EVALUATION STUDIES OF LONG-TERM HAIL DAMAGE REDUCTION PROGRAMS IN NORTH DAKOTA

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1. INTRODUCTION

Cloud modification activities have been conducted in North Dakota every year since 1951 with the exception of four years (1956-1958 and 1960). Application of the unproven science of cloud modification stems from the reported beneficial economic factors to the agrarian economy. Figure 1 from Johnson (1974) shows the annual losses related to weather, insects, and disease.

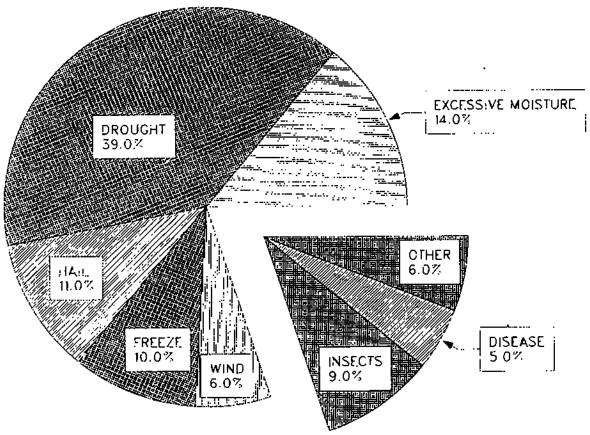

Fig. 1. Causes of Crop Damage in North Dakota

Hail and drought account for one half of the annual loss. Reduction of these losses, if only by a relative small percentage, would be beneficial to the small grain farmer in southwestern North Dakota. Potter and Sonka (1977) show that decreases in hail damage greater than 20%, with a 0-10% increase in rainfall, are economically beneficial. The study also shows there is a reduction in the annual variability of income with the reported income increase.

Southwestern North Dakota is the location of the longest perennial hail damage mitigation program using aircraft delivery seeding in the world. The program started in 1961 in a few townships in Bowman and Slope Counties. It now covers the original counties plus Hettinger County. This study compares surrounding areas shown in Figure 2, which have not conducted any major efforts in cloud modification, to the operational counties which have been contiguously seeded (1968 - 1984).

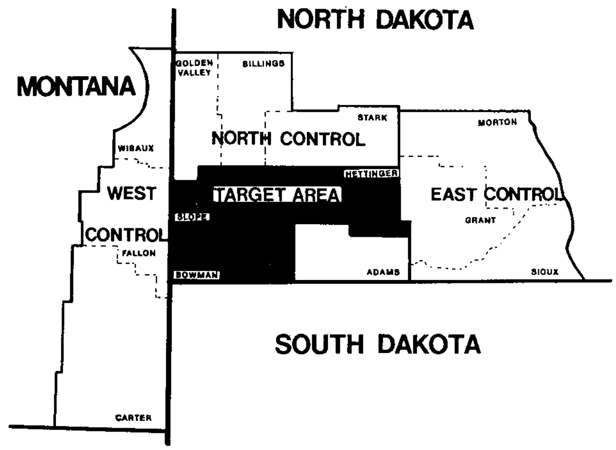

Fig. 2. Map of Target and Control Counties

Adams County, North Dakota and the surrounding counties of South Dakota have had seeding programs off and on during the years considered for this study, and have not been included.

Changnon (1977) calculated the average loss cost ratio for the crop reporting districts for the major loss states. The southwestern crop reporting district of North Dakota was the highest during the study period of 1948-1967. Figure 3 is a cumulative plot of North Dakota's loss cost data from 1924 through 1985.

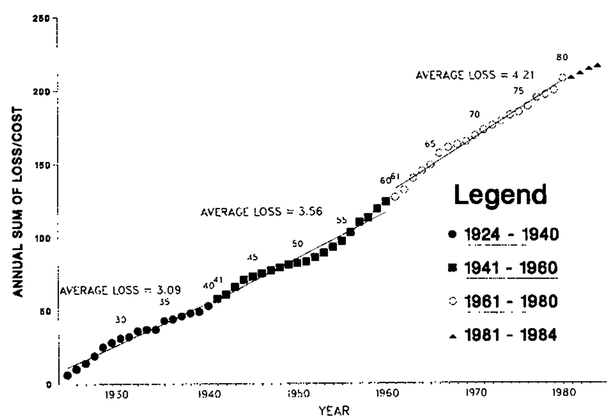

Fig. 3. North Dakota Accumulated Weighted Loss Cost (WLC)

Considering the averages of loss from 1961-1980, a 13 and 15 percent respective increase has occurred compared to the earlier periods.

