

Defining Damage: Geospatial Analysis of Crop Insurance Claims and Severe Weather Events

Genevieve Giammarco

Natural hazards such as hail and wind pose significant threats to agriculture and cropland, often causing billions of dollars in damage each year. The severity of crop damage can be measured using USDA indemnity data, or the amount of money farmers are given to make up for the loss of crops. Indemnity has been reported to be increasing over time since 1989 while the number of claims filed has remained steady. To understand why this temporal trend exists, we must determine what factors influence the amount of indemnity. This study assessed the influence of storm magnitude through a geospatial analysis of severe hail and wind events in comparison to indemnity across the Midwest region from 2008 to 2014. USDA indemnity data was mapped at county-level measures against hail events that had stones with a diameter of at least 25.4 mm (1 inch) and wind events with speeds of at least 38 knots (40 mph). There was no apparent spatial relationship between the severity of weather events and insurance indemnity. The severe weather events had a correlation with the location of farms while the crop insurance data did not, showing a concerning discrepancy for the future of food production. Thus, the severity of weather events was not a strong factor that influenced the calculation of crop insurance indemnity. Further research is needed to assess other potential factors that determine the USDA's crop insurance indemnity.

Introduction

Since 1980, there have been over 400 climate disasters that have resulted in billions of dollars in damage (1). Half of these disasters were severe weather events such as damaging winds, hail, and tornadoes. Together, losses from these events have totaled over \$510 billion in damage in the last 35 years (1). Though these losses are important to evaluate severe weather risk and disaster potential, they do not provide information on what, where, or how destroyed entities – like farmland or buildings – were damaged by severe weather hazards. For instance, the Midwest United States (U.S.) experiences significant crop damage from weather events since the area is favorable to both farming and hazard occurrence (2). Evaluating crop damage from severe wind and hail events in the Midwest provides another perspective on severe weather risk, exposure, and monetary losses. Specifically, this evaluation can be done using crop insurance data from the U.S. Department of Agriculture (USDA). The extent of damage is provided by the USDA through the reported indemnity, or the amount of money paid to farmers based on “the extent and magnitude of the damage” to crops (2, p. 970). In other words, indemnities are payments to help mitigate losses to farmers who have experienced impacts from hazards.

Previous studies have utilized indemnity as a metric for measuring the impact of severe weather on crops. However, the use of this metric also presents a

knowledge gap in the understanding of indemnity. While trends in crop losses from hail events have remained stable from 1989 to 2020, indemnities have increased over time (2). Researchers also found a spatial relationship between severe weather events and acreage of farmland, showing that farm characteristics have some influence on indemnity, but indemnity does not exactly align with these factors (2). Thus, this study shows that there is little known about how the USDA quantifies indemnity, or more specifically, how it defines the damage to crops. Understanding this disparity is critical for predicting the future of food production and supply within the U.S. as the climate continues to change. This study improves the understanding of the USDA's definition of crop damage through a geospatial analysis of midwestern U.S. crop insurance claim data as it relates to hail and severe wind events. Our analysis focuses on events and claims from 2008 and 2014, given data availability limitations and the record number of losses associated with severe weather and crops (i.e., >10 billion; [1]).

Hail is a form of frozen precipitation that falls from thunderstorms and most often occurs during the warm season from March through August (2-3). Damaging wind is defined as winds that exceed 40 mph and is also most likely to occur during the warm season months (4). In general, most severe hail and thunderstorm winds tend to occur east of the Rocky Mountains across the Great Plain region during the months of June and July (5). Localized convective storms that produce severe weather result

from moisture in large bodies of water, instability, and wind shear which describes the changing wind direction and speed from altitude. The juxtaposition of these severe weather ingredients is common across the Great Plains, leading to severe thunderstorm hazards such as hail and wind (3). Unfortunately, the production of severe weather often occurs in large areas where millions of acres of wheat, corn, soybeans, and other high demand crops are grown (2). Both hail and severe wind are also a topic of concern for agriculture in the Midwest since the risk, or potential of impact from a severe weather event, increases over time due to climate and landscape changes.

Rising global temperatures are predicted to increase the risk for more severe weather events in Midwestern states (6, 7). Studies predict that anthropogenic atmospheric warming will result in an increase in severe winds across the Midwest, while the rest of the country may see a significant decrease in severe wind events (6). Additionally, researchers predict that the atmosphere will become more favorable to convective instability over the central U.S. as temperatures rise, increasing the chances for more frequent and greater magnitude severe hail and wind events. These events are projected to occur more often in Spring and Summer when crops are planted and growing; thus, making the crops more vulnerable to severe hail impacts (7). In addition to climate change, human activity such as development sprawl and increasing population also influences crop exposure to severe weather.

Studies have found that crop production is growing more intense and becoming more specialized in concentrated areas. In other words, the total number of farms and total cropland area is decreasing over time, while remaining farms are increasing their output with less overall cropland areas (8). This is especially true in the Midwest where corn and wheat are most often produced (2). Together, a changing atmosphere coupled with increasingly vulnerable agricultural landscape means that the likelihood of losses on crops may increase over time. Nevertheless, indemnity can assist in mitigation efforts since revealing the underlying factors can show what can be changed in modern farming practices and how it can ensure the future of agriculture.

Methods

Crop loss insurance claim data was obtained from the USDA's website (9). Claims were organized by year in .csv files. Each file provided every claim reported through the USDA, detailing the county and state where the damage occurred, as well as the cause of loss and indemnity for each incident. This data was filtered on events where severe wind or hail were named as the cause of loss. Additionally, data was filtered to only show claims from the following Midwest States: Illinois, Indiana, Iowa, Kansas, Nebraska,

North Dakota, Michigan, Minnesota, Missouri, Ohio, South Dakota, and Wisconsin.

Before mapping the data, it was prepared and organized using Microsoft Excel. The indemnity for each claim was adjusted for inflation based on 2025 consumer-price index (CPI) values. The claims were then organized through a geographic information system (GIS); specifically, Environmental Systems Research Institute's (Esri) ArcGIS Pro Frequency Tool, which calculates the average indemnity for each county for 2008 and 2014. The newly determined indemnities were mapped at the county scale. The resulting county areas were then used to normalize the indemnity data per square mile given counties are a variety of total areas.

