Effect of Sampling Density on Areal Extent of Damaging Hail[1,2]

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One of the important design problems to be resolved in hail modification experiments concerns the number of surface sampling points necessary to measure adequately the areal extent of damaging hail. Schleusener *et al.* (1965) indicated that hailfall energies measured at Colorado observation points (passive hail pads) located 2 mi apart were poorly correlated (<0.5). After careful field studies of 6 damaging hailstorms, Changnon (1964) concluded that at least 1 observation point per 2 mi^2 was required to define accurately the areas of the damaging hail.

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[2] Insurance data were supplied largely by the Crop-Hail Insurance Actuarial Association.

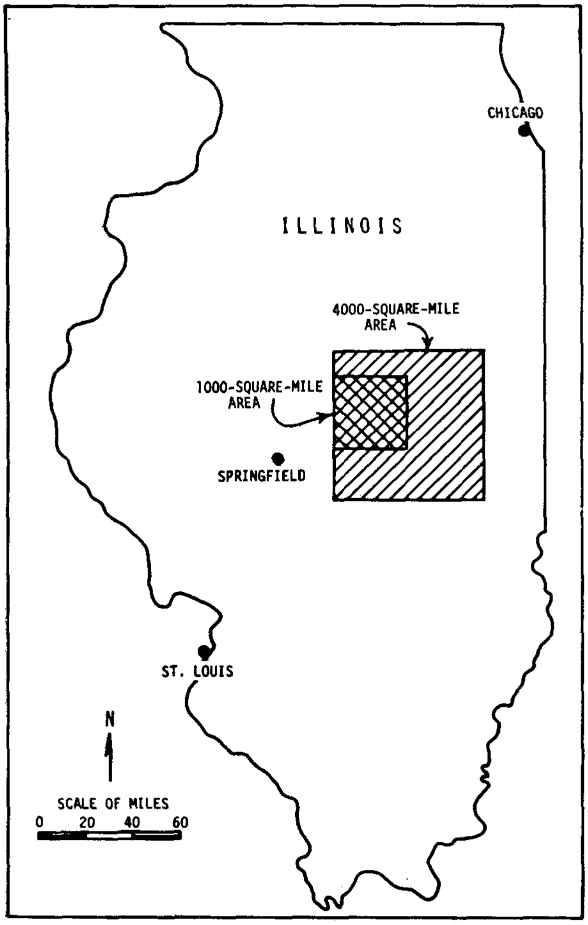

Fig. 1. Location of two study areas in Illinois.

Two square-shaped areas in central Illinois, one comprising 4000 and the other 1000 mi² located inside the larger one (Fig. 1), were chosen to make a statistical study of the surface sampling requirements for the areal measurement of damaging hail (Changnon *et al.* 1967). The insurance liability within these areas ex-

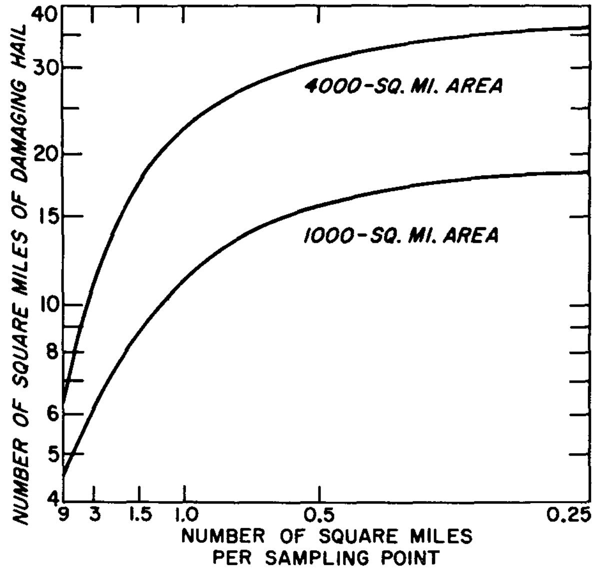

Fig. 2. Average areal extent of crop-damaging hail on a hailstorm day in Illinois based on different densities of sampling points in 1000- and 4000-mi² areas.

ceeded 85% of the total areal extent of each over an 11-yr period, 1952–1963.

Maps for each storm day were prepared showing the actual areas of paid losses using all the available insurance data which represented an average sampling density of 4 location points (farms) mi⁻². Transparent overlays at the same map scale with evenly distributed points representing observation sites with densities of 0.5, 1.0, 3.0 and 9.0 mi² were superimposed on each daily damage map to determine the area of damage defined by each density. The area of hail damage designated as measured by each point in a damage area was 0.25 mi².

