Costs of Catastrophe: An Analysis of Natural Hazards and Losses in Pennsylvania, 2000-2021

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Abstract

Losses from natural hazards in the United States are rising as development concentrates more people in hazard prone areas. In Pennsylvania, flooding, severe storms, and winter weather are among the most common natural hazards. Using county-level data from the Spatial Hazard Events and Losses Database for the United States (SHELDUS), this study explores the economic and human costs from natural hazard events in Pennsylvania from 2000 to 2021. During this time period, losses from natural hazards exceeded $3.7 billion in the Commonwealth, with over $3 million in property losses and more than $19 million in crop losses. These hazards resulted in 440 fatalities and over 1,000 injuries for the time period. Losses from natural hazards show distinct differences among urban and rural counties in Pennsylvania. An assessment of economic and human losses from natural hazards is critical for the development of strategies that effectively reduce their effects. Results of this analysis can contribute to a better understanding of the geographic variability in natural hazard impacts and can serve as a first step toward evaluating the effectiveness of existing hazard mitigation, disaster assistance, and disaster recovery policies in Pennsylvania.

Introduction

Billion-dollar weather and climate events in the United States have risen since 1980, with 403 events accounting for a total cost of more than $2.9 trillion. Disaster loss reduction, frequently called hazard mitigation, refers to actions taken before a disaster occurs that minimize the loss of life and property as a result of exposure and impacts of natural hazards.

Hazard mitigation promotes community resilience and is affordable, with options ranging from elevating structures to adopting and enforcing building codes (Godschalk et al. 2009). The National Institute of Building Sciences (NIBS) showed that hazard mitigation saves $6 on average for every $1 spent on federal grants and has the potential to save up to $13 per $1 invested.

To increase community resilience to disasters in Pennsylvania, there is a critical need to assess natural hazard events, losses, and their impacts on counties. This information is vital for making evidence-based decisions and developing strategies that successfully reduce the effects of natural hazards (Gall and Cutter 2016). Sound baseline data allow for a better understanding of the geographic variability in natural hazard impacts and can aid in evaluating the effectiveness of existing hazard mitigation, disaster assistance, and disaster recovery policies. Our knowledge of trends in hazards and losses at local levels of analysis is very limited. Disasters are inherently local so all actions to effectively reduce losses of life and property must be locally based.

Background and Methodology

Secondary data were obtained from the Spatial Hazard Events and Losses Database for the United States (SHELDUS), the only county-level dataset which includes direct property and crop losses and fatalities and injuries for natural hazards from 1960 to present. The following information was acquired for all 67 counties in the state of Pennsylvania from January 1, 2000 to December 31, 2021: hazards, property losses, crop losses, fatalities, and injuries. Data were adjusted for inflation and aggregated by county, year/month, and hazards which generated the least aggregated and most highly resolved data. Annual losses (property, crop, fatalities, and injuries) were summed for all hazards by county as well as property losses by hazard type and fatalities by hazard type.

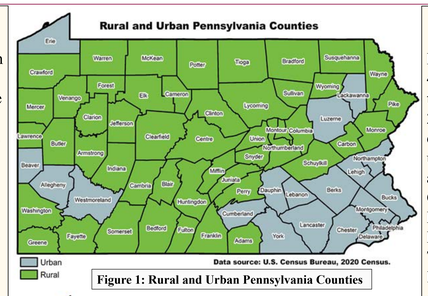

Figure 1: Rural and Urban Pennsylvania Counties

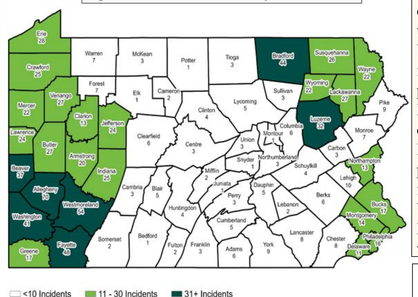

Figure 2: Flooding Incidents per County, 2000-2021

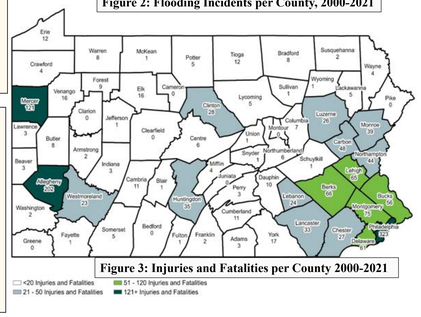

Figure 3: Injuries and Fatalities per County 2000-2021

Data and Analysis

Property losses from hazards in urban and rural counties have shown sharp increases and decreases over the 21-year time period (see Figure 4). For urban counties, the greatest property losses occurred in 2004, 2006, 2011, and 2021, altogether accounting for almost 64% of their total property losses, or $1.5 billion for the time period. In contrast, rural counties experienced the greatest property losses in 2003, 2004, 2006, and 2011, collectively accounting for more than 73% of their total property losses, or $1 billion. Interestingly, rural counties experienced higher losses than their urban counterparts in 2003, 2006, 2016, and 2019. While property losses showed a steady decline in urban counties from 2017 to 2020, losses skyrocketed in 2021, their second costliest year on record. Years with the highest property losses are consistent with hazard events that resulted in Presidential Disaster Declarations (PDDs), ranging from 3 to 12 in individual counties. Compared to urban counties, rural counties were issued a total of 287 declarations or more than 66% of the total PDDs declared in Pennsylvania.