The data on actual weather events was downloaded from NOAA's National Weather Service Storm Prediction Center (NWS SPC). Specifically, the SPC's severe weather GIS dataset (SVRGIS) provides hail and severe wind data as latitude and longitude points from 1955 to 2023. Once downloaded and uploaded into the GIS, the severe weather event (hail and wind reports) points were filtered to 2008 and 2014 to match the indemnity data. Additionally, these points were filtered to only show events where hailstones had a diameter of at least 25.4 mm (1 inch), and wind with speeds of at least 38 knots (40 mph). The filtered data was saved as a separate feature class for each year and severe weather type. This SVRGIS data was also run through Esri's Kernel Density tool to provide a general overview of its spatial patterns for each year.

In addition to these two datasets, we conducted analyses of farm size and number using data from the USDA Census of Agriculture. This data was grouped into a .csv file for every five years starting in 1997 and ending in 2022. Each file was compiled into one Excel sheet and filtered to just the Midwest region. The average (mean) acreage and number of farms were also calculated in Excel. This data was joined to a blank county shapefile and values normalized based on the county size in square miles.

All shapefiles and features classes were projected using the Albers Equal Area Conic coordinate system. Additional attributes were mapped to provide context through the locations of major roads and cities using publicly available feature classes. Both feature classes were filtered to show interstate highways and cities with a population of at least 250,000 people.

The datasets were further evaluated through percentile rankings. The NOAA weather events data was spatially joined to a county shapefile to determine the number of hail and severe wind events per county for 2008 and 2014. Then, these tables were exported to Excel where the count of events was normalized based on county area in units of square miles. The percentile ranking was calculated for each county using Excel where 1 was the highest rank representing the 100th percentile. This ranking means

that the number of events for the county was higher than nearly all the other counties in the Midwestern states. This calculation was repeated for the normalized indemnity. The top ranked counties for the normalized number of events for each event type were isolated along with their percentile ranking for indemnity per county size. Percentile rankings were also calculated for the average number of farms and average acreage per county square mile. The top ranked counties for both size and number were also pulled into a separate table.

Results

Hail Indemnity and Events

The hail events had distinct spatial distributions for both 2008 and 2014. In Figure 1.a, hail events were more common in the western states in 2008, particularly in Kansas and Nebraska. There was some activity in the eastern states such as Indiana and Illinois, but the magnitude of frequency was not as high as the events in the western states. Additionally, there is a spatial relationship between the frequency of these events and the proximity to populated areas as indicated by the major cities. This pattern is most likely due to the human reporting bias found in hail data (10).

The relationship between population density and hail events was more apparent in Figure 1.b. This figure also shows that the severe hail that occurred near cities had larger diameters than the ones that were farther away. Larger hailstones were found in the western states, particularly in Kansas and Nebraska. Indemnity followed a similar pattern where it was higher in the western states. However, there was no spatial relationship between indemnity and the presence of people.

There was no apparent spatial relationship between indemnity and hail events. For instance, Iowa did not have any major hail events and, predictably, its counties had low indemnities. However, Kansas had several hail events with significantly large stones, but the counties with a high indemnity per square mile were not affected by these events. The weak relationship was further exemplified in Nebraska (Figure 1.c) where the presence of an event did not mean there would have been a higher indemnity. Further, these hail events appeared to occur more along

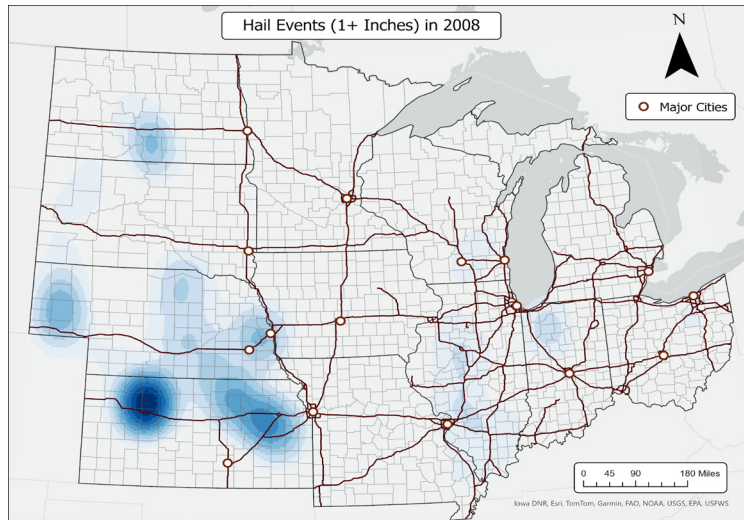


Figure 1.a. Kernel density of hail events during 2008.

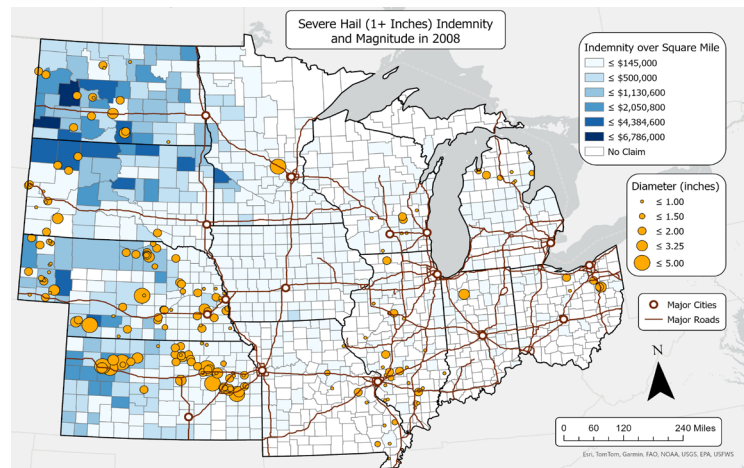


Figure 1.b. Overlay of severe hail events and indemnity in 2008.