The average number of storm days per area, as defined for each sampling density, is shown in Table 1. In the 1000-mi² area, a density of 1 point per 0.25 mi², on the average, detected twice as many days with

Table 1. Frequency of crop-damaging hailstorm days and variations in areal extents of damaging hail in 1000- and 4000-mi² regions as defined by different sampling densities and April–October data in 1952–1963 period.

Number of storm days per season	1000-mi² region: 9	3	1	0.5	0.25	4000-mi² region: 9	3	1	0.5	0.25
	Number of mi² damaged for each sampling point									
Average	6	10	11	12	13	11	16	17	18	19
Maximum	14	19	20	21	21	22	25	28	29	29
Minimum	1	3	3	4	4	5	6	7	9	9
	Number of mi² damaged per storm day									
Average	4.5	6.1	11.0	15.9	18.3	6.31	10.7	22.6	31.0	36.1
Maximum	21	51	156	200	218	76	242	713	856	913
Minimum	0	0	0	0	1	0	0	0	0	1
	Number of mi² damaged per season									
Average	27	59	123	192	237	69	174	385	560	680
Maximum	75	144	316	518	575	208	501	911	1002	1098
Minimum	3	6	13	20	27	17	52	98	169	186

TABLE 2. Per cent of total area of damaging hail in two regions measured by different densities of observation points during a crop season.

Number of storms days per season	Per cent of damaged area for given number of mi² per sampling point — 1000-mi² region				4000-mi² region			
	9	3	1	0.5	9	3	1	0.5
Average	11	25	67	85	10	26	70	86
Highest	13	30	75	91	13	28	77	96
Lowest	8	20	62	80	9	23	64	81

TABLE 3. Density of surface hail measurements in various hail study areas.

Study area	Years of operation	Number of measurement points (observers and/or hail pads)	Size of study area (mi²)	Area represented by each point (mi²)
South Dakota-Iowa-Minnesota (Frisby, 1963)	1961	22	7,500	341.0
Southwestern South Dakota (Stout and Changnon, 1966)	1966	91	3,000*	33.0
Central Illinois (Wilk, 1961)	1958–61	1000	22,250	22.3
Northeastern Colorado (Schleusener, 1962)	1959	200	3,400	17.0
Northwestern North Dakota (Koscielski, 1967)	1967	63	980*	15.6
Southwestern North Dakota (Butchbaker *et al.*, 1966)	1965	90	1,340*	14.9
Western Nebraska (Smith *et al.*, 1967)	1966	160	1,300*	8.1
Central Alberta (Summers and Paul, 1967)	1962–66	5000*	22,000	4.4
Eastern Illinois (Changnon *et al.*, 1967)	1967	135	400	2.9
South Africa (Carte, 1963)	1962–63	800	1,000	1.3
Oregon (Decker and Calvin, 1961)	1959	230	145	0.6

* Approximate value (true value unknown).

damaging hail as did 1 point in 9 mi². In one year (1953), the 1000-mi² area had 21 damaging hail days, as defined by 1 observation point per 0.25 mi², whereas a density of 1 point per 9 mi² detected damaging hail on only 7 days.

The average values for the areal extent of damaging hail on storm days also shows a considerable variation with sampling density (Fig. 2). In the 4000-mi² area, 16,000 sampling points (0.25 mi² per point) indicated that the average daily areal extent of damaging hail was 36 mi², whereas 445 points (9 mi² per point) measured only 6.3 mi² of damaging hail per day. Thus, on the average, a study area with 1 point per 9 mi² will measure only 18% of the actual daily areal extent of damaging hail and an area with 1 point per 3 mi² will measure only 30% of the daily damage area.

The crop-season averages in Table 1 were expressed as percentages of the total damaged hail area, as defined by 4 points mi^{-2}, and these values appear in Table 2. On the average, a hail network with a density of 1 point per 9 mi² in a 1000-mi² area measures 11% of the actual area of damaging hail in a season. In one year, this density measured a high of 13% and the 1-year low was 8%. A sampling network of 1 point mi^{-2} would measure only about 70% of the damaging hail in a crop season.

The number of surface sampling points in several recent hail studies is shown in Table 3. Values for the area sampled by each point reveal densities ranging from 1 point per 0.6 mi² to a high of 1 per 341 mi². Only the African and Oregon studies had a density of points that apparently would provide a reasonably accurate measure of the daily and seasonal areal extent of damaging hail.

In summary, the average and extreme values in Tables 1 and 2 indicate the magnitude of the potential measurement errors associated with varying densities of point hail data in Illinois. The results also indicate that a network comprised of 1 or more observation sites mi^{-2} is necessary to measure adequately the areal extent of damaging hail.

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