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Climate Crises Associated with Epidemiological, Environmental, and Ecosystem Effects of a Storm: Flooding, Landslides, and Damage to Urban and Rural Areas (Extreme Weather Events of Storm Daniel in Thessaly, Greece) †

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Abstract: The effects of climate crises and disasters must be managed appropriately. These effects can have a considerable influence on public health. This issue relates to epidemiological models and policy regarding climate factors, such as temperature, precipitation, humidity, and health results. Historical data were analyzed so that patterns and connections between climatic factors and health outcomes could be found. Epidemiological models were used to simulate the spread of illnesses. Climate variables were used as inputs to these models to determine their effect on the spread of disease. This study examines the current public health regulations concerning epidemiology, climate change, and establishing new policies or revising existing ones to address the issues found to protect public health. To conclude, immediate efforts are needed to save human lives, protect vulnerable wildlife, and improve public health. Ecological assessments need to be conducted to understand extreme weather events (such as Storm Daniel), monitor ecosystem recovery, and adapt management strategies as needed, as well as to develop disaster preparedness to reduce future risks.

Keywords: public health; climate crises; extreme weather events; Storm Daniel in Thessaly; epidemiological effects; environmental ecosystem

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1. Introduction

Several challenges are constantly affecting public health. The impacts of climate change are becoming more widespread. As a result, several issues related to human health and water resources have already emerged. The relationship between climate change and the environment must be reexamined to promote more sustainable behavioral choices and enhance public health [1]. The link between people and the environment must be reevaluated, and more sustainable behavioral choices must be encouraged. New scientific data show that new issues are constantly emerging [2]. When people, animals, and the environment interact intricately, pathogens with a high potential for epidemics and pandemics commonly emerge [3]. Additionally, bigger investments must be made to make the best use of the water resources already in place and conserve a lot of potable water [4]. The Hellenic National Meteorological Service named Storm Daniel after the country where it formed. Storm Daniel began to resemble a Medican as it made its way toward Libya. This hybrid phenomenon demonstrates traits of both mid-latitude storms and tropical cyclones. Storm Daniel reportedly dropped 750 mm of rain in 24 h at a station in the hamlet of Zagora, Greece, on the night of 5–7 September [1]. It is comparable to nearly 18 months' worth of rainfall. Many stations in Thessaly, central Greece, recorded 400 to 600 mm of rain in 48 h. Greece's agricultural center is Thessaly; hence, negative economic effects are anticipated to be significant. Many people lost their lives. On rooftops, many individuals sought safety. Storm Daniel, which produced heavy rains, struck sections of the central and eastern Mediterranean, causing disastrous flooding and a great loss of life in Libya, which was the worst-affected nation, as well as in Greece, Turkey, and Bulgaria [5,6]. Greece faced the largest wildfire in Europe's history, which wreaked havoc in the nation's northeast. These catastrophic events have recently destroyed lives and livelihoods in numerous nations around the world [5,6]. It is anticipated that as the world warms, more extreme rainfall events will hit, which will increase the severity of flooding [7]. As a result, precipitation events, whether they involve rain, snow, or hail, are more powerful and may cause greater floods in a warmer environment [7,8]. More than 80% of the moisture in clouds, and much more in tropical cyclones, comes from the ocean. This implies that hurricanes will intensify as the oceans warm up. Amounts of rainfall between 700 and 800 mm in 24 h have been recorded for the first time thanks to the slow-moving system's continuous and powerful thunderstorms [9]. It is important to note that these unprecedented rainfall accumulations are 10 to 15 times greater than usual for the entire month of September and are at or beyond the annual output [9,10]. In Thessaly, particularly in the seaside town of Volos, such heavy precipitation has caused devastating flash floods. Water contamination is a result of environmental changes and a changing climate in general [11]. Unforeseen events like pandemics can also exacerbate existing conditions and result in a situation that is challenging to rectify for public health [12,13]. When there are no renewable water sources or in places with high amounts of contaminated water, using conventional and unconventional water resources may be able to assist in alleviating the issue [12,13]. The purpose of this narrative review is to delve into the impact of climate crises associated with epidemiological, environmental, and ecosystem effects of the storm, including flooding, landslides, and damage to urban and rural areas, such as extreme weather events.