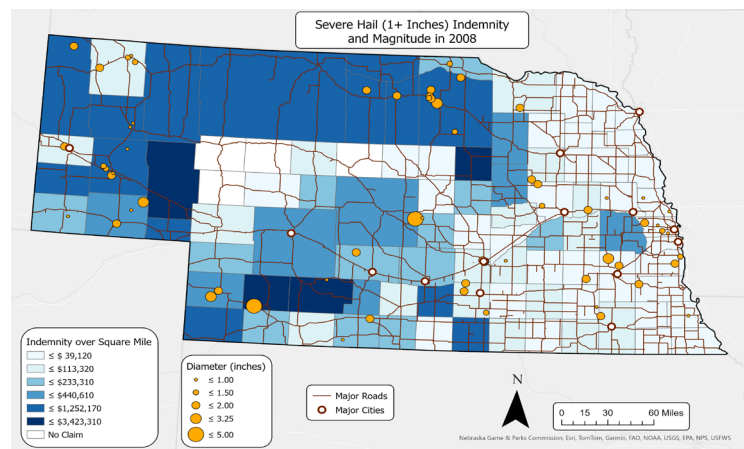


Figure 1.c. Overlay of hail events and indemnity in 2008 Nebraska.

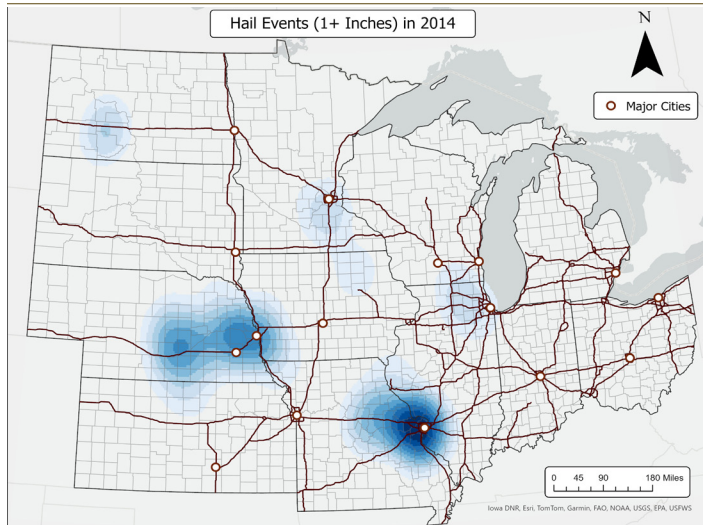


Figure 1.d. Kernel density of hail events in 2014.

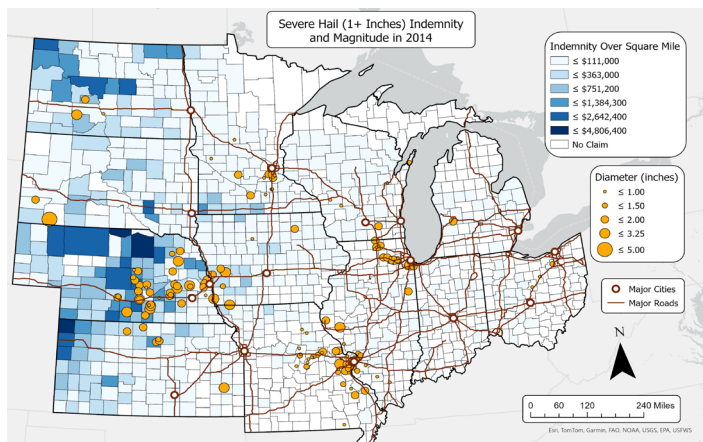


Figure 1.e. Overlay of hail events and indemnity in 2014.

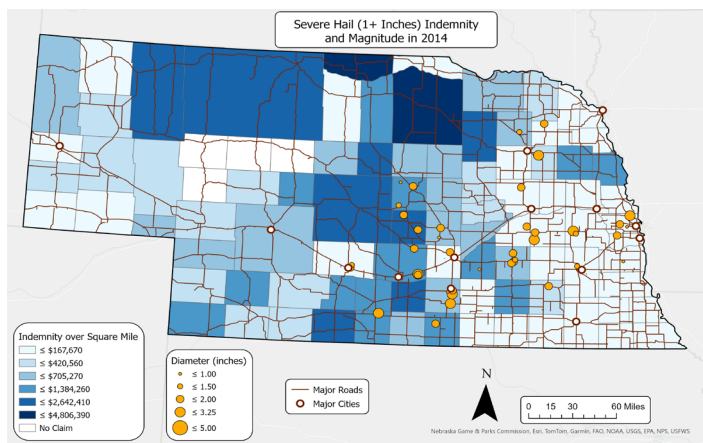


Figure 1.f. Overlay of hail events and indemnity in 2014 Nebraska.

major roads rather than near cities. However, indemnity did not have a strong spatial pattern at all aside from higher rates being found in western counties. It appears that the rate of indemnity is random and does not occur alongside any other geographic features.

During 2014, hail events had a different spatial pattern compared to 2008 (Figure 1.d). These events were more common in central Midwestern states, particularly the eastern side of Nebraska and Missouri. The rest of the region had high frequencies of events near cities as visualized by the kernel density clusters in Illinois and Minnesota.

Additionally, indemnity in 2014 followed a similar pattern seen in 2008 where rates were higher on the western side of the region (Figure 1.e). There were very low indemnities in the central and eastern part of the Midwest which did not correspond with the frequency of hail events. There was still no obvious spatial pattern to indemnity, although there was a potential relationship with hail events in Nebraska (Figure 1.e). Still, this relationship was weak and did not appear to be influenced by the actual number of events. For instance, a few counties in the middle of the state had several events and high indemnity rates while counties on the far western side had a similar frequency with very low indemnities. The size of hailstones also did not have an effect. The Nebraska counties with high indemnity saw hail events with stones that were up to two inches in diameter. Meanwhile, the eastern counties had stones up to five inches in diameter and still had low indemnities.

