An Analysis of
Cloud-Seeding Operations
in North Central Oregon

R. T. Beaumont

Agricultural Experiment Station
Oregon State College
Corvallis

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R. T. Beaumont
Assistant Water Forecaster
Oregon Agricultural Experiment Station

Cloud seeding in the area of Sherman, Gilliam, and Morrow counties in Oregon was conducted from September 1, 1950 to June 30, 1951 in an attempt to benefit wheat growers by increasing precipitation in the area.

The seeding was done by a Denver, Colorado, firm under a contract with Tri-County Weather Research, Incorporated, of Condon, Oregon, a non-profit organization representing the contributing farmers in the three counties.

The Oregon State College Agricultural Experiment Station was requested by the Oregon Wheat Commission to make an independent evaluation of the results of experimental cloud seeding in the tri-county area.

Seeding operations were conducted independently by the contract operator at such times and locations as the operator considered feasible. Records and important meteorological data were collected independently by the evaluating group. There was mutual exchange of some records between the operator and the evaluating group.

Description of the Seeded Area

The target area for cloud-seeding operations included 2,642,000 acres. Wheat is grown on approximately half of this acreage. The remaining half is mostly grass land with some forested area.

Topography of the area is typical rolling wheat land with elevations ranging from less than 500 feet on the northern border to a maximum of about 5,000 feet in southern Morrow County.

Climate of the tri-county area is dry with an annual average precipitation of 8 to 12 inches, occurring mostly in the fall, winter, and spring, with very little in the summer. The growing season varies from 200 days along the Columbia River to about 100 days in the southern part of the area.

*The analysis herein reported was conducted by the Oregon State College Agricultural Experiment Station in collaboration with the U. S. Soil Conservation Service, Medford, Oregon. Funds for the work were provided by the Oregon Wheat Commission.
The lower areas along the Columbia River experience greater extremes of temperature and receive generally less rainfall than the southern parts. They are also subject to climatic influences typical of the Columbia Gorge, such as the strong winds existing in the area. Thermal thunderstorms are frequent in summer months and damaging hail occurs most frequently in the southern portion of the three counties.

Seeding Methods

All cloud seeding done by the commercial operators was performed when actual storm conditions existed or were likely to exist. The purpose was to increase any natural precipitation which might have occurred.

This was accomplished by using ground generators which burned charcoal that was impregnated with a solution of silver iodide and acetone. These ground generators were placed, for the most part, to the west of the area to be seeded. Data on the exact location and efficiency of the generators were not furnished to the evaluating group by the operators.

The Payment Formula

Since the objective of the operations was to increase precipitation, payment to the operators was made on the basis of a special formula developed by the Oregon Agricultural Experiment Station.

The formula provided that if precipitation was insufficient to produce a good wheat crop, the payment would be a minimum. If favorable departures (or changes) which had occurred only twice in the past 20 years were repeated, the operators were to receive maximum payment, even though it would not necessarily mean that such increased precipitation could be credited entirely to cloud-seeding practices.

In computing the performance payments from this formula, two factors were considered: the total amount of precipitation occurring in the tri-county area and the ratio of tri-county precipitation compared to that of the control area.

Some objection was raised by the operator on the basis that new cloud-seeding projects were started after the formula was prepared, which might possibly have affected precipitation totals at one or more of the 30 stations in the control area.

This factor was taken into account by Experiment Station evaluators studying the operation, although payment for 1950-51 was based on the original contract. In view of the objection, however, a new formula has been prepared for future studies, eliminating stations which might be affected by other cloud-seeding projects. In the new formula, which was recommended to the directors of Tri-County Weather Research, Incorporated, all stations east of the Cascade Mountains have been eliminated and new ratios between tri-county stations and control stations have been computed.
Techniques Used in Evaluation

Statistical techniques

In carrying on an independent evaluation of the results of the cloud-seeding operations, it was necessary to use certain statistical techniques which would show the relationship of precipitation during the cloud-seeding period to the probable amount which would have occurred normally.

Precipitation patterns in the tri-county area were analyzed to determine how much, if any, significant change occurred from normal precipitation as compared with precipitation in a control area not affected by cloud seeding.

Statistical correlation was established between the tri-counties and the control area. By studying the precipitation in the control area and utilizing this correlation, it was possible to determine approximately what the precipitation of the tri-county area would have been without cloud seeding.

The next step was to measure the precipitation which fell in the tri-county area during the time seeding operations were conducted. The difference was then computed between the amount that actually fell on the area and the "statistical estimate" of what probably would have fallen anyway had there been no cloud seeding.

