"REVIEWED"

RESULTS OF HAIL SUPPRESSION EFFORTS IN NORTH DAKOTA AS SHOWN BY CROP HAIL INSURANCE DATA

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Abstract. An examination of crop-hail insurance data as a tool to evaluate hail suppression efforts in western North Dakota is presented. Six western North Dakota county (Target area) data are compared to twelve eastern Montana county (control area) data. Target/control seed years versus non-seed years wheat yields, insurance liability, and loss cost values are compared. The data analysis using double ratios and target/control comparisons suggests that a 17 to 41% lower hail insurance loss experience is found for the areas participating in the North Dakota cloud seeding project. The data suggest that the direction of the hail loss experience supports the goals of the North Dakota project, but cannot be used to establish unequivocally that the direction and its magnitude are the result of the cloud seeding efforts.

1. INTRODUCTION

The North Dakota Cloud Modification Project (NDCMP) has a long history in terms of scientific weather modification's brief history (dating from the 1940's discoveries of Schaefer, Langmuir, and Vonnegut). The NDCMP, under its present name, began in 1976 and has continued to date. Previously, various counties and groups of counties had contracted for weather modification using county generated tax monies and/or voluntary contributions by local farmers and ranchers. In early years (1950's), the primary goal of the seeding was to augment the precipitation in this semi-arid climate using ground based silver iodide generators. Hail suppression seeding began in southwestern North Dakota in 1961 using wingtip AgI-acetone generators; that project was initiated by local farmers Brewer and Fischer in an attempt to ameliorate the hail problem. Schock (1977) reviewed weather modification activities in the Dakotas and Minnesota through 1976.

The purpose of this paper is to present the results of an exploratory examination of crop-hail insurance data as a tool to evaluate the apparent effectiveness of the hail suppression aspect of the NDCMP. This evaluation is being conducted as part of the NOAA Weather Modification Program (WMP), as discussed by Reinking (1985).

2. THE DATA

2.1 CHIAA Data

The limitations of crop hail data are well documented (Changnon, 1985; Hsu and Changnon, 1983; CHIAA, staff, 1978). Even so, Crop Hail Insurance Actuarial Association (CHIAA) data are at times the only data available over the long term. Thus, many project evaluations and implied results using these data are in the weather modification literature (e.g., Changnon, 1975; Dennis et al., 1981; Changnon, 1977).

CHIAA data from 1924 through 1984 from Montana, North Dakota, and South Dakota provide the basis for this evaluation.

a) HAIL CLIMATOLOGY

Figure 1 shows a map depicting average historic county loss cost values using the total 1924-1984 hail insurance history for the region of interest. Included in the figure are the primary target area counties and related control area counties discussed in this paper. Loss cost (LC) is the aggregate dollar losses divided by dollar liability times 100. In this study, county data were used.

A historic weighted loss cost (WLC) climatology graph showing the Target (T) area and the selected Control (C) area in Montana is shown in Fig. 2. Weighted loss cost (WLC) in this study is the sum of all counties' dollar losses divided by the sum of all counties' dollar liability times

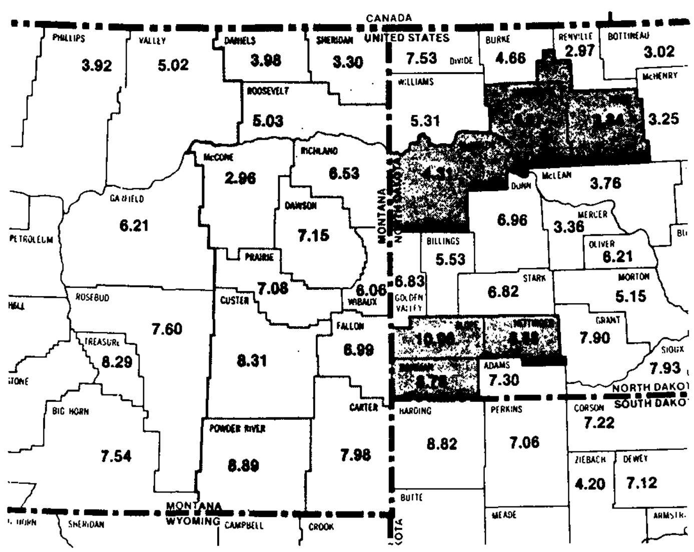

Fig. 1: Map showing the average (1924-1984) county loss cost values for the region of interest. The 6-county area in western North Dakota, the Target area; the 12-county area in eastern Montana, the Control area.

