SEVERE SUMMER HAILSTORMS IN ILLINOIS DURING 1915-50

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Purpose

As part of a hydro-climatological program for studying hail in Illinois, an investigation of days with severe summer hailstorms was made. In a 36-year period, 1915-50, the 18 days having the most severe hailstorms were selected for analysis.

One purpose of this study was to determine the amount of possible monetary loss from one storm, which is valuable information for agricultural interests and for insurance companies. Another purpose was to increase our knowledge of the meteorological characteristics at the surface displayed by severe hailstorms. It was desired to ascertain which, if any, surface characteristics of these storms correlated well with the amount of damage produced.

This study was made feasible by the availability of detailed U. S. Weather Bureau data. Large damage-producing hailstorms are well catalogued (Flora, 1956), and much more extensive data are available for these storms than for other more minor hailstorms.

Factors investigated in each storm include date and time of day, duration, maximum stone size, path size, and areal distribution. The association of the hailstorms with other types of weather, including rainfall and severe weather such as high winds and tornadoes, was studied. The types of synoptic weather producing these storms were determined also.

Available Data and Analytical Procedures

The original station records kept by the cooperative observers at the U. S. Weather Bureau stations in Illinois together with published and unpublished notes of the U. S. Weather Bureau furnished hail loss values for individual hail days occurring in the 1915-50 period. Summer was selected for the study period because more than 80% of the crop damage in Illinois from hail occurs in the months of June through August (Stout, Blackmer, Changnon, and Huff, 1959). It was decided to define hail severity by using the two parameters of normalized monetary loss from crop and property damages and per cent of farm value lost. Possibly, criteria such as stone sizes, path sizes, and areal distribution should be used to establish hailstorm severity in a climatological analysis, but data on these criteria are not as detailed nor as reliable as are the monetary loss data.

In order to determine the 18 most severe storm days on a monetary basis, it was necessary to normalize the data for the changing dollar value of crops and property in the 36-year period. It was also necessary to express the normalized crop loss as a per cent of the annual farm value for each year, in order to adjust the crop loss for changing acreage in crops and yield per acre. These crop losses were normalized to the 1910-14 index of prices received by farmers for grain and hay

crops (Illinois Agricultural Statistics, 1949). Similarly, property losses were normalized using index of prices paid for building materials based on the 1910-14 period. The annual farm value is a figure also normalized to this period. The 1910-14 period was used as the price reference period because of the stability of prices in that 5-year period and because Illinois agricultural statistics are based upon this period.

For each of the 40 days with the most severe hailstorms in the 1915-50 period the monetary loss from crops and property, after normalizing, and the per cent of annual farm value lost were computed. The total monetary values for each storm were compared and ranked, with rank one the highest value. The percentages of annual farm value losses for each storm also were compared and ranked, with the highest percentage assigned rank one. Therefore, for each storm, two separate rankings were obtained. These two rankings were averaged to obtain a single, final rank for each storm day. These average rankings were compared and the 18 highest ranked were selected as the 18 most severe hailstorm days in the 1915-50 period.

To measure the areal extent of hail in order to compare storm days, two methods of evaluation were used. A county occurrence evaluation was used, by which hail occurrence in any portion of a county was recorded as a county occurrence. In most instances an entire county was not affected by hail, but this method for describing areal extent of hail was useful because counties represent analytically convenient divisions of Illinois. The second method for evaluating areal extent utilized records from 40 U. S. Weather Bureau stations in and near Illinois. Each station had reliable hail records for the 1915-50 period, and the number of stations reporting hail on each storm day could be determined for measuring areal extent.

Analytical Results

Temporal Occurrence

Eighteen severe hailstorm days in the 36-year period were selected to furnish a sample number which would make each storm day equivalent to a 2-year recurrence storm day on the basis of a partial duration series. The actual number of years in which the 18 storm days occurred was 13. Three storm days occurred in 1948 and in 1925, and two in 1934. The specific dates of occurrence are given in Table 1. Nine of the 18 storm days occurred in July, the month when grain crops in Illinois are normally most susceptible to hail damage.

