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Helene disaster: The threat of poor management and climate change to human lives and assets

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Highlights

1. On September 26, 2024, Hurricane Helene, a record-breaking Category 4 storm, made landfall in Florida's Big Bend region before shifting northwest, bringing heavy rainfall and severe impacts to Georgia, South Carolina, North Carolina, Virginia, and Tennessee in the United States.
2. Satellite radar data acquired over seven cities in these four U.S. states indicate that over 31,000 buildings were damaged due to the Hurricane Helene.
3. Based on Zillow Home Value Index, the estimated value of threatened property is nearly $12.5 billion.
4. Helene killed at least 230 people, making it the deadliest hurricane in mainland U.S. since the devastating Hurricane Katrina in 2005
5. The damages caused by Hurricane Helene show how the compounding effects of multiple factors, including development in floodplains (local problem), and the specter of climate change (global problem), can amplify the impact of natural disasters.

Context

On Thursday, September 26, Category 4 Hurricane Helene made landfall ashore in the United States. After severely affecting Florida's Big Bend, this hurricane quickly turned toward the northwest, soaking the U.S. states of Georgia, South Carolina, North Carolina, Tennessee, and Virginia. With torrential rains and winds of up to 250 kilometers per hour (140 meters per hour)[1], Helene overwhelmed riverbanks, causing widespread flooding, destruction of roads and buildings, and loss of many lives. More than 4.2 million people in several states, including Tennessee and Virginia, lost power[1]. With the death toll of at least 230 fatalities[2], Helene is the deadliest hurricane to hit the mainland U.S. since the devastating Hurricane Katrina in 2005[3].

Findings

This Incident Brief by the United Nations University Institute for Water, Environment and Health (UNU-INWEH) provides a rough estimate of the value of the threatened properties by Hurricane Helen based on synthetic aperture radar (SAR) data from the Sentinel-1 satellite of the European Space Agency. The analysis is focused on seven cities, which were reportedly hit hardest by Helene, namely Asheville, Black Mountain, and Chimney Rock in North Carolina, Greenville in South Carolina, Steinhatchee and Tampa in Florida, and Valdosta in Georgia.

Between 14% to 25% of buildings in these cities had a 99% damage probability. Using the Microsoft database of building footprints data and the Zillow Home Value Index, the total value of over 31,000 buildings that were damaged at high likelihood in these cities is estimated to be nearly $12.5 billion.