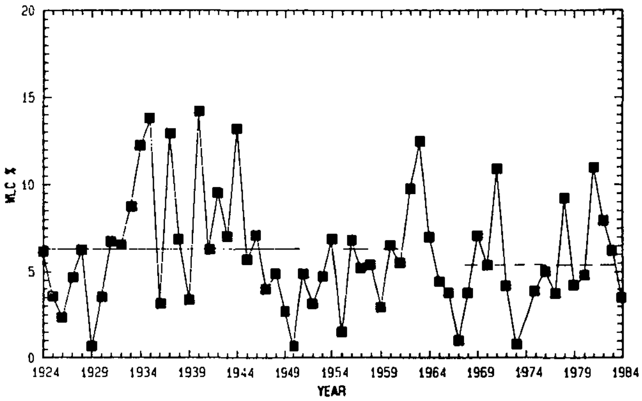

Fig. 2a: Plot of historic annual Control area weighted loss cost values. The historic period mean used in the analysis is shown by the solid line, and the mean seeded years loss cost by the dashed line.

100; all counties meaning those in the target area pooled and those in the control area pooled. The high variability in year to year hail loss experience is readily apparent. Partial seed years identified by circles in Fig. 2b were omitted from this analysis since one or more counties were not in the program during these years. Further climatological characteristics of North Dakota and Upper Great Plains hail events are discussed in NDWMB (1980) and Changnon (1984).

b) INSURANCE LIABILITY HISTORY

Figure 3 shows a history of target and control liability in actual dollars; no correction was made for inflation or cost-of-living variations. The linear correlation coefficient between yearly control and target insurance liability values was 0.92. There are certain trends in the data which likely account for variations in insurance history; for example, following disastrous hail loss years, there is a slight trend to insure against hail disasters in subsequent years. In very dry years, when anticipated crop yields are low, little insurance is purchased. There may be other factors in amounts of insurance purchased, such as cost of insurance (premium rates) versus anticipated market value of the crops.

It should be noted that we estimate the liability insurance to represent, in usual years, about 8 to 10% of the crop values reported.

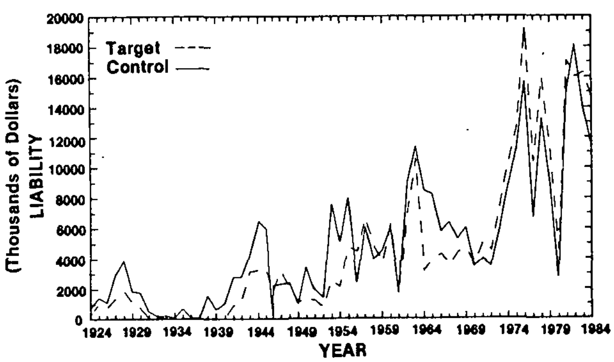

Fig. 3: Plot of Target area (dashed line) and Control area (solid line) annual total insurance liability in thousands of dollars (1924-1984).

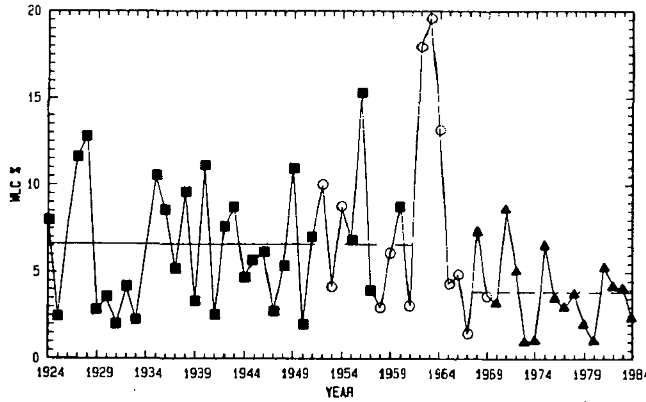

Fig. 2b: Plot of Target area weighted loss cost values. Squares indicate no-seed years; circles, partial seed years (omitted from analysis); and triangles represent the operational seeded years included in this evaluation (1968, and 1970 through 1984).

The data in Fig. 3 also supports the selection of a control area larger than the target area; the less dense cropping pattern in eastern Montana led us to enlarge our control area to provide near equal insurance liability between the target and control areas. Such choices do add to the question of comparability between areas; different liability patterns may necessarily lead to different loss experience.

2.2 Crop History

Figure 4 shows a history of the average yield (bushels/acre) of all wheat grown in the target and control areas. These data were supplied by the states of Montana and North Dakota's Agricultural Statistical Reporting Services.