Deaths and injuries due to natural hazards in rural and urban counties from 2000 to 2021 show distinct trends over time (see Figures 5 and 6). The deadliest hazards in Pennsylvania are heat, flooding, and wind accounting for nearly 85% of all hazards occurring. Winter weather, lightning, wind, and heat are responsible for nearly 70% of injuries (see Table 2). Heat appears to pose a greater risk to those living in urban counties accounting for 269 deaths and 168 injuries from 2000 to 2021. This finding suggests that additional measures should be undertaken to mitigate the impacts of heat, especially among vulnerable populations like the elderly and those living in poverty.

Urban and rural trends regarding flooding are also interesting. While flooding in rural counties accounts for $1.1 billion in property losses, it is responsible for $23,345.34 in property losses per capita. This is in contrast to flooding in urban counties which accounts for $1.8 billion in property losses, and $4,711.38 in losses per capita.

Hurricanes and tropical storms have a stronger impact in urban counties. More than $8.7 million in property losses were incurred in urban counties, equating to $19.85 per capita. This is in sharp contrast to $440k in property losses in rural counties and $2.59 per capita.

Property losses from severe storms are nearly equal in urban and rural counties clocking in at more than $43 million, respectively. However, property losses per capita in rural counties are $669 compared to $99 in urban counties. Urban counties experienced more deaths and injuries from severe storms than their rural counterparts.

Winter weather accounts for more than $146 million in property losses in urban counties compared to $59.9 million in rural counties. However, rural residents incur $743 in property losses per capita compared to $438 among urban residents. While more deaths from winter weather hazards occur in urban counties, rural counties experience more injuries.

Hazard Type	Property Losses	Percent of Total	Property Losses Per Capita	Percent of Total
Avalanche	$15,317.82	0.00%	$0.01	0.00%
Flooding	$2,931,085,498.36	79.35%	$28,056.72	81.93%
Hail	$7,116,336.48	0.19%	$69.42	0.20%
Heat	$43,767.36	0.00%	$0.04	0.00%
Hurricane/Tropical Storm	$9,149,705.40	0.25%	$22.44	0.07%
Landslide	$124,193.21	0.00%	$0.73	0.00%
Lightning	$20,890,565.33	0.57%	$67.09	0.20%
Severe Storm/Thunderstorm	$87,637,547.37	2.37%	$768.70	2.24%
Tornado	$191,610,924.42	5.19%	$2,467.12	7.20%
Wildfire	$1,951,067.01	0.05%	$8.30	0.02%
Wind	$237,869,798.14	6.44%	$1,600.07	4.67%
Winter Weather	$206,243,354.49	5.58%	$1,182.60	3.45%
Hazard Total	$3,693,738,075.38		$34,243.25	

Table 1: Property Losses by Hazard Type, 2000-2021

Hazard Type	Injuries	Percent of Total
Winter Weather	231.5	21.47%
Lightning	179	16.60%
Wind	173	16.05%
Heat	172	15.96%
Severe Storm/Thunderstorm	123.5	11.46%
Flooding	106	9.83%
Tornado	92	8.53%
Wildfire	1	0.09%

Table 2: Number of Injuries by Hazard Type, 2000 – 2021

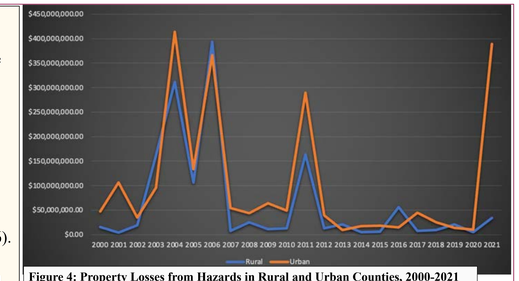

Figure 4: Property Losses from Hazards in Rural and Urban Counties, 2000-2021

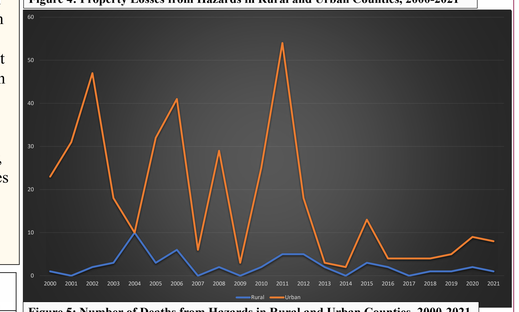

Figure 5: Number of Deaths from Hazards in Rural and Urban Counties, 2000-2021

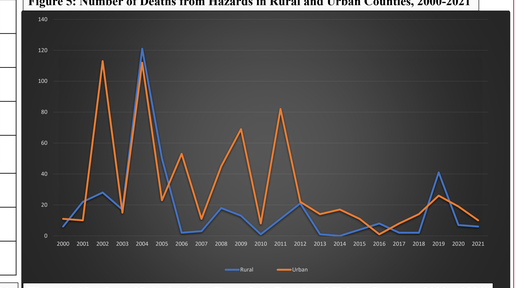

Figure 6: Number of Injuries from Hazards in Rural and Urban Counties, 2000 – 2021

