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Economic Benefits of Crop-Hail Reduction Efforts in North Dakota

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The estimated total economic impact of a statewide hail suppression program in the ten-year study period ranged from $68 million to $161 million, with a ten-year annual average of $97.8 million in total economic impacts. Only six crops were considered in this study: wheat, barley, oats, corn (grain), sunflowers, and flax. Benefits for other crops, including forage, are not included.

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The Crop-Hail Insurance Actuarial Association (CHIAA) gathered and prepared the crop-hail insurance data processed to prepare this analysis. They also provided telephone assistance in interpreting some of the coding used. Their assistance is much appreciated and was important to this report.

Processing of CHIAA data required extensive and precise computer programming and debugging by the second author.

The CHIAA data were computed and summarized by years and counties using the amount of liability ($ crop value insured), amount of premium ($ charged for insurance), amount of loss in dollars, and the loss-cost ratio as a percent of dollars loss divided by dollars liability and multiplied by 100. The loss-cost ratio was computed for six crops individually and combined by counties and years.

The detailed crop production data are from the North Dakota Tax Assessment Model which the Agricultural Economics Department conducts for the State of North Dakota. The National Agricultural Statistical Service collected and prepared the data which it publishes jointly with North Dakota State University.

The authors appreciate the assistance of Mr. Larry Stearns, a graduate student in Agricultural Economics, who explored gross crop returns per acre of treated and non-treated counties using the Statistical Analysis System on the North Dakota State University mainframe computer.

The authors extend their appreciation to the staff of the Department of Agricultural Economics who reviewed the manuscript. Their insights and comments have improved this manuscript.

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Highlights

North Dakota farmers and ranchers experience substantial annual losses of farm output because of hail. The loss-cost ratio is a measure of the total dollar losses due to hail divided by the total dollars of insured liability multiplied by 100 for a selected time period and county. Annual county loss-cost ratios vary greatly from year-to-year so 10-year averages are used here.

A recent study concluded that crop-hail damage in the North Dakota Cloud Modification Project target area averaged about 43.5 percent less during its operational period for the six crops studied.

Estimates of crop-hail losses and crop savings with cloud seeding for all counties are based on crop production and hail data for the 1976-1985 period. These estimates require multiplying each county's annual value of crop production by its annual loss-cost ratio to get the expected loss and multiplying the expected loss by the 43.5 percent reduction factor to estimate the crop output savable per acre with cloud seeding. This is that portion of crop output not lost or value of crop production savable with cloud seeding. The 47 non-treated counties had a 10-year average annual crop output savable with cloud seeding of $23 million, which averages $1.49 per acre for the six crops used in this study.

The six treated counties already had achieved the 43.5 percent reduction in crop losses, so these calculations required adjusting to a non-seeding situation and calculating losses from that setting. The 10-year average annual crop output savable was $2.21 per acre for the six treated counties.

A final calculation considers the total economic impacts of all crop output savable as this saved crop output increases marketings in their communities and across the state. The overall contribution of the increased marketings and increased sales of related goods and services throughout the economy are calculated to have a total economic impact of $8.15 an acre for the six treated counties.

The estimated total statewide economic impact of cloud seeding for the study period ranged from a low of $68 million in 1976, to a high in 1980 of $161 million, and a 10-year annual average of $97.8 million in total economic impacts.

Economic Benefits of Reducing Crop-Hail Losses In North Dakota

By

Jerome E. Johnson, Randal C. Coon, and John W. Enz

Most North Dakotans recognize and accept the great natural variability of the weather of their state. Its mid-continental location in the lee of the Rocky Mountains results in large monthly, daily, and day-to-day temperature changes, moderate precipitation that is irregular in space (coverage) and time, generally low humidities, and nearly continuous wind

North Dakotans also recognize that this climatic variability greatly influences their social and economic livelihoods. Most evident are blizzards that lead to closings of schools, highways, and shopping centers; cancellation of social events; traffic delays, fender benders, and injuries. Heavy spring and summer rainfalls lodge and damage crops and runoff overflows culverts, roads, and city storm sewers. Hail can damage crops and gardens, cars and homes, and results in time lost to fix the repairables plus other costs.

Severe and extensive droughts (for example, 1988) have a major impact on North Dakota agriculture and agribusinesses, households, and the state's economy. Some areas of the state experience soil water deficiencies every year, creating a continuing problem for many farmers and communities

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North Dakota is a uniquely agricultural state. Sales of crops typically produce about 55 percent of annual cash farm income in North Dakota, with livestock contributing 23 percent and government payments near 22 percent. Pasture, range, and hay lands provide the basis for an extensive livestock industry in south central and western North Dakota. Both crop and forage lands can be impacted by major hail events.

The North Dakota Atmospheric Resource Board (NDARB) is concerned with losses due to hail. This economic study of losses utilizes results of a recent study funded by the Board and data available from the Crop-Hail Insurance Actuarial Association (CHIAA) and from other sources in the state. CHIAA has been gathering data on crop-hail insurance and losses for several decades.

This study is premised on the following finding:

Smith, Miller Jr., and Mielke Jr.[1] concluded that the crop-hail damage in the target area of the North Dakota Cloud Modification Project averaged about 43.5 percent lower during the operational period. The Board funded the study and Smith et al. used CHIAA data for 1976 through 1985 for the six crops that are included here. It is called the Smith et al. reduction factor throughout this report to properly credit their work.

Methods of Analysis

Computing the economic impacts of hail and possible benefits due to cloud seeding for each county and year required six steps: **1**),

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[1]Smith, Paul L., James R. Miller, Jr., and Paul W. Mielke, Jr. An Exploratory Study of Crop-Hail Insurance Data for Evidence of Seeding Effects in North Dakota. Rapid City (SD): South Dakota School of Mines and Technology, Institute of Atmospheric Studies, June 1987, p 10.

Calculating crop-hail loss-cost ratios by counties for 10 years using the CHIAA data set, **2**) computing gross values of production for each of the six crops used in the Smith et al. study for the years 1976-1985 using the North Dakota Tax Assessment Model data set, **3**) multiplying county loss-cost ratios times county values of crop production to measure county value of production (crop sales) lost each year due to hail, **4**) multiplying the county value of crop production lost by the Smith et al. reduction factor (0.435) to determine **crop output potentially savable** through cloud seeding for hail suppression, **5**) applying multipliers to measure what the value of crop output savable would mean to community and state economies, and **6**) dividing findings by total acres of the six crops in each county to provide a common per-acre base for the analysis.