Stepping away from the spatial observations, Table 1.a showed there was no relationship between the indemnity and hail event data. For instance, in 2008, Greene County in Missouri had opposite rankings for number of events and indemnity per square mile. Meanwhile, during the same year, Scott County in Kansas had very similar, if not equal, ranking for both categories. Counties in 2014 had a similar lack of patterns. For both years, it seemed the highest ranked counties for number of events have a near zero ranking for indemnity. Additionally, the top ranked counties in 2008 were mainly found in Kansas which paralleled the spatial pattern from Figure 1.a. The top ranked counties in 2014 did not follow the previously observed spatial pattern. Instead, these counties were mainly from Iowa which did not experience hail events with large hail stones (Figure 1.d and 1.e).

	Number of Events per Square Mile (PCTL)	Indemnity per Square Mile (PCTL)
Counties in 2008		
Sedgwick County, Kansas	1	0.782
Greene County, Missouri	0.999	0
Johnson County, Kansas	0.998	0
Polk County, Iowa	0.997	0.735
Hennepin County, Minnesota	0.996	0.429
Leavenworth County, Kansas	0.995	0
Scott County, Kansas	0.994	0.99
Wright County, Minnesota	0.993	0.845
Jackson County, Missouri	0.992	0.672
Rush County, Kansas	0.991	0.835
Cloud County, Kansas	0.99	0.924
Hall County, Nebraska	0.989	0.993
Elk County, Kansas	0.988	0
Douglas County, Kansas	0.987	0.452
Lane County, Kansas	0.986	0.941
Counties in 2014		
Bay County, Michigan	1	0.547
Adams County, Missouri	0.999	1
Marion County, Indiana	0.998	0.431
Butler County, Iowa	0.997	0.893
Clay County, Missouri	0.996	0
Polk County, Iowa	0.995	0.509
Garfield County, Nebraska	0.994	0.928
Warren County, Iowa	0.993	0.837
Story County, Iowa	0.992	0.818
York County, Nebraska	0.991	0.995
Shawnee County, Kansas	0.99	0.675
Minnehaha County, South Dakota	0.989	0.82
Ford County, Kansas	0.988	0.919
Douglas County, Nebraska	0.987	0.831
Milwaukee County, Wisconsin	0.986	0

Table 1.a. Midwestern counties percentile (PCTL) for number of events and indemnity per square mile.
The rankings range from 0 to 1 where 1 means the 100th percentile.

Wind Indemnity and Events

The severe wind events had a different pattern from the severe hail events. In 2008, there were more wind events in the eastern states like Illinois, Indiana, Ohio, and Wisconsin. The only western state with a high density of wind events was Nebraska, and only on its eastern side near a major city. The concentration of wind events was more scattered than that of hail events. Rather than a few large clusters, there were several small clusters around the region near major cities (Figure 2.a).

There was also little variation in the speed of these events in 2008 (Figure 2.b). Most of these wind events were under 72 knots (83 mph) with only a few events reaching speeds of 104 knots (120 mph). The faster winds occurred throughout Indiana and on the eastern side of Kansas and Nebraska. Indemnity was higher in western states, mirroring the indemnity pattern for hail (Figure 1.b and 1.e). Though most counties with higher indemnities per square mile were on the far western boundary of the Midwest, a few outliers were closer to central states with no relationship to wind events, such as in Wisconsin and Iowa.

Though Nebraska experienced stronger winds than the rest of the Central Plains region, the majority of the state's events were up to 63 knots (73 mph) in 2008 (Figure 2.c). Most of these events corresponded with the locations of major roads and cities, but the counties did not have high indemnities. Like the rest of the region, higher indemnity rates were found toward the west while more events occurred toward the east.

Severe wind patterns did not change greatly in 2014 (Figure 2.d). There were many small clusters in the eastern states except for Nebraska. Further, these clusters have slightly moved closer to central states, specifically to Missouri, which did not witness nearly as many events in 2008.

The 2014 events also had stronger speeds than the ones from 2008, but they were not as frequent and were more dispersed across the region (Figure 2.e). Indemnity was also not as high in 2014. The few counties with high rates of indemnity were on the western edge of the region, especially Nebraska and Kansas. There was some slight overlap between indemnity and wind events in North

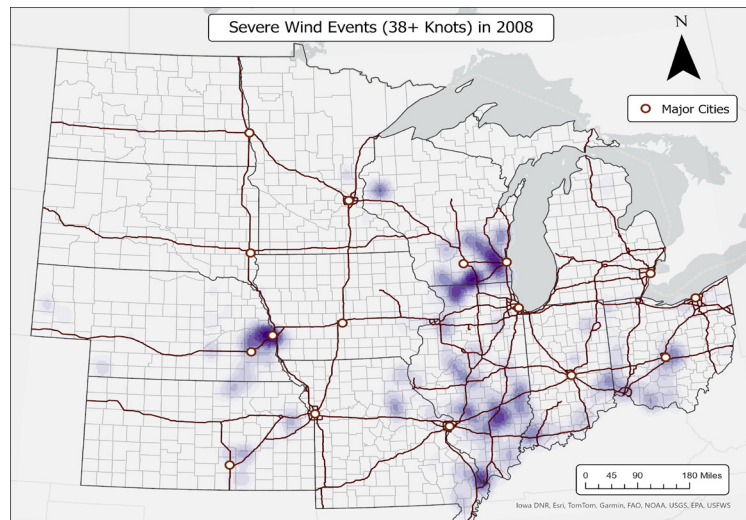


Figure 2.a. Kernel density of severe wind events in 2008.

