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Research Article

DETERMINATION OF THE IMPORTANCE OF GREEN AREAS IN DISASTER MANAGEMENT AND SUGGESTIONS FOR PLANNING

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ABSTRACT. Disasters occur when natural events affect humans and the built environment. After the Industrial Revolution, the urban population increased suddenly and rapidly. Urban areas with the densest population are the places most affected by disasters. Post-disaster destruction is commonly evaluated in terms of the built environment. The damage to the green areas and vegetation in the urban areas after the disaster is neglected. After disasters such as floods, erosion, fire, cyclones, or earthquakes, serious changes and losses are experienced in vegetation cover. Green areas, which have very important roles in reducing the risk and damage of disasters, are used as emergency assembly areas or temporary shelter areas after disasters. In this study, the destruction of vegetation after disasters and its effects on disasters are analyzed through case studies. In this direction, suggestions are made for planning and designing green infrastructure that is more resistant to natural disasters in the renewal process of urban areas. The study aims to reveal the importance of green areas and vegetation at each phase of disaster management.

Keywords: *Green infrastructure, landscape architecture, ecosystem services, risk, destruction, ornamental plants*

INTRODUCTION

Disasters are natural, technological, or man-made events that affect people and societies by causing physical, economic, and social losses, interrupting or disrupting daily life [1]. The concept of disaster management has been developed to minimize losses of disaster. Disaster management consists of four stages: mitigation, preparation, response, and recovery [2]. The most effective methods to prevent losses are pre-disaster measures, disaster preparation, and planning. In addition, the actions to be taken during and after the disaster also reduce the losses to be experienced afterward [3].

Loss of life, injury, damage to and destruction of properties and production disruption of lifestyle, loss of livelihood, disruption to essential services, damage to natural infrastructure, disruption to governmental systems, national economic loss, and sociological and psychological effects are the impacts of disasters [4]. Although disasters have many negative effects, post-disaster losses are concentrated on certain topics. Because it cannot be replaced, the loss of human life has the greatest impact. Since property and economic losses affect daily life, they are the main issues that are prioritized to explain the effects of the disaster.

Changes in land use such as expansion of the built environment, reduction of green and wetlands, and deforestation increase the risk of disasters [5]. In other words, the damages of disasters on the built environment are constantly discussed, but the fact that the built environment increases vulnerability to disasters is barely mentioned. Physical losses in disasters in urban areas are also revealed by determining the loss of life and property. Urban are constituted of built and non-built areas. However, the destructiveness of the disaster is generally defined through the built environment. Destruction of vegetation, green areas, or wetlands in non-built areas is ignored. For example, the Emergency Events Database (EM-DAT) is one of the first international sources of information on disasters [6]. The reports include the impacts of disasters such as deaths, people affected, and economic damage, but there is no information on the loss of green space or vegetation. In the Sendai Framework Monitor platform developed by the United Nations to collect data to measure countries' policies and actions to reduce disaster risk, data on green infrastructure losses are not reported. Instead, losses of services associated with agricultural land are monitored. Since news and official databases do not have data on green infrastructure losses, it is not possible to determine the actual disaster-related losses of ecosystems [1].

Post-disaster destruction is commonly evaluated for the built environment. The damage to the green areas and vegetation in the urban areas after the disaster is neglected. The study aims to reveal the importance of green areas and vegetation at each phase of disaster management.

ECOSYSTEM SERVICES

Ecosystem services are the essential benefits that people obtain from natural ecosystems. These services support life and contribute to well-being [7]. Ecosystem services are divided into four subcategories according to the benefits derived from the ecosystem: provisioning, regulating, supporting, and cultural services. Provisioning services include products derived from the ecosystem such as food, raw materials, medicinal resources, freshwater, and fibers [1]. Regulating services refers to the benefits derived from the regulation of ecosystem processes, such as regulating air quality, climate, water, erosion, disease and pest, and extreme events [8, 9, 10]. Supporting services refer to intangible benefits derived from the ecosystem such as soil formation, photosynthesis, nutrient cycling, and biodiversity. Cultural services refer to services necessary to produce all other ecosystem services such as mental and physical health, recreation and ecotourism, aesthetic values, sense of place, and education [11, 12, 13]. In the assessment of ecosystem services, the ecosystem is categorized into marine, coastal, inland water, forest, and woodland, dryland/grassland, mountains, cultivated areas, poles, and cities [7].