This study aims to assess the short and long-term impacts of Storm Daniel and analyze its effects in Thessaly, Greece. The focus is on flooding, landslides, and damage to both urban and rural areas. The scope of the study analyzes the effectiveness of mitigation and adaptation strategies and evaluate the resilience of urban and rural areas to such events.

2. Methodology

The methodology followed was based on a bibliographic search of review and research studies, which were drawn from the international databases Medline, PubMed, CINAHL, and the Greek database Iatrotek, with keywords such as public health, climate crises, extreme weather events, Daniel in Thessaly, epidemiological effects, and environmental ecosystem. The criterion for excluding the articles was them being in a language other than English, French, Italian, and Greek. In the context of the information provided, the term "modelling techniques, forecasting methods, and diagrams" includes a variety of strategies and tools used for analyzing data, projecting trends, and visually representing information. Modelling techniques can involve statistical models, machine learning algorithms, or simulation methods. Forecasting methods involve predicting future outcomes based on historical data and trends. Diagrams, such as flowcharts or decision trees, are visual aids used to illustrate relationships and processes. Combining geographically weighted regression (GWR) with machine learning algorithms can be a powerful approach for making predictions. This integration allows for the creation of a model that captures local variations in environmental factors, population dynamics, and other relevant variables. This combined approach enables more accurate predictions and targeted interventions in high-risk areas. Utilizing moderate resolution imaging spectroradiometer (MODIS) land cover type data, like MCD12Q1, can provide valuable insights for predictive modelling. Land cover information helps assess environmental factors affecting habitats, disease transmission, environmental hygiene impacts, and public health. It is important to consider other variables such as temperature, precipitation, and vegetation indices in order to develop a comprehensive model. In addition, incorporating machine learning algorithms that cover both spatial and temporal dimensions is recommended for precise predictions.

Modelling Techniques

All ecosystems are being impacted by environmental changes brought on by climate change and human activity. It is vital to comprehend how these changes occur in order to employ methods to do so and forecast potential outcomes. Diagrams that illustrate the causes and effects of climate crises over time and in specific locations can be analyzed. Rainfall is particularly significant since it has an impact on weather and water recourses [9]. Three steps have been utilized in the rainfall modeling technique. The selection of meteorological stations is the initial step. The Larissa weather station, which is one kilometer from the Pineios River, was chosen for the current investigation because its rainfall data might make a substantial contribution to the applicable models used in the flooding simulation. After that, the curves were estimated by analyzing data for the Larissa station provided by the Hellenic National Meteorological Services and the National Observatory of Athens, considering the seasons, as well as the recurring periods and years that will be used for the environmental simulations, as well as the (15) intensity of the rainfall calculation [9,11,14]. The average depth of rainfall per hour divided by the time interval (i = hr/d), where d represents the amount of rainfall in millimeters per hour, was used to compute the intensity of the rainfall [15]. With a bi-parameter power law, the rainfall intensity hr for a given return period T and duration d may be determined [14–16]:

$$hr\ (T) = a(T) \cdot d\ n \tag{1}$$

A simple linear regression analysis in a bi-logarithmic scale can be used to estimate the rainfall curve parameters a [mm/hn] and n [-]. The hydraulic model given below was created using the exact functional curves calibrated using the probabilistic approach, and the n parameter approximates a constant value (0.41). GIS modeling was used and employed, and certain spatial data were retrieved from the Hellenic National Meteorological Service (HNMS), website map data, and other spatial information to obtain the data needed for the hydrological modeling [15–19]. After processing a digital model with spatial resolution trimmed using the river watershed border, the extension and average slope were determined using geoprocessing tools. Rivers and creek networks were similarly trimmed along watershed boundaries, and the length of the major rivers was approximated. Total annual average precipitation was calculated by processing monthly mean rainfall maps available in other work [15]. In contrast, rainfall model parameters were calculated using maps of Gumbel extreme rainfall statistics produced as part of the STRADA project at a 250 m spatial resolution [19]. The parameters were computed as follows:

$$\alpha = \theta 2,\ (b)\ \lambda = \exp\ (\theta 1\ \theta 2), \tag{2}$$

where θ1 and θ2 are the parameters of the Gumbel distribution [20].

