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Hydrometeorological Disasters in the Context of the Climate Crisis: A Regional Disaster Inventory Study in Türkiye

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Abstract

The rapid growth of the global population, irregular urbanization and industrialization, present challenges to the sustainability of life and the world is currently facing an increasing prevalence of both natural and anthropogenic disasters. Climate change further exacerbates this situation by contributing to the rising frequency and intensity of hydrometeorological events. To effectively minimize the negative impacts of disasters, knowing assessing and analyzingtheir frequency, intensity, and consequences is essential. This necessitates the development of comprehensive disaster inventories. Such studies involve collecting and analyzing critical data to identify and manage potential disaster risks within specific regions. In this present study evaluates the long-term diversity of hydrometeorological disasters in the Sakarya, Kocaeli, and Istanbul provinces, situated in the Çatalca-Kocaeli section in the Marmara Region of Turkey. The study utilizes data from the General Directorate of Meteorology to analyze hydrometeorological disasters occurring from 1975 to 2020 across these provinces, with a focus on diversity, frequency, damages, and fatalities, evaluated on both an annual and seasonal basis. Damages are classified as light, moderate, or severe. This inventory is designed to offer valuable insights for researchers and policymakers aimed at mitigating loss of life and property damage. Additionally, it encompasses recommendations for disaster risk reduction strategies.

Keywords

Hydrometeorological Disaster, Disaster Inventory, Sakarya, Kocaeli, Istanbul, Loss of Life and Property

İklim Krizinde Hidrometeorolojik Afetler: Türkiye'de Bölgesel Bir Afet Envanter Çalışması

Özet

Küresel olarak, dünya şu anda doğal ve insan kaynaklı artan afetler ile karşı karşıyadır. İklim değişikliği de, hidrometeorolojik afetlerin sıklığı ve yoğunluğunun arttırarak bu durumu daha da kötüleştirmektedir. Afetlerin olumsuz etkilerini en aza indirmek için; bunların sıklığını, yoğunluğunu ve sonuçlarını bilmek, değerlendirmek ve analiz etmek esastır. Bu da afet envanterlerinin geliştirilmesini gerektirir ki bu tür çalışmalar, bölgesel olarak potansiyel afet risklerini tanımlamayı ve yönetmeyi amaçlayan kritik verilerin toplanmasını ve analitik olarak değerlendirilmesini içerir. Bu çalışmada, Türkiye'nin Marmara Bölgesi'nin Çatalca-Kocaeli bölümünde yer alan Sakarya, Kocaeli ve İstanbul illerindeki hidrometeorolojik afetlerin uzun vadeli çeşitliliği değerlendirilmiştir. Çalışmada; Meteoroloji Genel Müdürlüğü'nün verileri kullanılarak 1975-2020 yılları arasında meydana gelen hidrometeorolojik afet çeşitliliği, oluş sıklığı, zarar durumu ve bu afetlerden kaynaklanan ölümler hem yıllık ve hem mevsimlik olarak değerlendirilmiş ve afet envanteri oluşturulmuştur. Ayrıca, afetlerin yarattığı hasar durumu hafif, orta ve ağır hasar olarak sınıflandırılarak incelenmiştir. Bu envanter çalışması, yirmi milyondan fazla nüfusun yaşadığı bölgede; can kaybı, mal hasarı ve zarar görebilirliği en aza indirmeyi amaçlayan yönetim, planlama ve uygulama önlemleri açısından araştırmacılar ve yöneticiler için stratejik bilgiler sunmayı amaçlamaktadır. Son olarak da, bölgesel bir perspektiften afet riskinin azaltılması için alınması gereken temel önlemlere ilişkin tavsiyelerde sunulmaktadır.

Anahtar Sözcükler

Hidrometeorolojik Afetler, Afet Envanteri, Sakarya, Kocaeli, İstanbul, Can-Mal Kaybı

1. Introduction

The swift escalation of the global population, coupled with accelerated urbanization, industrialization, and inadequate land management practices, is contributing to increasingly complex environmental challenges, as well as a rise in natural disasters and the attendant loss of life and property. The threats and risks associated with hydrometeorological disasters are increasing due to both inadequate planning strategies and the impacts of the climate crisis (Avcı & Ünsal, 2023).

Hydrometeorological disasters are natural events precipitated by water and atmospheric phenomena. These disasters generally result from the interplay between atmospheric and hydrological systems, significantly affecting human life, natural resources, and infrastructure.

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Hydrometeorological disasters associated with atmospheric phenomena such as precipitation, temperature fluctuations, and pressure variations—encompass a range of events including droughts, heatwaves, wildfires, cold waves, tornadoes, hailstorms, lightning, hurricanes, tempests, floods, snow storm, heavy snowfall, and fog. The ramifications of climate change are intensifying the occurrence, severity, and duration of hydrometeorological events by altering temperature and water cycles (Kadıoğlu, 2011a). For instance, relief and lithological characteristics, when combined with adverse climatic conditions, result in intensive landslide occurrences, subsequently amplifying flood-related damages (Avcı, 2023).

Between 2000 and 2006, there was a 187% surge in disaster occurrences globally compared to the period from 1987 to 1998 (Hoyois et al., 2007). From 1998 to 2017, a striking 91% of nature-based disasters worldwide were attributable to climate-related factors, with floods being the most prevalent type, accounting for 43% of incidents, followed by storm-related disasters at 28%. Additionally, between 2010 and 2020, approximately 1.7 billion individuals were impacted by climate and weather-related disasters (Aygün, 2020).

The Mediterranean Basin, which encompasses Türkiye, is among the most susceptible regions globally to the effects of climate change. The country, characterized by diverse climate zones, experiences a variety of severe hydrometeorological events that culminate in disasters (Kadıoğlu, 2011b). A projected increase in temperature of 2°C is anticipated to elevate both the frequency and severity of disasters in Turkey, including heatwaves, wildfires, droughts, and floods. Since the early 2000s, there has been a notable rise in the incidence of hydrometeorological disasters, with storms, floods, hail, frost, snow, and drought resulting in both loss of life and significant economic impact (Meteoroloji Genel Müdürlüğü, 2016). For example, in 2017, approximately 60% of individuals affected by disasters were impacted by floods, while storms accounted for 85% of the economic damages (The International Disaster Database, 2020), (Figure 1). Looking ahead, it is expected that there will be a marked increase in extreme rainfall events, daily maximum precipitation, rainfall intensity, flood occurrences, drought duration, and the frequency of storms (Demircan et al., 2017).

