Wetlands Versus Coastal Development: Effects on Flood Damage

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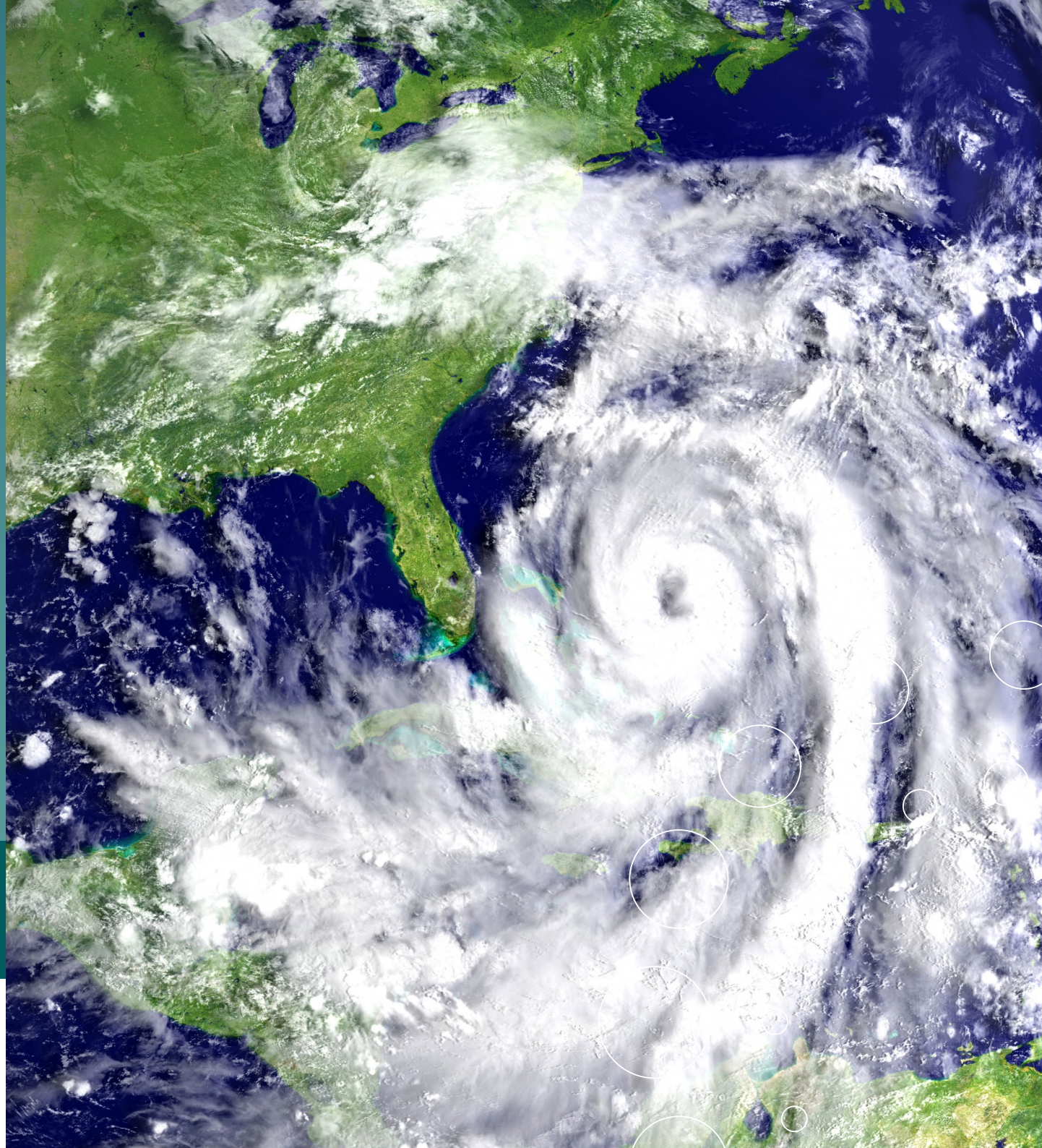

Wetlands Versus Coastal Development: Effects on Flood Damage

Hurricane storm surges pose serious damage risks to the United States' coastlines. Tidal wetlands protect communities by acting as barriers, reducing the effects of these surges. However, simultaneous coastal development and wetland loss can lead to increased damage during storm surges. Using the 2008 Hurricane Ike as a case study, Dr Siddharth Narayan from East Carolina University and colleagues demonstrated the costly impact that continued coastal development and increased real estate value have on the damages caused during storm surges, as well as the important but locally variable role that existing wetlands play in reducing these impacts.

Hurricane Storm Surges

When hurricanes hit the coastlines of the United States (US), storm surges are one of the main causes of inland flooding and the dominant cause of damage to infrastructure and people's lives. Between 1900 and 2017, hurricanes caused $2 trillion worth of economic damages and led to the loss of more than 16,000 lives across the continental US.

Tidal wetlands act as natural barriers to these storm surges, reducing the extent and height of flooding, which minimises damage to infrastructure and the number of lives lost. However, the loss of wetlands due to property development along shorelines reduces coastal protection from storm surges – increasing the risk of damage to people and infrastructure.

This pressing concern is the focus of recent work by Dr Siddharth Narayan from East Carolina University, together with lead author Zaid Al-attabi and co-authors Yicheng Xu and Georgette Tso. Using the 2008 Hurricane Ike as a case study, the researchers modelled the effects of combined wetland loss and coastal development on storm surge extent and damage caused in Galveston Bay, Texas, over 10-year timescales. Looking at the effects of Hurricane Ike on the Galveston Bay region represents a useful example for assessing damage risk as the area is densely populated, at risk from hurricanes, and has large areas of tidal wetlands.