3. Results

3.1. Environmental Impacts

Epidemiological models and policies might be affected by addressing a climate issue that is linked to environmental and ecological components. Understanding and minimizing these effects are essential. Climate crises and disasters can have serious repercussions for public health. Additionally, it is important to identify and document current issues with water resource management caused by both climate change and human activities. [5,14,15]. Flooding, landslides, and destruction in both urban and rural regions are among the storm's epidemiological, environmental, and ecosystem repercussions. The hydrologic reaction of the main local watercourses, including the Acheloos, Pineios, Spercheios, and Kifissos rivers, is still underway. The EFAS system's estimates predict extremely high flood peaks over the 100 year return period, which might potentially damage the key urban districts in the area. Thessaly's capital city of Larissa, which is home to 150,000 people, has been experiencing flooding of the Pineios River since 6 September, while Lamia, a city of 75,000 people in Central Greece, has been experiencing flooding of the Spercheios River. Shown in Figures 1 and 2 are the impact of the chain hydrograph for the hydrological section of Larissa, Pineios River, as well as the Thessaly Geographical wide range in the projected population [16,17]. Despite the reasonably consistent hydrological estimates, there is still a wide range in the projected population that could be impacted, which is between 5000 and 25,000 in Thessaly and Central Greece combined, mostly depending on how well the flood defenses are working. Storm Daniel battered Greece, has dumped precipitation volumes that are on par with or even higher than the annual average, leading to significant flash floods.