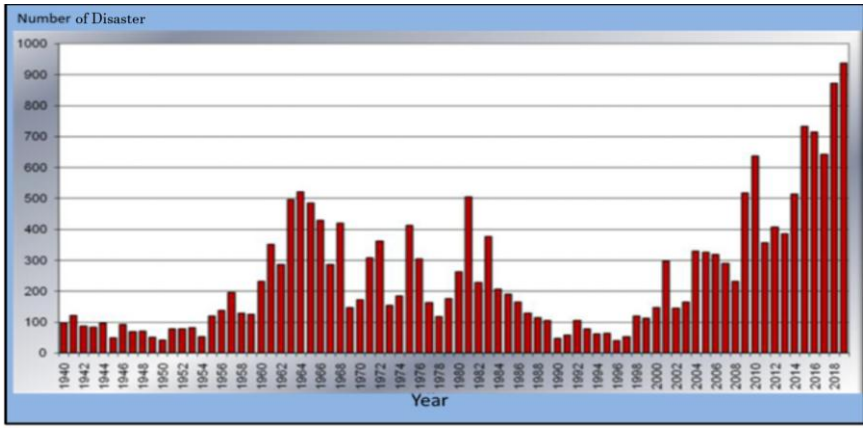

Figure 1: Meteorological disasters observed in Turkey during the period 1940-2019 (Meteoroloji Genel Müdürlüğü, 2016)

In light of the rising frequency and magnitude of disasters, it is imperative to analyze historical events and develop future projections to enhance both regional and sectoral strategic planning, as well as to implement necessary preventive measures. This context highlights the critical need to comprehend disaster histories and identify emerging trends. Disaster Inventory Studies, undertaken to facilitate this understanding, serve as valuable instruments for assessing the spatial and temporal distribution of disasters and for evaluating global disaster forecasting models. These studies, which examine the diverse range of disasters, are essential for mitigating the effects of both natural and anthropogenic disasters on a global scale, ensuring the establishment of safe living conditions, and equipping communities to respond effectively to such challenges.

Numerous studies have examined the assessment of disaster diversity and the compilation of disaster inventories. A significant portion of the scientific research conducted in this area consists of inventory studies that facilitate post-disaster management planning and logistical considerations (Ozguven & Ozbay, 2011). One noteworthy study by Yadavalli et al. (2015) proposed and analyzed a disaster inventory model focused on essential materials and supplies required in the aftermath of a disaster. Another research endeavor aimed to enhance existing databases by creating a comprehensive digitized global flood inventory covering the period from 1998 to 2008 (Adhikari et al., 2010). Ekinci et al. (2020) conducted a temporal and spatial analysis of various natural disasters, including landslides, avalanches, rockfalls, and floods within the boundaries of Bitlis province. Based on the damages incurred, risk values were assessed, and a risk classification was established. Additionally, research has been conducted on data repositories that systematically organize and store information related to disasters. One such study examined databases that regularly and methodically maintain information about disasters both domestically and globally (Duman & Gökgöz, 2018). Furthermore, in the development of the Australian Natural Disaster Resilience Index, a design was implemented based on the common characteristics of resilience assessment. This study employed a top-down approach utilizing indicators derived from national-level secondary data (Parsons et al., 2016).

In another study, the flood disaster that occurred in Kastamonu-Bozkurt in 2021 was analyzed based on the morphometric parameters of the basin. The analysis results indicate that urban areas within the river basin affected by floods have doubled over the past thirty years (Avcı & Ünsal, 2023). Özdemir and Özkaynak Yolcu (2024) conducted a study aimed at enhancing the flood resilience of residential areas and mitigating the impacts of potential disasters. In a study conducted by Kundzewicz et al. (2013), the relationship between hydrometeorological disasters and climate change was examined at both global and regional levels. In other study examining management strategies in natural disasters, the concept of risk reduction in disaster management and risk reduction efforts at both national and international levels are explained. After addressing disaster management and its importance, the concept of risk reduction in disaster management and related efforts at national and international levels are elaborated (Tümer, 2024).

This study evaluates the meteorological disasters that transpired in Istanbul, Kocaeli, and Sakarya three of Turkey's most populous provinces between 1975 and 2020, culminating in the creation of a comprehensive disaster inventory. Together, these provinces account for approximately one-quarter of Turkey's population, which exceeds 85 million individuals. The geographical alignment of these three provinces along an east-west axis contributes to their similar weather and climate conditions. Given the region's physical and demographic characteristics, coupled with the size of the exposed population, the impact values associated with disasters in this area are markedly substantial. Recognizing the well-developed industrial and agricultural sectors, alongside the dense population, underscores the importance of understanding historical disaster events and implementing preventative measures against potential future incidents. In light of these considerations, this study meticulously examines the disasters that have occurred in these provinces and compiles a disaster information inventory. The findings detail the types, frequency, magnitude, and damage status of hydrometeorological disasters in the region, accompanied by recommendations for measures aimed at mitigating potential damages. Disasters have been systematically analyzed on an annual and seasonal basis over ten-year intervals. The assessment includes data on damage and fatalities associated with these disasters, along with their respective locations and dates. The objective of this study is to establish a comprehensive reference source concerning disasters in the three provinces, to underscore the impact of these events, to foster the development of a disaster-aware society, and to offer a valuable resource for decision-makers, practitioners, and researchers in the field.

2. Material And Method

2.1 Study Area

Figure 2 present the Çatalca-Kocaeli region constitutes a significant geographic area that encompasses Istanbul, the most populous city in Turkey, along with the provinces of Kocaeli and Sakarya (41°N 29°E). The region stretches from Istanbul's Çatalca Peninsula in the west to the Sakarya River in the east. It is bordered by the Black Sea to the north and the Sea of Marmara to the south. This geographical region includes the entirety of Istanbul, all of Kocaeli, and a significant portion of Sakarya. Among the most notable geographical features of the region are the Çatalca Peninsula, the Kocaeli Plateau, and the Sakarya Plain (T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2022). The region is one of Turkey's most economically developed and densely populated areas. The commercial and cultural richness of Istanbul, the strong industrial base of Kocaeli, and the agricultural-industrial integration of Sakarya enhance the economic diversity and importance of the region. Spanning along the Black Sea and Marmara coasts, this region also holds strategic significance due to its position at the intersection of major transportation networks (Doğanay & Orhan, 2019; Atalay, 2011).