The 43.5 percent reduction in crop losses is a potential savings because of cloud seeding, but is not absolutely certain. The reduction in crop losses due to hail treatment means more of the crop is available to be marketed or used on the farm. We express that as "crop output savable" for want of better terminology.

A CHIAA tape for North Dakota provided detailed data on crop-hail insurance contracts and losses by townships, counties, and years. Computer processing calculated hail loss ratios and the economic measures by counties for all years 1976 to 1985. This analysis is limited to hail losses of six crops: wheat and durum, barley, oats, flax, sunflowers, and corn grain. Results of this analysis better represent the western portion of the state, which includes the areas in the Smith et al. study. The eastern farming areas have more of total land in crops, while the Valley

areas include the higher returns of potatoes, sugarbeets, and other crops that were not a part of the Smith et al. study.

This study considers both the two treated areas and all other counties in developing estimates of crop-hail loss-cost ratios, possible crop sales lost due to hail, a conversion to crop output savable due to treatment, and the overall economic impacts of treatment on the state economy. The two treated areas consist of six target counties: South includes Bowman, Hettinger, and Slope counties, and North has McKenzie, Mountrail, and Ward counties.

This report opens with an economic base discussion and chart to indicate the importance of agriculture to each region of the state. It continues with definitions of terms to be used and presents loss-cost ratios by counties and the gross crop returns for the six crops. It applies the Smith et al. finding to the gross crop returns for each of 10 years to measure the possible crop output savable and converts the possible crop output savable to obtain the overall economic impacts of hail reduction to the state. The final step is to express most estimates as 10-year averages per acre for each county.

Ellickson (1951) reported that the chance of hail is about the same for all farms in a given locality, but the extent of damage varies with the crops grown. Tomatoes and vine crops are easily damaged by hail and are slow to recover. Sugarbeet leaves are easily destroyed by hail but the plants recover quickly. Crops harvested early in a season are exposed to hailstorms for a shorter time and suffer less from hail.

Jones (1969) found that the average United States loss to hail is about 1.3 percent of annual value of crop production, with the high rate of 3.5 percent in the Northern Plains. Next highest loss is about 2.5 percent of crop output in the Mountain region. Only 1.2 percent of the crop is damaged in the Corn Belt but total dollar loss is large because of the high value of the crops grown. The Lake States and the Appalacian regions have the next highest rate of hail loss.

An Agricultural State

North Dakota depends heavily on crop and livestock production for a substantial portion of its new wealth. The economic base consists of five major activities contributing new wealth to the regional economies. The 1987 figures are measured in inflation-adjusted 1980 dollars. A comparison of components of the 1987 economic base for eight regions of the state economy indicates a strong dependence on agriculture (see Figures 1 and 2). The eight state planning regions are shown in Figure 1.