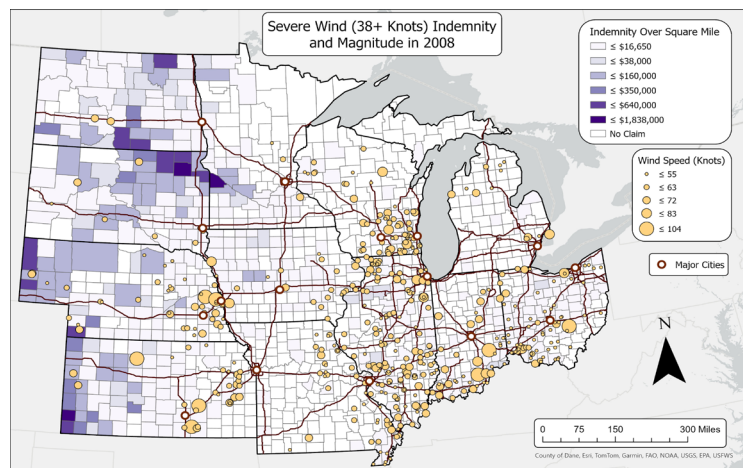


Figure 2.b. Overlay of severe wind events and crop indemnity in 2008.

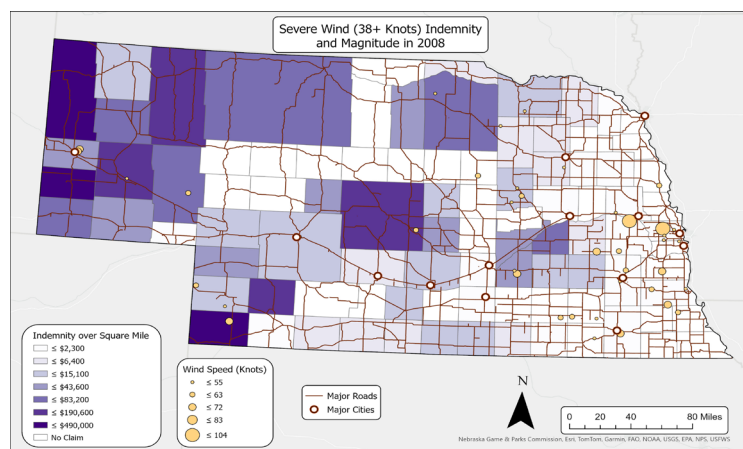


Figure 2.c. Overlay of severe wind events and indemnity in 2008

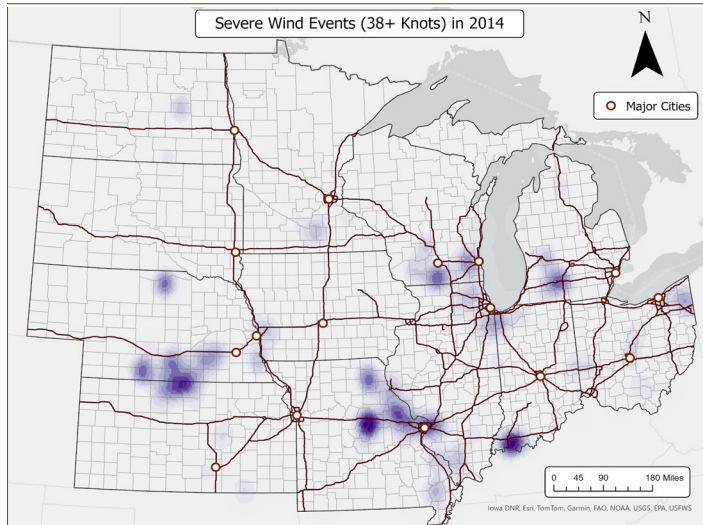


Figure 2.d. Kernel density of severe wind events in 2014.

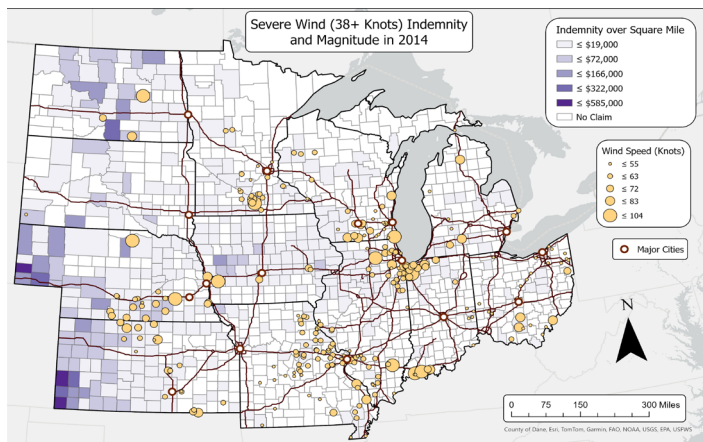


Figure 2.e. Overlay map of severe wind events and indemnity in 2014.

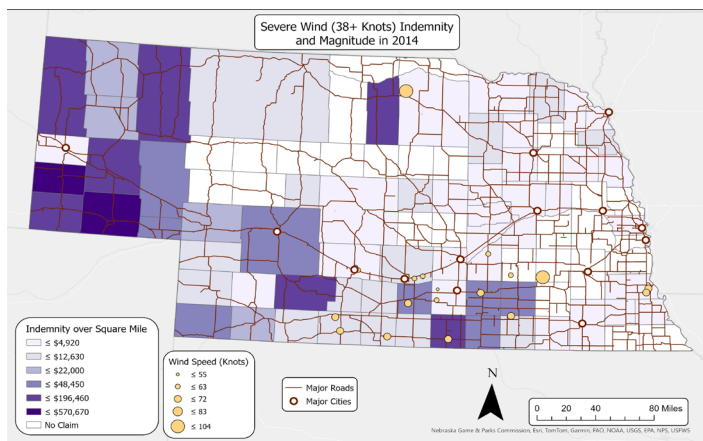


Figure 2.f. Overlay of severe wind events and indemnity in 2014 Nebraska.

Dakota, but this pattern was not seen anywhere else in the region.

There was a slight shift in the location of wind events in Nebraska from 2008 to 2014 (Figure 2.f). In 2014, there were more events towards the southern central counties while 2008 saw more events in the far eastern counties (Figure 2.c). There was still little variation in wind speeds with most events reaching 55 knots (about 63 mph) with a few outliers reaching up to 104 knots (about 120 mph). The higher rates of indemnity appeared to be in western and southern counties that were close to the state's borders. Though the wind events in 2014 were in the southern counties, they did not overlap with high indemnity counties.