The time of occurrence and duration of the hailstorms on the 18 storm days also were investigated. On three of the 18 days, hailstorms occurred at two distinctly different times, separated by a period of two hours or more with no hail. Therefore, 21 periods of hail were analyzed as separate time events, and the time analyses were based on these 21 samples.

The 2-hour period when hail formation was most frequent was from 3:00 to 5:00 P.M. CST as 9 of the 21 hail periods were initiated in these two hours. Twenty of the hail periods began in the 11:00 A.M. to

TABLE 1.—Monetary losses and percent of annual farm value lost by damages produced by 18 most severe summer hailstorm days, 1915-50.

Rank	Storm date	Total storm loss, in thousands of dollars, normalized to 1910-14 price indices	% of total storm loss		Total storm crop loss as % of annual farm value
			Crop damages	Property damages	
1.....	8/17/48	3,173	99.8	0.2	0.26
2.....	7/28/43	2,719	88.0	12.0	0.31
3.....	7/22–23/31	665	99.8	0.2	0.38
4.....	7/10/34	1,152	43.5	56.5	0.20
5.....	6/20–21/15	399	85.1	14.9	0.08
6.....	7/13/34	351	98.8	1.2	0.14
7.....	8/18/25	351	100.0	0.0	0.08
8.....	7/1–2/33	273	100.0	0.0	0.13
9.....	6/14/48	503	95.0	5.0	0.04
10.....	8/29/48	478	100.0	0.0	0.04
11.....	8/18/46	410	97.6	2.4	0.03
12.....	8/9/25	265	100.0	0.0	0.06
13.....	7/24/25	255	98.8	1.2	0.06
14.....	8/9/32	134	82.2	17.8	0.06
15.....	7/10/30	112	97.2	2.8	0.04
16.....	7/25/38	118	76.8	23.2	0.03
17.....	6/25/44	214	80.9	19.1	0.02
18.....	7/21/27	116	97.3	2.7	0.03

11:00 P.M. CST period. Hail began at 4:00 A.M. CST in the one exception. The 6-hour period of most frequent hail initiation was 3:00 to 9:00 P.M. CST with 15 of the 21 hail periods beginning in this time period. Lemon (1943) reported that one-third of 2105 damaging hailstorms in the Middle West began in the 2-hour period after 4:00 P.M. CST. Lemon also found that 68% of 2105 damaging hailstorms in the Middle West began in the 6-hour period beginning at 1:00 P.M. CST.

The average duration of the hail periods was 2.4 hrs. and the median duration was 2.0 hrs. The greatest duration for one storm period was 6.5 hrs. and the shortest duration was 0.4 hrs. There was no correlation between variations in hailstorm duration and amount of damage produced by each storm.

Monetary Losses

Monetary losses produced by the eighteen storm days ranged from a high of $3,172,508 to a low of $112,472, as normalized by 1910-14 price indices. Three storm days each produced more than one million dollars in damage, and 13 had losses in excess of a quarter of a million dollars. The 18 storm days produced a total of $11,687,500 in losses for an average of $649,305. A summary of losses for each storm day, as presented in Table 1, shows that losses from crop damages accounted for a large proportion of

the total loss in most storms. On only one storm day did property damage exceed crop damage, and on four storm days no property losses were recorded.

The right-hand column in Table 1 lists for each storm day the percentage of annual farm value lost because of crop damages (Illinois Agricultural Statistics, 1949). This was the other major factor used in evaluating the storm days and in assigning rank values to them. A wide range exists in these values (Table 1), from 0.02% up to 0.38% with an average of 0.11 % per storm. These percentages appear to be small in relation to the Illinois farm value in any one year, but for a more realistic present-day impression, a percentage loss in 1954 such as suffered in the July 1931 storm would amount to $4,700,000 in 1954 dollars (Illinois Agricultural Statistics, 1958).