With these figures, it was possible to make a mathematical analysis to determine whether the difference between the "statistical estimate" of normal rainfall and the actual rainfall of the area represented a significant departure from normal or whether it might have occurred by chance.

Geographical techniques

A geographical distribution study of all precipitation occurring in the Northwest was made by plotting daily weather maps. Daily precipitation amounts were plotted as per cent of the station's monthly normals on these maps. Similar maps were made for monthly totals and a single map was constructed to represent the entire 10-month period (Figure 1).

Precipitation amounts shown on Figure 1 are expressed as per cent of normal for the 10-month period of cloud-seeding operations.

Figure 2 shows the position of areas in the Northwest which received proportionately more precipitation in relation to normal than others on seeded days only. This map was prepared from 84 daily maps, plotted for days when seeding operations were conducted and at least 5 per cent of the monthly normal precipitation fell at some observation station within the tri-county area. Maps were not plotted for days when less than the 5 per cent fell since, on these days, there were no definite areas of proportionally higher amounts of precipitation.
Analysis of the Results

Final objective of the evaluation was to determine whether cloud seeding had any measurable economic effect upon precipitation for the contract period in the tri-county area.

The first step in analyzing statistical information was to relate precipitation in the past 20 years within the tri-county area to precipitation within an upwind district including the Willamette Valley and Puget Sound Areas, which were believed to be unaffected by cloud seeding. Eight stations were used in the Oregon tri-county area, located at Arlington, Condon, Kent, Mikkalo, Morgan, Moro, Heppner, and Wasco. Nine control-area stations were located at Eugene, Corvallis, Portland and Salem, and in Washington at Centralia, Olympia, Tacoma, Seattle, and Vancouver.

The original payment formula was based on a network of 30 control stations, but the initiation of new cloud-seeding projects made it necessary to discard this network and set up the new 9-station control area to avoid possible interference with normal precipitation at control stations.

Information collected from all tri-county and control-area stations was analyzed, using the statistical procedures described earlier. From this statistical work it was learned that 8 of the 10 months had favorable departures. This means actual precipitation amounts were greater than statistically estimated amounts. For 2 months, September and November, actual precipitation amounts were less than statistically estimated amounts.

The size of these monthly departures from the statistically estimated amounts was such that all could have occurred by chance this year. It may be significant, however, that this year had more months with favorable departures than any of the past 20 years.

There appears to be no evidence that on marginal days when only small amounts of precipitation were likely to occur that such precipitation was increased greatly by cloud seeding, since on 54 days when seeding operations were conducted, totals were less than 5 per cent of the observation station's monthly normals in tri-county. In terms of actual inches of precipitation this would be generally less than one-twentieth of an inch for most tri-county stations.

Figure 1 represents the precipitation in the Northwest as per cent of normal for the 10 months of cloud-seeding operations. It shows that the greatest amounts of precipitation in relation to normal were received east of the Cascade range in Oregon and Washington. To the east of the tri-county area, totals decreased—with a large area along the Washington, Oregon and Idaho border receiving below normal amounts.

The tri-county area appears to be in a transitional zone between two high centers to the west and north and lower areas to the east.
While the effect of cloud seeding is not apparent from this map (Figure 1), there appears to be no immediate downwind effect to the east causing large increases in precipitation. Greatest departures from normal in Oregon were found in the areas where equipment was believed to be located, or west of tri-county. This might suggest a more local influence by cloud seeding than was expected. Some other areas, however, where no cloud-seeding equipment was known to be operating, also showed increases as large as these.

From Figure 2 on which the aggregate of the precipitation highs have been plotted for days of cloud-seeding operations, there appears to be no definite pattern of these areas in relation to the tri-county area.

Conclusions

1. There is no evidence that cloud seeding established or resulted in establishment of any systematic precipitation pattern in the Northwest month after month during these operations.

2. Favorable departures did occur between tri-county precipitation stations and control stations of Washington and Oregon as based on statistical estimates. These were not statistically significant, however, and therefore may have been due entirely to chance.

3. Evidence indicates that cloud seeding did not substantially increase precipitation when performed on marginal days when only small amounts of precipitation were likely to occur.

4. In view of the departures which did occur this past year, it is felt that one year of operation is not sufficient to draw definite conclusions as to the real economic possibilities of cloud seeding. The station recommends, therefore, that this project be continued, if possible, to provide additional information.
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Precipitation 10 Month Total
Sept. 1950 - June 1951 Inclusive
Percent of Normal

Figure 1.

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Geographical locations of precipitation highs
Sept. 1950 - June 1951

Figure 2.