Climate change has caused billions of dollars in flood damages

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In a new study, Stanford researchers report that intensifying precipitation contributed one-third of the financial costs of flooding in the United States over the past three decades, totaling almost $75 billion

of the estimated $199 billion in flood damages from 1988 to 2017.

The research, published Jan. 11 in the journal *Proceedings of the National Academy of Sciences*, helps to resolve a long-standing debate about the role of climate change in the rising costs of flooding and provides new insight into the financial costs of global warming overall.

"The fact that extreme precipitation has been increasing and will likely increase in the future is well known, but what effect that has had on financial damages has been uncertain," said lead author Frances Davenport, a Ph.D. student in Earth system science at Stanford's School of Earth, Energy & Environmental Sciences (Stanford Earth). "Our analysis allows us to isolate how much of those changes in precipitation translate to changes in the cost of flooding, both now and in the future."

The global insurance company Munich Re calls flooding "the number-one natural peril in the U.S." However, although flooding is one of the most common, widespread and costly natural hazards, whether climate change has contributed to the rising financial costs of flooding—and if so, how much—has been a topic of debate, including in the most recent climate change assessments from the U.S. government and the Intergovernmental Panel on Climate Change.

At the crux of that debate is the question of whether or not the increasing trend in the cost of flooding in the U.S. has been driven primarily by socioeconomic factors like population growth, housing development and increasing property values. Most previous research has focused either on very detailed case studies (for example, of individual disasters or long-term changes in individual states) or on correlations between precipitation and flood damages for the U.S. overall.

In an effort to close this gap, the researchers started with higher resolution climate and socioeconomic data. They then applied advanced

methods from economics to quantify the relationship between historical precipitation variations and historical flooding costs, along with methods from statistics and climate science to evaluate the impact of changes in precipitation on total flooding costs. Together, these analyses revealed that climate change has contributed substantially to the growing cost of flooding in the U.S., and that exceeding the levels of global warming agreed upon in the United Nations Paris Agreement is very likely to lead to greater intensification of the kinds of extreme precipitation events that have been most costly and devastating in recent decades.

"Previous studies have analyzed pieces of this puzzle, but this is the first study to combine rigorous economic analysis of the historical relationships between climate and flooding costs with really careful extreme event analyses in both historical observations and global climate models, across the whole United States," said senior author and climate scientist Noah Diffenbaugh, the Kara J. Foundation Professor at Stanford Earth.

"By bringing all those pieces together, this framework provides a novel quantification not only of how much historical changes in precipitation have contributed to the costs of flooding, but also how greenhouse gases influence the kinds of precipitation events that cause the most damaging flooding events," Diffenbaugh added.

The researchers liken isolating the role of changing precipitation to other questions of cause and effect, such as determining how much an increase in minimum wage will affect local employment, or how many wins an individual player contributes to the overall success of a basketball team. In this case, the research team started by developing an economic model based on observed precipitation and monthly reports of flood damage, controlling for other factors that might affect flooding costs like increases in home values. They then calculated the change in extreme precipitation in each state over the study period. Finally, they used the

model to calculate what the economic damages would have been if those changes in extreme precipitation had not occurred.

"This counterfactual analysis is similar to computing how many games the Los Angeles Lakers would have won, with and without the addition of LeBron James, holding all other players constant," said study co-author and economist Marshall Burke, an associate professor of Earth system science.

Applying this framework, the research team found that—when totaled across all the individual states—changes in precipitation accounted for 36 percent of the actual flooding costs that occurred in the U.S. from 1988 to 2017. The effect of changing precipitation was primarily driven by increases in extreme precipitation, which have been responsible for the largest share of flooding costs historically.

"What we find is that, even in states where the long-term mean precipitation hasn't changed, in most cases the wettest events have intensified, increasing the financial damages relative to what would have occurred without the changes in precipitation," said Davenport, who received a Stanford Interdisciplinary Graduate Fellowship in 2020.

The researchers emphasize that, by providing a new quantification of the scale of the financial costs of climate change, their findings have implications beyond flooding in the U.S.

"Accurately and comprehensively tallying the past and future costs of climate change is key to making good policy decisions," said Burke. "This work shows that past climate change has already cost the U.S. economy billions of dollars, just due to flood damages alone."

The authors envision their approach being applied to different natural hazards, to climate impacts in different sectors of the economy and to

other regions of the globe to help understand the costs and benefits of climate adaptation and mitigation actions.

"That these results are as robust and definitive as they are really advances our understanding of the role of historical precipitation changes in the financial costs of flooding," Diffenbaugh said. "But, more broadly, the framework that we developed provides an objective basis for estimating what it will cost to adapt to continued climate change and the economic value of avoiding higher levels of global warming in the future."

More information: Frances V. Davenport el al., "Contribution of historical precipitation change to US flood damages," *PNAS* (2020). www.pnas.org/cgi/doi/10.1073/pnas.2017524118

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