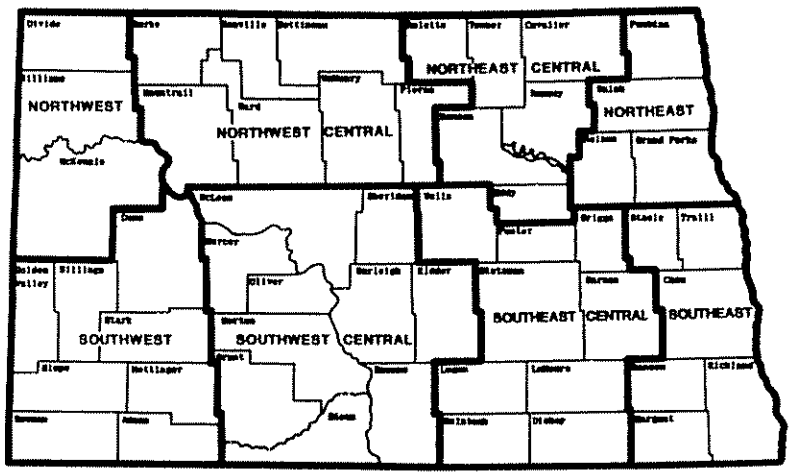

Figure 1. State Planning Regions of North Dakota

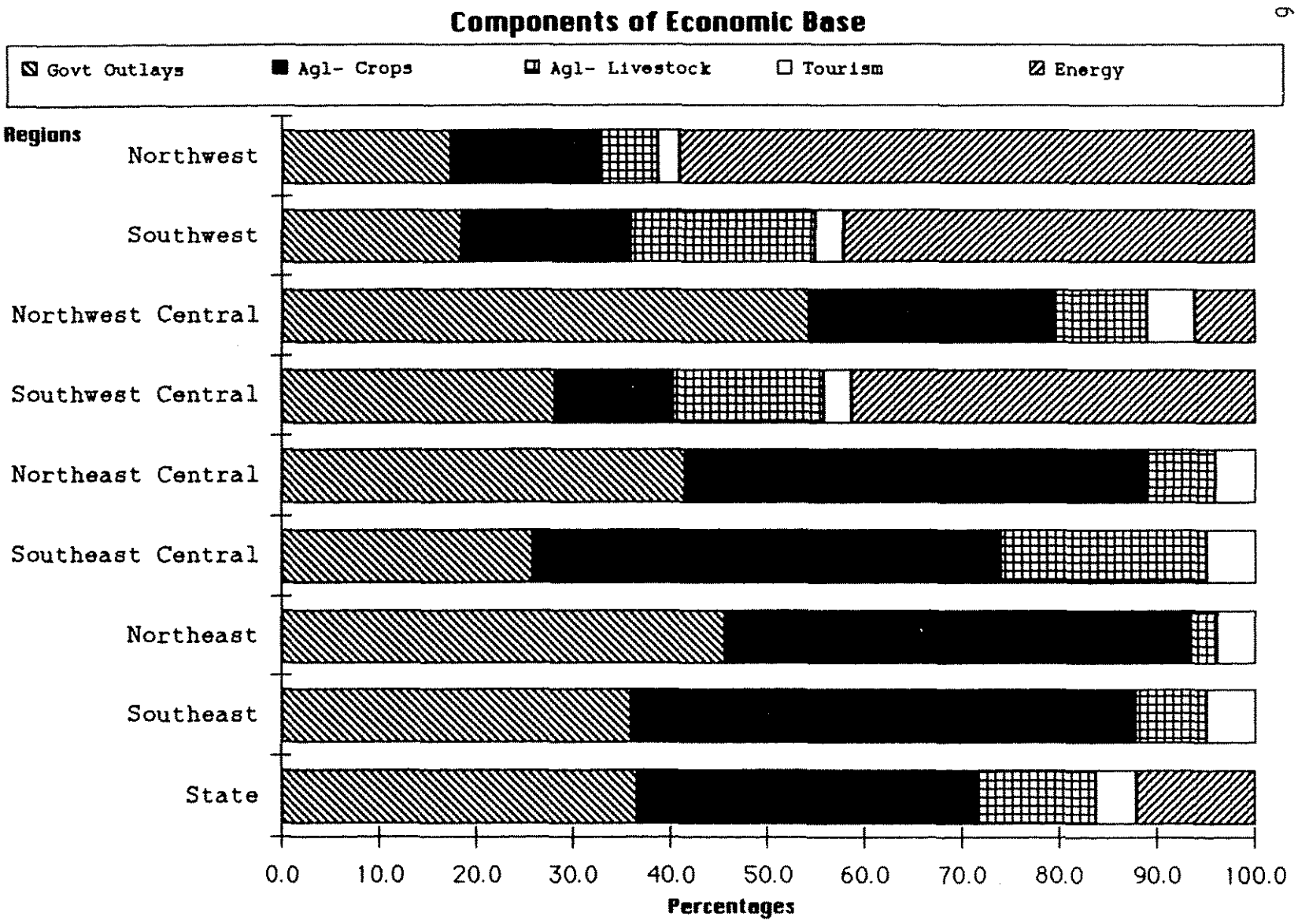

Figure 2. Composition in 1987 of the Economic Bases of the Eight State Planning Regions of North Dakota. (Measured in constant 1980 = 100 dollars)

The Northwest, Southwest, and Southwest Central regions depend heavily on energy for their economic activities. The energy earnings, even with the lower oil prices in 1987, were large enough to provide them great economic strength. Energy accounted for 57 percent of the new wealth in 1987 in the Northwest, 40 percent in the Southwest, and 39 percent in the Southwest Central region.

The Southwest region also relied heavily on livestock (18 percent) and crop (17 percent) production and federal outlays (17 percent) for its economic base activities. The economic base of the Southwest Central region (which includes the State Capitol) obtained 39 percent of its earnings from energy, a growing 26 percent from federal government outlays, and 15 percent from livestock.

Federal government outlays made up 49 percent of all revenues in the Northwest Central region, which includes the large Minot Air Base. These outlays also were important in the Northeast Central (40 percent) and Northeast regions (40 percent). Federal government outlays provided about a third of all state revenues in 1987.

Crop production accounted for a major portion of the economic bases in the Northwest Central (23 percent), Northeast Central (46 percent), Northeast (43 percent), Southeast (44 percent), and Southeast Central (45 percent) regions. These regions also derive a significant portion of their economic base from federal government outlays.

Some Study Concepts

Loss-cost ratio is the total dollar losses due to hail divided by total dollars of insured liability times 100. This ratio is calculated

for a selected period for a specific area (county). It is the dollars of loss per $100 liability resulting from hail damages to an insured crop. The ratio is based on data in the CHIAA tape by townships, crops, and policies by years.

Weighted loss-cost ratios were computed for each county for each year and a simple 10-year average weighted loss-cost ratio for each county was developed. Weighting can be adjusted by including specified crops, selected policy forms which have different deductibles, locations (given as township factors), and time periods. Annual loss-cost ratios show great fluctuations from year to year, so averaging is necessary to obtain representative figures.

County Values of Crop Production per acre are the yearly dollar values of the six crops produced in each county. They were computed using annual county data gathered and published by the National Agricultural Statistical Service of the U.S. Department of Agriculture. Data for the period 1976 to 1985 included crop acreages, yields, production by counties, and crop prices.

Possible Crop Sales Lost due to Hail per acre is the calculated value of crop production lost because of damage or reduced yields due to hail storms. These losses were computed by taking the county annual value of crop production for the six crops times the county loss-cost ratios year by year.

Possible Crop output savable due to Hail Treatment start with the above defined county crop sales lost multiplied by the Smith et al

reduction factor. Smith et al. found a reduction in crop hail damage of 43.5 percent, which yields the amount of crop output savable due to cloud seeding. Crop output savable would be the "first round" or direct economic benefit of successful cloud seeding. Separate equations were used for the non-treated and the six treated counties and are explained in examples below.

1) Potential annual crop output savable due to cloud seeding in each non-treated county is defined by:

Value of crop production x County Loss-cost ratio x 0.435

for each of the 10 years, 1976-1985. It represents the amount of annual gross crop returns that would not have been lost if hail reduction efforts had achieved the 43.5 percent level reported by Smith et al.

An example: Ten-year averages were developed to compensate for year-to-year variability. This hypothetical calculation is given for the untreated county of Sheridan by using the numbers reported (in Figures 4 and 3) below as follows:

10-year Average annual value of crop production =	**$ 75.66 / acre**
10-year Average annual loss-cost ratio (5.58%)	**× 0.0558**
Crop sales lost for six crops due to hail	**$ 4.22 / acre**
Smith et al. reduction factor (43.5%)	**× 0.435**
10-year Average annual crop output savable because of cloud seeding)=	**$ 1.84 / acre.**

The gross value of crop production per acre was multiplied by the loss-cost ratio to give an estimated crop sales lost for the six crops because of hail. Treating reduces losses by 43.5 percent, or by about $1.84 an acre. The Sheridan County 10-year average annual crop output savable because of cloud seeding was computed at $1.85 per acre, which is

close to the $1.84 per acre obtained in the example using the simple 10-year average numbers. This is a sizable reduction in crop losses from successful cloud seeding. An average crop sales loss of $2.37 an acre ($4.22 gross hail loss, less $1.85 (43.5 percent) reduction in hail damage due to seeding) would still occur because treating isn't successful on every storm.

2) Annual possible crop output savable due to hail treatment for each <u>treated county</u> is defined by:

$$\left[\frac{\textit{Value of crop production} \times \textit{Loss-cost ratio}}{\textit{Adjusted factor } (1.0 - 0.435).} \right] \text{ Less } \left[\textit{Value of crop production} \times \textit{its Loss-cost ratio} \right]$$

The numerator of the equation calculates total crop sales lost per acre as in the first equation, but that must be first divided by a factor for this is a treated county, and finally the value of crop output savable due to treating is deducted. A treated county already has reduced losses due to hail treatment by an estimated 43.5 percent. Here the loss-cost ratio understates the loss by the adjustment factor of (1 - 0.435). Using Bowman County numbers as an example:

Gross crop returns per acre for 6-crops:	**$ 54.53 / acre**
Loss-cost ratio	**x 0.0596**
Crop sales lost with treatment (actual)	**$ 3.25 / acre**
Adjusting factor (1.0 - 0.435)	**÷ 0.565**
Crop sales lost without treatment	**$ 5.75**
Crop output saved by treating ($ 5.75 - 3.25) =	**$ 2.50 / acre**

Crop output savable in this treated county is the amount that would have been lost if there had been no treatment ($3.25/acre) adjusted for treatment having been used ($3.25 / (1 - 0.435) = $5.75) *less* the expected loss without treatment ($5.75 - $3.25 = $2.50 / acre) for a smaller loss because of cloud seeding. The reduction in crop losses of $2.50 per acre is the crop output saved attributable to seeding. It is the potential crop sales lost adjusted for the effect of treating less the expected crop sales lost based on the observed loss-cost ratio for the county.