The climate of the Çatalca-Kocaeli section generally exhibits transitional characteristics between the Black Sea and Mediterranean climates. Due to its location and geographical structure, the region has developed a unique climatic character. Summers are mild and moderately humid, with average temperatures ranging between 22-25°C, and the heat is not excessively oppressive. Winters are mild and rainy, with temperatures rarely dropping below 0°C. Although snowfall occurs, it does not remain on the ground for long periods. Precipitation is observed throughout the year, with the highest amounts recorded in autumn and winter. The annual average precipitation ranges between 600-800 mm. Humidity levels are generally high, which can create a stifling effect, particularly during the summer months. The moderating influence of the sea is evident in the coastal areas, while inland areas exhibit slightly more pronounced continental climate characteristics. In the southern parts closer to the Sea of Marmara, the effects of the Mediterranean climate are noticeable. Summers in these areas are hot and dry, while winters are mild and rainy. The amount of precipitation is lower compared to the Black Sea climate (Meteoroloji Genel Müdürlüğü, 2016).

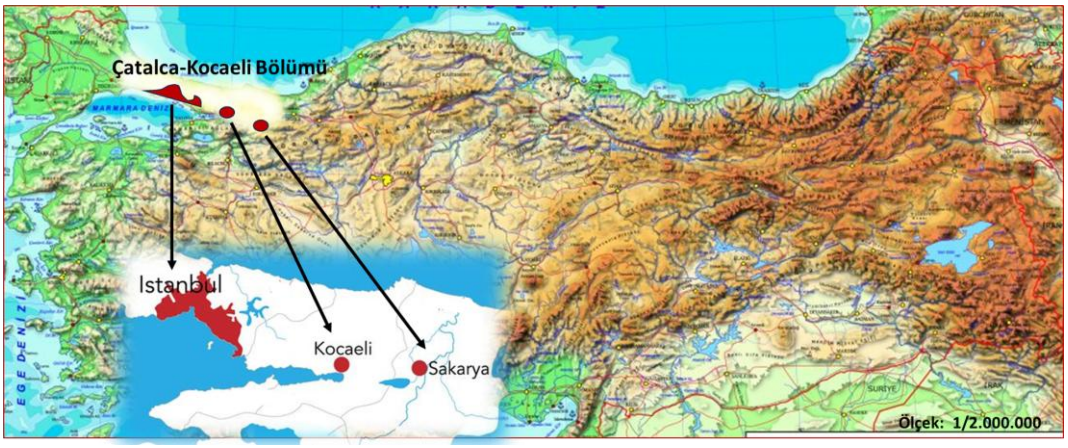

Figure 2: Location map of region and provinces in the study area

a) Sakarya: The province is an increasingly significant area in Turkey, boasting a population of 1,075,463. It is shaped by the climatic influences of the Marmara and Black Sea regions. Temperatures can fall below 0°C for approximately forty days each year, while they may exceed 30°C for up to thirty days. The region experiences an average annual precipitation of 840mm, distributed over roughly 130 rainy days. Of this precipitation, approximately 96% is consistent, whereas 4% is characterized by heavy downpours. The economy of the province is predominantly driven by industry and agriculture, with the agricultural sector employing 65% of the workforce, underscoring its national significance (İkiel, 2018).

b) Kocaeli: Kocaeli boasts a total population of 1,997,258 residents (Türkiye İstatistik Kurumu, 2022). The city has experienced significant development in various sectors, including industry, agriculture, fishing, animal husbandry, and tourism. Contributing 13% to the nation's industrial output, Kocaeli ranks as the second-largest industrial hub in Turkey, following Istanbul. Its climate features warm and dry summers, contrasted with rainy winters, and exhibits mild temperatures relative to the national average. The annual average temperature is recorded at 14.8°C, with total yearly precipitation surpassing 1000mm. The predominant wind direction is from the north and northeast. Industry constitutes 73% of Kocaeli's economic activities, and in 2019, the city achieved a ranking of fifth in the country based on gross domestic product. Notably, Kocaeli accounts for 5% of Turkey's total exports. The province is serviced by two major highways and an intercity road, in addition to a comprehensive railway network extending 312 km (T.C. Kültür ve Turizm Bakanlığı, 2022).

c) Istanbul: Istanbul, situated in the northwest of Turkey, serves as a crucial link between the continents of Europe and Asia. The city experiences a minimum temperature that can drop to -11°C and a maximum that can soar to 40°C, with an average relative humidity of 75% The climate features dry and hot summers, while winters are characterized by mild and rainy conditions. With a population of 15,655,924, Istanbul is the most populous city in Turkey. It leads the nation in industrial, commercial, financial, and tourism sectors and is ranked thirty-fourth globally in economic performance. The city contributes to 20% of Turkey's workforce and accounts for 50% of its exports. Istanbul is home to the largest enterprises in industries such as manufacturing, trade, transportation, and tourism. The city's infrastructure is enhanced by three bridges spanning the Bosphorus and a road tunnel beneath it, supplemented by a total railway line of 152 km (İstanbul Valiliği, 2022).

2.2 Method

In this study, official records pertaining to hydrometeorological disasters from the Çatalca Kocaeli Department of the General Directorate of Meteorology in the Marmara Region have been meticulously analyzed. The research encompasses data from the provinces of Istanbul, Kocaeli, and Sakarya over a span of forty-five years, specifically from 1975 to 2020. Consequently, the research adopts a quantitative approach. No sampling methodology was employed; instead, all available records from this period were thoroughly reviewed and incorporated into the study. The analysis includes the years in which hydrometeorological disasters occurred, their types, frequency, as well as the documented damages resulting from these disasters, including casualties (both fatalities and injuries). Furthermore, the study examines the temporal and seasonal distribution of these disasters, drawing from the extraordinary event reports issued by the General Directorate of Meteorology. The disasters were systematically categorized and analyzed according to the severity of damage incurred: minor, moderate, and severe. The types of disasters evaluated in the study include: Storm, heavy storm, drought, snow, snowstorm, heavy snowfall, tornado, rainfall, harmful rainfall without flooding, flood, lightning, hail, frost, fog, strong fog, landslide, flooding, heavy rainfall, fire, hoarfrost, and extreme cold. Data analysis was conducted using the SPSS 22.0 software program.

