A SOURCE OF DATA FOR HAIL SUPPRESSION STUDIES

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Abstract. In analyzing past hail suppression cloud seeding programs, the best test of hail suppression efforts to reduce crop-hail damage is the amount of money paid out on insured crop acres. The National Crop Insurance Services data supply these data. The size of the sample that these data represent and the homogeneity of the sample across the state can be determined by looking at the total utilized cropland acres in each county and the total liability for each county. Weighted Loss Cost values are preferred over Simple Loss Cost values in the analysis of crop-loss due to hail damage.

1. SOURCES OF DATA AND LIMITATIONS

The two main sources of hail data available are National Weather Service Reports and Crop-Hail Insurance data. Only four weather reporting stations in South Dakota have any quality hail-day records which extend back over a period of time longer than a few years. Furthermore, hail-day data are not necessarily measures of hail damage suffered (Changnon, 1969). The volunteer weather observer may also fail to observe small hail falls or occurrences of hail by night (Changnon, 1969). The Crop-Hail Insurance data maintained by the National Crop Insurance Services (NCIS) in Chicago give a statewide coverage of insurance losses paid along with the total insured liability. Since these NCIS data are used by the crop-hail insurance industry to set premium rates for crop-hail protection, they must accurately reflect the actual amount of crop-hail damage sustained in an area. The reliability and accuracy of the NCIS data must be above reproach.

The NCIS data were employed in this study because of the widespread liability coverage in South Dakota and because the most meaningful measure of the success or failure of a hail modification program would be reflected in the insurance data. These NCIS statistics are compiled from about 75 per cent of the hail insurance industry in the United States (Heverly, personal communication). About five to seven and one-half per cent of the crops of South Dakota are insured for hail damage and therefore the NCIS data present hail damage information on about 3.75 to 5.6 per cent of the cropland across the state. (Donnan, et al, 1976, p. 45). The NCIS data are a meaningful expression since they are available for a representative portion of the cropland acres across the state. In addition, the data do reflect the actual amount of crop-hail damage sustained by the crops (Changnon, 1969). No crop-hail data are available for the non-insured acres of the state. This study is based only on data for the insured acres.

Although hail insurance data appear to be the best measure for evaluating hail suppression projects, direct comparisons of the loss in one month with the loss in another month cannot be made. Similarly, comparison of losses for one year cannot be made with another year without certain adjustments. The adjustments to consider for analyzing changes between crop seasons and years include the following factors: 1) the varying susceptibility of a crop to hail damage during the growing and maturing seasons, 2) the varying amount of liability from year to year, and 3) the changing value of the dollar and hence the value of the crop between years.

The NCIS employs a crop conversion factor to account for the different damage susceptibilities various crops will experience during hail storms (Heverly, personal communication). The use of these conversion factors equates all crops to that of wheat, i.e., the damage suffered by a crop is converted in value to record keeping as though it were wheat. This conversion of the hail data by the NCIS all but eliminates the problems of degrees of susceptibility to hail damage for different crops.

The problems of variations during the growing season of a crop to hail damage are not of concern in a study such as this. The NCIS data do not include day-to-day data, so day-to-day comparison of hail occurrence is not possible. The timing of hail occurrence and of the hail damage are not in question. Rather, a look at total growing season changes in the rates of crop-hail damage are being considered.

The value used in the NCIS data to measure the occurrence and intensity of hail is the loss cost value. This loss cost value is nothing but a per cent pay out, based on the ratio of dollars paid out to total dollars of protection. All things being equal, if the total liability decreases, the total dollars paid out would also decrease accordingly. Conversely, as total liability increases from one year to another, all things being equal, one would expect more money to be paid out in crop-hail damage claims.

A major advantage of using the NCIS data then, is that these data are a direct measure of the hail damage, and thus are the most meaningful quantitative data for use in evaluating modification efforts. Because these data are already being

routinely compiled by the insurance companies, they can be obtained at a relatively low cost.