Many disasters recorded in recent years are climate-related disasters [14]. “Ecosystem services mitigate hazard exposure and reduce vulnerability” [15]. Regulating and supporting services of ecosystem services play an important role in adapting to the adverse effects of climate change and reducing disaster risk [1]. For example, coral reefs can dissipate wave energy [16], mangroves in coastal forests can protect the coastline [17], wetlands can regulate flood events [18], slopes with dense forests can protect from avalanches, forests improve air quality, provide carbon storage, affect precipitation and water availability, green areas reduce heat stress [19, 20, 21]. In

addition, the enabling and cultural services of ecosystem services improve human health and well-being and help to increase the capacity of society to cope with disasters.

IMPACT OF DISASTER IN THE NEWS

Quantitative data have been reported more than qualitative data in determining losses due to ecosystem services [1]. This results in the neglect of losses in the intangible or unquantifiable impacts of the ecosystem mentioned above [22]. Part of this problem is to understand the destruction of vegetation and green areas in post-disaster losses only in the context of economic losses or the destruction of infrastructure systems.

In the news reports, while talking about the impact of the disaster, there is information about the loss of life and property, but there is nothing about the loss of vegetation. For instance, Fig. 1 illustrates the damage caused by major forest fires in Turkey and around the world. These fires have significantly damaged forested areas and destroyed vegetation. However, the media often focuses more on the impact of fires on the built environment than on the natural environment.

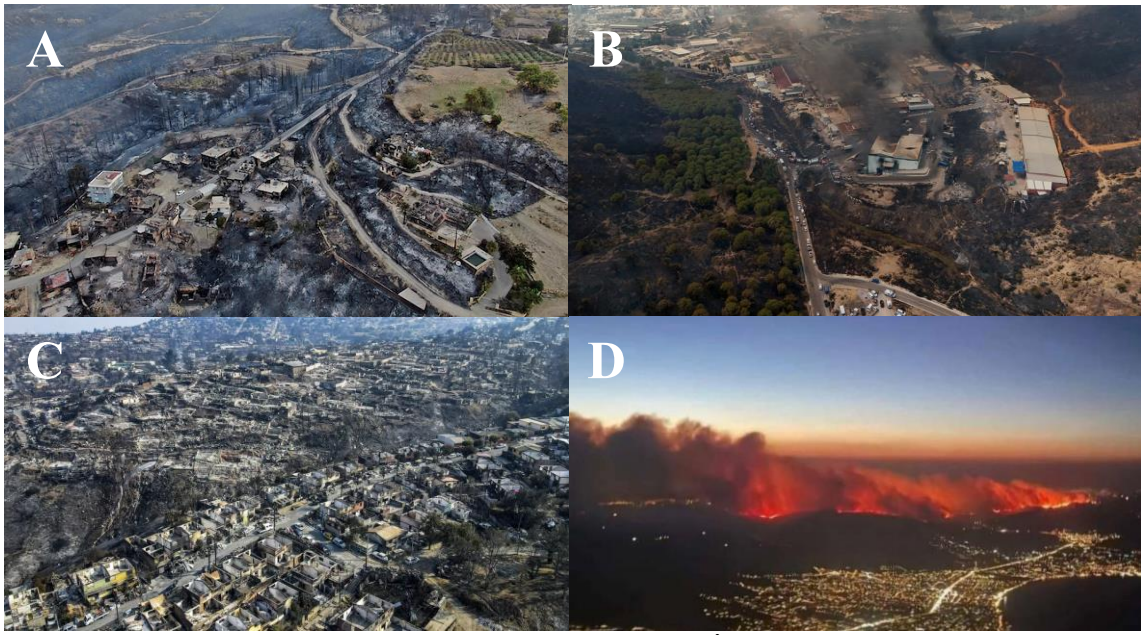


Fig. 1. *A: Forest fire in Antalya [23], B: forest fire in İzmir [24], C: forest fire in Chile [25], D: forest fire in Greece [26].*