Maximum Hailstone Sizes

The maximum size of hailstones occurring in each of the 18 storm days was expressed in stone diameter. If stones were elliptical, the greatest diameter measurable for the stone was used in this analysis. On all storm days the maximum diameter found exceeded 1 in. The average diameter of the largest hailstones was 1.9 in. The largest hailstones found in any of the storms were 4 in. in diameter and these occurred in the June 1915 storm. In this storm, many cattle and hogs in the open fields were killed by the hail. Three of the other storm days had hailstone data also worthy of mention. The storm of June 14, 1948, produced hail 4 in. deep along a path 4 by 16 mi. with occasional drifts of hailstones up to 4 ft. deep. The storm of August 9, 1925, produced hail to a depth of 3 in. over a path 3 by 24 mi. During the July 10, 1934, storm, slabs of hail the size of coffee saucers were reported. In general, differences in the maximum size of the stones, in the range of 1 to 4 in. in diameter, had no apparent effect on the amount of damage produced by the storms.

Areal Distribution

Hailstorm path sizes. Complete data on all the hail paths which occurred in the 18 storm days were not available. However, sizes of many of the major paths were recorded as to width and length in miles. From the 18 storm days accurate path size data were available for 14 hail paths, and these 14 paths were associated with 15% of the total loss of the 18 storm days. Analysis of the path sizes indicated that the average width was 4 mi. with widths varying from 2 mi. to 10 mi. Lemon (1943) reported that the average path width for 2105 damaging hailstorms in the Middle West was 1.5 mi. The average length of the 14 paths was 18 mi; the shortest path was 8 mi. and the longest path length, 40 mi. The amount of loss associated with a path did not appear to be a function of path length or width.

Number of separate areas of hail in each storm. Areal analysis of the hail reports for the 18 storm days revealed that frequently two or more noncontiguous areas of hail occurred on a storm day. The basis used to define these separate areas

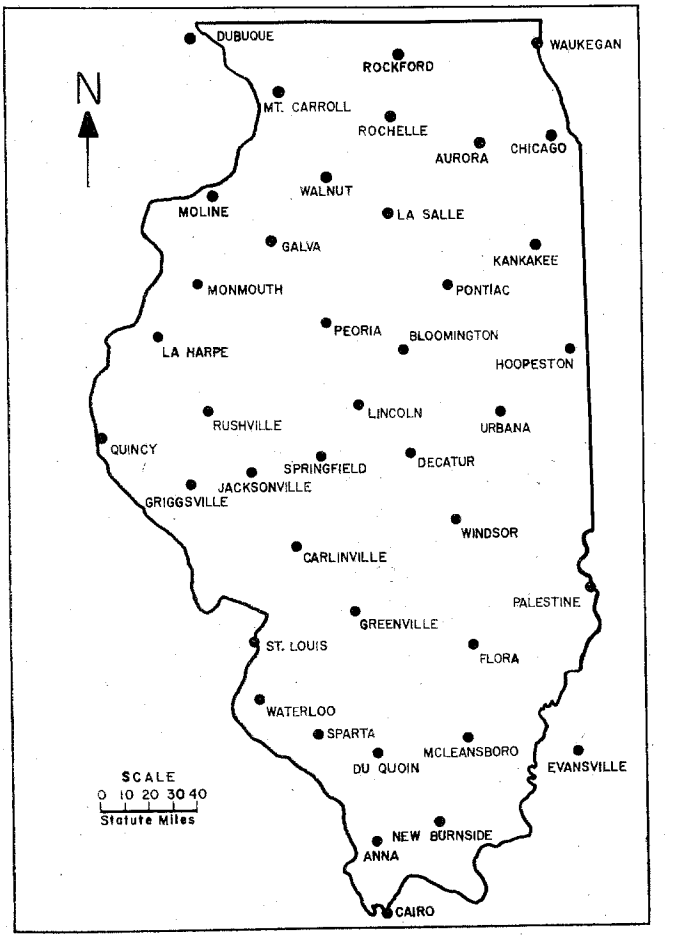

Fig. 1.—Forty U. S. weather stations with reliable hail records in 1915-50.

of hail on a storm date was a distance of at least 40 miles with no hail reports between hail areas. Using this basis, 12 of the storm days had two or more distinct hail areas and seven of these had three hail areas. This analysis indicated that 37 hail areas were produced by the 18 storm days. In general, the severest of the 18 storm days were the days with three or more hail areas.