2. PROCEDURES

Crop-hail insurance data were obtained from the NCIS for the state of South Dakota for the period 1948-1982. The data are for each county by year and include: 1) the annual amount of liability (in thousands of dollars), and 2) the annual loss cost value.

A test to determine the homogeneity of insurance liability with respect to seeding status (seeded and nonseeded counties) was performed. This was accomplished to determine if crop insurance practices for protection from hail damage in seeded counties was any different from that in nonseed counties. It was shown that the percent of crops insured in a county tend to be relatively uniform across the state.

The NCIS just started collecting data in 1985 pertaining to the number of acres insured on a county basis. Therefore, obtaining a surrogate measure for the total insured acres by county was necessary. This measure was based on the available data on total liability by county and total utilized cropland acres by county.

Data for cropland utilized acres were available on a county basis for the years 1956-1975 from the South Dakota Crop and Livestock Reporting Service. Since no seeding activity took place in South Dakota for the years 1956-1960, the period 1956-1975 was selected to test for the distribution of hail insurance and to test for the differences between seeded and nonseeded counties with respect to crop insuring practices.

The counties range in size from 405 square miles (Clay County) to 3465 square miles (Meade County). The per cent of the county farmland in utilized cropland acres ranges from a low of three per cent (Shannon County) to a high of over 70 per cent (Lincoln County). Total county utilized cropland acres range from a low of 33,000 acres (Custer county) to a high of 616,000 acres (Brown County). To simply compare the total liability on a county basis would be meaningless in light of the varying sizes and amounts of utilized cropland acres for the counties.

Liability, the total value for which crops are insured against hail damage, is a function of how many acres of crops are being grown: that is, a function of the number of utilized cropland acres. The larger counties or the counties with more utilized cropland acres have a potential for a higher insured crop value or liability. The smaller counties, or the counties with a lower number of utilized cropland acres tend to have a lower total liability. Since total liability for a county is the only available measure of the amount of insurance, it is used as surrogate for the number of insured acres in a county.

To obtain a comparable measure, the average percent of the total state utilized cropland acres by county was determined. This value was calculated by dividing each county's total number of utilized acres by the state total number of utilized acres times 100. This value, the county's per cent of the state's total, was multiplied by the total state liability to obtain an expected liability by county on a yearly basis for each of the years 1961-1975.

For each year (1961-1975), a difference of mean t-test was performed on the 67 paired values of expected and observed liabilities (Table I). At the 0.05 level of significance, the null hypothesis of no difference in the mean could not be rejected. This test of the difference of means shows that a model of proportional allocation of liability based on cropland utilization is not significantly different from that which has been observed. These implications lead to the conclusion that insured acres are proportional to cropland utilization, and therefore, represent, on the average, a five per cent sample proportionally distributed over the state.

Table I

A Two-Tailed Paired-Sample T-Test for the Difference Between Means of Observed and Expected Liability for Each County of South Dakota for Each Year 1961-1975

Year	Mean Diff	S.D.	Std. Error	Calc. T	Prob>|T|
1961	0.34	400.26	48.90	0.01	0.9944
1962	0.79	455.66	55.66	0.01	0.9887
1963	0.33	434.13	53.04	0.01	0.9951
1964	0.52	381.92	46.66	0.01	0.9911
1965	0.52	458.58	56.02	0.01	0.9926
1966	0.55	469.22	57.32	0.01	0.9923
1967	0.06	520.01	63.53	0.01	0.9993
1968	0.36	500.25	61.11	0.01	0.9953
1969	0.71	498.02	60.84	0.01	0.9906
1970	0.36	459.39	56.12	0.01	0.9949
1971	0.18	614.60	75.08	0.00	0.9981
1972	0.45	504.82	61.67	0.01	0.9942
1973	0.60	618.30	75.53	0.01	0.9937
1974	0.78	909.10	111.06	0.01	0.9944
1975	0.83	1040.98	127.17	0.01	0.9948