3. Findings and Discussion

An analysis of hydrometeorological disasters in Kocaeli, Sakarya, and Istanbul has been conducted, focusing on their occurrence by year and season. Figure 3 illustrates the distribution and percentages of meteorological disaster incidents specifically in Sakarya province. Within Sakarya, the recorded disaster events include 58 instances of flooding, 26 storms, 8 droughts, 14 snow events, 7 tornadoes, 30 rainfall occurrences, 3 lightning strikes, 25 hail events, 1 frost incident, 3 landslides, 28 heavy rainfall events, 1 fire, 1 instance of harmful rain that did not result in flooding, and 1 frost event. The aggregate total of such disasters amounts to 234, with flooding being identified as the predominant type of disaster.

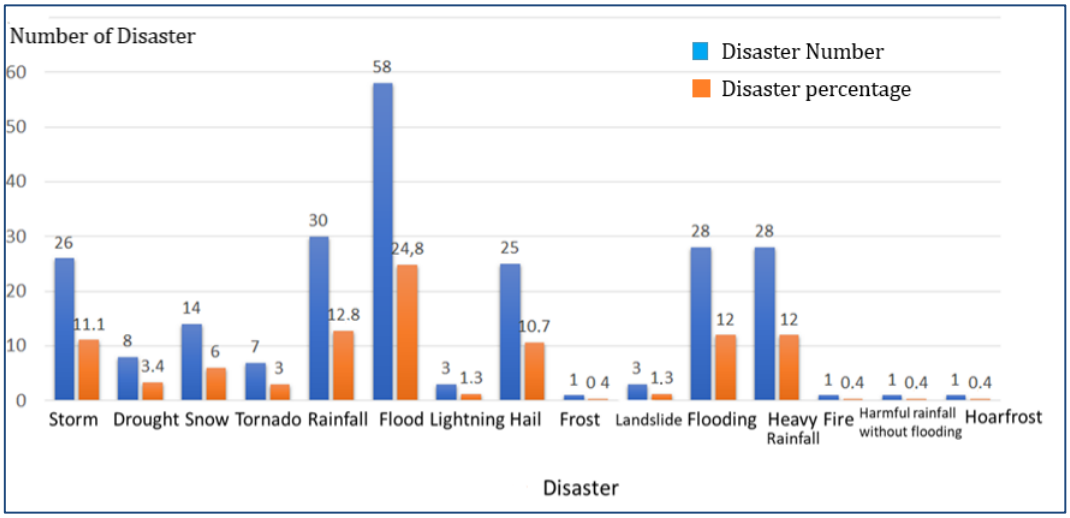

Figure 3: Distribution and percentages of the number of general meteorological disasters in Sakarya

Figure 4 presents the distribution and percentages of general hydrometeorological disaster occurrences in Kocaeli province. During the observed period, a total of 100 storms, 3 droughts, 15 snow events, 16 tornadoes, 47 rainfall incidents, 71 floods, 12 lightning strikes, 21 hail, 1 frost event, 5 instances of fog, 1 landslide, 26 occurrences of water inundation, 28 heavy rain events, and 1 fire were recorded. The cumulative total of documented disasters is 347, with storms being identified as the most prevalent disaster type.

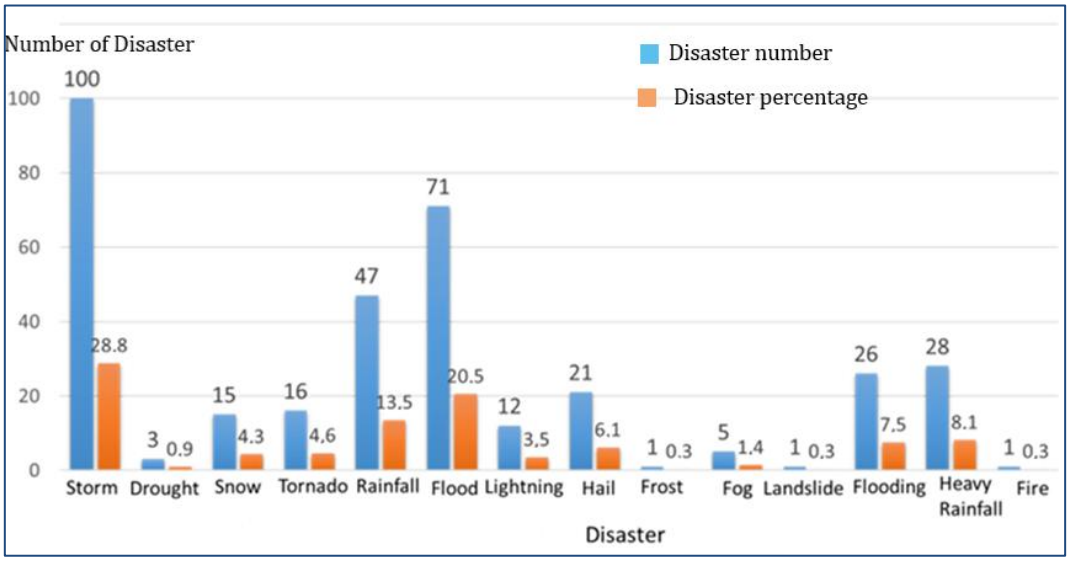

Figure 4: Distribution and percentages of the number of general meteorological disasters in Kocaeli

Figure 5 illustrates the distribution and percentages of general meteorological disasters in Istanbul from 1975 to 2020. During this period, Istanbul encountered a total of 125 storms, 40 snow events, 65 tornadoes, 48 rainfall incidents, 95 floods, 4 lightning strikes, 29 hail occurrences, 2 frosts, 14 fog events, 1 landslide, 49 instances of water inundation, 53 cases of heavy rainfall, 1 fire, 2 non-flooding rain events that caused damage, 5 severe cold spells, 2 occurrences of

continuous snowfall beyond typical levels, 2 full storms, 1 snowstorm, 1 instance of dense fog, and 1 frost. In total, 540 meteorological disasters were recorded, with storms representing the most frequent occurrence.