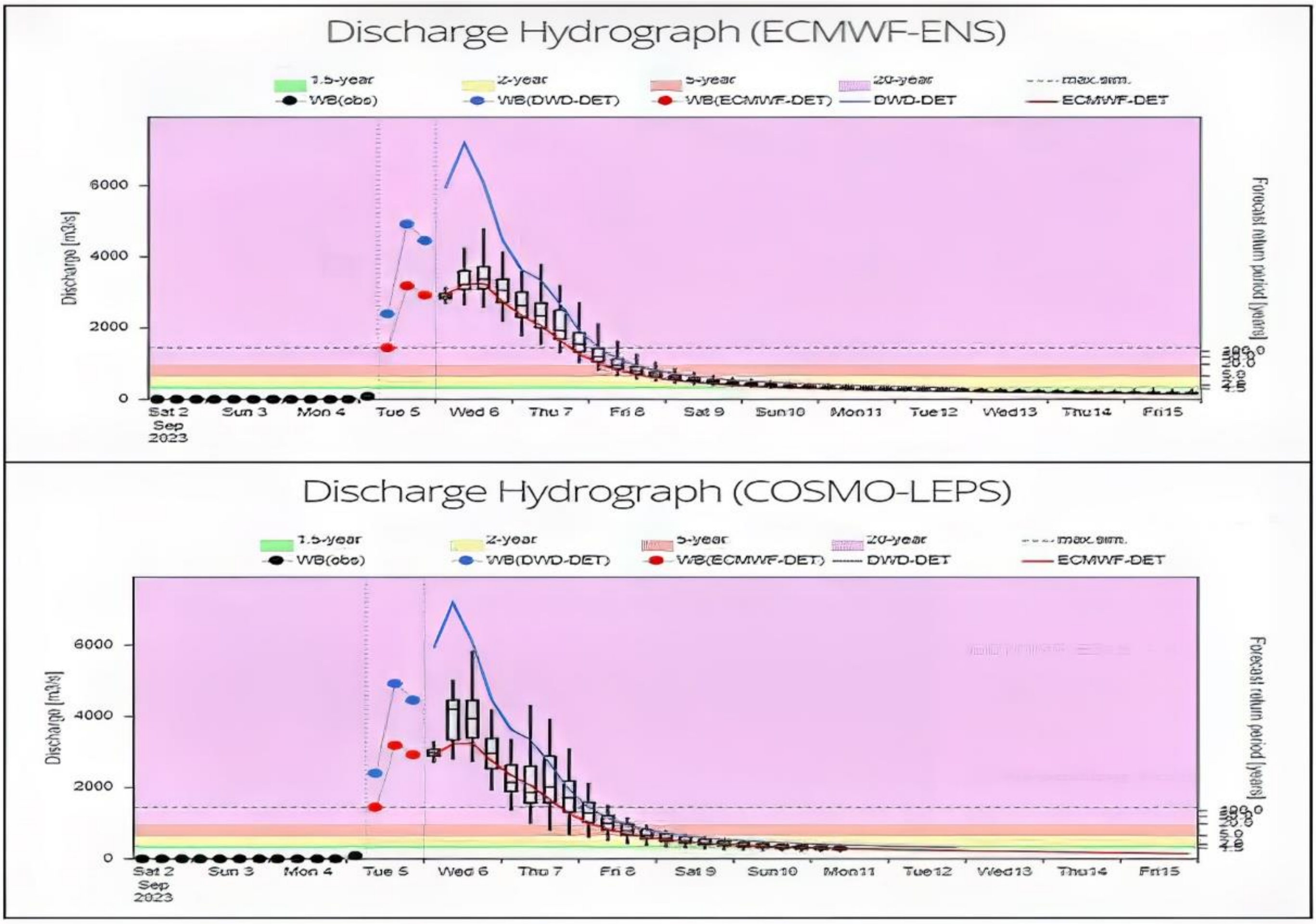

Figure 1. EFAS chain hydrograph for the hydrological section of Larissa, Pineios River [17].

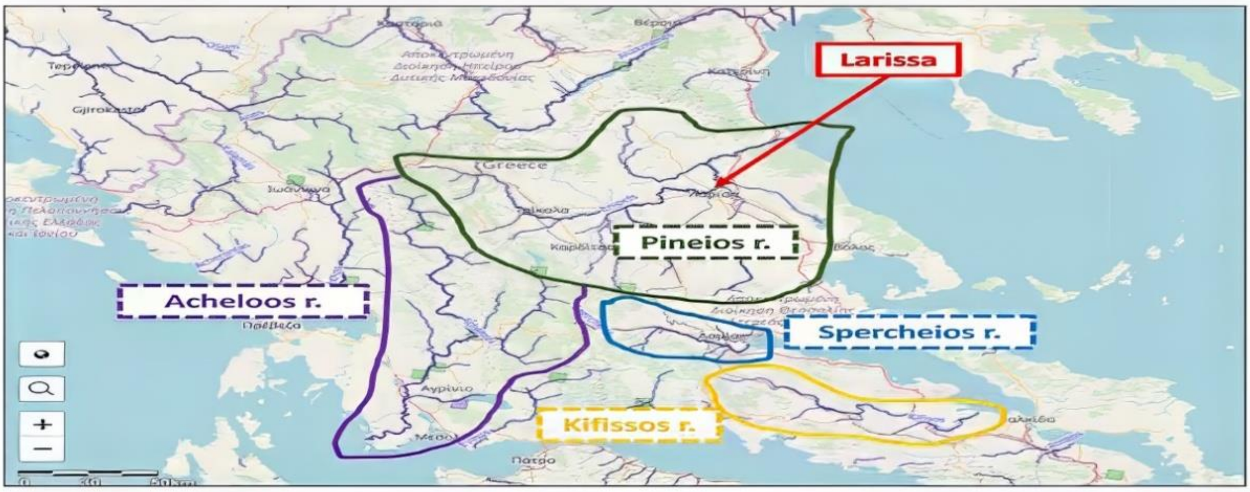

Figure 2. The European Flood Awareness System (EFAS), showing the Pineios, Acheloos, and Spercheios rivers in the Thessaly Geographical wide range in the projected population [18].

Addressing a climate crisis is associated with the environmental and ecosystem dimensions in epidemiology models and policies. Climate crises and disasters can have significant impacts on environmental hygiene and public health, and understanding and mitigating these effects is crucial [12,19,20].

3.1.1. Extreme Weather

Climate crises and climate change form one specific category of extreme weather, namely, tropical cyclones and hurricanes, which have already been discussed. Other severe weather events and potential links to climate change are shown in Figure 3, as well as the impact of extreme weather and the demonstration of how a shift in average temperature influences the frequency of extreme heat [21,22].