The dry years stand out in this data set; e.g., 1934 and 1936 are among the extremely poor crop years of the "dirty thirties." Improved

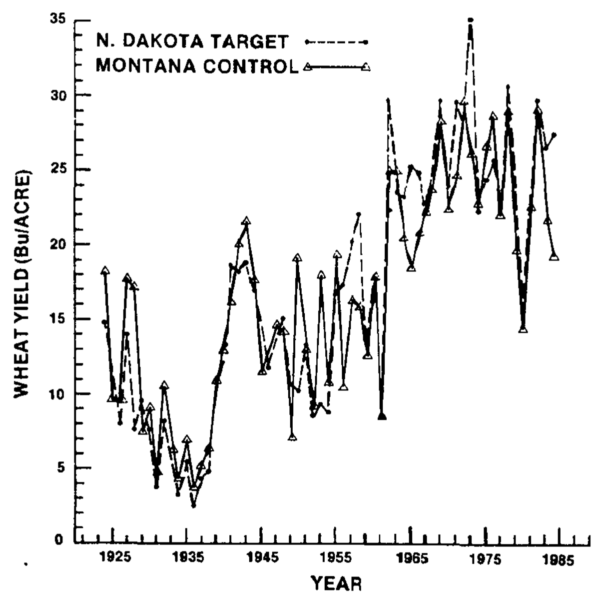

Fig. 4: Plot of Target area (dashed line) and Control area (solid line) average annual wheat yield in bushels per acre.

farming practices including summer fallow and evolving hybrid seed technology likely account for the general trend toward increased yields. The linear correlation coefficient between control and target area yearly wheat yields is 0.90.

3. DATA ANALYSIS

Some preliminary comparisons between several sub-target areas and sub-control areas were made by calculating target and control area Weighted Loss Cost (WLC) values for various configurations (Fuhs, 1986). These results, not shown, using rank tests on T/C ratios suggest a trend toward decreased hail experience in sub-target areas as compared to sub-control areas. Averaging the double ratios, Fuhs' analysis suggested a mean decrease in hail loss experience of about 22%, but without strong statistical significance.

It was later decided to lump all target counties together and use the 12 eastern Montana counties as an upwind control area. This configuration is shown in Fig. 1. This selection helps alleviate problems about contamination, which might be a concern if the counties located between the two districts conducting seeding operations or downwind counties were used as control areas.

For the analysis here, a seed year was defined to be a summer season during which at least 75% or more of the target area shown in Fig. 1 was under contract to be treated.

Examination of the data in Fig. 2a shows that the Control area in eastern Montana experienced a trend toward lower WLC values during the Target seeding years (but to a lesser degree than the target area). Mean WLC values in the Control area were 6.29 and 5.40 in historic and project years, respectively -- a 14% lower insurance loss experience during seed years.

Examination of the data in Fig. 2b shows that Target mean WLC values were 6.58 during the historic period and 3.88 in the seed period. This would suggest a 41% lower insurance loss experience during the project years.

Table 1 shows a summary of these WLC data including means, medians, and standard deviations. The Double Ratio DR = $(T/C)_S/(T/C)_{NS}$ suggests a 31% lower hail insurance loss experience using mean WLC values. One could question the use of the mean to represent central tendency using CHIAA data since loss cost values are not normally distributed. Thus, the Double Ratio using medians (.83) is also presented in Table 1, suggesting an experience on the order of 17% lower.

Double Ratios of Target/Control-Seed/No-Seed wheat yield values (Fig. 4) support the idea that western North Dakota has improved wheat yields more than eastern Montana. Using the same years' data for wheat yields as were used in Table 1, the Double Ratios are 1.14 using average values and 1.08 using median values. These increased yield rates lend support to success toward either or both NDCMP goals -- those of decreased hail damage and rain enhancement.

Figure 5 is a scatter plot of 16 seeded year (triangles) and 30 historic year (squares) Target versus Control WLC values. Least squares lines are drawn and suggest a trend similar to that revealed by the Double Ratio. Table 2 summarizes the analysis using this data set. One possible interpretation of Fig. 5 is that the inter-year variability of hail loss experience in the early years was greater than during the seeded years; this suggestion is supported by comparing the standard error of estimates for historic (3.39) versus seed (1.84) years in Table 2. The data in Fig. 5 also reinforces the notion that the older loss cost data is sparse and of lesser value for use in evaluations than the later years' data.