When it comes to percentile rankings, there was no relationship between the indemnity and number of events (Table 2.a). Top ranked counties in 2008 appeared to have opposite values between both categories where most had no indemnity even with a high frequency of events. The counties that did have indemnities still did not see high rates with a maximum ranking in 69th percentile. In 2014, there was a similar pattern with top ranked counties having no indemnities. However, the indemnities that were present were much higher, ranging from the 91st to the 69th percentiles.

The top ranked counties in 2008 for frequency per square mile mirrored the spatial pattern in Figure 2.a. Most of these counties were in Indiana which had several clusters of wind events during this year. However, Nebraska and Wisconsin also had many events based off the map, but few of their counties had the highest percentile ranking. Most of the counties with top percentile rankings for frequency per square mile in 2014 were in Michigan. While this state experienced many wind events, there appeared to be a higher density of event frequency in Missouri, Nebraska, and Wisconsin (Figure 2.d). These states only had one county that had a high percentile ranking for frequency per square mile.

Farm Size and Frequency

There was a prominent spatial distribution of farm size and frequency in the Midwest. Figure 3.a showed the average acreage from 1997 to 2022. There was a band that extended from North Dakota through Iowa and Illinois that ended in the western portion of Ohio. This band had higher average rates of farm acreage with at least 470 acres per square mile. Although this band also covers the eastern half of Nebraska, the rates of

	Number of Events per Square Mile (PCTL)	Indemnity per Square Mile (PCTL)
Counties in 2008		
DuPage County, Illinois	1	0
Polk County, Iowa	0.999	0.921
Vigo County, Indiana	0.998	0
Hendricks County, Indiana	0.997	0.795
Greene County, Missouri	0.996	0
Lucas County, Ohio	0.995	0.805
Sedgwick County, Kansas	0.994	0.62
Lorain County, Ohio	0.993	0.596
Kane County, Illinois	0.992	0
Stephenson County, Illinois	0.991	0.882
Cook County, Illinois	0.99	0
Marion County, Indiana	0.989	0
Morgan County, Indiana	0.988	0
Putnam County, Indiana	0.987	0.681
Union County, Iowa	0.986	0
Counties in 2014		
Oakland County, Michigan	1	0
Macomb County, Michigan	0.999	0
La Crosse County, Wisconsin	0.998	0.755
Wayne County, Michigan	0.997	0
Polk County, Iowa	0.996	0.69
Washtenaw County, Michigan	0.995	0
Lawrence County, Ohio	0.994	0.704
Adams County, Nebraska	0.993	0.787
Linn County, Iowa	0.992	0.716
Genesee County, Michigan	0.991	0
Marion County, Indiana	0.99	0
Franklin County, Ohio	0.989	0
Greene County, Missouri	0.988	0
Lincoln County, Nebraska	0.987	0.907
Noble County, Indiana	0.986	0

Table 2.a. Midwestern counties percentile (PCTL) for number of wind events and indemnity per square mile.
The rankings range from 0 to 1 where 1 means the 100th percentile.

indemnity were interestingly located on the opposite side of the state. When it came to the reported severe weather events, though, there was a spatial relationship between the location of the events and the average farm size. The part of Nebraska with more farm acreage was also where there were more reports of severe wind and severe hail.

The average number of farms per square mile had a different spatial distribution than the average farm size. The band in Figure 3.a of counties with high acreage was still present but was now a band of counties with a low number of farms per square mile (Figure 3.b). This inverse relationship implied a concentration of farmland with a small number of farms that are large. Nebraska appeared to have a lot of farms throughout the state without any particular distribution. Comparing Nebraska in Figures 3.a and 3.b showed that the western part of the state has many small farms while the eastern side saw a concentration of large farms near major cities. However, this spatial pattern did not follow the distribution of severe weather events or indemnity.

The relationship between the average number and acreage of farms can also be seen in Table 3.a. Although there was no obvious relationship between the percentile rankings for these categories, the inconsistency provides more evidence that the Midwest states have few of large farms. For instance, Renville County in Minnesota ranked in the 99th percentile for farm acreage but was in the 15th percentile for number of farms. Other counties share this pattern, showing that there may be few farms in these counties, but the ones that were present were large in acreage. There were some counties that ranked high in both size and number, like Mississippi County in Missouri, but these counties were not common and can be considered outliers.

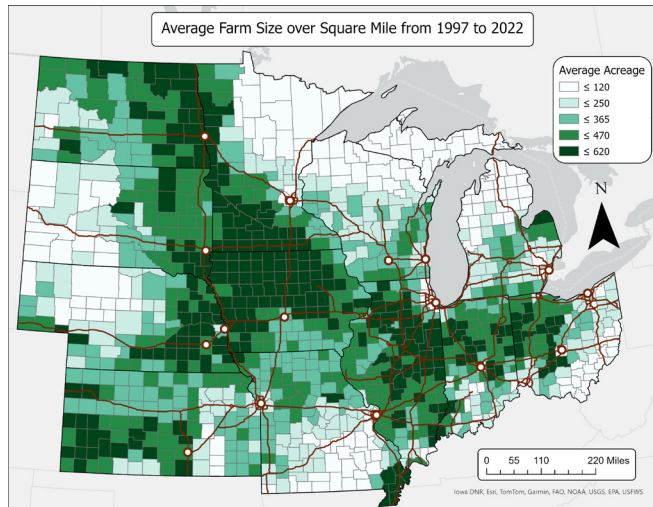


Figure 3.a. Average farm acreage per square mile from 1997 to 2022.