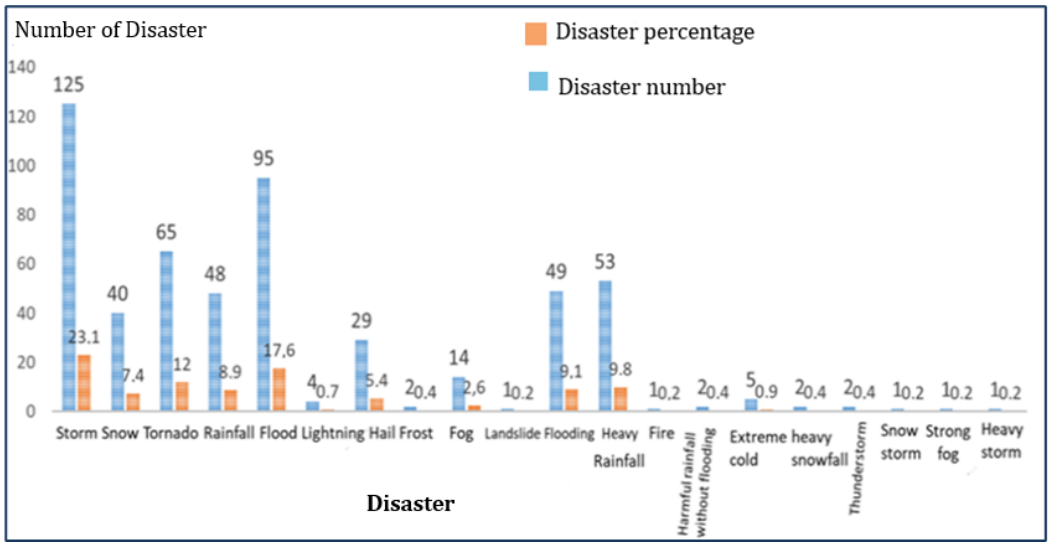

Figure 5: Distribution and percentages of the number of general meteorological disasters in Istanbul

A total of 251 storms, 11 droughts, 69 snowfalls, 88 tornadoes, 125 rainfall events, 224 floods, 19 lightning strikes, 75 hail, 4 frosts, 19 fog incidents, 5 landslides, 103 water inundations, 109 heavy rainfalls, 3 fires, 3 occurrences of harmful rainfall without resulting in flooding, 1 frost, 5 severe cold spells, 2 instances of continuous snowfall surpassing the norm, 2 full storms, 1 snowstorm, 1 heavy fog, and 1 strong storm were recorded across three provinces. The cumulative total of meteorological disasters was 1,121, with storms identified as the most prevalent type of disaster.

An analysis of the distribution of meteorological disasters by season reveals 167 events in spring, 417 in summer, 242 in autumn, and 295 in winter. A detailed overview of the number of disasters and their seasonal distribution is provided in Table 1.

Table 1: Seasonal distribution of total number of meteorological disasters in Kocaeli, Sakarya and Istanbul provinces (Meteoroloji Genel Müdürlüğü, 2016)

Disaster	Spring		Summer		Autum		Winter	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Storm, Heavy storm	55	32.9	29	6.7	48	19.8	123	41.7
Drought	4	2.4	5	1.2	2	0.8		
Snow, snow storm, heavy snowfall	5	3	-	-	-	-	65	22
Tornado	11	6.6	9	2.2	15	6.2	53	18
Rainfall, Harmful rainfall without flooding	17	10.2	57	13.7	41	16.9	10	3.4
Flood	24	14.4	123	29.3	66	27.3	12	4.1
Lightning	2	1.2	13	3.1	3	1.2	2	0.3
Hail	26	15.6	40	9.6	9	3.7		
Frost	2	0.6	-	-	-	-	4	1
Fog, Strong fog	4	2.4	-	-	8	3.3	8	2.7
Landslide	1	0.6	3	0.7	-	-	1	0.3
Flooding	7	4.2	66	15.8	25	10.3	5	1.7
Heavy Rainfall	7	4.2	70	16.8	25	10.3	7	2.4
Fire	1	0,6	2	0,5	-	-	-	-
Hoarfrost	1	0,6	-	-	-	-	-	-
Extreme cold	-	-	-	-	-		5	1.7

In Kocaeli, the predominant weather phenomena during the spring season include storms and floods, while summer is characterized by floods accompanied by rainfall. The fall season is marked by a continuation of floods and storms, and winter typically experiences storms and snowfall. In Sakarya, spring is marked by significant occurrences of hail and floods, followed by summer, which is defined by floods, waterlogging, and heavy rainfall. The fall season brings further floods and precipitation, while winter is characterized by storms and snow.

In Istanbul, spring generally presents with storms, floods, and hail, contrasting with summer, which is notable for floods and intense rainfall. During the fall, floods and storms prevail, whereas winter is marked by storms and tornado activity.

It is essential to assess the changes and increases in the frequency of disasters occurring annually and seasonally for effective future planning. Figure 6 illustrates the trends in disaster occurrences over the years in Sakarya Province. Notably, floods and heavy rainfall have shown a consistent upward trajectory. It is observed that floods have been recurrent annually since 2014, leading to predictions of an increased frequency of such events in the future. The escalating incidents of heavy rains and flooding in recent years underscore the necessity for a thorough review of the existing infrastructure, urban planning, and building stock, along with the implementation of appropriate measures. Comparative analysis of storm occurrences over the years reveals a significant upward trend in recent times. Consequently, it is imperative to issue timely warnings to residents along the Black Sea coast of the province, particularly those engaged in fishing activities. Tornado occurrences have been documented since 2015, with a discernible increase in frequency. Of particular concern is the notable rise in tornado events recorded in the northern coastal region of the city in recent years compared to earlier periods. Prior to the onset of a tornado, it is crucial to alert the public and undertake preventive measures to mitigate potential damages, such as roof damage and fallen trees. Additionally, it is important to note that landslides have been reported in years marked by flooding and heavy rainfall events. As hail have become increasingly significant in recent years, it is anticipated that their frequency will continue to escalate in the future. In light of the impact of hail, it is essential to implement initiatives that advocate for farmers in the region, which holds considerable agricultural importance, to obtain crop insurance and disseminate early warning notifications. While droughts are relatively uncommon, the diminishing water resources and the agricultural sector's dependence on water in the area underscore the necessity for widespread adoption of water conservation practices.