In 1975, there was a total of 14,190,000 utilized cropland acres in South Dakota. The total state value of crops insured against hail damage was $107,226,000. By using an average value of $100 insured value per acre (Shane, 1986), the estimated number of insured acres is 1,070,000. This value represents about seven and one-half per cent of the total utilized cropland acres for 1975. By employing the NCIS crop-hail data, a sample of seven and one-half per cent of the utilized cropland acres has been obtained. As shown above, the liability is evenly distributed over the utilized cropland acres for each county. These data also imply that the insured acres

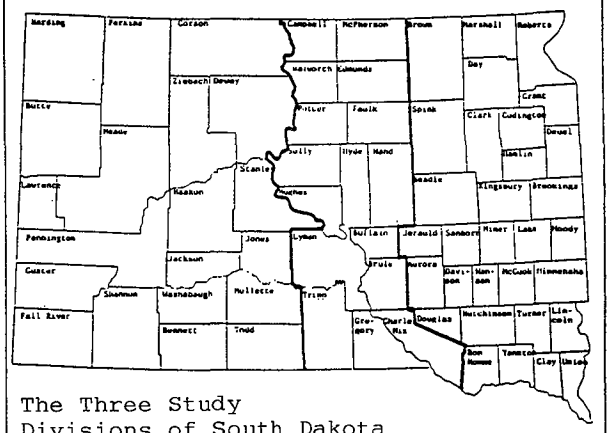
are evenly distributed over the utilized cropland acres in each county.

The NCIS data can be used as a basis for examining hail damage to crops. These data are homogeneous with respect to distribution over the utilized cropland acres.

3. METHOD OF STUDY

One of the first questions which had to be addressed before further analysis of the hail damage data for South Dakota could be performed, was the question of homogeneity or heterogeneity of the state with respect to insurance liability and land utilization. To deal with this question, the average per cent of utilized cropland acres was computed for each county. The adjusted average liability (the liability expressed in terms of 1982 dollars) for each county over the period 1948-1982 was calculated. Based on the findings presented in these two figures, the state was divided into three areas (Figure I). An analysis of variance on

Figure 1



The Three Study Divisions of South Dakota

the percent of utilized cropland acres between regions was performed (Table II). This test compared the means of the utilized cropland acres of all the counties of each area over the years 1956-1975. A similar test was performed on the difference of means of adjusted liability between areas over the years 1948-1982. This test compared the means of the counties' liabilities adjusted to 1982 dollars over the 35 years of record. The results indicate that the three areas are distinctly different at the 0.05 significance level with respect to utilized cropland acres and adjusted liability.

A final group of tests was performed to test the homogeneity of the transformed adjusted liability values (county liability divided by the number of utilized cropland acres in the county) over the seeded and nonseeded counties. A t-test of the difference of means of the transformed adjusted liabilities of the seeded and nonseeded counties for the years 1972, 1973, 1974, and 1975 was performed. For each of the four years the results indicate no difference at the 0.05 significance level (Table III).

Table II

Results of Analysis of Variance on Percent of Utilized Cropland Acres Between Regions of South Dakota: 1956-1975 Data

Source	DF	SS	MS	F
Between	2	27534.8	13767.4	216.63*
Within	64	4067.4	63.6	
Total	66	31602.2		
Contrast				
Area 1 vs Area 2, 3	1	20652.8		324.97*
Area 2 vs Area 3	1	5158.3		81.17*

*Significant at the 0.05 level.