Overall economic impact is the total value of direct crop output savable because of cloud seeding plus the indirect and induced changes that result from those losses not occurring. Indirect and induced changes are those that result from the multiplier effect, or the increases in business activity due to subsequent rounds of increased spending and respending of the original dollars.

Economic impact can be broadly defined as the resultant increase or decrease in economic activity resulting from expansion or shrinkage of a particular firm, industry, or sector in the area economy.[2]

Annual Loss-cost Ratios Show Great Variability Annual weighted loss-cost ratios were computed for each county and are presented for 10 southwestern counties in Figure 3 to emphasize the strong annual variability in hail losses as measured by crop-hail loss-cost ratios. Losses for each year are presented to show how greatly losses vary from

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[2]For more information see: Coon, Randal C., F. Larry Leistritz, Thor A. Hertsgaard, and Arlen G. Leholm. 1985. The North Dakota Input-Output Model: A Tool for Analyzing Economic Linkages. Fargo: North Dakota State University Department of Agricultural Economics Report No. 187.

year to year. The loss-cost ratios for each county are presented as vertical bars from left to right for the years 1976 to 1985.

The largest loss-cost ratio for the six crops (see Figure 3) was in Oliver County at 33.4 in 1977, with large ratios shown for both Morton and Golden Valley counties in 1983. Sioux County had loss-cost ratios of 26 in 1980 and 20 in 1981. Stark County had high loss-cost percentages near 21 percent in both 1977 and 1981.

Annual loss-cost ratios represent the chance any one farmer in a given county has of having a crop-hail loss. The 10-year average would be the chances in a county in a similar 10-year period.

Ten-year Average Annual Loss-cost Ratios Hail events vary greatly from year to year as shown in Figure 3, so a 10-year study period was used in the Smith et al. study and in this study. Ten-year weighted average annual loss-cost ratios were calculated for each county for the 10 years of 1976-1985 (Figure 4). Ratios vary from the lows in Ward, Sargent, and Richland counties to the highs in Slope and Morton counties. A band of high average 10-year loss-cost ratios enclose Golden Valley, Slope, Stark, Hettinger, Morton, Grant, and Sioux counties. An area of medium-high ratios include Sheridan, Wells, Eddy, Foster, Kidder, Stutsman, Barnes, LaMoure, and Ransom counties.

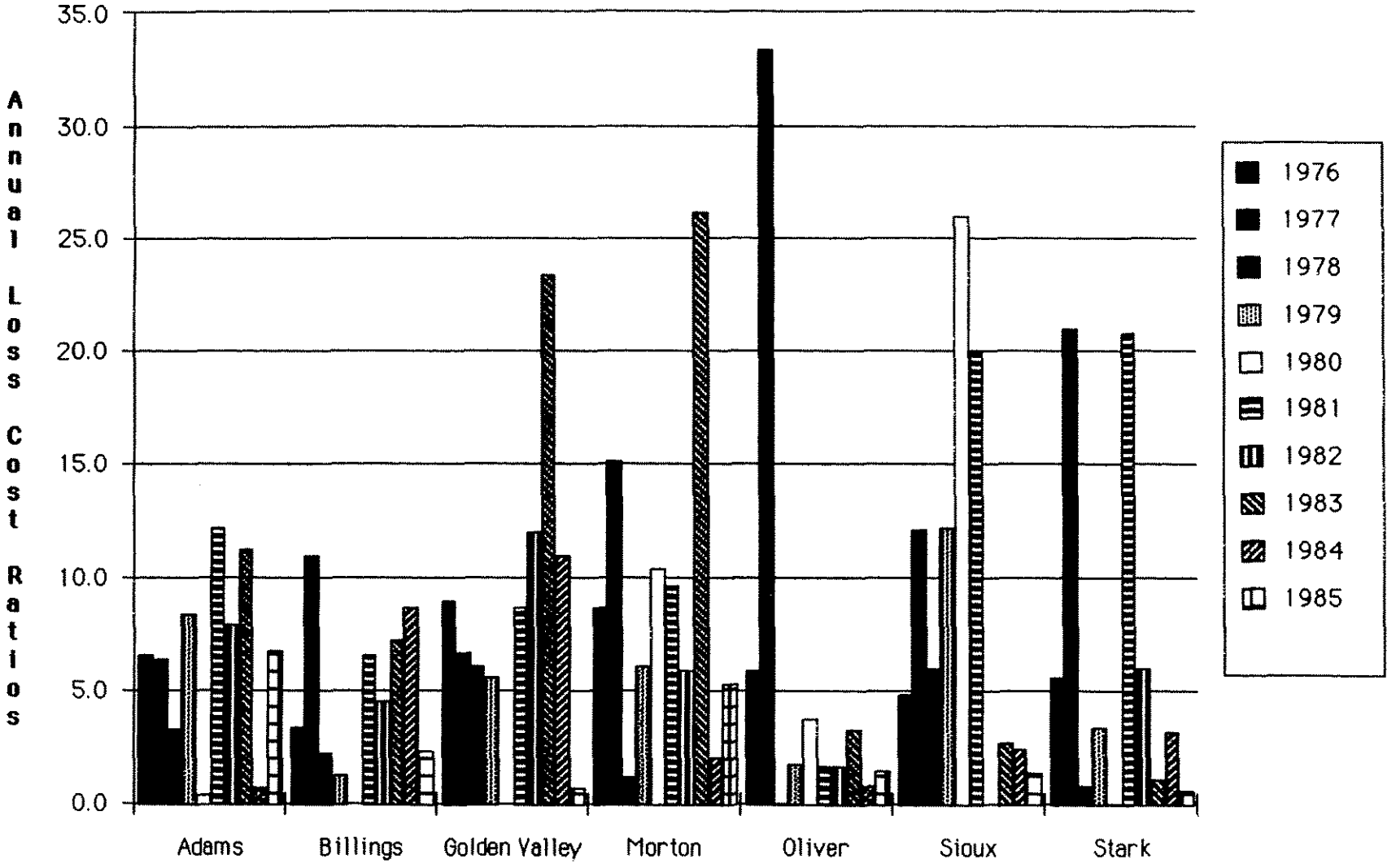

Figure 3. Annual Loss-Cost Ratios for Seven Non-Treated Counties in Southwestern North Dakota, With Years Presented in order of 1976 to 1985 for Each County