TABLE 1

Summary of WLC Data Shown in Figure 2

	Target Area	Control Area	T/C Ratio
Historic Period:			
No. Years	30	30	
Median WLC (%)	6.12	6.21	.99
Mean WLC (%)	6.58	6.29	1.05
Std. Dev.	3.51	3.65	
Seeded Period:			
No. Years	16	16	
Median WLC (%)	3.66	4.45	.82
Mean WLC (%)	3.88	5.40	.72
Std. Dev.	2.21	2.87	
Seed/Historic Ratio:			Double Ratio
Ratio of Medians	.60	.72	.83
Ratio of Means	.59	.86	.69

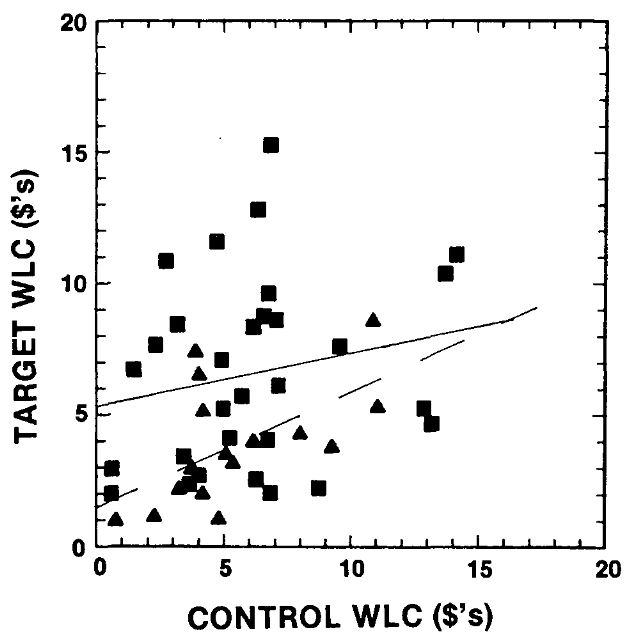

Fig. 5: Scatter plot of Target vs. Control area WLC values in the historic period (squares) and during the seed years (triangles). Least squares lines are shown for comparative purposes (dashed, seed years; solid, historic years).

TABLE 2

Summary of Least Squares Lines
Shown in Figure 5

	Historic Years	Seed Years
Correlation Coefficient (r)	.19	.55
Slope of line	.20	.43
Intercept	5.3	1.6
STD Error of Est.	3.39	1.84

This and other inherent weaknesses of the hail insurance data make it extremely difficult, if not impossible, to draw firm conclusions.

Figure 6 shows a diagram of WLC ratios plotted over the entire historical period from 1924-1984. The WLC ratios were obtained by taking a ratio of the Target counties WLC values to the WLC values in the Control. The squares represent no-seed years; the open circles, partial seed years; and the triangles, seed years. Certain trends are readily apparent. There appear to be definite cycles involving low and high WLC ratios which last approximately 20 years. The dust bowl years of the 1930's are marked by relatively low ratios, followed by an upswing after World War II. This upswing, in turn, is followed by another downswing during the seed years. These types of patterns make cloud seeding programs difficult to analyze. Are we in a period of lower ratios due to a climatic cyclic change? Or, can the lower values be attributed to weather modification? Or, is it a combination of both?

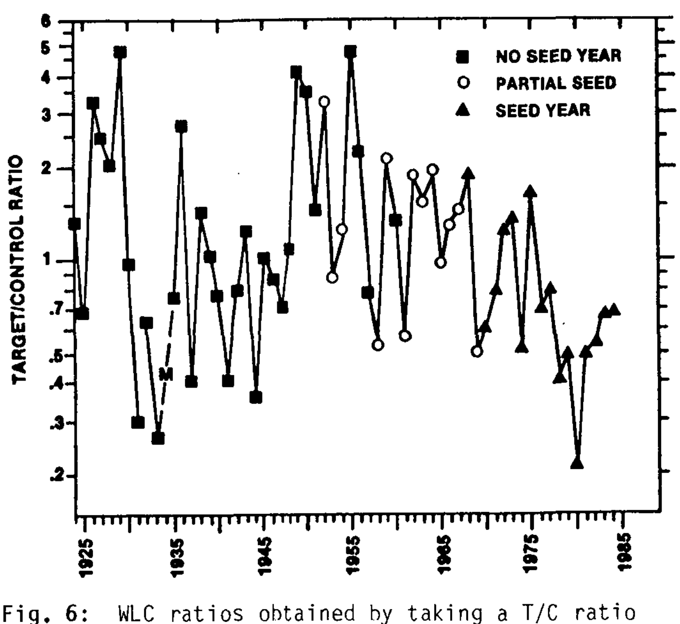

Fig. 6: WLC ratios obtained by taking a T/C ratio of Combined Target and West Control. The squares represent no-seed years; circles, partial seed years; and triangles, the operational seed years; 1934 had missing insurance data.