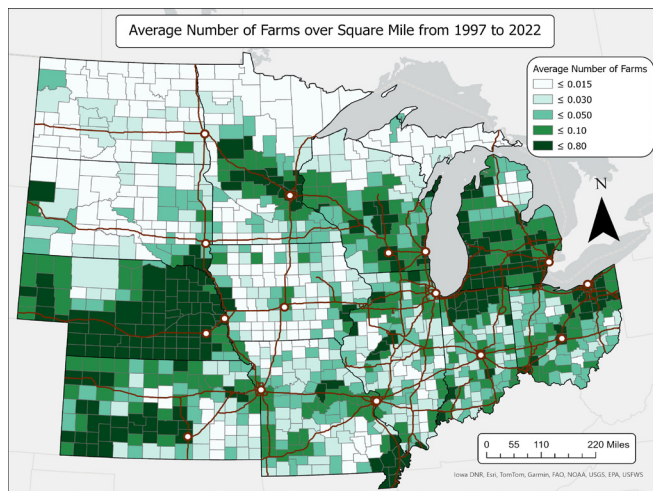


Figure 3.b. The average number of farms per square mile from 1997 to 2022.

Discussion

This study intended to provide a better understanding of the USDA indemnity data and attempt to figure out how it is calculated based on spatial and statistical relationships of indemnity and reports of hail and severe wind events. The results show that there is no strong relationship between indemnity and the frequency of weather events (Figures 1. b, 1.e, 2.b, and 2.e). However, this study did provide insight into

County Name	Average Farm Size in Acres per Square Mile (PCTL)	Average Number of Farms per Square Mile (PCTL)
Mississippi County, Missouri	1	0.95
Renville County, Minnesota	0.999	0.149
Grundy County, Iowa	0.998	0.128
Clay County, South Dakota	0.997	0.887
Traill County, North Dakota	0.996	0.024
Putnam County, Ohio	0.995	0.528
Benton County, Indiana	0.994	0.181
Pemiscot County, Missouri	0.993	0.946
Sioux County, Iowa	0.992	0.745
Palo Alto County, Iowa	0.991	0.653
Martin County, Minnesota	0.99	0.262
Cass County, North Dakota	0.989	0.202
Kossuth County, Iowa	0.988	0.167
Dodge County, Nebraska	0.987	0.985
Wright County, Iowa	0.986	0.038

Table 3.a. Midwestern counties percentile (PCTL) number and acreage of farms. The rankings range from 0 to 1 where 1 means the 100th percentile.

potential factors that influence indemnity such as the site and situational factors of the affected area as well as the magnitude of severe weather.

The specific context of a location appears to have an influence on the reported weather data. The spatial distribution of hail and severe wind matched with the locations of major cities. This pattern can be seen especially in Figures 1.b, 1.d, 2.b, and 2.d where hail and severe wind events in eastern states were clustered around major cities. A closer look at Nebraska also showed these events overlapped with the presence of roads (Figures 1.c, 1.f, 2.c, and 2.f). This spatial relationship can be explained by the fact that these weather events will only be considered important when they affect people or property. A severe weather event that did not affect a city or farm would likely not be reported, so the frequency of events would concentrate around the frequency of people and property. This relationship between severe weather and the presence of people is a possible reason why there was no relationship between the frequency of events and indemnity. The indemnity is solely for crops, and, based on Figures 3.a and 3.b, agricultural land is not as likely to be near highly populated cities. As a result, indemnity will be present where there is farmland while events are more likely to be reported where there are people.

The presence of people can also mean differences in insurance coverage. Though the percentile rankings also did not show a relationship between the NOAA and USDA datasets, it did show a variance in indemnity between counties within the same state. For instance, in 2008, Lane and Sedgwick County in Kansas were ranked in the 100th and 99th percentiles for number of hail events per square mile, respectively. Meanwhile they also ranked in the 78th and 94th percentile for indemnity per square mile, respectively (Table 1.a). Both counties have a near equal normalized number of hail events, yet the difference in indemnity is wide. A potential reason is because the city of Wichita is in Sedgwick County. The presence of a city and its high population could mean that farmers in this county may receive insurance from other sources, or that their coverage from the USDA differs from what farms in predominantly rural counties would have. Either way, this discrepancy implies a social and policy factor that influences indemnity.

This variance in indemnity can also be explained through the climatology of hail and the physical geography of the Midwest. The cities that experienced frequent hail events in 2008 and 2014 were St Louis, Chicago, and the Twin Cities (Figures 1.d and 1.e), all of which are located near large bodies of water where localized convective storms can occur (3). Additionally, these events were frequent in the western states which border on the Rocky Mountains whose high elevation can also allow for localized convective storms (4). Further, there was a fluctuation in the hail indemnity per square mile between nearby

counties, particularly in Nebraska (Figures 1.c and 1.f). This difference is likely because these events were isolated hail occurrences which originated from the presence of the Rockies, meaning that two nearby counties could vary in frequency even with similar physical features (3).

When it comes to wind events and indemnity, there were more reported wind events on the eastern side of the region which can be explained by topography (Figures 2.b and 2.d). For the Midwest, severe winds that cause damage are often created from frontal activity where air masses meet. Sometimes these winds can be associated with thunderstorms and raised elevations, but winds are most frequently created from the fronts in this region (5). Likely, the frontal activity is why there are many severe wind events that are not as severe in the central part of the Midwest region. Nebraska's western counties had higher rates of indemnity (Figures 2.c and 2.f). These counties are close to the Rockies and will experience stronger winds. As a result, we can infer that the magnitude of severe wind events does play a role in determining indemnity.

The influence of magnitude is exemplified with the percentile rankings for wind events. There was a discrepancy between the counties that were in higher percentiles (Table 2.a) and the overall spatial visualization of frequency (Figure 2.d). The main reason for this difference is that the spatial clusters were calculated based off the total count of wind events in 2014 while the rankings were from the number of events per square mile. However, even with the normalization, the percentile rankings showed no relationship with indemnity aside from outliers like Polk County, Iowa in 2008. This county has the second highest ranking for number of events per square mile and ranked in the 92nd percentile for indemnity per square mile. A neighboring county, Union County, ranked in the top 15 counties for number of events for 2008, yet had no indemnity. The difference between these counties can be potentially explained with the approximate magnitude of events. Polk County experienced a wind event with speeds of at least 63 knots (72 mph) near its major city Des Moines (Figure 2.b). Meanwhile, Union County did not experience any wind events that met the minimum threshold of 38 knots (43 mph). Though both counties did experience a similar number of events, the frequency alone is not a major factor in determining indemnity. Rather, these counties show that the magnitude of events has a large influence, causing more damage to crop and requiring more money to cover the loss.