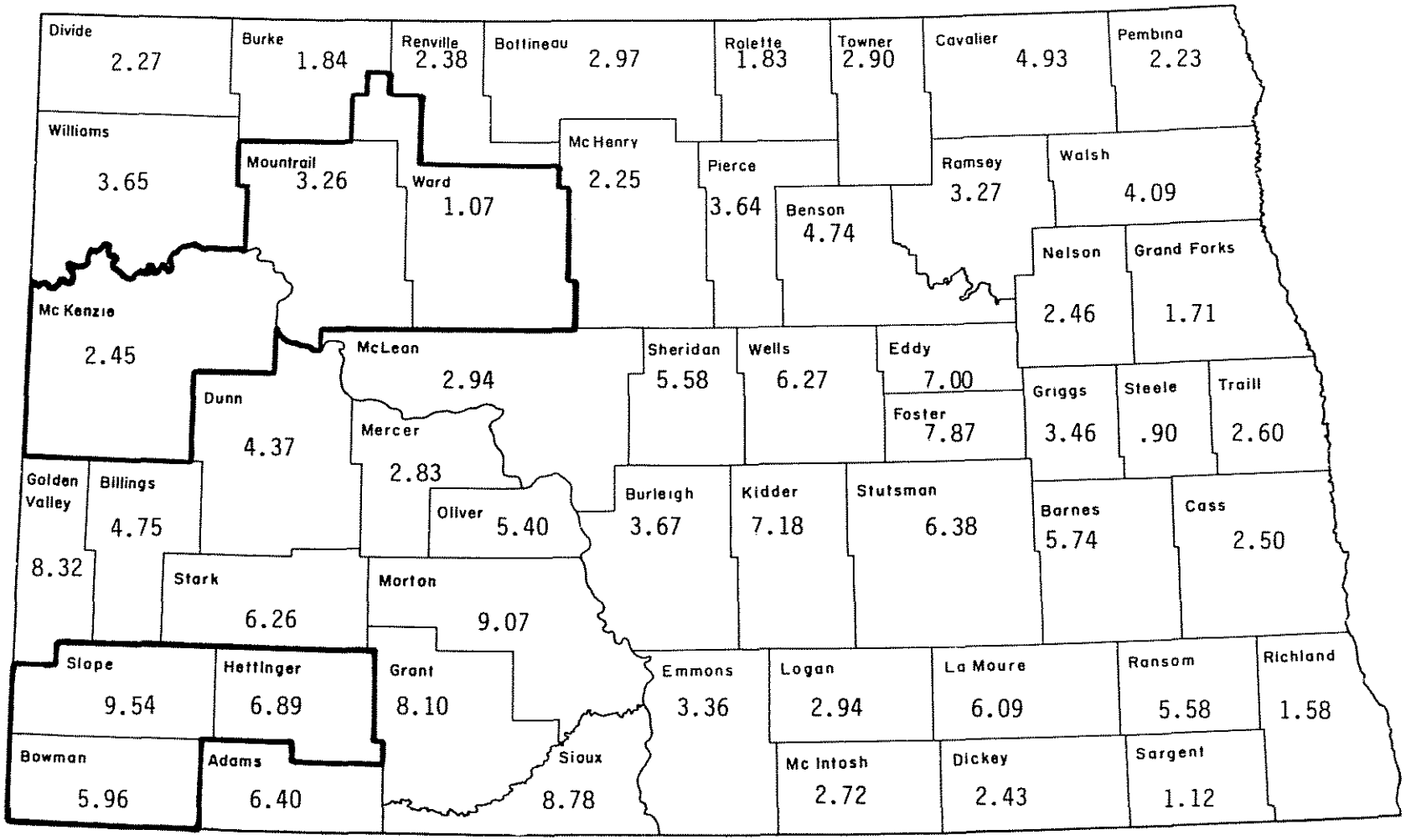

Figure 4. Ten-Year Average Loss-Cost Ratios By Counties, North Dakota. Averages for the 1976-1985 period

Values of Crop Production Annual values of crop production for the six crops of wheat and durum, barley, oats, flax, sunflowers, and corn for grain were calculated for each of 10 years, 1976-1985, for each county The Smith et al. study did not deal with other crops or range and pasture land nor does this study.

Annual gross values of crop production for the six crops were calculated and weighted by the number of acres in these six crops in each county and averaged to create the 10-year average annual gross returns per acre of those crops as presented in Figure 5. The values are reported in nominal or current dollar terms, not adjusted for inflation.

The 10-year average annual gross crop returns per acre for the six crops studied vary from the lows in Sioux, Billings, and Emmons counties to the highs in Richland and Traill counties

The gross returns per acre do not include the high value speciality crops of eastern North Dakota or truck crop farms found near cities. Specifically, neither potatoes nor sugarbeets are included.

Annual gross returns or value of production for North Dakota for the six crops ranged from a low of $1.0 billion in 1977 to a 10-year average of $1.5 billion or about $88.43 an acre planted to the six crops.

The annual gross returns for the six crops for the six treated counties totalled in nominal dollars a low of about $82 million in 1977 to a high of $179 million in 1982 The 10-year average annual figure was $132,731,897, or $78.22 per acre growing these six crops.

Total gross returns for all crops averaged about $2 billion a year as measured in nominal dollars for the 1976-85 period. The low year in gross

