"NON-REVIEWED"

ECONOMIC IMPACTS OF CLOUD SEEDING IN SOUTHWEST MINNESOTA

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I. INTRODUCTION/SCOPE

The purpose of this paper is to identify the economic impacts associated with weather modification in Southwest Minnesota. Although it is recognized that cloud seeding could directly affect many sectors of the economy, the scope is restricted to the direct benefits on agricultural production and first order income and sales taxes returned to Minnesota. Sectors not covered by this report include electrical power generation, municipal and agricultural surface and underground water supplies, recreation, and wildlife. That is, crop yield response to precipitation change estimates are used to derive dollar benefit figures. These dollar benefits are based on the assumption that an actual cloud seeding program could produce timely increases in growing season precipitation equal to those derived hypothetically, or about 1.00" (15 percent above the 50 year median).

II. SUMMARY

Using the technique of multiple curvilinear regression, the parameters most affecting crop production were identified. These parameters include preseason precipitation, growing season precipitation and maximum temperature, an interaction term of maximum temperature and seasonal precipitation and the overall time trend of production during the past 50 years.

Growing season precipitation (July-August) was then altered according to a generally accepted change model and the effect on crop yield computed, other factors remaining constant.

The results indicated potential increases in corn yield of up to 3 bushels per acre and increases in soybean yield of up to 1.1 bushels per acre due to incremental increases in growing season rainfall. These yield improvements vary from county to county. The figures given are for Nobles County in southwest Minnesota. Based on 1977 prices, this could amount to $5.70 per acre and $6.70 per acre, respectively for corn and soybeans. These compare favorably with the $0.10 per acre costs of operational cloud seeding.

III. THE RELATIONSHIP OF WEATHER TO CROP YIELDS

In assessing the impacts of weather modification on Minnesota's southwest agricultural production, it is first necessary to understand how "natural" weather affects production. McQuigg (1975), identified three factors that determine overall crop production. These are:

A. Time/Technology.

Isolating and interpreting each of these influences is a difficult task, and one that cannot be done to an arbitrary degree of accuracy. Thompson (1969), approximated the influence of technology through the use of time as a proxy variable. The overall trend of production through the antecedent 50 years was estimated with two linear functions. The "ARE" team (1974) utilized a quadratic expression to estimate the time trend. The Montana Agricultural Experiment Station, MSU (1973) also used a quadratic time expression. Likewise, Enz (1976) derived quadratic time expressions for each of five Minnesota counties for corn and soybean production. Because Enz (1976) performed his work on Minnesota crop production exclusively, it forms the basis for the results and conclusions herein expressed. For a good discussion of the overall problems associated with the regression of crop yields against time/weather, the reader is referred to McQuigg (1975), and for those aspects peculiar to Minnesota, Enz (1976).

