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FINAL REPORT
to
National Science Foundation
on
Research Conducted Under Grant NSF-G10036

"HAIL SUPPRESSION EVALUATION"

by

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"HAIL SUPPRESSION EVALUATION"

I. INTRODUCTION

Northeastern Colorado is near the center of maximum hailstorm frequency in the United States, located at the junction of the borders of Colorado, Wyoming, and Nebraska (1)* . Since hailstorm losses in this region are high, it is not surprising that interest developed in programs of weather modification having the purpose of attempting to reduce hail. Such programs were conducted in northeastern Colorado in 1951, and also in 1958 (2).

However, as has been true in other locations where hail suppression projects have been operated (3), clear-cut evidence on the effectiveness of these operations in reducing hail has not been presented.

The Northeast Colorado Hail Suppression Association contracted with Weather Modification Company of San Jose, California for the operation of a hail suppression program from 15 May to 15 September 1959. In April of 1959 the author was asked by members of the Board of Directors of the Association to conduct an evaluation study on the project. Funds for collection of field data were made available through Colorado State University. Analysis of the data was supported by National Science Foundation Grant NSF-G10036.

II. OBJECTIVE

The objective of the study was to determine if evidence could or could not be found that an operational program of hail suppression in northeastern Colorado was effective in reducing hail occurrences.

A supplemental objective that developed during the course of the study was to determine the effect on precipitation amounts of the cloud seeding measures taken during the hail suppression program.

* Numbers refer to appended references.

III. PROCEDURE

Details of the hail suppression operation are given in a report published by the Weather Modification Company (4), and by Henderson (5). Data collected for the evaluation study included information on rain and hail, reports of the cloud-seeding operation, information on historical records of damage to sugar beets and other crops grown in the area, and reports of precipitation and other weather phenomena from standard Weather Bureau sources. Details of the procedure followed are presented elsewhere (6, B, C, D, E). An innovation in the study was the development of simple instrumentation to estimate the parameter of hail impact energy per unit area with aluminum and styrofoam passive recorders. (A).

IV. RESULTS

Results of the study are presented in detail in papers prepared by the author (6, B, C, D, E). A summary of the results, extracted from these papers, follows:

The results of this study are based on limited observations made during an operational program and are not based on complete observations taken during a designed experiment. For this reason the results cannot be considered conclusive, but rather of a preliminary nature. The evidence at hand suggests the following preliminary evaluation of the effects of cloud seeding on hail and precipitation.

1. Cloud seeding probably was associated with decreases in hail intensity and areal extent in some cases during the summer of 1959 in NE Colorado.
2. In other cases no changes could be detected in hail intensity and areal extent associated with cloud seeding.
3. A few cases suggest that there might have been an increase in hail intensity associated with the cloud seeding.
4. A comparison of hail events from 15 May - 15 September indicates a reduction in hail impact energy (considered to be

related to crop damage) associated with the seeding. However, the differences observed were small, and are not considered statistically significant.

5. Precipitation for May - August 1959 was higher than normal for the southern half of the "target" area, and higher than in adjacent areas, except to the northeast. Silver iodide particles might reasonably be expected to be carried to the northeast during this period of time by the prevailing winds.
6. A target-control analysis of precipitation indicates a positive precipitation anomaly for the area included in the cloud seeding program.

REMARKS

Comparison of hailstones on a case-history basis seems to provide the strongest evidence for a decrease in hail intensity and areal extent associated with cloud seeding. This apparently favorable effect is also suggested for the season by comparing hail impact energy values for seeded and non-seeded cases. In a target-control analysis of precipitation, 8 out of 10 storms in 1959 indicated a positive precipitation anomaly associated with the seeding program. The likelihood of getting this distribution by chance from an unbiased population is less than five (5) per cent.

As is true with evaluation of precipitation increase, the determination of what hail would have been without seeding is most difficult. Analyses of data from a carefully designed experiment offers the promise of providing more positive and complete information in a minimum of time.

V. DISCUSSION OF RESULTS

A discussion of the economic benefits that might accrue from a reduction in hail or an increase in rain is presented in Appendix A . This analysis indicates that only a small hail suppression effect and/or a precipitation increase is required to give a net economic benefit equal to or greater than the cost of the weather modification program.

A breakdown giving the source of support for the hail suppression operation is given in Appendix B . (6).

These data suggest that if a satisfactory evidence of the effectiveness of cloud seeding for hail suppression and/or precipitation increase were to be obtained, economic considerations would probably justify increased use of weather modification programs.

Because of these important economic considerations, further research on the problem is necessary. Since there are difficulties in interpretation of data collected during an operational weather modification program, it is planned to emphasize the study of the physical processes of hail formation in research in the immediate future, and to develop techniques that will permit more positive conclusions than can be stated on the basis of the present study.

The writer has been asked frequently to express his opinion on the effectiveness of the hail suppression operation. The reply has been that after a detailed study of the 1959 operation, the attitude of the writer has changed from that of a complete skeptic to that of a cautious optimist in believing that the 1959 operation did provide some evidence that cloud seeding can modify favorably - at least on some occasions - hailstorms and rainstorms in a beneficial manner.

VI. REFERENCES

(Not supported by NSF Grant NSF-G10036)

1. Yearbook of Agriculture. Climate and Man. U.S. Dept. of Agric., 1941.
2. Frank, Sidney R., Survey and history of hail-suppression operations in the United States. Final report of the Advisory Committee on Weather Control, Vol. II, U.S. Gov't Printing Office, 1957.
3. International Conference on Hailstorms, Verona, Italy, August, 1960. (Papers pending publication in NUBILA.)
4. Henderson, Thomas, J., Northeast Colorado Hail Suppression Project. Final Report - 1959. Weather Modification Company, San Jose, Calif.