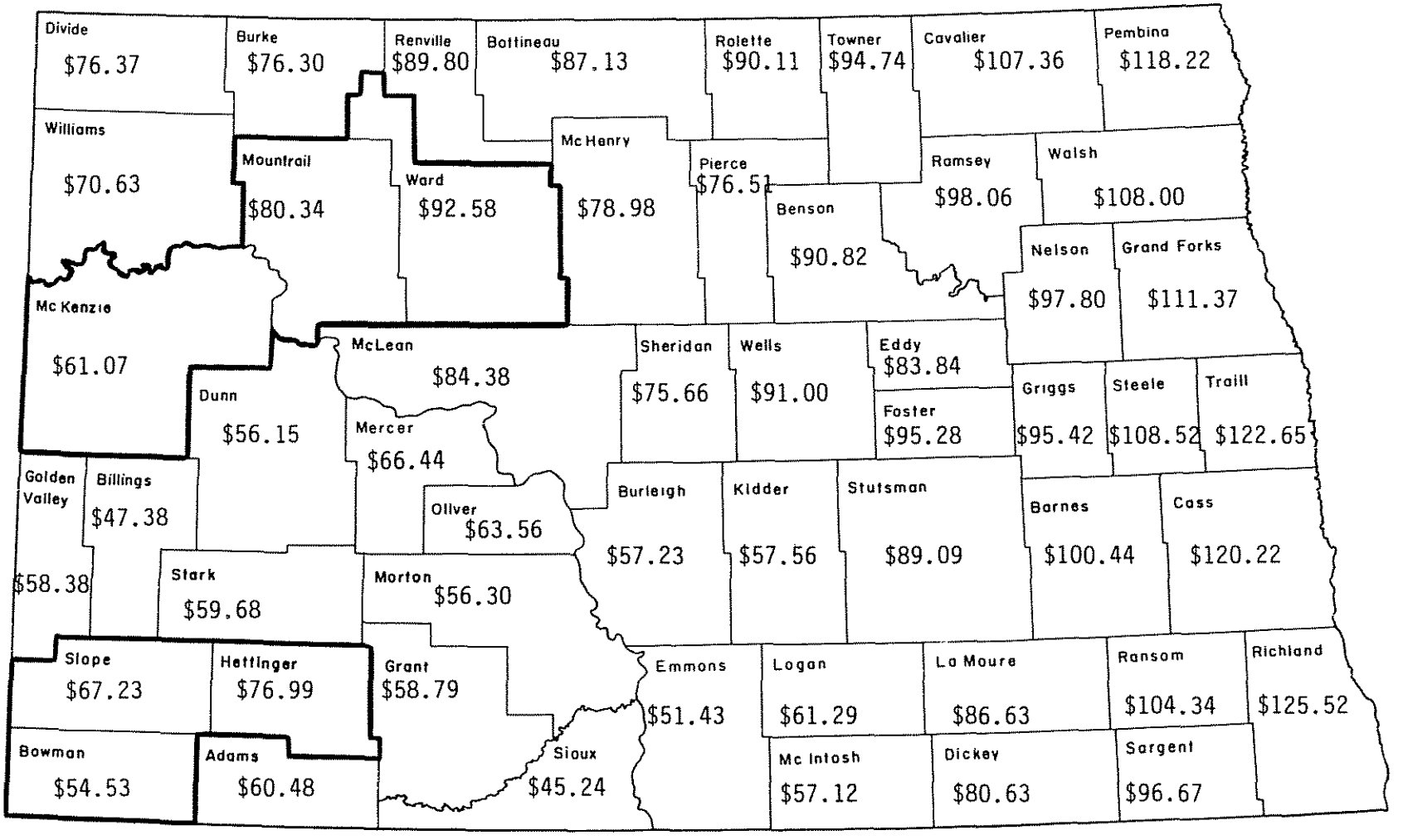

Figure 5. Ten-Year Average Annual Gross Returns Per Acre By Counties for Six Crops Used in the Analysis, North Dakota, for 1976-1985 period

value of crop production for all 53 counties was $1.33 billion in 1977, with a high of $2.56 billion in 1981.

The percentages of gross returns of the six crops to total value of all crops were computed for each county for the 10-year period 1976-85 (Figure 6). This ratio presents an indication of how well the results of this study for the six crops fit the state as a whole. The ratio for the six crops to the all-crops total ranged from 50 percent in Sioux and Walsh counties to highs of 97 percent in Cavalier and Renville counties. The six treated county ratio averaged 88 percent while the other 47 counties earned about 75 percent of their total gross crop returns from the six crops included in this study.

Possible crop output savable due to cloud seeding. This first measure of possible economic benefits from hail treatment was calculated by applying the annual loss-cost ratios and the Smith et al. factor estimate to the annual gross value of production of the six crops for each county. It measures annual crop output savable due to hail treatment.

As described above, two equations were used: one for the six treated counties and another for all other counties. Each year had a different crop-hail loss-cost ratio to be applied to its annual value of crop production of the six crops, adjusted for possible reduction because of cloud seeding, and a 10-year average was developed for each county.

For the six treated counties, the annual value of production of the six crops is multiplied by the loss-cost ratio and then divided by (one minus the Smith et al. reduction factor). From that value is subtracted the value of crop production, and it is multiplied by the loss-cost ratio.