Number of weather bureau stations reporting hail in each storm. On eight storm days hail was reported at four or more of the 40 U. S. Weather Bureau stations used in this analysis (Fig. 1). The greatest number of stations reporting hail on any one day was nine on August

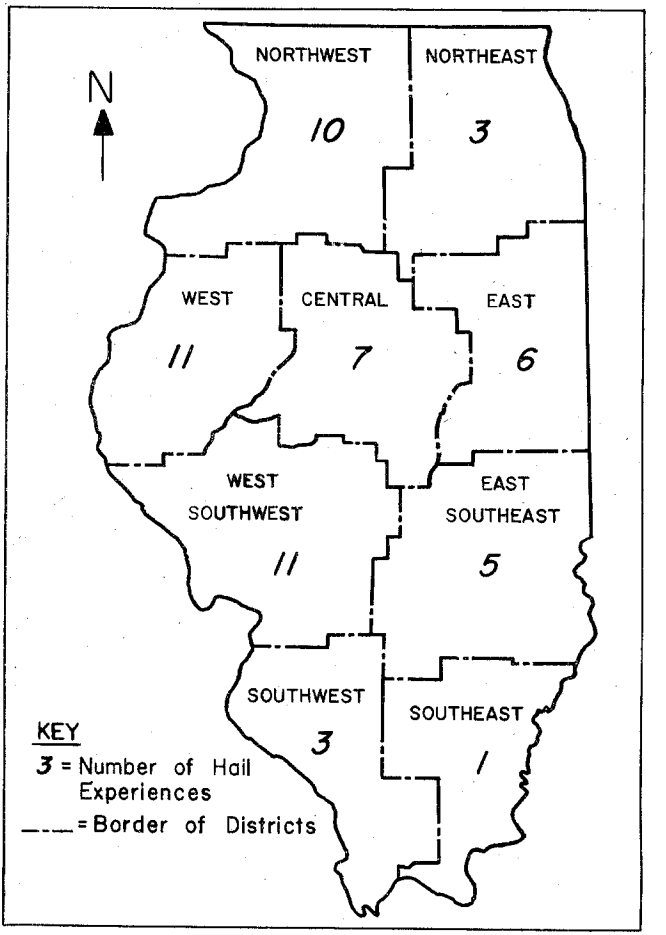

Fig. 2.—Number of times that each crop district was affected by the 18 most severe summer hailstorms.

17, 1948. On a monetary basis, this storm day was classified as the most severe of the 18. Flora (1956) in his listing of severe Illinois hail storms also classified this hailstorm day as the worst on record in Illinois, although his loss data were not normalized for changing prices. In general, there is a good relationship between the rank or severity of the storms and the number of Weather Bureau stations reporting hail.

Regional and county distributions of hail. From detailed areal plots of hail on each storm day, the number of times each county experienced hail was determined. Utilizing these data, the number of times these 18 storm days produced hail in each

U. S. Weather Bureau crop-reporting district (Illinois Agricultural Statistics, 1958) also was plotted. The areal frequency results for the nine Illinois crop-reporting districts, which are areas of approximately equal size, are shown in Figure 2. Since hailstorms during most of the 18 days affected more than one district, the total number of occurrences was 57, exceeding the number of storm days by a factor of three. Inspection of Figure 2 shows that the upper two-thirds of the western portion of Illinois had the greatest number of experiences with the three westernmost districts having almost equal frequencies. The number of occurrences by districts diminishes rapidly to the south and east from the high incidence region in the west.

To obtain a more detailed description of areal distribution, the number of times each county experienced hail resulting from the 18 storm days was plotted (Fig. 3). The pattern is similar to that in Figure 2, although the concentration in western Illinois separates, on the county basis, into two distinct areas of most frequent experience. The most prominent area, with four or more experiences, extends northeastward from Adams County for 200 miles into Carroll County. A secondary maximum occurs in three counties: Morgan, Sangamon, and Montgomery. Areas of no experience are shown in portions of northeastern, eastern, and southern Illinois. The general distribution pattern revealed by this map relates well to the average summer hail distribution in Illinois (Huff and Changnon, 1959).

To describe the county distribution of hail damage, the number of times each county experienced hail damage is shown in Figure 4. The pattern is generally similar to that in Figure 3 except that the areal frequency values are lower and the areas of high incidence are smaller. The entire southeastern half of Illinois except for a few isolated areas, had no hail damage. Three counties, Whiteside, Warren, and Hancock, had the greatest frequency of damaging hail experiences.