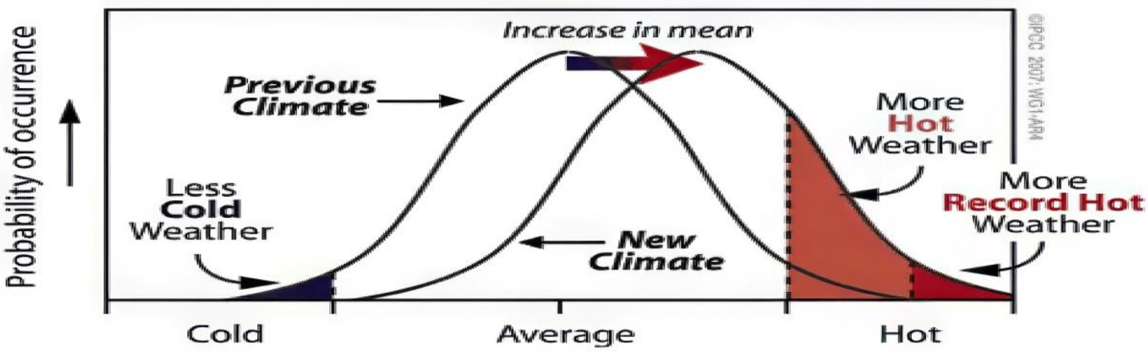

Figure 3. Demonstration of how a shift in average temperature influences the frequency of extreme heat [21].

3.1.2. Storm Daniel

Storm Daniel's access to water resources remained inactive in the places where the storm hit. As a result, water became increasingly contaminated, having an impact on both human health and all of the territory's flora and wildlife [23–25]. The management of public health audit services is frequently handled improperly by local or national authorities [20,25,26]. It is essential to educate and inspire public health personnel for the delivery of high-quality services, the maintenance of job satisfaction, and the acceptance of this joint work by the entire local and global population. Political actions have impacts and exacerbate employee fatigue [27–29]. Furthermore, loss of life, soil erosion, sediment runoff, increased erosion, loss of biodiversity, and disruption of ecosystem services are among the impacts. The situation dramatically changed after the hit from Storm Daniel while being overwhelmed by the waters of streams and tributaries of the Pineios; around 750,000 acres were flooded, 97% of which was arable land, raising concerns for the next day regarding food sufficiency. The Enipeas collect water from Mount Orthrys in Fthiotida; exit the Thessalian plain; meet the Sofaditis River; and head towards Pineio, Kalentzis, and Karambalis. They also head to Pineios. All four rivers meet each other before entering Pineios, together with the waters of the torrents above Farsala and Larissa.

3.2. Addressing Response Efforts

- Search, Rescue Operations Cleanup, and Restoration: Immediate efforts must be made to save human lives and protect vulnerable wildlife. Removal of debris and contaminants from floodwaters and restoration of affected natural habitats are crucial. Implementation of erosion control measures are necessary to prevent further soil erosion and sedimentation.
- Monitoring, Research Policy, and Planning: Ongoing monitoring of the affected ecosystems is necessary to assess recovery progress and conduct research to understand the long-term impacts. Development or revision of policies related to land use, floodplain management, and disaster preparedness are necessary to reduce future risks [5,6,8,16,29].

4. Discussion

Extreme weather events on the Earth are undeniable signs of climate change. Effective methods are needed to limit cities' exposure and vulnerability to such dangers. This work aims to contribute to the cultural and technical debate on the regulation of urban transformations for mitigating the effects of global warming, with a concentration on Mediterranean Sea cities [30]. Global climate change models predict changes in regional rainfall, floods, sea levels, and illness trends, but they lack attention to indirect impacts on chemical risk assessment and occupational and environmental health. Heat waves, precipitation, and storms are expected to rise because of climate change, influencing pollutant behavior and interactions with living creatures and potentially initiating severe occurrences [19]. Climate change will have an impact on water availability and quality. Increased precipitation has been anticipated for some places, including Europe, America, and Asia, whereas significant droughts have been forecast for others, including Africa, Asia, and the Mediterranean; the implications are area- or region-specific ones [31]. Climate crises have a wide range of consequences, including changes in human migration due to changes in rainfall patterns or sea level rise, heat-related mortality, and mutations in infectious disease vectors [20,25–32]. Furthermore, prognostic models imply that the geographic distribution and annual number of generations of agricultural pests will be affected [32–35]. The increase in frequency and intensity of heat waves, precipitation, and storms may lead to changes in pollutant behavior and fate, interactions with living species, and thresholds that trigger unfavorable events. Climate crises will bring about new temperature and precipitation patterns, ecosystems, and hydrological processes, which are likely to result in different responses to toxic levels of pollutants [20].