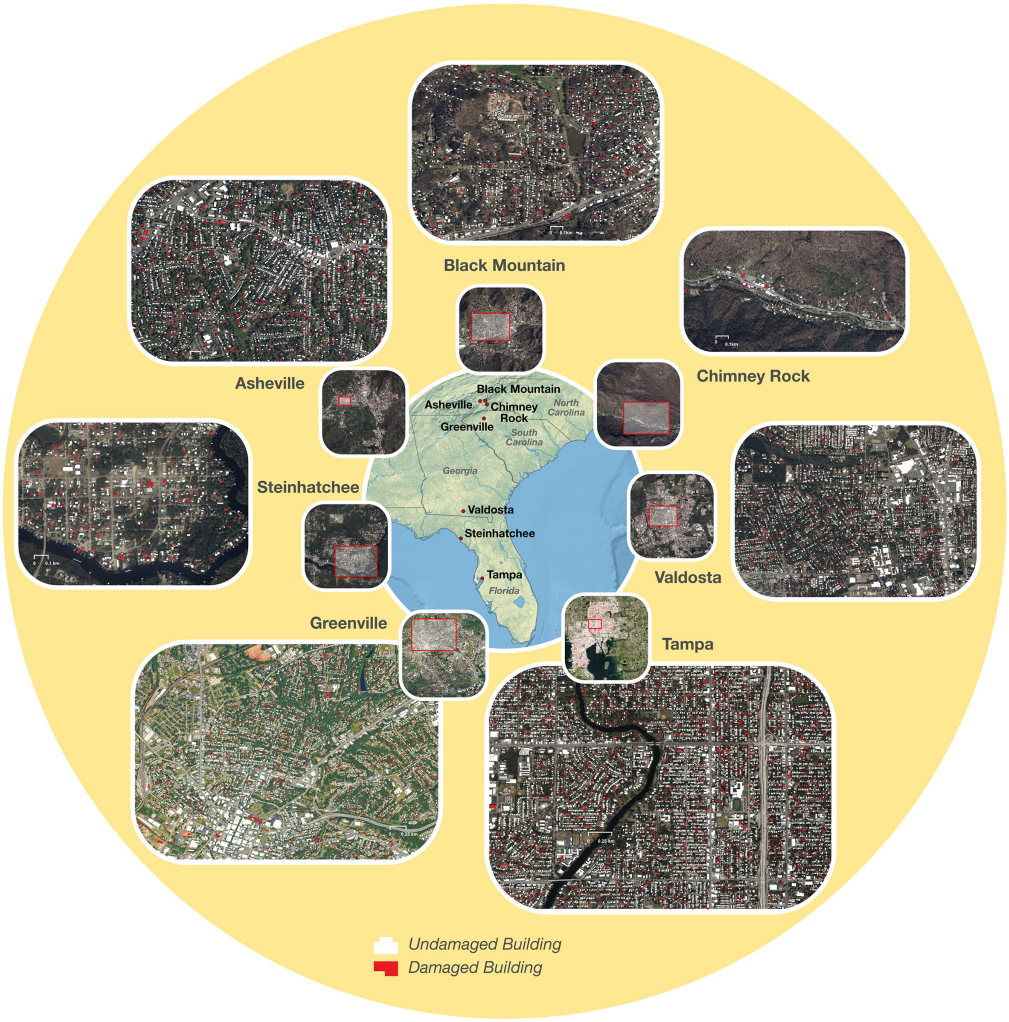

Figure 1. Building damage map. Damage probability for each building is calculated by applying a Bayesian image classification framework[4,5] to the interferometric coherence map of a SAR interferogram covering the hurricane event. Buildings with a damage probability exceeding 99% are highlighted in red for clear identification.

City	Total No. Building	Damaged Building (No.)	Damaged Building (%)	Threatened Property Value (US$)
Asheville	30,729	6,157	20	3,006,160,285
Black Mountain, NC	4,197	803	19	389,715,131
Chimney Rock, NC	196	33	17	15,784,146
Greenville, SC	20,958	5,098	24	1,780,580,441
Steinhatchee, FL	1,430	367	25	103,910,174
Tampa, FL	108,949	15,092	14	659,8252,483
Valdosta, GA	19,006	3,459	18	56,4062,692

Table 1. Total number of buildings, damaged buildings and the value of threatened properties in the main U.S. cities affected by Hurricane Helene

Recommendations

There are lessons to learn from Helene's disaster that help improve preparedness for disasters and community resilience. This tragic event in the southeast U.S. is a poignant example of the confluence of multiple factors, including urban development in floodplains (local human impact) and the specter of climate change (global human impact), with compounding effects that amplify the impact of natural disasters and hazards[6].

While a single climatic extreme event cannot be entirely attributed to climate change, it is well-known that climate change is a grim contributor to the immense rainfall, flooding, and destruction of hurricanes such as Helene[7]. As the world grapples with the consequences of a changing climate, the United States, too, is experiencing more erratic and unexpected weather extremes[8]. So, the unusually intense precipitation event due to Hurricane Helene may be attributed, in part, to a warming atmosphere with a higher capacity to hold moisture[7,9]. Ground-based observations and future projections indicate that the frequency and severity of such extreme precipitation events have increased and are expected to rise further[10,11]. This heightened frequency and intensity of extreme precipitation[12] are a stark reminder of the urgent need for adaptive measures in the face of this rapidly changing climate worldwide, reflecting the broader global challenge of climate change.

Nonetheless, the damages caused by extreme climate events such as floods and hurricanes cannot be blamed only on global climate change. The repeating stories of destructive floods around the world have one other local side that is often overlooked/ In recent decades, human settlements have expanded significantly into flood-prone areas worldwide[13], including the U.S. Southeast[14], a factor that drastically amplified the impact of Hurricane Helene. Many of these vulnerable communities are located in river valleys or downstream of dams, areas particularly susceptible to sudden and significant water discharges, further exacerbating the risk of severe flooding. The Appalachia, located in the central and southern sections of the Appalachian Mountains of the eastern U.S., is particularly vulnerable, with the record of experiencing nearly 20 federally declared flooding disasters in the last decade, costing 230 lives and at least $1 billion[15]. Urbanization and expansion of paved areas continue to reduce natural water absorption areas[16], leading to higher runoff into rivers and flood systems. Additionally, aging (flood protection) infrastructure plays a significant role in amplifying the destructive effects of extreme events and heightening the associated disaster risks[17,18]. A 2021 report by the American Society of Civil Engineers (ASCE) rated U.S. infrastructure—including airports, schools, roads, bridges, dams, and levees—as mostly in "mediocre" or "poor" condition, with only railways achieving a "good" rating[19]. The ASCE report estimated that $786 billion is needed to address the road maintenance backlog, $125 billion for bridges, and $45.2 billion for railways[20].

It is noteworthy that the legacy systems, including levees, dams, bridges, roads, and electrical grids, have not been originally designed to endure the growing severity of hurricanes exacerbated by climate change[21,22]. As these structures deteriorate, their vulnerability to failure during extreme weather events increases, resulting in structural failures, widespread flooding, power outages, and significant disruptions to transportation networks and emergency response operations, as was experienced during Hurricane Helene.

Final Remark

As extreme weather events, such as Hurricane Helene, become increasingly frequent, it is essential to reconsider development practices in flood-prone regions. The complex factors that exacerbated the impact of Hurricane Helene show that addressing these challenges will require a comprehensive approach, including investments in resilient infrastructure, improved land-use planning, stricter building codes, and the development of mitigation and adaptation measures to manage the increasing climate risks. This approach should also integrate evidence-based policy, cutting-edge research and education, strategies for climate change mitigation and adaptation, as well as the transfer and implementation of advanced technologies. Such a multi-disciplinary framework is vital for building resilience against the growing impacts of climate variability. By learning from Helene, we can take significant steps towards a more resilient future.