Table III

Results of T-Test of Difference of Means on Transformed ADjusted Liabilities Between Seeded and Nonseeded Counties

Transformed adjusted liability (TAL) is defined as the insured liability of a county divided by that county's number of utilized cropland acres

	1972	1973	1974	1975	
S	26	42	46	45	# of Co.
	7.21	7.79	11.72	12.07	Mean
	5.64	5.18	7.20	7.48	S.D.
N	41	25	21	22	# of Co.
	7.90	7.27	9.97	11.33	Mean
	4.97	5.34	4.83	4.94	S.D.
	0.52	0.39	-1.02	-0.42	Computed t
	1.99	1.99	1.99	1.99	Tabulated t

S=Seeded Counties : N=Nonseeded Counties

The three areas as defined in Figure I are distinctly different allowing comparisons to be made between these areas. In addition, the adjusted liability proved to be homogeneous with respect to seed status, making liability a valid measure for analysis of the seeded versus nonseeded counties.

4. MEASURE OF LOSS COST

4.1 Simple Average Loss Cost

Measures of loss cost over space or time can be obtained through a process of simple averaging. For example, the average loss cost for the state on a yearly basis is obtained by summing the loss costs for each county for the desired year and dividing this value by the number of counties (67). The loss cost averages

can also be accomplished on the basis of seeded and nonseeded counties by summing the loss cost values for the seeded counties and dividing by the number of counties of record, and summing the loss cost values for the nonseeded counties and dividing this sum by the number of counties of record. Similarly, average loss cost values can be calculated on the basis of the areas of the state and the seeded and nonseeded status of the counties included in those areas.

The employment of the average loss cost value does have its disadvantages. Since loss cost is simply a ratio of losses paid out to total insured liability, extreme local events, such as low liability, have a greater weight than is appropriate.

4.2 Weighted Average Loss Cost

When several counties as a group for a single year or a single county over several years were compared, a weighted loss cost value was employed. This weighted loss cost value as suggested by Rose and Jameson (1986) avoids an extreme local event of low liability linked with high loss cost from having a greater weight than is appropriate in expressing losses. The weighted loss cost is obtained by dividing the total dollar losses paid out by the total dollar liability times 100. The weighted loss cost average for a county is obtained by summing the products of each year's loss cost and corresponding liability, and dividing this sum by the sum of the liabilities over all years. Similarly, average weighted loss cost values can be obtained on an area based on all years of record, and state averages on the basis of seeded or nonseeded years.

The following example points out the effect of an extreme local event of low liability linked with high loss cost for a single county within a group of counties. This occurrence would cause a much higher average loss cost value than appropriate. For the year 1961, Pennington and Fall River Counties made up a group of contiguous seeded counties in western South Dakota. Pennington had a total liability of $254,000 with a loss cost value of 2.07, while Fall River County had a total liability of $6000 and a loss cost value of 40.16. The simple average of the loss cost values for the two counties is 21.11; this is implying that $21.11 was paid out for each $100 of insured liability for the two county area, or a total $63,330. The actual losses paid out were $5257.80 for Pennington County and $2409.60 for Fall River County: a total of $7,667.40. The actual amount paid out is far less than the amount which the simple average loss cost value of the area would suggest. The weighted loss cost value for the two county area is 2.949, and when it is multiplied by total liability, it does yield the correct total amount of losses paid out.

The weighted averaging process has the disadvantage of not taking into account the time value of money. In the temporal vein, the value of the liabilities and hence the loss costs are dependent on the changing value of the dollar over the years. This suggests that an additional transformation of the liability be made by expressing liability in constant dollars.

The adjusted weighted average of loss cost takes into account the time-value of money. The adjusted weighted average loss cost is computed by summing the products of the loss cost values and liability and a dollar conversion factor divided by the sum of the products of the liability and a dollar conversion factor. The Gross National Product (GNP) inflation factor was employed in this study. Other indices such as personal consumption expenditures could be employed, but the GNP was selected in this study as the most meaningful reflection of overall inflation.

5. CONCLUSION

The analysis of past cloud seeding programs designed to suppression crop-hail damage, can be accomplished utilizing the crop-hail insurance data maintained by the National Crop Insurance Service (NCIS). These data were shown to be a uniformly distributed, representative sample of the cropland in South Dakota. The employment of the weighted loss cost proved to be desired over the simple weighted loss cost value in the analysis.

6. REFERENCES

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