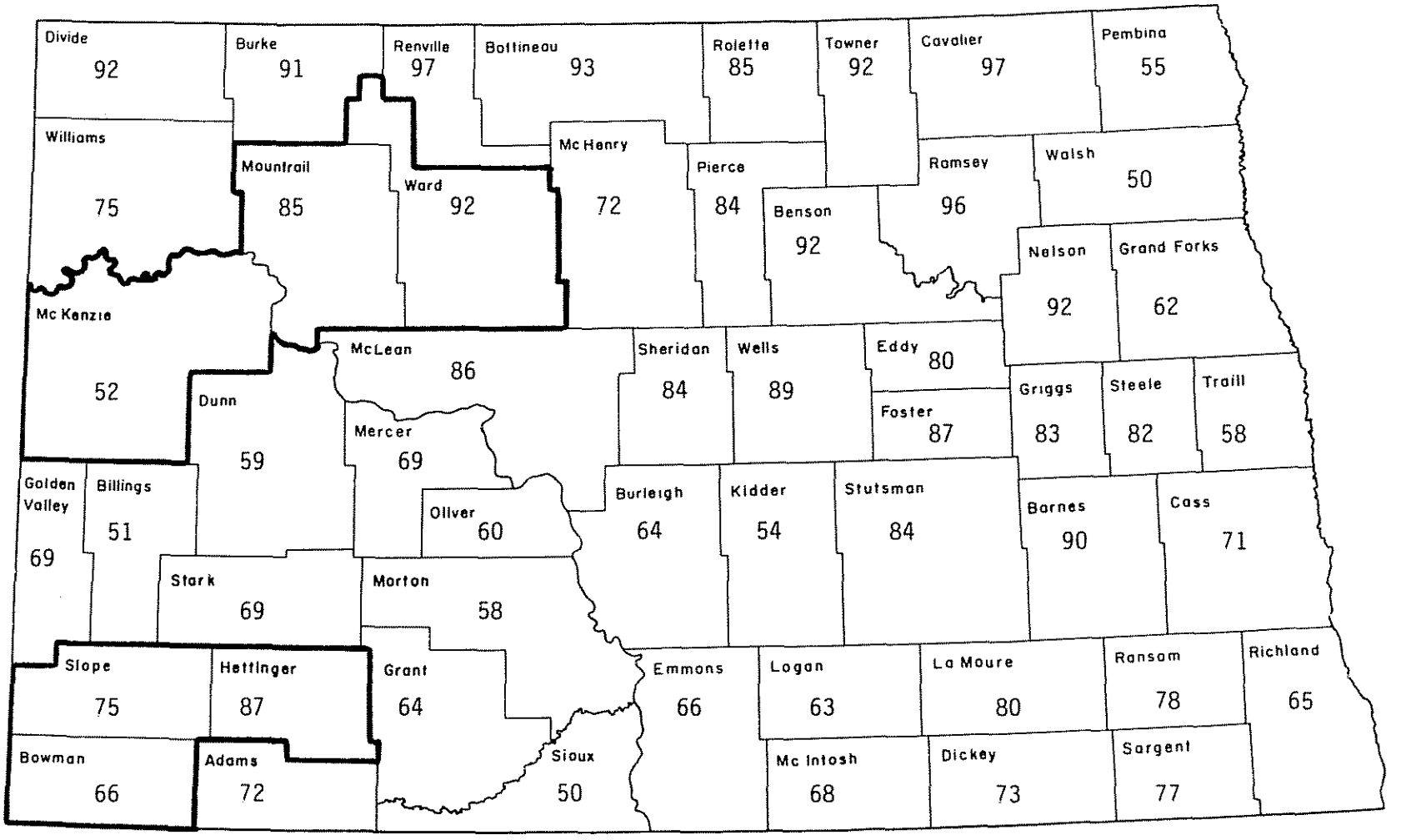

Figure 6. Ten-year Average Percentage of Gross Returns for the Six Crops to Total Returns for All Crops, By Counties, North Dakota, for 1976-1985 period

This equation thus calculates the total expected loss in crop sales, which is adjusted upward because there was treatment, minus the 43 5 percent reduced loss (or crop output savable) with cloud seeding.

For the non-treated counties, possible crop output savable because of cloud seeding is the annual gross value of production of the six crops multiplied by the loss-cost ratio for each county, then multiplied by the Smith et al. reduction factor of 0.435.

Annual crop output savable represents the value of crop production that might have been available for sale because of cloud seeding for the 1976-1985 period. The 10 years of annual crop output savable for each county were averaged, divided by the number of acres in the six crops in each county, and presented in Figure 7. Assumed crop output savable per acre because of seeding varies from lows in Steele and Sargent counties to the highs in Adams and Slope counties.

State totals of crop output savable assuming cloud seeding based on the six crops varied from a low of $14,871,000 in 1984 to a high of $43,732,000 in 1980, with a 10-year average of $26,547,000 for the 1976-1985 period. The 10-year statewide average crop output savable because of hail treatment was about $1.56 per acre growing these six crops.

The 47 non-treated counties had a 10-year average annual crop output savable assuming successful hail treatment of $23 million, which averages $1.49 per acre growing these six crops.

Total annual crop output savable for the six treated counties had a low of $798,855 in 1980, a high of $8,816,213 in 1981, and a 10-year

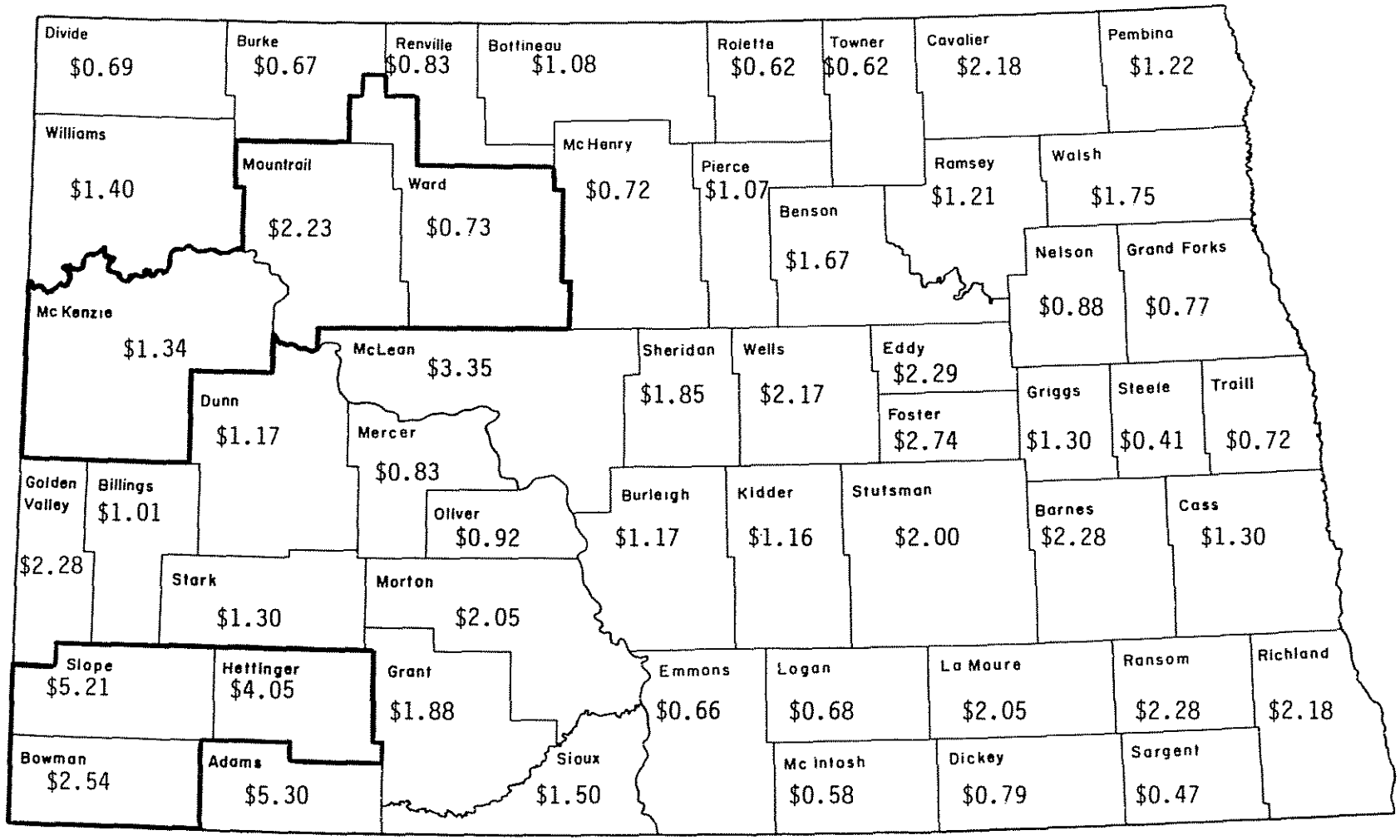

Figure 7. Ten-Year Average Annual Crop Output Savable Per Acre Because of Cloud Seeding, by Counties, North Dakota, for 1976-1985 period

average annual figure of $3,754,411. The 10-year average came to $2.21 per acre for the six treated counties.