Figure 3 agrees with the Changnon (1984) report of increased loss trend of the upper Midwest. How the seeded areas have fared during this time period still remains a question.

Research studies in the region have been suggestive of a hail damage mitigation technology. Two in particular have been the Butchbaker (1970) and the North Dakota Pilot Project (NDPP). The Butchbaker study used hailpads, raingauges, and 3-cm radar to consider the effectiveness of the operational program during 1967 -1969. The study concludes that there was a 30% to 60% reduction in hail energy in the target area as compared to the north, west, and south control areas. In a separate study, the NDPP concluded that there was, "tentative evidence that seeding at rates of approximately 1 kg/hr was associated with reduction of hail at the ground" (Miller, et al, 1975.)

2. ANALYSIS

The analyses used in this study are double mass plots of weighted loss cost,

$$R = (L_o \div L_a) * 100$$

where L_o is the dollar loss incurred during a given year and county and L_a is the dollar liability sold during the same year and county.

Using loss cost data for a target or control area comprised of more than one county, one should avoid an extreme local event (e.g. a major loss or no loss in one county) from having a greater weight than appropriate. To assure even weighting, the insurance industry (CHIAA 1978) uses weighted loss cost data (R_w). R_w is defined by

$$R_w = \frac{\sum L_{oi}}{\sum L_{ai}} * 100$$

where i denotes the number of counties comprising a target or control area. The weighted loss cost is the aggregate dollar losses over a region divided by the total dollar liability sold times 100.

Schock (1977) summarized the cloud modification activities from 1951 through 1976 for the upper Midwest, and licenses and permits from the three state region document activity since 1977. These records show that from 1968 through 1984 the target area as described in Figure 2 was seeded and the adjacent control areas were not. In the pre-seeded period, e. g. before 1961, no seeding was done for hail damage reduction and no seeding was being done by aircraft. Years in which seeding effected a major portion of a target or control area, have been eliminated from the non-seeded time period. The period of 1961-1967 has been excluded from the analysis because major portions of the target area were not participating in the seeding program.

Figure 4 is a historical comparison of the target area before seeding was conducted (1948-1960) to the seeded period of (1968-1984). The

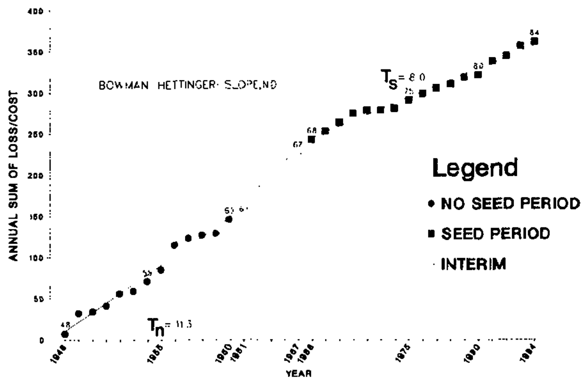

Fig. 4. Target Area Accumulated WLC

average loss for the non-seeded period is 11.3% while the seeded period is 8.0 percent. This 29% reduction in loss is somewhat surprising given the regional increase as described by Changnon (1984) and the trends shown in Figure 3. The control areas show trends more in line with the the regional hail patterns as shown in Table 1.

TABLE 1

	AVERAGE LOSS SEEDED PERIOD 1968 - 1984	AVERAGE LOSS NON-SEEDED PERIOD 1948 - 1960	PERCENTAGE CHANGE
TARGET	8.0	11.3	-29%
NORTH CONTROL	7.3	7.3	0%
WEST CONTROL	9.2	6.1	+51%
EAST CONTROL	8.5	6.4	+33%

Figures 5, 6, and 7 are double mass plots of the target area to the surrounding west, north, and east control areas respectively. The Figures are cumulative plots of the annual target loss cost to the annual control loss cost by year. The beginning and ending years are noted on the graph for the seeded, no seed, and interim time periods. Reference years between the end points are also included. Some years are missing for various reasons such as no data or seeding in the no seed period. Average loss figures are listed near the time period (seeded or no seed) plot for comparison of average losses between target (T) and control (C).