Modelling Storm Surges

Dr Narayan and colleagues used a two-dimensional hydrodynamic storm surge model to review the combined impact of tidal wetland loss and property development on damages in 2008, and if Hurricane Ike had hit the same region in 2019. Once the model was set up and validated to simulate the storm surge extent and height of Hurricane Ike in 2008 across Galveston Bay, the extent of flooding and subsequent damages were assessed across three scenarios:

1. 2008 'Baseline' – the model mimics conditions at the time when Hurricane Ike struck.
2. 2008 'No Wetlands' – the model replaces tidal wetlands existing in 2008 with open water to review the protection benefits of tidal wetlands on storm surge damages.
3. 2019 'Present Day Hurricane Ike' – the model uses the recorded sea level in 2019, the rise of sea level between 2008 and 2019, and how land use has changed (wetland versus property development) since 2008.

Subsequently, Dr Narayan used these scenarios to share his insights on the positive effects of tidal wetlands and the economic damages that come with increased coastal development.

Why Conserving Tidal Wetlands is Critical

This modelling by Dr Narayan and his colleagues highlights the importance of conserving tidal wetlands to protect coastlines from storm surges. Across the 2008 scenarios modelled, tidal wetlands reduced the storm surge flood height by between 0.25 and 0.9 m and the peak flooding extent by 112 km2. Additionally, the tidal wetlands protected approximately 18,000 people from the flooding.

The importance of these tidal wetlands is reinforced by the modelling of storm surge flooding with no tidal wetlands in place to protect the coastline (2008 'No Wetlands' scenario). In this scenario, total tidal wetland loss would have increased the flooding across Galveston Bay, resulting in more people being impacted and a wider area being subject to extreme flood

depths. Dr Narayan estimates that, on average, the tidal wetlands prevented an astonishing $1.1 million per km2 of damages during storm surge flooding.

According to the modelling, the presence of tidal wetlands had a negative effect in very few areas. In these areas, flooding depth and damages increased, although this contributed to less than 0.3% of the baseline losses seen in 2008.

Damage Risks of Coastal Development and Real Estate Value

If Hurricane Ike had hit Galveston Bay in 2019, the extent of flooding caused by the storm surge would have been very similar to that seen in 2008. The damages that would have been caused in 2019, however, would have been approximately 35% greater – about $2.52 billion more. Dr Narayan highlights that coastal development and increases in real estate value between 2008 and 2019 would have been responsible for 99.7% of this increase. Of that 99.7%, nearly 90% would have been a result of increased real estate values alone. To put this in context, the average value of wetlands across the bay during Ike was >$1 million per km^2.

From 2008 to 2019, there was a net tidal wetland loss of less than 4% (31 km^2) in the Galveston Bay area. This loss would have aggravated the damages of the storm surge but pales into insignificance when compared to the effects of the increase in real estate value over the same period.

What Can We Learn?

While storm surges are the primary physical cause of flooding during hurricanes, the primary driver of risk from flooding over the last decade has been continued coastal development that increases exposure. Climate change will only worsen the damage risks posed by storm surges, leading to further economic and social losses in the future. Dr Narayan's work has highlighted the importance of development in driving flood risk, and the ability of tidal wetlands to protect these communities and infrastructure. This ability, coupled with effective conservation efforts, which resulted in a minimal net loss of tidal wetlands between 2008 and 2019 in the Galveston Bay area, emphasises the importance of maintaining and restoring these natural barriers to protect the coastlines.

Dr Narayan's team's work also shows that the benefits of tidal wetlands during a storm are highly spatially variable. In some places, the presence of wetlands could also worsen the situation by increasing flood heights.

Dr Narayan's work focused solely on hurricane-generated storm surge damages across the Galveston Bay area. Wave-induced flooding can also play a significant role in influencing flooding extent and damage during a hurricane. Tidal wetlands act as effective barriers to wave-induced flooding by reducing wave height. In future work, factoring in wave-induced flooding to the modelled scenarios will further help constrain damages and the effectiveness of tidal wetlands. In addition, increased resolution to the modelling would assist with understanding flooding effects on a finer scale, which would benefit planners and restoration projects, providing clear advice on where best to develop and best to protect.

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Hurricane Irma, Florida.

MEET THE RESEARCHERS

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Dr Siddharth Narayan is an Assistant Professor at East Carolina University investigating coastal hazards. His research focuses on understanding how coastal hazards interact with coastal ecosystems such as wetlands and reefs, and how these can be managed and restored to reduce risks to coastal communities. Dr Narayan obtained his PhD in Coastal Engineering from the University of Southampton (UK) before moving to the University of California (USA) as a Postdoctoral Fellow and then a Research Scientist on coastal nature-based adaptation.

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Dr Zaid Al-Attabi is a Postdoctoral Researcher at East Carolina University, where he works alongside Dr Narayan using numerical modelling to simulate the interaction of coastal processes (waves, surges) with reefs and vegetation. Dr Al-Attabi obtained his Bachelor of Science and Master of Science degrees from the University of Basrah (Iraq) before moving to the University of South Carolina (USA), where he obtained his PhD in Physical Oceanography.

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FURTHER READING

Z Al-Attabi, Y Xu, G Tso, S Narayan, The impacts of tidal wetland loss and coastal development on storm surge damages to people and property: a Hurricane Ike case-study, *Scientific Reports*, 2023, 13(1), 4620. https://doi.org/10.1038/s41598-023-31409-x

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