A Mann Whitney rank test was applied to 16 seed year and 31 historic T/C ratios. The significance value of 0.02 suggests that seeded T/C ratios were less than the historic T/C ratios. Further studies relating hail to rainfall and other variables may aid in our understanding of these trends.

Figure 7 is a double mass plot of cumulative historical WLC values (1924-1984). The two lines plotted are for the historical years and seeded years portions of the double mass curve. The historical years slope was .79 and the seed years slope is .62. This comparison suggests that during the seed years, the relative rate of growth of hail losses in the Target area is about 78% of the relative rate of growth of hail losses during the historical years; this suggests an average target-area hail experience during the seed years 22% below the historic years. Climatic changes or seeding effects could account for the changes in slope noted. The in-between years include the early 1950's ground seeding period, and the partial seed years of the 1960's, a period during which the slope was greatest. Are these temporal climatic changes or can they be associated with the State of North Dakota's cloud seeding efforts? Since we are not dealing with a controlled experiment, and the data analysis is all post hoc, we may never have a final answer.

4. DISCUSSION

The use of CHIAA data to assist in the evaluation of the NDCMP lends support to the hypothesis that ice-phase seeding in western North Dakota can help ameliorate the hail damage problems experienced by farmers in counties participating in the program. Specific hailfall reduction estimates vary but appear to be in the 17 to 31% range using Target Control comparisons.

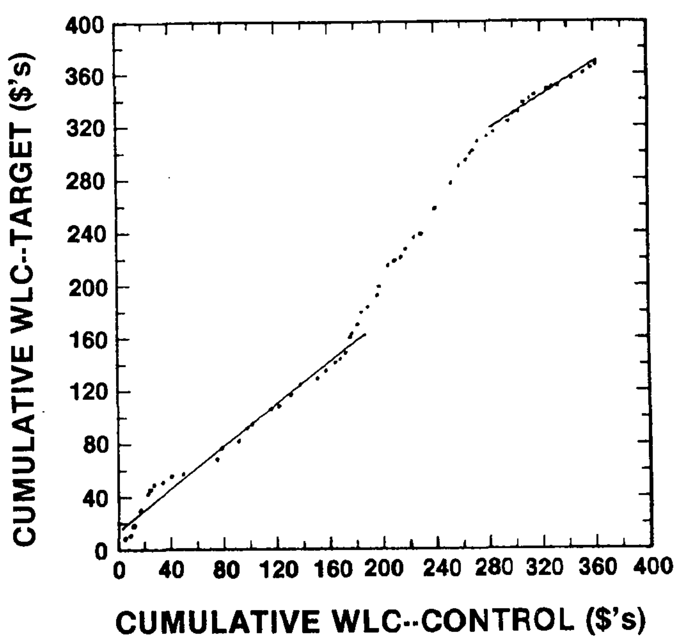

Fig. 7: Cumulative double mass plot of WLC values in Target vs. Control areas. Each dot represents one year's data. Least squares lines are shown for historic (lower left) and seeded years (upper right).

If seed years' data and historic data in the Target area are compared, exclusive of the Control area, these ratios suggest up to a 40% lower hail loss was experienced during the 16 seeding years considered.

There are other considerations which, if included in the analysis, may modify these suggested hail suppression trends. The present analysis includes Target counties in the years 1970-1972 in which the northern Target area was under a 3 to 1, S/NS randomized cloud seeding project; thus, some storms were by design left untreated for analysis purposes (Miller et al., 1975). In the 1960's, storms were seeded primarily in daylight hours only, and thus nighttime hailstorms were left untreated.

Weather radars manned by meteorologists were added to the program in the late 1960's, adding greatly to early detection and thus earlier interception of potential hailstorms. In spite of ground radar and more and higher performance aircraft, Smith et al. (1985) found that a significant portion of clouds posing a hail threat were not treated in a timely manner. Some of this is due to available aircraft being assigned to work the hailstorms posing the greatest threat, and thus hailstorms showing lesser threat were many times left untreated until equipment became available.

In spite of some of these operational shortcomings, the analysis suggests that some progress is being made to suppress hail in western North Dakota.

The data analysis presented is designed to generate questions, speculation, and hopefully useful ideas about the evaluation of hail suppression operations using available crop-hail insurance data. In conclusion, we are encouraged by the direction that the data indicate the hail experience in western North Dakota have taken, but cannot establish unequivocally that the direction is a result of the cloud seeding efforts. We encourage suggestions by readers aimed at helping to find ways to use these data more effectively in our attempts to identify cause and effect relationships on such operational hail suppression projects.

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