Farm size and number were also potential factors in influencing indemnity. Figures 3.a and 3.b show an almost inverse relationship between the number of farms and the average acreage of farmland, especially when it comes to the band of land stretching from North Dakota and ending in Ohio. Table 3.a supports this observation, showing that most of the counties with the most farm

acreage has few actual farms. This pattern mirrors that observed by Spangler, implying that these large farms are specialized in growing a few types of crops (9). This pattern of land use shows a cause of concern for food production. Figures 3.a and 3.b show that the presence and size of farms do not appear to have an influence on indemnity since there is no apparent spatial relationship. However, this study did not control crop type which could influence indemnity based on demand of the crop. As a result, a farm specialized in corn could produce a much larger indemnity than a farm that grows a variety of crops. Additionally, the trends in farmland show a potential area of future research focusing on how crop type may influence indemnity to contribute to the larger question of how it is determined.

Although this study did find potential factors that influence indemnity, there were also limitations from the scope and scale of the data. The Midwest region provided a lot of severe weather data with varying frequencies and magnitudes. However, the indemnity data did not have an obvious spatial or statistical pattern throughout the region. Future studies should have a smaller scale of focus, looking at just one state or event just a few counties. A good case study would be Nebraska for the variations in indemnity and severe weather data. Additionally, the two years of interest had a lot of data, but focusing on just one year can allow future research to dive deeper into specific USDA policies and rules that may affect indemnity and insurance coverage in general. Further, some data was based on general trends over time, like farm number and size. Looking at data from one year means this additional data can be more focused and will provide supplemental context on other matters such as crop types.

Overall, this study found that there are more factors that go into indemnity than the occurrence of a severe weather event. There is evidence that this metric is influenced by the magnitude of weather as well as the geographic context of a location. Transparency on the USDA policies is imperative during a time of ever-changing policies, intensifying weather, and fluctuations in prices. The public should be aware about the state of food production in the U.S. for their own wellbeing and the interests of the country.

REFERENCES

1. NOAA National Centers for Environmental Information. (2025). U.S. billion-dollar weather and climate disasters. <https://www.ncei.noaa.gov/access/billions/>
2. Bundy, L., Gensini, V. and Russo, M. (2022). Insured corn losses in the United States from weather and climate perils. *Journal of Applied Meteorology and Climatology* 61(8) pp. 969-988. <https://journals.ametsoc.org/view/journals/apme/61/8/JAMC-D-21-0245.1.xml>
3. Changnon, S. A., & Changnon, D. (2000). Long-term fluctuations in hail incidences in the United States. *Journal of Climate*, 13(3), pp.

- 658–664. [https://doi.org/10.1175/1520-0442\(2000\)013<0658:LTFIHI>2.0.CO;2](https://doi.org/10.1175/1520-0442(2000)013<0658:LTFIHI>2.0.CO;2)
4. Changnon, S.A. (2009). Temporal and spatial distributions of windstorm damages in the United States. *Climatic Change* 94, pp. 473–482. <https://doi.org/10.1007/s10584-008-9518-6>
5. Tang, B. H., Gensini, V. A., & Homeyer, C. R. (2019). Trends in United States large hail environments and observations. *Npj Climate and Atmospheric Science*, 2(1), 45. <https://doi.org/10.1038/s41612-019-0103-7>
6. Zha, J., Shen, C., Li, Z., Wu, J., Zhao, D., Fan, W., Sun, M., Azorin-Molina, C., & Deng, K. (2021). Projected changes in global terrestrial near-surface wind speed in 1.5 °C–4.0 °C global warming levels. *Environmental Research Letters*, 16(11), 114016. <https://doi.org/10.1088/1748-9326/ac2fdd>
7. Raupach, T. H., Martius, O., Allen, J. T., Kunz, M., Lasher-Trapp, S., Mohr, S., Rasmussen, K. L., Trapp, R. J., & Zhang, Q. (2021). The effects of climate change on hailstorms. *Nature Reviews Earth & Environment*, 2(3), 213–226. <https://doi.org/10.1038/s43017-020-00133-9>
8. Spangler, K., Burchfield, E. K., & Schumacher, B. (2020). Past and current dynamics of U. S. Agricultural land use and policy. *Frontiers in Sustainable Food Systems*, 4, 98. <https://doi.org/10.3389/fsufs.2020.00098>
9. Risk Management Agency (USDA). (2025). *Cause of loss*. <https://www.rma.usda.gov/tools-reports/summary-of-business/cause-loss>
10. Allen, J. T., & Tippett, M. K. (2015). The characteristics of United States hail reports: 1955-2014. *E-Journal of Severe Storms Meteorology*, 10(3), 1–31. <https://doi.org/10.55599/ejssm.v10i3.60>



Author

Genevieve Giammarco

Genevieve Giammarco ('25 CLAS) is a recent graduate of Villanova University, holding bachelor's degrees in Geography and Communication, with a specialization in Geographic Information Systems (GIS) and a concentration in Rhetorical Studies. She developed an interest in the geospatial patterns of hazardous weather through her participation in the Villanova Social Science Apprenticeship (VSSA). Her research also explores the rhetoric of environmental justice movements, which earned her recognition as a finalist for the St. Catherine of Siena Undergraduate Peace and Justice Research Award. Currently, Genevieve works as a Data Technician for an energy infrastructure company in King of Prussia, PA, and plans to further pursue her research interests in graduate school.



Mentor

Dr. Stephen Strader

Dr. Stephen Strader is a hazards geographer, atmospheric scientist, and geographic information systems (GIS) analyst with interests in natural hazards and societal impacts, severe and local storms, and geospatial science applications. My research is primarily concentrated on the spatiotemporal changes in meteorological and environmental hazard exposure and future changes in severe weather risk and vulnerability.