A news report after a flood disaster in Bartın in 2016: “It was determined that 40.8 kilograms of rainfall fell in Göçgündemirci region of Kastamonu Cide-Bartın road where passenger buses, midibuses carrying funerals and other *vehicles* stayed. Many *houses* and *workplaces* were flooded in Kurucaşile district center, Tekkeönü Village, Çakraz holiday resort of Amasra, and Göçgündemirci Village. Houses were damaged, some *houses* collapsed...” [27]. They mentioned the damage to roads, vehicles, houses, and workplaces. However, although there is a great loss of vegetation, which can be seen in Figure 2A, there is no information about loss in the news. Figure 2C and Figure 2D show the floods experienced in Bartın in recent years. The news report about this flood: “Water was released from the discharge tunnels of Kozcağız Dam in Kozcağız

town of Bartın. While the waters rose at night in Kavaklık Neighbourhood, the 4-storey *building* belonging to Kemal Ünal collapsed. Since the building was evacuated before, *there was no loss* of life or injury. Ten *houses* in the neighborhood were also evacuated. It was stated that 50 *workplaces* and houses were flooded in Kozcağız due to the rainfall...” [28]. Again, they mention the loss of houses and workplaces, and there is nothing about vegetation loss. Another flood disaster from Antalya in 2022 (Figure 2B): “The heavy rainfall effective in Antalya Korkuteli Dereköy and Sülekler neighborhood caused damage to the *settlements*. *Houses* and *barns* were damaged because of the stream overflow after the hail. While the neighborhood turned into a *mud lake* due to flooding, 48 *animals died...Fruit trees* and vegetable saplings were damaged. Some *houses* are uninhabitable...” [29]. They mentioned damage to settlements, and they also mentioned damage to fruit trees and vegetable saplings in the news. However, economic losses than vegetation losses are discussed here.



Fig. 2. *A: flood disaster in Bartın in 2016 [27], B: flood disaster in Antalya in 2022 [29], C-D: flood disaster in Bartın in 2022 [28].*

Landslides are one of the disasters with the highest loss of vegetation. Only landslide disasters are mostly reported when they affect the built environment or people. Figure 3 shows a few examples of disasters affecting the built environment and vegetation.



Fig. 3. *A: landslide disaster in Brazil [30], B: landslide disaster in Colombia [31], C: landslide disaster in India [32], D: landslide disaster in Türkiye [33].*

GREY OR GREEN INFRASTRUCTURE?

In this study, the role and importance of grey and green infrastructure systems in disaster mitigation are explained through the tsunami disaster. The primary function of coastal barriers such as coastal forests, seawalls, and breakwaters is to absorb the impact forces and delay the flow of tsunamis from large storm waves [34]. High seawalls built as grey infrastructure reflect incoming waves to the sea, while permeable structures such as coastal forests, which are green infrastructure, partly reflect and partly transmit incoming waves. As the high-energy wave passes through the vegetation, the energy is gradually absorbed, and the impact of the tsunami is greatly reduced [35]. After the 2011 Great East Japan tsunami, the importance of improving coastal vegetation as well as coastal grey infrastructure systems has become evident (Figure 4) [36, 37].



Fig. 4. *10-meter-high seawalls were destroyed by the 2011 tsunami [38].*

Green infrastructure can be defined as natural or semi-natural areas that provide ecosystem services [1]. Coastal forests are one of the vital green infrastructure systems that strengthen defenses against environmental threats. Coastal vegetation and trees protect coasts against natural disasters by protecting against hurricanes, coastal erosion, and wind damage [39]. The power of coastal vegetation in defense against natural disasters is especially associated with the tsunami disaster. Because it has been realized that coastal vegetation acts as a barrier preventing the destructive effects of tsunamis in large tsunamis. After the 2004 Indian Ocean, 2006 Pangandaran, and 2011 Great East Japan tsunamis, coastal vegetation was reported to have decreased [40, 41, 42, 43]. During the Pangandaran tsunami, it was found that the 40 m wide vegetation belt on the shore reduced the waves that reached 7 m in height to 1.6 m [44]. In the 2019 Anak Krakatau tsunami, the effect of vegetation on reducing the force of the tsunami for waves less than 5 m was observed [45]. In the 2018 Sulawesi tsunami, it was observed that coconut groves on the coast prevented ships and various debris from traveling inland and reduced the damage to the built environment [35].