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Open Research

European Space Agency, Sentinel-1 SAR images were obtained through Alaska Satellite Facilities[23]. Microsoft's building footprint data were obtained from https://github.com/microsoft/USBuildingFootprints/tree/master

REFERENCES

1. Millions without power after Helene makes landfall. Power Grid. Retrieved from https://www.power-grid.com/td/outage-management/millions-without-power-after-helene-makes-landfall/. (Power Grid. (2024, September 26)).
2. Hurricane Helene live updates: Helene unleashes devastation across the Southeast. ABC News. Retrieved from https://abcnews.go.com/US/live-updates/hurricane-helene/?id=113931821. (ABC News. (2024, September 26)).
3. Cann, C., Honosky, S. & Seaton, I. in USA TODAY (2024).
4. Sherpa, S. F. & Shirzaei, M. Countrywide flood exposure analysis using Sentinel1 synthetic aperture radar data: Case study of 2019 Iran flood. Journal of Flood Risk Management 15, e12770 (2022).
5. Sherpa, S. F., Shirzaei, M., Ojha, C., Werth, S. & Hostache, R. Probabilistic Mapping of August 2018 Flood of Kerala, India, Using Space-Borne Synthetic Aperture Radar. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 13, 896-913 (2020).
6. AghaKouchak, A. et al. Climate Extremes and Compound Hazards in a Warming World. Annual Review of Earth and Planetary Sciences 48 (2020).
7. Raymond, Z. Hurricane Helene and climate change. The New York Times. Retrieved from https://www.nytimes.com/2024/10/09/climate/hurricane-helene-climate-change.html on October 28, 2024. (2024).
8. Jay, A. K. et al. Ch. 1. Overview: Understanding risks, impacts, and responses. In: Fifth National Climate Assessment. Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds. U.S. Global Change Research Program, Washington, DC, USA. https://doi.org/10.7930/NCA5.2023.CH1. (2023).
9. Nuccitelli, D. Climate change made Hurricane Helene and other 2024 disasters more damaging, scientists find. Yale Climate Connections. Retrieved from https://yaleclimateconnections.org/2024/10/climate-change-made-hurricane-helene-and-other-2024-disasters-more-damaging-scientists-find/. (2024, October).
10. Papalexiou, S. M. & Montanari, A. Global and regional increase of precipitation extremes under global warming. Water Resources Research 55, 4901-4914 (2019).
11. Trenberth, K. E. Changes in precipitation with climate change. Climate research 47, 123-138 (2011).
12. Ragno, E. et al. Quantifying changes in future intensity duration frequency curves using multimodel ensemble simulations. Water Resources Research 54, 1751-1764 (2018).
13. Rentschler, J. et al. Global evidence of rapid urban growth in flood zones nce 1985. Nature 622, 87-92 (2023).
14. Burby, R. J. Flood insurance and floodplain management: the US experience. Global Environmental Change Part B: Environmental Hazards 3, 111-122 (2001).
15. Kuhnline, D. New platform seeks to boost flood resiliency in Central Appalachia. https://appvoices.org/2024/08/30/flood-resiliency-platform/. ((2024, August 30)).
16. Sun, X., Crittenden, J. C., Li, F., Lu, Z. & Dou, X. Urban expansion simulation and the spatio-temporal changes of ecosystem services, a case study in Atlanta Metropolitan area, USA. Science of the Total Environment 622, 974-987 (2018).
17. Vahedifard, F., Azhar, M., Brown, D. C. & Madani, K. Inequity Behind Levees: The Case of the United States of America, United Nations University Institute for Water, Environment and Health (UNU-INWEH), Hamilton, Ontario, Canada. (2023).
18. Perera, D., Smakhtin, V., Williams, S., North, T. & Curry, A. Ageing water storage infrastructure: An emerging global risk. UNU-INWEH Report Series 11, 25 (2021).
19. (ASCE), A. S. o. C. E. Infrastructure Report Card. http://www.infrastructurereportcard.org/. [Accessed 12 December 2022]. (2021).
20. Ohenhen, L. O., Shirzaei, M. & Barnard, P. L. Slowly but surely: Exposure of communities and infrastructure to subsidence on the US east coast. PNAS nexus 3, pgad426 (2024).
21. Mikellidou, C. V., Shakou, L. M., Boustras, G. & Dimopoulos, C. Energy critical infrastructures at risk from climate change: A state of the art review. Safety Science 110, 110-120 (2018).
22. Neumann, J. E. et al. Climate change risks to US infrastructure: impacts on roads, bridges, coastal development, and urban drainage. Climatic Change 131, 97-109 (2015).
23. ASF. Copernicus Sentinel data. Retrieved from Alaska Satellite Facilities (ASF) DAAC on October 20, 2024 at https://search.asf.alaska.edu, processed by ESA. . (2024).

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