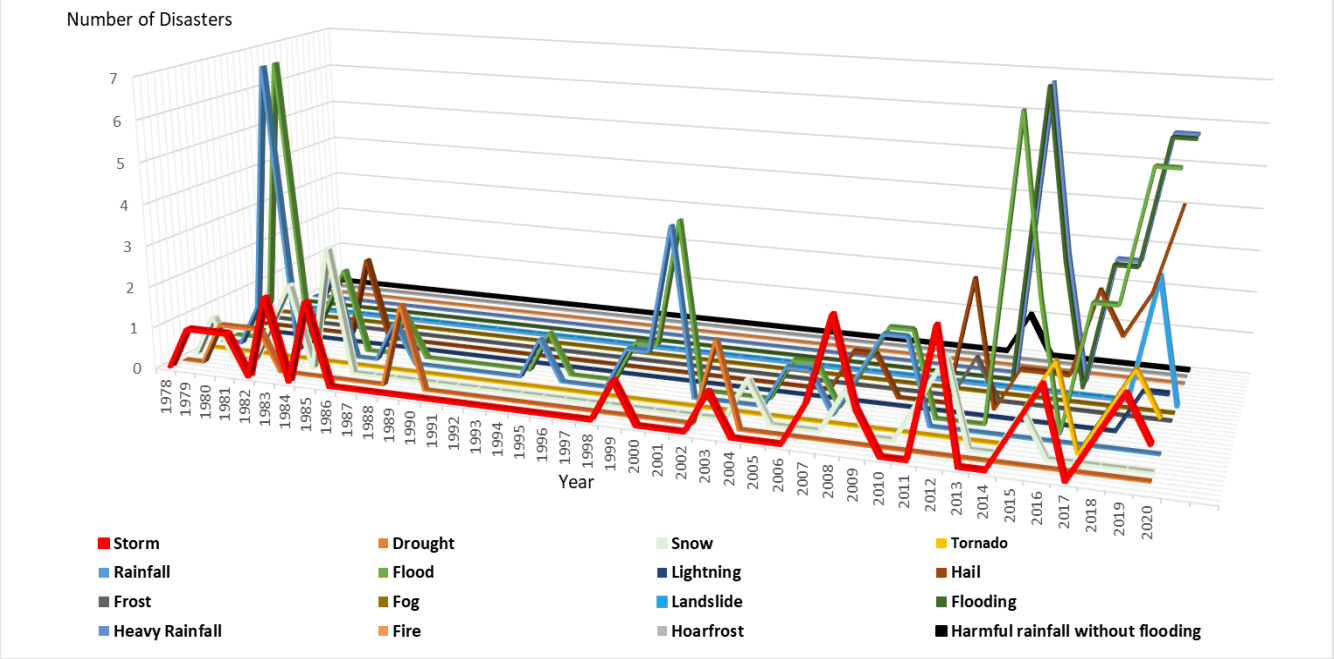

Figure 6: Change in meteorological disasters in Sakarya province

In the Kocaeli province, the predominant natural disasters, ranked in order of prevalence, are storms, floods, heavy rainfall and hail. Since 2001, there has been a marked increase in the incidence of these disasters. The frequency of storms has notably escalated, particularly in recent years. Flood events have been occurring with increasing regularity each year, and the patterns of rainfall and flooding appear to be closely related. Additionally, landslides have become more frequent during periods of significant flooding and heavy rainfall. The trend of severe rainfall and flooding has intensified since 2014, indicating a continual rise in these occurrences. Waterlogging has had a particularly pronounced impact over the past three years compared to earlier periods. Tornadoes were first recorded in 2013 and have emerged as a significant concern in the past two years. Given the implications of climate change, it is probable that the incidence of tornado events will increase in the future. Although the occurrence of droughts remains low, their frequency appears to be on the rise and warrants consideration for future implications. Furthermore, the incidence of lightning strikes and hail has generally increased. As the frequency of hail-related disasters is upwardly trending, it is essential to implement alert systems to mitigate potential damages (Figure 7).

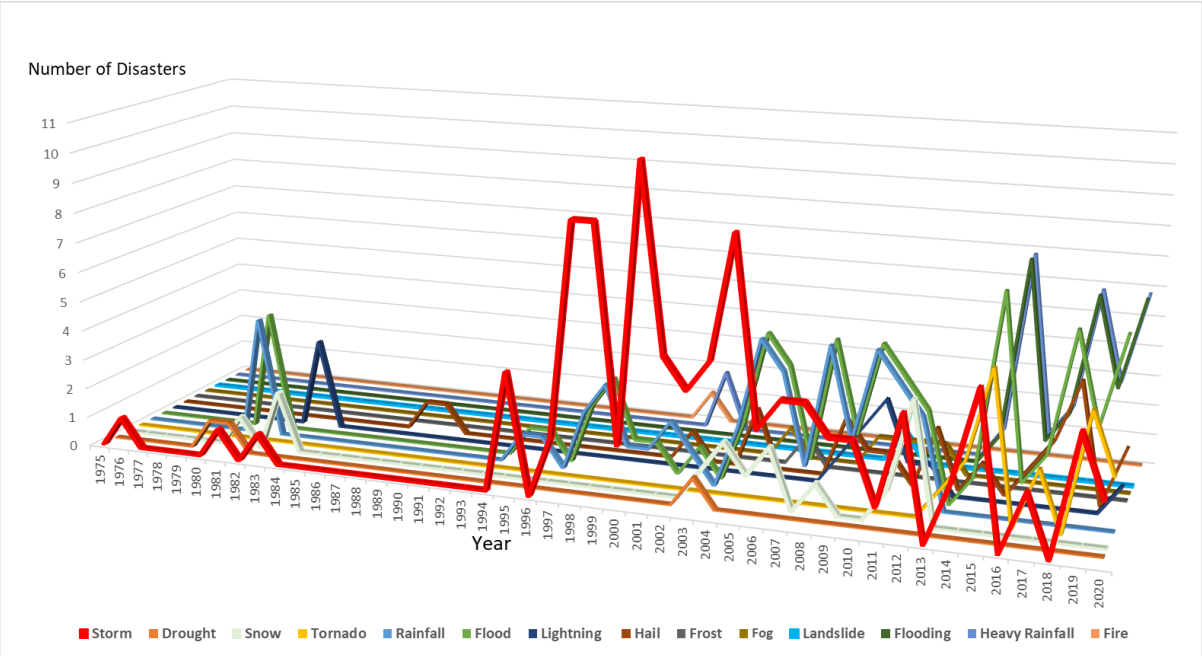

Figure 7: Changes in meteorological disasters in Kocaeli Province

Between 1975 and 2020, Istanbul witnessed a significant increase in the occurrence of storms, floods, tornadoes, heavy rains events. Notably, post-2010, there has been a marked rise in the frequency of such disasters. An analysis of the trends reveals that storms are the predominant form of disaster, with their frequency notably escalating since 2006. The persistent occurrence of storm-related incidents from 2006 to the present underscores the necessity for Istanbul, recognized as one of the world's major cities, to enhance its preparedness in mitigating potential damages. The annual observation of waterlogging since 2013 is particularly noteworthy, indicating a concerning trend of increasing frequency. A significant contributing factor to the unanticipated floods alongside infrastructural inadequacies and suboptimal land use—is attributed to global climate change. Since 2014, heavy rainfall has markedly intensified, with the last three years exhibiting particularly severe impacts compared to previous years. Flooding events and heavy rainfall occurrences have generally shown a parallel increase. The frequency of floods has been rising since 2004, and the occurrence of floods over eight consecutive years since 2012 highlights a troubling escalation in their severity. Given the ongoing trend of flood events in recent years, it is probable that their frequency will continue to augment in the future. The increasing frequency of heavy rainfall, flooding, and disaster incidents in recent years underscores the need for a comprehensive evaluation of Istanbul's infrastructure. Given the city's size and unique characteristics, it is imperative to implement the necessary precautions. There has also been a noticeable rise in tornado occurrences. The timing of tornado activity, floods and heavy rainfall coincides with incidents of lightning strikes and landslides. Furthermore, there is a significant increase in hail events, particularly in recent years. Additionally, it is crucial to adopt measures to mitigate the effects of fog, which has become more prevalent, especially to ensure that urban transportation remains unaffected (Figure 8).