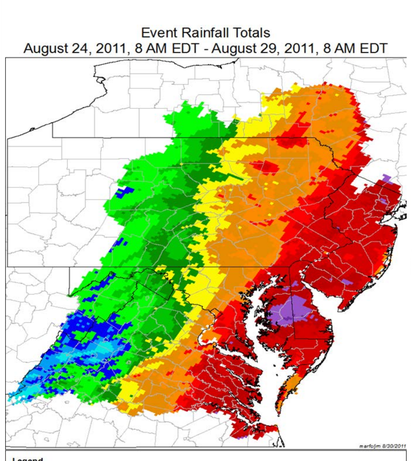

Figure 7: Total rainfall from Hurricane Irene just two weeks before Tropical Storm Lee flooded the area

Figure 8: Hershey Giant Center Aftermath of Tropical Storm Lee

Figure 9: Examples of Erosion from Tropical Storm Lee

Figure 10: I-80 Deserted after Snowmageddon

Figure 11: PennDOT Removing Snow

Figure 12: Snowmageddon, 2010 Aftermath in Western Pennsylvania

Figure 13: Snowmageddon, PennDOT Snow Removal, 2010

Solutions and Success

From 2000 to 2021, natural hazards cost Pennsylvania more than $3.7 billion, with $19 million stemming from crop losses and $3.6 billion from property losses. This equated to over $34,000 in total losses per capita. Hazard mitigation planning provides an opportunity to proactively assess risk and discourage development away from hazard prone areas and as a result has been shown to improve disaster preparedness and reduce vulnerability. Land-use planning and zoning regulations should be integrated with other plans including, but not limited to stormwater management, floodplain management, transportation, open space, disaster recovery, climate change, and hazard mitigation to reduce duplication of effort and improve efficiency among key partners. Rural areas in particular stand to benefit from practices and policies that require coordination between emergency managers, land-use planners, floodplain managers, utility companies, watershed and environmental protection specialists, GIS analysts and others across several state agencies, such as the Departments of Environmental Protection, Health Community and Economic Development, Transportation, and Conservation and Natural Resources.

Figure 14: Flooding in Middletown After Tropical Storm Lee

Figure 15: Stream Restoration Project

Case Study: Tropical Storm Lee, September 6-8, 2011:

Tropical Storm Lee dumped between 6 and 12 inches of rainfall in northeastern Pennsylvania over a 48-hour period, which resulted in catastrophic flooding on several small streams, creeks, and larger tributaries of the Susquehanna River that had not been seen since Hurricane Agnes in 1972. Given the extremely saturated conditions of the soil due to above-average rainfall in August, moisture from Tropical Storm Lee could not be absorbed into the soil and immediately ran off, leading to rapidly rising streams which placed people and property at risk. A major spike in property losses occurred during 2011, resulting from damages incurred during Tropical Storm Lee and Hurricane Irene, both of which hit Pennsylvania in September about ten days apart (see Figure 4).

Tropical Storm Lee's damage to highways, bridges, and other transportation infrastructure, exceeded $400 million. It completely destroyed over 1,000 homes and businesses, and reports show at least minor damage to more than 16,000 homes and businesses. Tropical Storm Lee was not only destructive to physical property, but it also effected the geology and channel patterns for streams within the watersheds. Over 6,700,000 cubic meters of gravel was mobilized during the flooding across four different Pennsylvania watersheds (Kochel et al. 2016).

Case Study: Snowmageddon February 5-10, 2010

In early February 2010, Pennsylvania was hit by two major snowstorms just four days apart. The storm on February 5, brought about 18 inches of snowfall, while the second dropped 10-20 inches in some parts of the state. Snow accumulated on powerlines resulting in widespread outages for more than 70,000 residents. Portions of I-80, I-78, I-295, and the PA/NJ turnpike were closed for two days following the storm. The state prioritized winter weather preparedness, cancelling school and activities in advance of the storm to prevent people from traveling in dangerous conditions. Winter weather is responsible for the highest number of injuries from 2000-2021.

Previous studies have shown that 56%-74% of winter weather related injuries occurred due to slipping or falling on snow or ice. Fall-related injuries were more common among adults aged 18-64, and the majority of injuries took place on weekdays during the morning hours of 7-11, likely due to the commute to work or school (Gevitz et al. 2017).

It is critical for counties to have hazard mitigation measures in place to minimize winter weather related injuries and deaths. Timely snow and ice removal, adequate lighting of streets and walkways in urban counties like Philadelphia, issuance of weather alerts and warnings, and safe walkway designs can reduce risk throughout the year but especially during the winter months. Winter weather is a frequent hazard that affects Pennsylvania residents, with disruptions to transportation, energy, and infrastructure networks.

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Acknowledgements

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