Fig. 5. *The figure demonstrates how coconut groves effectively trapped a ship and various other debris during the tsunami after the 2018 Sulawesi earthquake [35].*

Multiple factors such as the extent of coastal forests, the density of vegetation cover, and the root, trunk, and leaf structure of trees are determinants in reducing the impact of disasters on coastal vegetation and forests [46, 47]. Therefore, some parameters that should be considered in the planning and protection of coastal forests have been developed. The simulations established in the studies conducted for this purpose have found that a 200 m wide coastal forest reduces the tsunami force of 3 m by at least 80% and reduces the flow velocity by at least 70% [48]. In another study, it was calculated that a pine forest at least 20 m wide was needed to withstand a flow depth of three meters [49]. Coastal forests consisting of trees with dense roots and intricate aerial structures such as *Rhizophora spp.* (Red mangroves), *Casuarina equisetifolia*, *Pandanus odoratissimus*, and *Pterocarpus indicus* play an important role in reducing the impact of tsunami (Figure 6) [35].

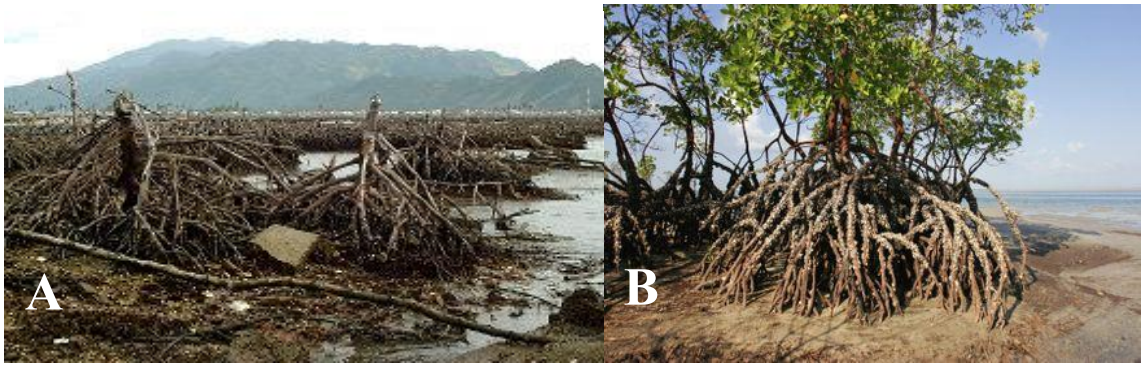


Fig. 6. *A: 2004 mangrove trees damaged by the tsunami in Indonesia [50], B: Rhizophora spp. (Red Mangroves) with a dense, complex root structure [51].*

CONCLUSION

Disasters are catastrophic events that have devastating effects on humans, animals, and nature. However, the factors used to determine the scale of a disaster often prioritize quantifiable impacts and direct effects on human life. This approach frequently overlooks the destruction of natural habitats and ecosystems, which are essential for the continuation of human life. Restoring ecosystems damaged by disasters is a lengthy process that requires meticulous care and monitoring. Since ensuring the sustainability of these systems is vital for human survival, it is imperative to assess vegetation and ecosystem damage following disasters and initiate the recovery process as soon as possible.

Multi-layered systems that combine grey and green infrastructure systems should be developed to reduce disaster impact. However, ecosystem development and protection have many challenges. To build ecologically friendly mitigation systems, processes like long periods, regular monitoring and maintenance, and raising awareness of society need to be planned and managed. In this regard, there is a need for collective efforts of all institutions having a role in disaster management, local administrations, urban planners, landscape architects, architects, and related professional disciplines such as civil engineers and the public. For these efforts to be successful, the destructive effects of disasters on the ecosystem must be known and awareness must be raised on disaster management.

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