Synoptic Weather

The type of surface synoptic conditions associated with the occurrence of the 18 hailstorm days was investigated. No analysis of upper-air data was performed due to the lack of these data during most of the 36-year period of study. Analysis of surface weather conditions revealed that four different surface weather types were associated with the hailstorms on the eighteen days. As might be expected, squall lines were the most frequent type of weather associated with hailstorms, eight storm days having squall lines. The number of cold front cases was five with four cases being associated with warm fronts. One hailstorm day was associated with air mass conditions.

Associated Weather Conditions

Severe weather. All but four of the severe storm days had associated reports of high surface winds. Nine of these 14 storm days with high surface winds had wind damages in addition to the hail damages. The

storm of August 17, 1948, had a tornado in addition to high surface wind reports. In several of the storms, damages from lightning were reported. In most instances, these reports of wind and lightning damages were in the area of hail damage. The presence of high wind velocities serves to increase the damage potential from hail.

Rainfall. The daily rainfall pattern associated with each of the 18 storm days was plotted using U. S. Weather Bureau records (1915-51). From these maps, studies of the association of rainfall and hail were made by comparing the location of hail areas with respect to the cores in the daily rainfall pattern, by ascertaining mean daily rainfall values for the hail areas, and by determining the state-wide rank of the highest daily rainfall value found in the hail areas of each storm day.

To ascertain the juxtaposition of the hail area and the rainfall cores, the hail areas were described as being either in or out of a rainfall core. A rainfall core was defined as a region of relatively heavy rainfall having appreciable decreases in rainfall amounts away from the region in two or more directions. As mentioned previously, there were 37 separate areas of hail on the 18 hail days. Thirty-four of these hail areas were found to lie within rainfall cores which indicated that a relationship existed between areas of maximum rainfall and hail incidence areas. A previous study of the relationship of hail occurrences to rainfall cores based on severe spring hailstorm days in Illinois (Huff and Changnon, 1959) indicated that 63% of the hail occurrences were in rainfall cores as compared to 92% in these 18 summer hailstorm days.

To obtain an estimate of the areal significance of the heavy rainfall found within the hail areas, the highest point rainfall value occurring in a hail area for each storm was selected. This value then was compared with all point values in the area of Illinois with no hail occurrences, and the highest hail area value was assigned a rank in relation to all other high values in Illinois. This analysis revealed that, in 13 of the 18 storm days, the highest point rainfall in the hail area ranked either first or second for the entire state on those 13 storm days.

Conclusions

The 18 most severe summer hailstorm days in the 1915-50 period produced losses which appear large to the average Illinois citizen and farmer, but the actual amount of the Illinois annual farm value destroyed by the most severe hailstorm day was minor, only 0.38 percent of the total. The greatest amount of damage on one storm day, normalized to 1910-14 price indices, was $3,172,508, which occurred on August 17, 1948.

The hailstorms on the 18 days occurred most frequently in the late afternoon and early evening, and the duration of hail averaged 2.4 hrs. No correlation existed between storm duration and amount of monetary loss. Maximum hailstone sizes associated with the extremely severe summer hailstorms were at least 1 in. in diameter, although the amount