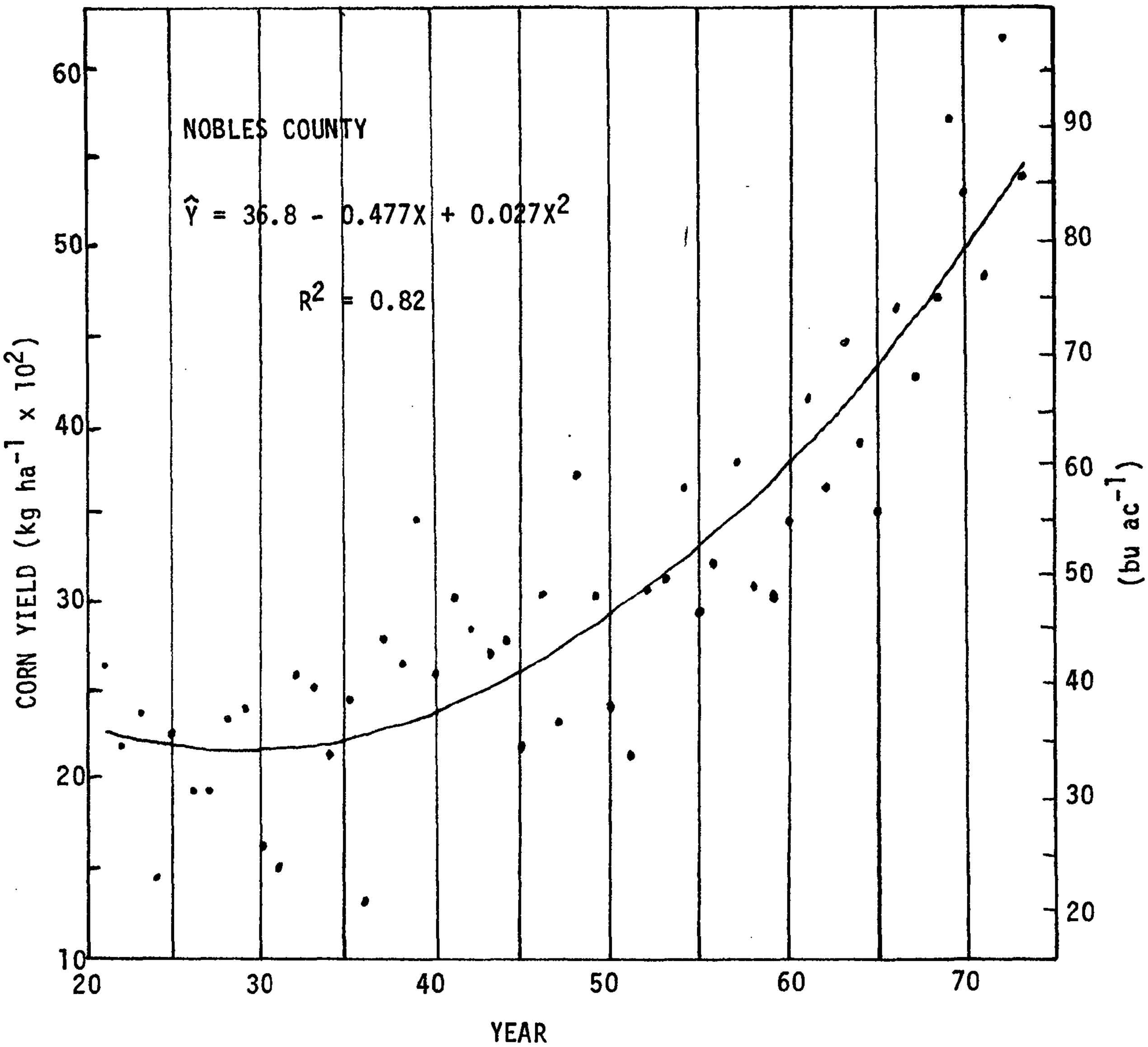
Figure 1 illustrates corn production in Nobles County for the period 1921 to 1973 and the curve derived for the overall time/technology trend.

B. Weather

The scatter about the curve in Figure 1 is attributed to the influence of weather and random factors. In considering those variables that might best explain this scatter, the investigator is limited only by his imagination (Enz, 1976). After repeated trials of various parameters, Enz (1976) found that the following were most satisfactory:

1. Pre-growing season precipitation;
2. Growing season precipitation;
3. Growing season mean maximum temperature;
4. An interaction of two and three in product form; and,
5. Two, three and four squared.

Together, these explained only about one-half of the variation in yield unaccounted for by the quadratic time curve. By dividing the growing season into weekly increments, however, the most critical period for each of the parameters was delineated. For example, in Nobles County, it was found that precipitation played its greatest role in determining corn production during the mid-July period. Interestingly, the effect of precipitation was greater (lesser) with less (more) pre-growing season precipitation, and with average pre-growing season precipitation was found to be beneficial to some degree during the entire growing season. This is an important determinant of the operational period for any cloud seeding program to be undertaken in that area.



ACTUAL CORN YIELDS AND THE CALCULATED TREND DUE TO TECHNOLOGY IN NOBLES COUNTY

Figure 1
[Figure 4-5, Enz(1976)]

Enz (1976) then investigated the effects of a hypothetical cloud seeding program by modeling presumed changes in precipitation according to Changnon and Huff (1971). Here, the effects of cloud seeding upon precipitation were varied with the size of the storm, being progressively smaller with the larger storms. This is reasonable in light of results reported by various operators and investigators (Atmospherics Incorporated, 1976; Changnon and Huff, 1971; Changnon, 1977). Enz (1976) simulated increases in corn yields of up to 3.0 bushels per acre and 1.1 bushels per acre for soybeans in Nobles County. Nobles County is used as an example because it has been part of the target area for a modern operational cloud seeding project, and historically has been a water-short area of Minnesota (Atmospherics Incorporated, 1976).

