris	Hisaronu District	Individual rivers longer than 10 km flowing into a sea or lake	TO BE
Muğla	Marmaris	Içmeler District	risky due to it is in priority class	TO BE
Muğla	Marmaris	Karaca District	risky due to its land structure	TO BE
Muğla	Marmaris	Orhaniye District	risky due to its land structure	TO BE
Muğla	Marmaris	Osmaniye District	risky due to its land structure	TO BE
Muğla	Marmaris	Selimiye District	risky due to its land structure	TO BE
Muğla	Marmaris	Taslica District	risky due to its land structure	TO BE
Muğla	Marmaris	Turgut District	Individual rivers longer than 10 km flowing into a sea or lake	TO BE
Muğla	Marmaris	Turunc District	risky due to its land structure	TO BE
Muğla	Marmaris	Yesilbelde District	risky due to its land structure	TO BE
Muğla	Marmaris	Beldibi District	risky because it is a Provincial and District Center that is historically flooded or on alluvium.	TO BE
Muğla	Marmaris	Central	risky because it is a Provincial and District Center that is historically flooded or on alluvium.	TO BE

According to the A.F.A.D. report (year), the 500-year flood recurrence flow rate in the Marmaris district's flood risk assessment indicates that residential buildings account for 61% of the damage to structures and commercial buildings for 39%. Industrial facilities caused less than 1% of the damage to buildings. These ratios were 53% residential and 47% commercial structures for the 100-year flood recurrence flow rate and 55% residential and 45% commercial structures for the 50-year flood recurrence flow rate.

Consequently, actions about flood risk and climate change should be performed;

- Failure to install protective building materials such as insulation and drainage where the groundwater level is close to the surface, or improper installation where they are in place, increases the risk of flooding. For this reason, these conditions in buildings and infrastructures should be corrected appropriately, considering future flood risk scenarios.

- The issuance of occupancy permits in areas with high flood risk should be reconsidered through regulations as climate change will cause more structural problems in the buildings in these areas.

- Carrying out terracing works on cultivated lands to prevent the loss of plants, nutrients, and elements in the soil against the possibility of surface runoff and flooding on sloping lands in rural areas and informing farmers on this issue will reduce flood risks.

- In the current situation, flood risk can be eliminated by providing an adequate cross-section of structures with insufficient cross-sections that may cause flooding, especially in settlements.

-In addition, legislation on mass movements must be revised and updated in line with climate scenarios.

-It is also necessary to reduce pressures on our water resources through water reuse, rain harvesting, water conservation, and education.

Forest fires are a significant disaster that requires safeguards since they also enhance the likelihood of floods, even though there are many other reasons why they could occur. Forest fires are caused by increased average temperatures brought on by climate change. Actions that, in this case, can be taken to reduce the risk of fire;

-Regarding fire risk, there are problems such as the difficulty of fire trucks reaching historical places such as the Grand Bazaar in Marmaris. In addition, most of the buildings here are built in adjacent order. Increasing urban traffic in the province day by day (Bodrum, Marmaris, Fethiye, Datça vehicle traffic increases due to the population density in the summer months, and the traffic density causes delays in reaching fires, and there is an increase in vehicle fires with vehicle density.) (The number of vehicle fires as of March 2018-2021 is 420).

-Early fire warning systems should be developed in yacht harbors, boatyards, shipyards, factories, hotels, and hostels (the number of ship fires as of March 2018-2021 is 27).

- In meteorological events (extreme winds and hurricanes), regular maintenance of the electrical wires should be carried out at specified intervals,

as sagging in the summer and stretching in the winter causes short circuits and fires under the power lines.

-Unauthorized persons should not inspect chimneys, and experts should regularly clean chimneys to prevent chimney fires and subsequent house fires (As of March 2018-2021, chimney fires are 164).

-According to statistics, garbage container fires were the most common fire in the district, followed by house and open area fires.

- Awareness-raising activities on the benefits of leaving crop residues on the ground and the harms of stubble burning should be increased.

In order to meet targeted safety and performance levels when designing structures and infrastructure systems in the future, existing design codes and standards must be adapted to reflect global climate change. In this respect, existing buildings and infrastructure systems should be evaluated in terms of risks by considering climate change scenarios, necessary measures, and reinforcements should be made. In addition, for the new buildings to be constructed, decision-makers, architects, engineers, urban planners, and all relevant institutions should work together by taking advantage of climate change scenarios and minimizing the damages that may occur by adjusting the existing regulations and plans.

As a result, zoning plans and building reinforcements should be prioritized by considering future climate change scenarios, especially by institutions such as G.D.M (General Directory of Meteorology). While taking these measures; the increasing population should be addressed. It has been scientifically demonstrated that disasters that will occur as a result of climate change will trigger other disasters. It is essential to have a holistic approach instead of focusing on taking measures for a single type of disaster due to increasing air temperatures and forest fires, which in turn leads to an increase in floods. More work is needed to examine the differences between the impacts of recurrent disasters (of the same hazard type), cascading and sequential disasters, and combined disasters with different hazard types.

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