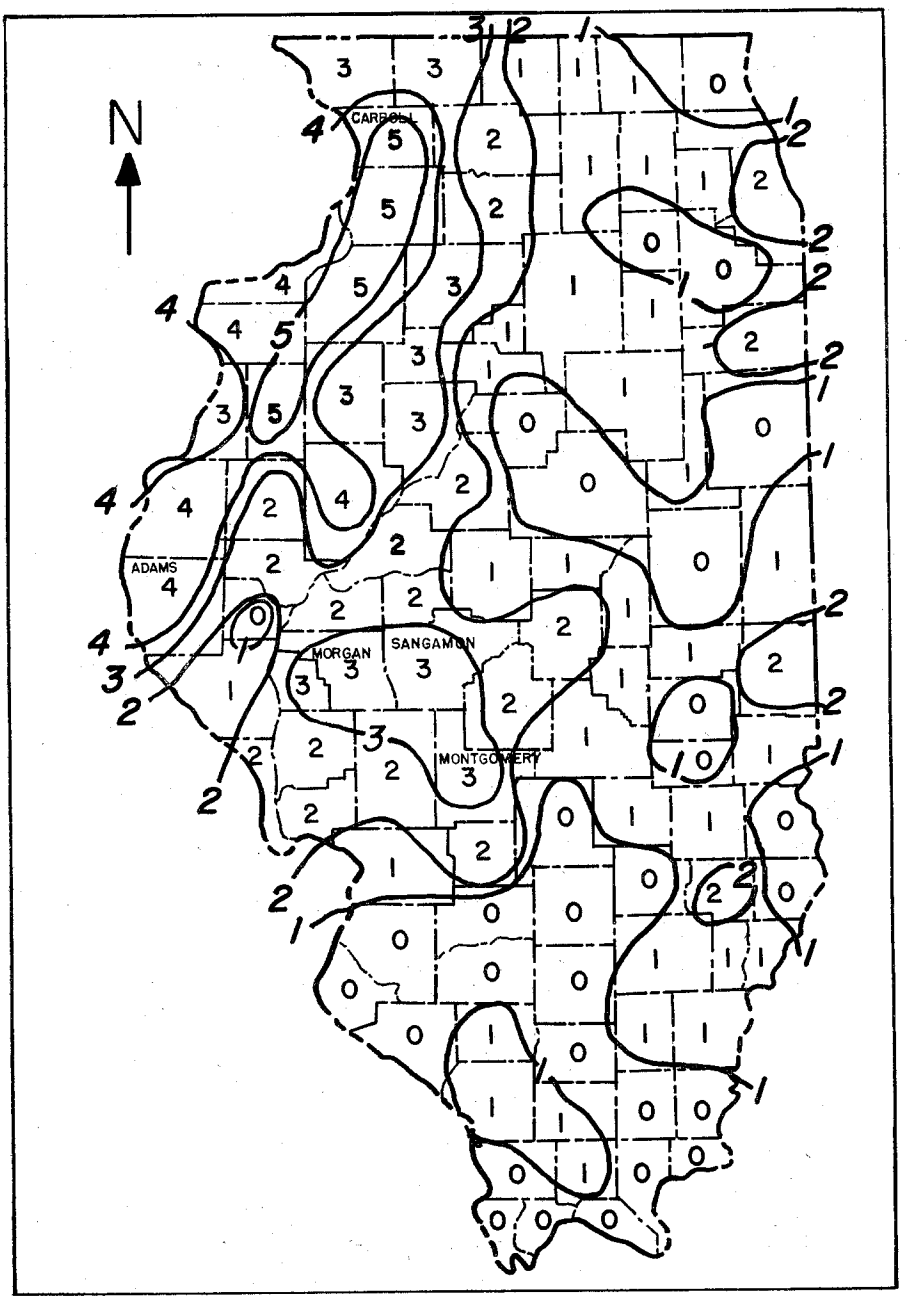

Fig. 3.—Number of times each county experienced hail produced by the 18 most severe storms.