C. Noise

Random "noise" or random fluctuations not attributable to any given set of factors, such as machinery breakdowns, pests, or most recently energy/fuel constraints.

IV ECONOMIC ANALYSIS

Using the above per-acre yield improvements and 1977 prices taken from Minnesota Agricultural Statistics (1978), per-acre dollar figures can be derived. The 1977 statewide average price received for corn-for-grain was $1.90 per bushel. With 3.0 bushel per acre increase in corn yield in Nobles County this translates into $5.70 per acre gross benefit.

The state-wide average price received for soybeans was $5.60 per bushel. With the 1.1 bushel per acre increase in soybean yield in Nobles County this translates into $6.16 per acre gross benefit.

The dollar benefits were derived by using the maximum yield increases reported as possible by Enz (1976). In Nobles County this could vary down to 1.0 bushel per acre for corn and 0.0 bushel per acre for soybeans. This places lower limits on gross dollar benefits of $1.90 per acre for corn and $0.0 per acre for soybeans with medians of $3.80 per acre for corn and $3.08 per acre for soybeans.

The costs of operational cloud seeding can be expected to vary with the particular project location being considered. Costs have generally increased with time due to improvements in the type of equipment being utilized and inflation. Ten cents per acre per year is conservatively high (Changnon and Huff, 1971; Atmospherics Incorporated, 1976).

Thus, utilizing Nobles County as an example, which is cautioned as being representative of only a limited area of the State of Minnesota, a benefit/cost ratio for operational cloud seeding can be estimated at 35:1, assuming a July-August project.

V MINNESOTA'S RETURN

Using total acreage figures from Minnesota Agricultural Statistics (1978), these per-acre dollar benefits can be translated into total dollar benefits on a county basis. For example, Nobles County in 1977 harvested 166,500 acres of corn and 145,700 acres of soybeans. This gives a gross benefit for Nobles County of $1.08 million using the figures developed in the previous section. The Research Office of the Minnesota Department of Revenue estimated that, through first order income and sales taxes, the State would experience a revenue return of about $130,000. (See appendix).

The four counties of Pipestone, Murray, Rock and Nobles form a natural climatic grouping. Indeed, these four were jointly involved in a cloud seeding project in 1976 (Atmospherics Incorporated, 1976). The yield improvement and benefit figures, derived for Nobles County by Enz (1976), are thus applicable in a broad sense to the four-county group. Again using acreage and price information from Minnesota Agricultural Statistics (1978), total dollar benefits for the four-county group were estimated at $3.05 million. Of this amount, Revenue Research estimated State revenues of some $337,000 or 12 percent of the total benefits. These figures suggest that given an effective cloud seeding program, and the assumptions made, a very favorable economic impact could result.

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APPENDIX I

County	Harvested Acreage		Value of Estimated Additional Yield	
	Corn	Soybeans	Corn	Soybeans
Murray	147,000	119,600	$ 558,600	$ 368,368
Nobles	166,500	145,700	632,700	448,756
Pipestone	88,500	23,400	336,300	72,072
Rock	116,000	64,000	440,800	197,120
Total	518,000	352,700	$1,968,400	$1,086,316

County	Additional Income Tax			Additional Sales Tax			Total Tax
	Corn	Soybeans	Total	Corn	Soybeans	Total	
Murray	$ 63,122	$ 41,626	$104,748	$ 6,522	$ 4,301	$10,823	$115,571
Nobles	71,495	50,709	122,204	4,576	3,245	7,821	130,025
Pipestone	38,002	8,144	46,146	4,245	910	5,155	51,301
Rock	49,810	22,275	72,085	5,341	2,388	7,729	79,814
Total	$222,429	$122,754	$345,183	$20,684	$10,844	$31,528	$376,711

*Prepared by Minnesota Department of Revenue