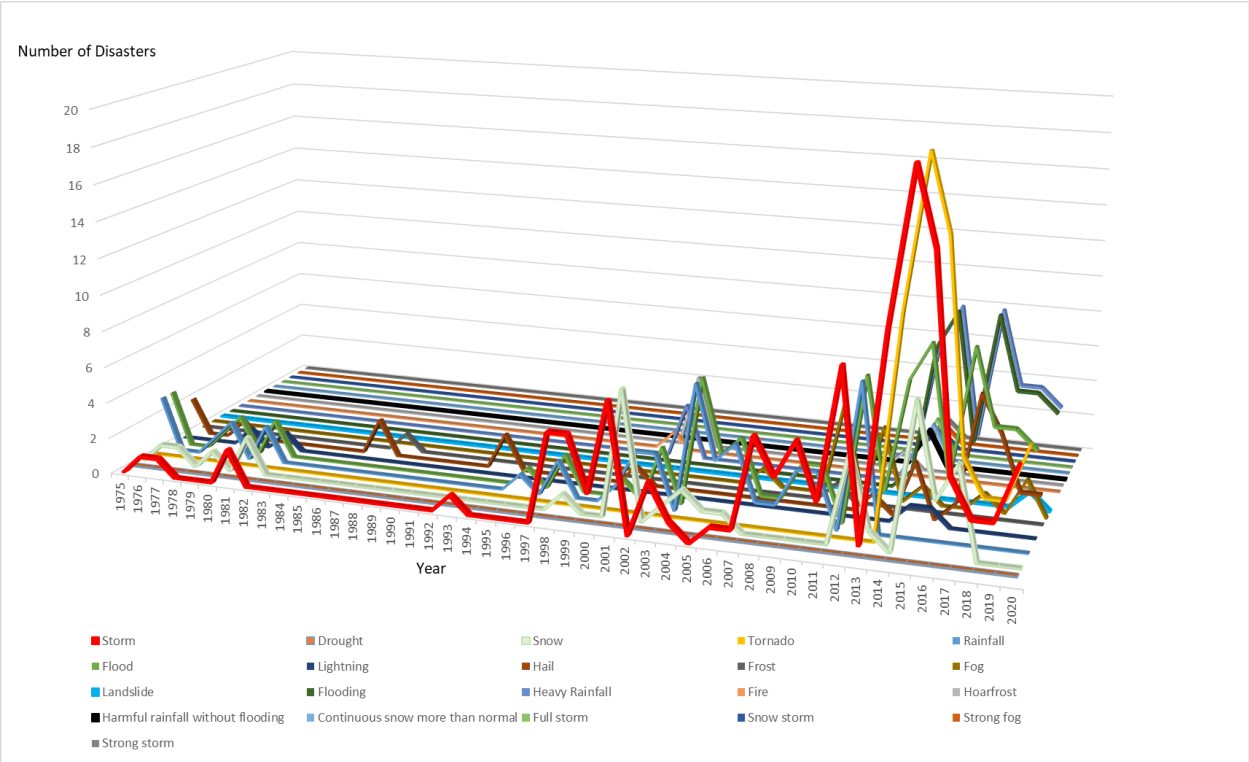

Figure 8: Changes in meteorological disasters in Istanbul Province

Across three provinces, storms are most frequently observed in Istanbul, which also experiences a range of other meteorological phenomena including droughts, rainfall, floods, hail, frosts, fog, waterlogging, heavy rains, severe cold, excessive snowfall, damaging non-flood-related rains, tornadoes, and snow-related disasters. Kocaeli records the highest incidence of lightning strikes, with 12 occurrences, while landslides are predominantly observed in Sakarya, with a reported 3 incidents.

In comparison to other regions of Turkey, certain types of disasters, such as snowfall, may be less frequent in the working area. However, it is crucial to acknowledge that the impact, damage incurred, and economic challenges associated with these disasters can be substantially greater, influenced by factors such as population density, geographical characteristics, and the status of economic and urban development. Consequently, the severity of disasters occurring in regions like Istanbul, Kocaeli, and Sakarya strategically significant areas for the country in terms of population, agriculture, and industry is notably high. This underscores the growing necessity of understanding the historical context of disasters to effectively implement potential disaster prevention measures in these regions.

In Turkey, floods and waterlogging represent some of the most prevalent natural disasters, accounting for 15% of all incidents and resulting in substantial economic damage. Given the anticipated impacts of climate change on our country, this percentage is particularly noteworthy. On a global scale, flood statistics indicate that they constitute the majority of natural disasters at 44%, followed by storms at 28%. These figures closely align with those observed in the provinces included in the study (Centre for Research on the Epidemiology of Disasters, 2017)

3.1. Meteorological Disaster-Related Fatalities

In the combined regions of Kocaeli, Sakarya, and Istanbul, the most prevalent meteorological disasters included storms, floods, rainfall, heavy rainfall, inundation, and tornadoes. Storms and tornadoes accounted for the highest number of fatalities, resulting in a total of 20 deaths across the three provinces.

Figure 9 present, in Kocaeli, storms and tornadoes emerged as the primary cause of fatalities, with 5 deaths recorded. Among these, 4 were attributable to storms and tornadoes, while 1 resulted from heavy rainfall, flooding, and inundation. In Sakarya, the deadliest events included heavy rainfall, flooding, inundation, landslides, and lightning strikes, leading to a total of 3 fatalities. Specifically, this included 1 death due to heavy rainfall and flooding, 1 from a landslide, and 1 from lightning. In Istanbul, meteorological disasters resulted in a total of 12 deaths, with snowfall being the predominant cause. Across Turkey, the most deadly disasters between 2010 and 2020 were floods and storms.