Implications for Research and Practice

The community's engagement resulted in the establishment of social groups that were more aware of their socio-environmental and public health obligations, in addition to the benefits of working as a group. The role of the community resulted in the development of social groups that were more aware of their socio-environmental and public health responsibilities. Flooding is produced by extreme rainfall events with a recurrence time of more than 15 years. The flood barrier would limit the inundated areas and safeguard the vulnerable towns. Flooding is the major extreme natural hazard threatening the Thessaly area and the local rivers, and the innovative applications and methodology discussed herein should account for the hydraulic model having an even higher specification. The

Normalized Difference Vegetation Index (NDVI) may be utilized to improve the spatial resolution of rainfall data from the Tropical Rainfall Measuring Mission (TRMM) in the basin, and the approach demonstrated here is universally applicable to other semiarid and dry portions of the world. The given methodology is broad in nature and applicable to various semi-arid parts of the world, and NDVI can also be utilized to accurately downscale TRMM precipitation are shown in Figure 4 [36].

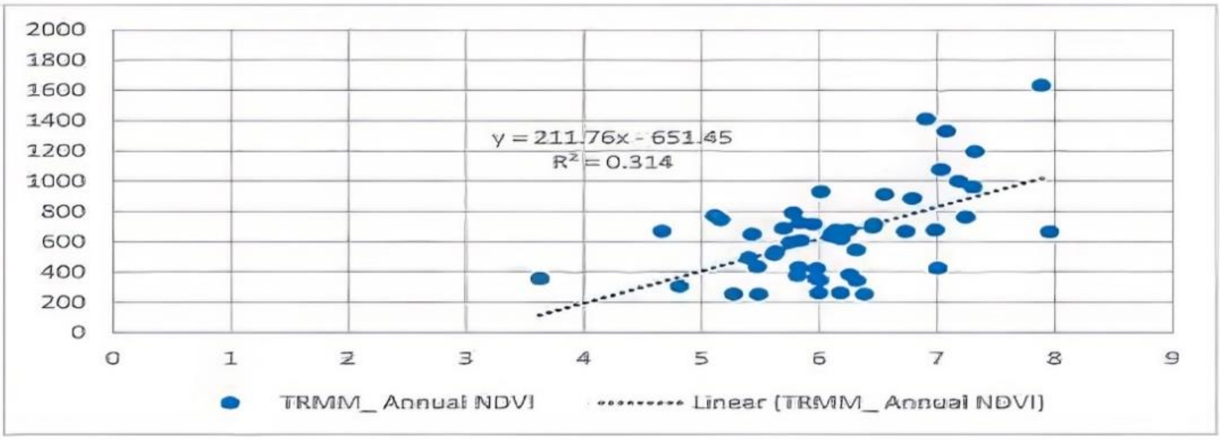

Figure 4. Relationship between NDVI and TRMM, adapted from Yasmeen et al. (2022) [36].

5. Conclusions

All actions should be carried out with consideration for the interconnectedness of human and ecological systems to restore both the environment and the communities that depend on it. Additionally, climate change, crises, and disaster adaptation strategies should be integrated to build resilience to future extreme weather events like storms. Ultimately, a holistic approach that considers both the immediate and long-term consequences of storms on ecosystems is crucial for preserving biodiversity, ecosystem services, and the overall health of the environment. These immediate and long-term effects on ecosystems must be addressed by prioritizing habitat restoration and protection efforts and conducting ecological assessments to understand the extent of the damage. Moreover, the implementation of conservation measures for endangered and vulnerable species and monitoring ecosystem recovery, and adaptation management strategies as needed are crucial. Sustainable land use and disaster preparedness must be promoted to reduce future risks. Finally, engaging in public awareness and education campaigns highlights the importance of ecosystem conservation. Future studies are needed that will focus on expanding this strategy at a greater temporal resolution to reduce future risks. Ecological assessments must be utilized for extreme weather events, such as Storm Daniel, to be comprehended. Finally, ecosystem recovery and disaster preparedness should be systematically monitored.

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