5. Henderson, Thomas J., Suppression of hail in northeast Colorado and other sections of the United States. Paper prepared for International Conference on Hailstorms in Verona, Italy, pending publication in NUBILA. 1960.
6. Schleusener, Richard A., Preliminary report on research conducted concurrently with the hail suppression program of the Weather Modification Company in 1959 in northeast Colorado. (Chapter VIII of reference 4.)
7. Rudel, A. K., Personal communication 3 October 1959. (Mr. Rudel was president of the Northeast Colorado Hail Suppression Association, Inc.)

(Supported in whole, or in part, by NSF Grant NSF-G10036)

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- B. Schleusener, Richard A., Hailstorm damage to crops in northeastern Colorado and an analysis of precipitation anomalies associated with a cloud seeding program in 1959. Presented to a meeting of the American Society of Sugar Beet Technologists in Salt Lake City on 2 February 1960. Presently pending publication in the Journal of the Society. CER60RAS1.
- C. Schleusener, Richard A., Hail events in northeastern Colorado in 1959, including an evaluation of a hail suppression program. Presented to a meeting of the American Meteorological Society, Santa Barbara, California, 5 April 1960. CER60RAS7.
- D. Schleusener, Richard A., A review of research on hail. Colorado Farm and Home Research 10(2):1-3, 1960.
- E. Schleusener, Richard A., The 1959 hail suppression effort in Colorado, and evidence of its effectiveness. Presented at the International Conference on Hailstorms in Verona, Italy in August, 1960. Pending publication in NUBILA.

VII. SUMMARY OF RESEARCH

Period October 1959 - January 1960

Personnel:

Richard A. Schleusener, Project Leader

Paul C. Jennings

Consultants

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APPENDICES

APPENDIX A.

Economic Analysis of Benefits Associated with Assumed Changes in Hail Intensity and Precipitation Amounts.

An Estimate of the economic benefit that would be associated with an assumed hail suppression effect can be obtained by applying loss experience on sugar beets as obtained from records from the Great Western Sugar Company, to crop production statistics from selected areas of northeast Colorado.

Analysis of records from the Great Western Sugar Company for the period 1937 to 1939 and 1946 to 1958, indicates an average annual damage to beets of the "heavy damage" category (*) of 15 per cent of the total acres of sugar beets planted for the Ovid, Sterling, and Fort Morgan districts of the GWSC (**). Since crop hail insurance rates for winter wheat are twice those for sugar beets (#), it is not unreasonable to expect an average annual loss to winter wheat of at least the same percentage, that is 15 per cent.

The production records for winter wheat alone in Logan, Phillips, and Sedgwick Counties show an average annual production of over \$15,000,000 for winter wheat produced in the period 1948-57 (##).

* Garner, Lester. Personal communication: "Damage is heavy when the damage is so severe that new leaves entirely have to be grown." (Mr. Garner is Manager of the Sterling District of Great Western Sugar Company.)

** Hodges, Hayden, Jr. "Synoptic patterns associated with hail occurrence in NE Colorado", unpublished report CER59HH29; Civil Engineering Section, Colorado State University, 1959.

Crop-Hail Insurance Actuarial Association. Rates and rules for crop-hail insurance, Colorado 1959.

Colorado Agricultural statistics, 1948-1957.

Destruction of an average of 15 per cent of this crop each year indicates an average annual dollar loss on winter wheat in Logan, Phillips, and Sedgwick Counties in excess of \$ 2,600,000.

Thus, if the cost of a hail suppression program were \$65,000 annually for these three counties, a reduction in hail loss $\frac{\$65,000}{\$2,600,000}$, or about 2.5 per cent, would give a reduction in dollar loss to winter wheat alone that would be equal to the cost of the seeding program.

A similar analysis can be made on the potential economic value of a change in precipitation amounts that might result from the cloud seeding program. The average summertime precipitation at Sterling is about 10 inches from May to September. If this amount could be increased about 10 per cent, one additional inch depth of precipitation would result. This depth of water on 3400 square miles (the approximate size of the target area for 1959), represents a volume of approximately 180,000 acre feet. The value of this volume of water would depend to a large extent on the land use within the area where it would be used. For the range land a value of \$1.00 per acre foot might be assumed. The cost of pumping irrigation water from wells can exceed \$10.00 per acre foot. An average value of \$5.00 per acre foot is not unreasonable.

Multiplying 180,000 acre feet by \$5.00 value gives an estimate of \$900,000 potential annual benefit from a 10 per cent precipitation increase over the area of the cloud seeding operation in 1959 in NE Colorado.

The foregoing estimates of hail suppression effects and precipitation increase are for illustrative purposes only. They are intended to show the potential value of success in attempts at weather modification.

APPENDIX B.

Sources of Support for 1959 Hail Suppression Operation in North-eastern Colorado.

(This was for the weather modification operation, and not financial support for the research.)

The following information was obtained from Mr. A. K. Rudel, President of the Northeast Colorado Hail Suppression Association:

1. The recommended contribution per acre was \$ 0.15 for dry land and \$ 0.50 for irrigated land.
2. Nine hundred ninety-one (991) separate individuals contributed to the 1959 program. (A total of about \$ 65,000 was raised.)
3. No specific information was available on the size of the farming operations of each contributor, but as a general rule the larger farmers would contribute about \$ 100.00. Very few contributions exceeded \$ 100.00.
4. No breakdown was made between dryland and irrigated farmers, but most of the donations came from dryland farmers. Also, the individual donations were much larger from the dryland farmers.