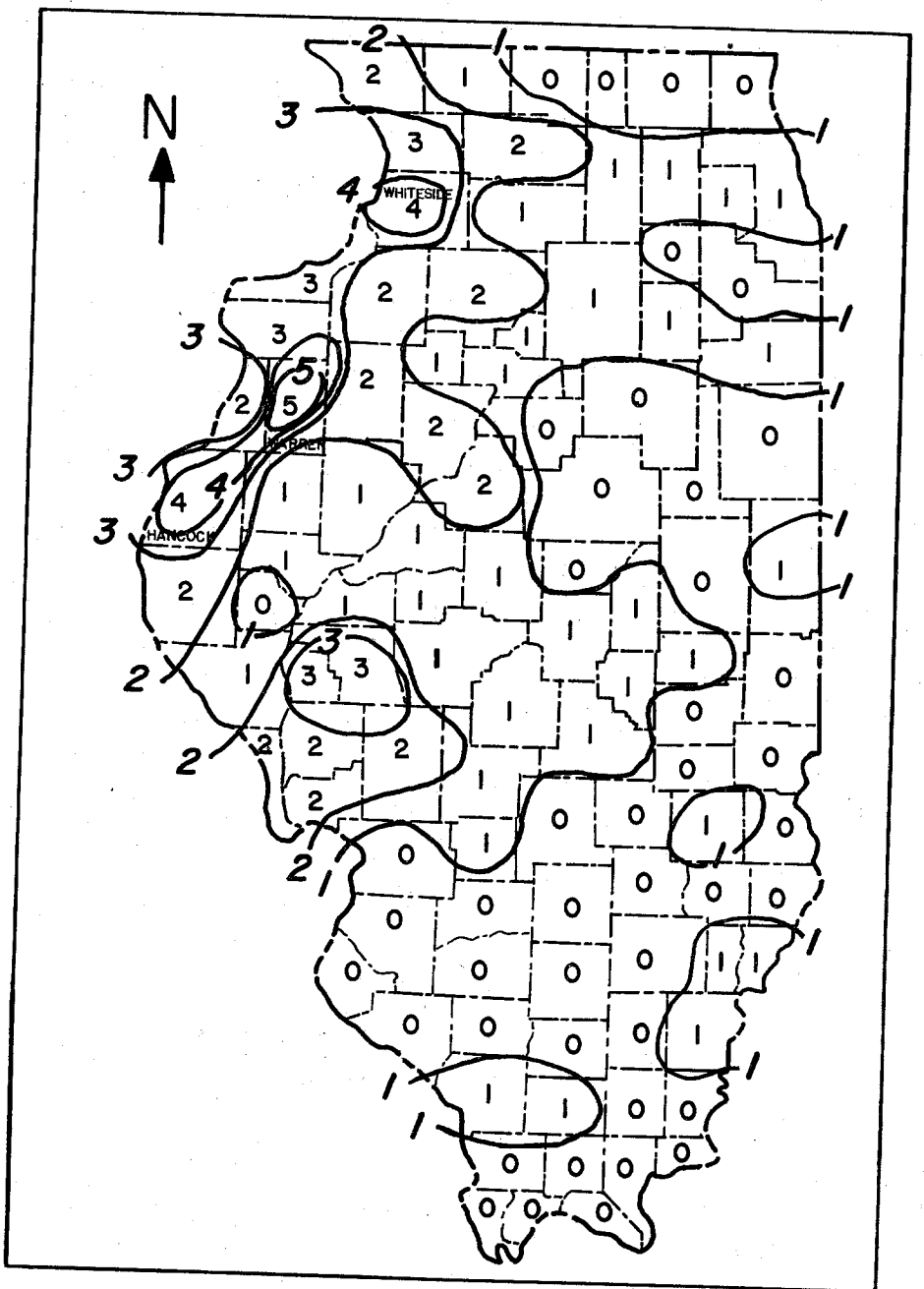

Fig. 4.—Number of times each county experienced hail damage resulting from the 18 most severe hailstorms.

of damage produced by a storm was not a function of maximum stone size, differences occurring in the range from one to four inches in diameter. Path sizes associated with the severe hailstorms varied considerably. The average path width was 4 mi. and the average length was 18 mi. There appeared to be no relation between the path size and the amount of damage produced.

Based on the 18 storm days studied, summer hailstorm damage was most frequent in western, northwestern, and southwestern Illinois, and was least frequent in southern Illinois. The areal extent of hail and hail damage varied considerably between storms, and occasionally the damage area was relatively small. However, normally the larger the area of hail, the greater was the damage. Therefore, areal extent of hail appears to be one of the best surface factors correlated with the amount of monetary loss.

The investigation of synoptic weather types associated with the severe summer hailstorms indicated that there was no single weather type which could be considered the predominating cause of these hailstorms. Most of the severe hailstorms were accompanied by high surface winds which increased crop damage from hail. The occurrence of high winds appears to be a second factor correlated well with the amount of damage. The areas of hail were frequently associated with heavy rainfall, often greater than 0.9 inch per day, and 92% of the hail areas were found in the rainfall cores. Frequently, the highest rainfall value in the hail area was the highest in Illinois for that date. However, the extent or intensity of rainfall did not always reflect the amount of hail damage.

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