Overall economic impacts of crop output savable by cloud seeding This applies multipliers to the annual estimates of crop output savable assuming hail treatment to measure the total economic impact on the local economies at the community and state levels

Crop output savable because of cloud seeding means greater farm marketings, with more crop flowing through the marketing channels, more dollars earned by truckers, elevator operators, various grain handlers and others of the trade-- meaning an extensive series of increased spending and respendings.

The annual total economic impacts of crop sales lost were computed for each county and divided by the number of acres in the six crops in each county to obtain 10-year average overall economic impacts per acre, which are presented in Figure 8.

Total economic impacts of crop output savable because of cloud seeding at the state level was found to range from a low of $68,052,000 in 1976 to a high in 1980 of $161,158,000 and a 10-year average of $97,834,000.

For the six treated counties, the total economic impact of crop output savable had a low of $2,945,000 in 1980 and a high of $32,487,000 in 1981. Their 10-year average annual total economic impact was $13,837,400 or $8.15 per acre growing the six crops.

Total economic benefits of reducing hail losses in North Dakota includes both crop output savable because of cloud seeding and the

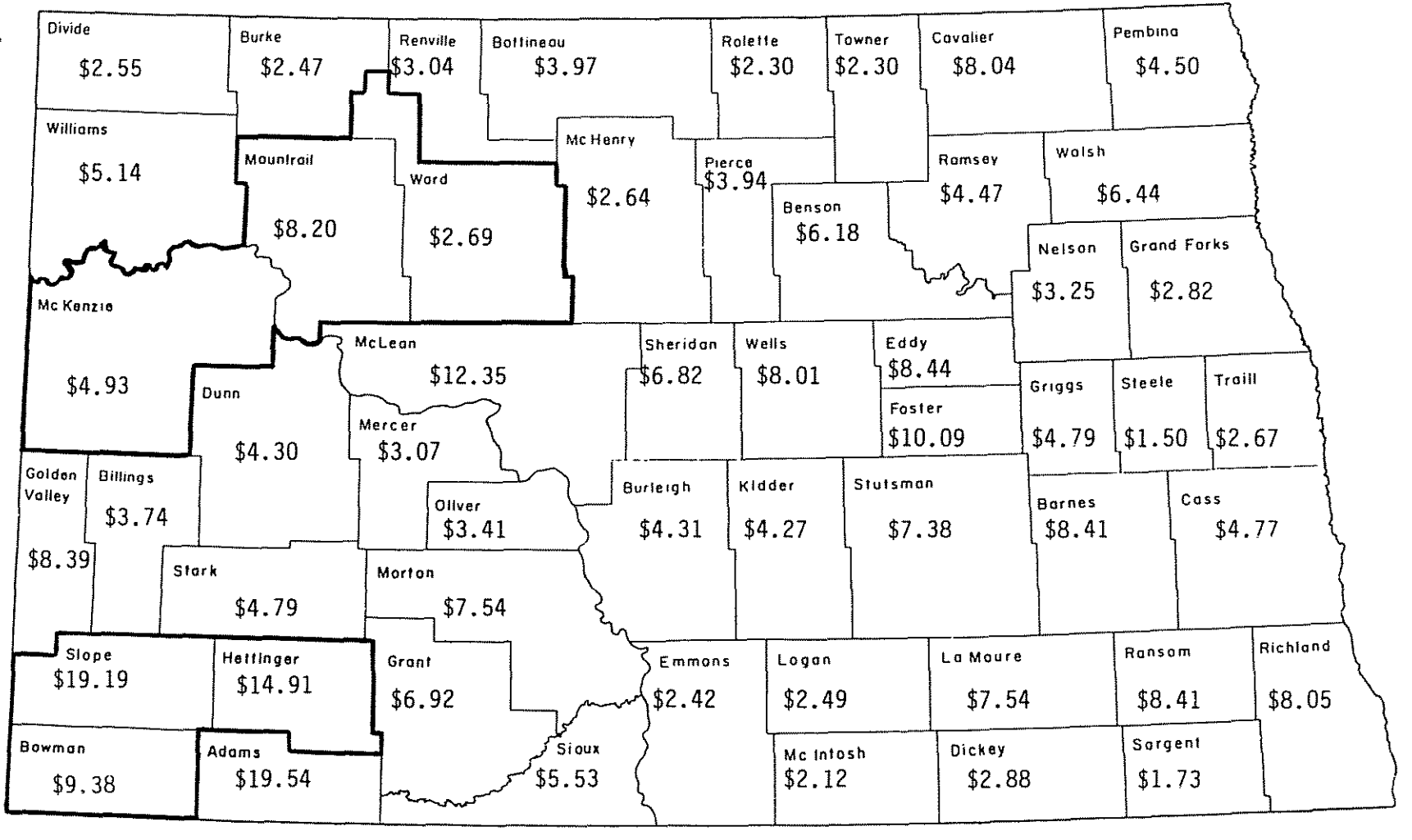

Figure 8. Ten-Year Average Annual Overall Economic Impacts Per Acre Because of Cloud Seeding for Six Crops, by Counties, North Dakota, for 1976-1985 period

subsequent increase in spending and respendings of the earnings that the larger crop sales would have produced. The economic benefits may vary among counties, but the 10-year average annual estimates provide a reasonable basis for evaluation of the hail suppression cloud seeding program

Possible direct benefits in the treated six counties can be estimated by applying the Smith et al. reduction factor to the loss-cost ratio and cropping data to produce these estimated direct crop output savables because of cloud seeding:

County	Savings per acre		Crop Acres		Indicated Savings
Bowman	$ 2.54	x	155,020	=	$ 393,751
Hettinger	$ 4.05	x	314,750	=	1,274,738
McKenzie	$ 1.34	x	198,710	=	266,271
Mountrail	$ 2.23	x	328,730	=	773,068
Slope	$ 5.21	x	129,280	=	673,549
Ward	$ 0.73	x	570,440	=	416,421

The 10-year average annual savings was $3,754,411 for all six treated counties, for an average of $2.21 per acre for the six crops used throughout this analysis. Reduced damages to pasture and range lands should increase the indicated benefits, as would similar damage reductions to crops other than the six upon which this study is based. The $2.21 per acre of direct crop output savable becomes a total economic impact of $8.15 an acre for the six treated counties

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