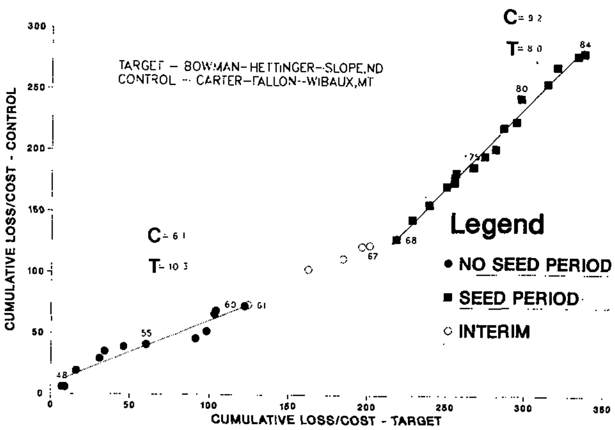

Fig. 5. Target vs. West Control Accumulated WLC

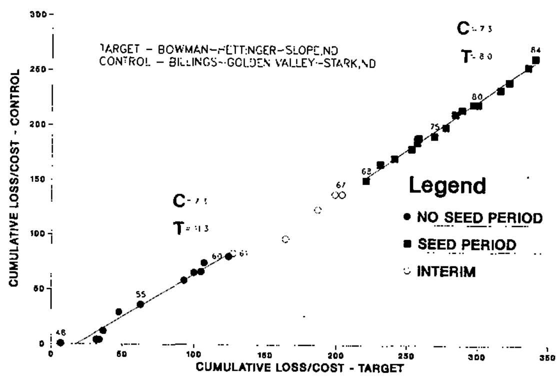

Fig. 6. Target vs. North Control Accumulated WLC

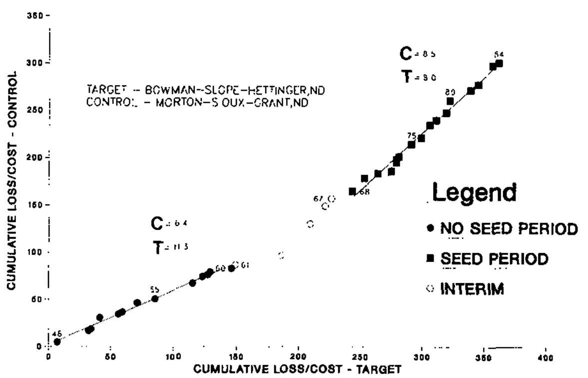

Fig. 7. Target vs. East Control Accumulated WLC

The west and east controls depict sharp discontinuities in slope between the non-seeded periods and the seeded periods, while the north control shows little change. The change of slope in the west and east controls comes from the combined effect of rising loss cost in the controls and the noted decreases in the target. Yet no discernable change can be seen in the double mass plot of the target and the north control.

A series of statistical tests were performed on the data sets represented in Figures 4 - 7 using the Mann-Whitney U test. The tests were designed to address three questions: 1) Do the populations of the seeded period differ in location from the populations of the non-seeded period within the target or a control?, 2) Are the populations different in location between the target area and the controls in the pre-seeded time period?, and 3) are the populations different in location between the target and the controls in the seeded time period?

Assumptions are of course made with such testing as to the drawing of a random continuous sample from independent populations, that may only differ in location and not in the function of the distribution. The testing as described is a two sided test and p-values were always considered at .10.

The first category is a historical comparison between the seeded period and the nonseeded period. Of the target and the three controls, only the east control has a test statistic U value below the calculated critical U. This suggests the seeded years have a different population than the non-seeded period in a non-seeded region downwind of the target area. One must consider that the north control is also downwind of the target area and no change was suggested in this direction. As shown in Figure 7 the control loss cost average for the non-seeded period was 6.4% while the average during the seeded period increased to 8.5%.

The second category has three tests for population changes between the target and the controls before seeding started in 1961. The average loss costs as depicted in Table 1 would suggest that the target would have a different population than the controls. Both the west and east controls show test statistics that imply different populations than the target area in the preseeded time period. The Mann-Whitney test does not suggest that the north control is different from the target for the number of years sampled despite the differences in average losses.

The third category is the comparisons of the target and controls during the seeded time period. None of the tests show a difference in the populations between the seeded target and the controls.

3. SUMMARY AND CONCLUSIONS

An exploratory look at a long-term seeding program, which is operating in one of the most severe hail prone regions of the United States, has been conducted. Using hail insurance data, a historical and target-control analysis attempt has been completed. The changes in loss cost averages are impressive, but due to the nature of the variability in hail losses as recoreded by insurance data, are not solely convincing. Subsequent testing by the Mann-Whitney U test shows the disparity of loss equalized between the target and the east and west control. The north control, seemingly consistent in its history of loss over the past third of a century, presents an opportunity for further study.

One can only consider the possibility that the target may be experiencing a climatiological increase in hail loss and the seeding may be having a far greater effect than measured, or the climatology is providing what many think and believe is a seeding effect. Regardless of the possibilities it is certain that only detailed physical studies conducted through well designed field experiments and supported analyses will unlock the answers to understanding the questions of hail damage reduction seeding.

4. REFERENCES

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