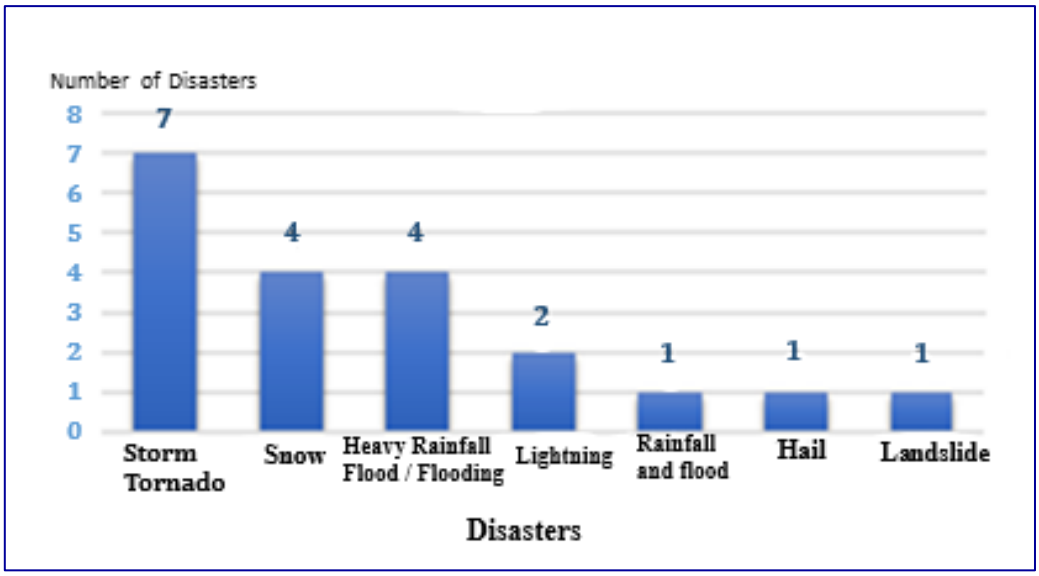

Figure 9: Distribution of the number of deaths caused by meteorological disasters in Kocaeli, Sakarya and Istanbul provinces for 1975-2020

3.2. Damage Assessment Following Disasters

In the provinces of Kocaeli, Sakarya, and Istanbul, the damage resulting from disasters has been categorized into light, medium, and heavy damage. Light damage includes broken tree branches, damage to parks, and missing roof tiles. Medium damage encompasses flooding of residences and damage to agricultural products. Heavy damage pertains to all disasters resulting in fatalities and forest fires.

In terms of the extent of damage, Istanbul ranks first, followed by Kocaeli and Sakarya. Across all three provinces, disasters primarily resulted in medium damage, with light damage being the second most common. Heavy damage has been the least frequently reported category across the provinces.

According to the data presented in Table 2, which shows the number of damages identified based on the damage classification, Istanbul has experienced the most significant impact in terms of the total damage caused by hydrometeorological disasters. High population density and concentrated urban development exacerbate the severity of disasters and increase the number of fatalities.

Table 2: Number of damages according to damage classification

City	Slight damage	Moderate damage	Heavy damage
Sakarya	143	187	17
Kocaeli	56	172	6
İstanbul	210	298	32

4. Conclusion And Suggestions

Currently, we are witnessing an increase in the frequency and intensity of disasters, driven by the climate crisis, particularly as a result of population growth, unplanned urbanization, and industrialization. Predictions indicate that we are likely to encounter even more catastrophic disasters in the future.

According to climate change projection studies conducted for Turkey, the average annual temperature is anticipated to increase by 1.5-2.0°C during the period from 2016 to 2040 and by 1.5-4.0°C from 2041 to 2070 (Demircan et al., 2017). Consequently, it is expected that hydrometeorological disasters will occur with greater frequency in our country in the forthcoming years. Given that past disasters in a region are likely to reoccur, maintaining a disaster inventory will be instrumental in guiding the necessary measures. Disaster inventories function as reference documents that present the current situation and establish a database for proposals and plans aimed at addressing the increasing frequency and severity of climate change-induced disasters. They also serve as a valuable indicator to mitigate human-induced land use errors, poor planning, and urbanization, which exacerbate disasters and their impacts. With these plans in place, we can conduct analyses of the current situation, perform hazard and risk assessments, implement disaster risk reduction actions, and engage in monitoring and evaluation. Utilizing the inventories created will enable the formulation of disaster risk reduction plans that effectively diminish risks at the local level.

In this context, the inventory developed in this study delineates the types, frequency, and magnitude of hydro-meteorological disasters, alongside an assessment of the current damage situation. It also offers recommendations regarding necessary measures and establishes a database aimed at mitigating damages.

If risk and damage reduction strategies are effectively implemented within disaster management processes, the losses resulting from disasters can be minimized. While developed countries prioritize preventive measures prior to the occurrence of disasters, such measures in undeveloped or developing nations are frequently insufficient. Enhancing public awareness about disasters and conducting disaster drills can significantly improve communities' capacity to manage disasters and unforeseen emergencies (Chou et al., 2015). Customized training for diverse target groups can help reduce social and economic losses from disasters and accelerate recovery efforts post-event (Dufty, 2008). Urban planning should incorporate potential disaster risks, enabling projections based on historical disaster data. Areas deemed unsuitable for construction should not be designated for settlement, illegal construction should be curtailed, and building permits should not be issued in flood-prone riverbeds.

Agricultural insurance should be expanded and necessary awareness must be raised in response to product losses and damages caused by disasters in agricultural areas. The beds of streams in agricultural lands should be cleaned. Non-structural methods such as flood zones, land expropriation, laws, special usage and construction permits, disaster management, and insurance should also be utilized. The use of disaster early warning systems should be made widespread (Kadıoğlu & Özdamar, 2008).

In our country, the Disaster and Emergency Management Authority (AFAD) was established to monitor, assess, and identify risks, reduce them, and coordinate disaster responses from a central point. The disaster risk reduction plans prepared with the establishment of AFAD serve as a guiding framework for both central and local governments in planning. This will create more resilient settlements against disasters and minimize losses caused by them (Afet ve Acil Durum Yönetimi Başkanlığı, 2022).

Preparing disaster inventories ensures accurate information and timely intervention. Globally, efforts are being made to enhance disaster resilience, track knowledge production in the field, and strengthen the relationship between practical disaster resilience assessments and resilience principles.

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