A Benefit-Cost Analysis of the West Central Texas Weather Modification Program

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INTRODUCTION

The purpose of this analysis is to provide a framework for assessing the benefits and costs of the West Central Texas Weather Modification Program which plans to operate from April through October and encompass 4.9 million acres in 9 counties. This discussion is intended to assist the Working Committee of local elected officials and citizens within the region to consider the merits at the county-level as well as regionally of a West Central Texas Weather Modification Program. The study area for this analysis is comprised of the following counties: Brown, Callahan, Coke, Coleman, Comanche, Eastland, Nolan, Runnels, and Taylor.

At previous meetings of the Working Committee, a number of possible benefits from rainfall enhancement efforts were identified to be significant to the citizens of West Central Texas. Among the benefits listed were: 1) increased agricultural production, 2) improved opportunities for economic stability and future growth, 3) decreased surface and ground water consumption, 4) enhanced landscape appearance, 5) increased reservoir levels, 6) replenishment of aquifers, 7) increased and higher quality forage for wildlife, 8) increased lake and river levels, and 9) fire suppression. While it is difficult to dispute the validity of the latter six beneficial impacts, this analysis will focus primarily on the first three. Environmental and recreational benefits undoubtedly result from increased rainfall, but are difficult to quantify without conjecture. However, the reductions in irrigation activity, increased agricultural production, and resulting economic impact are easier to compute with some degree of accuracy. It is this process that will be described throughout the remainder of this study.

ESTABLISHING A BASELINE FOR PROGRAM EFFECTIVENESS

The state's longest-running cloud seeding program is headquarted in Big Spring, Texas and operated by the Colorado River Municipal Water District (CRMWD). The operational area includes fifteen counties within and near the Permian Basin of West Texas. Cloud seeding is conducted primarily during the spring, summer, and fall months, when convective or cumulus cloud systems are present. Over the 29 year existence of the program, precipitation analysis has shown a 35 percent increase for rain reporting stations within the target area, as compared to only a 12 percent increase for reporting stations outside of the target area (CRMWD, 2000).

For the purpose of this analysis, the benefits of a weather modification program are calculated based on the region realizing one additional inch of timely rainfall as a result of program efforts. Throughout the 9 county region, the typical normal rainfall expected approaches 20 inches annually. <u>Thus, this analysis quantifies the agricultural impacts of a five percent increase in normal rainfall.</u> This falls well below the range of observed effects from other weather modification programs in the state, but allows for results to be factored up to examine efficiency levels consistent with individual expectations. For example, if you wanted to look at the impacts of a ten percent increase in timely rainfall, you would simply double all benefit estimates to provide these impact values.

ASSESSING THE AGRICULTURAL INVENTORY OF THE REGION

The impact of additional rainfall in the West Central Texas region is, in large part, determined by the cropping and livestock patterns of the area. The four predominant agricultural commodities produced in the 9 county study area are cotton, sorghum, wheat and beef cattle. The average cropping acreages and livestock inventories for each of the counties were obtained from the Texas Agricultural Statistics Service (TASS) for 1992 - 1998. Table 1 shows the historical production acreages and beef cattle inventories by county and cumulatively for the region. It can be noted that this region includes 51,542 irrigated acres and dry land cropping totals of 114,718 acres for cotton, 85,450 acres for sorghum, and 432,184 acres for wheat. Historical beef cattle production includes 232,286 head of beef cows and 122,777 head of stocker cattle, which are fed to weights appropriate for entry into feedlot facilities.

The effect of additional timely rainfall on irrigated acres is fairly evident. An additional one-inch of timely rainfall would reduce the need for irrigation proportionately, by one acre inch. With 51,542 irrigated acres, this would imply a decrease in irrigation application of 51,542 acre inches (or 4,295 acre feet). According to Texas Water Development Board (TWDB) projections, the regional demand for irrigation water is 66,215 acre feet for agricultural crops (TWDB, 2000). Thus, a 4,295 acre feet savings would imply a reduction in irrigation water use of 6.5 percent.

AGRONOMIC AND GRAZING RESPONSES

Each agricultural commodity responds uniquely to additional water. Information related to the expected agronomic response for dry land crops was provided by Dr. Billy Warrick, Extension Agronomist, Texas Agricultural Extension Service. It was estimated that an additional inch of rainfall during the April to October period would provide the following per acre increases in yield: 35 pounds of cotton lint, 56.7 pounds of cottonseed, 150 pounds of sorghum, and 1 bushel of wheat (Warrick, 2000). The rather low estimate of yield response for wheat can be explained in large part by the timing of additional rain resulting from weather modification. This period does improve conditions for wheat, but to a lesser extent than would be realized if the rainfall occurred during more critical periods.

The impact of additional rainfall upon beef cattle stocking rates and stocker calf daily gain is more difficult to determine. Intuitively, additional timely rainfall would provide moisture to produce increased grazing forages, which in turn would allow for increased stocking rates and higher daily gain rates for livestock. For the purposes of this analysis, it was assumed that the one additional inch of rainfall (5% increase above normal) would result in the ability to increase stocking rates of beef cows by one half the proportional increase (2.5% in stocking rate) and would increase the average daily gain of stocker cattle by one half the proportional increase (2.5% increase in average daily gain). This means that the one additional inch of rainfall would allow a rancher to increase their 200 cow herd to 205 cows. Likewise, it implies that instead of the typical 1.75 pound per day gain expected from stocker cattle, the gain would increase to 1.80 pounds per day. This amounts to a 9 pound per head increase for the typical stocker calf fed for 180 days.

VALUING IRRIGATION SAVINGS AND INCREASED AGRICULTURAL PRODUCTION

In order to examine the value of the additional agricultural production, the cost of irrigation was applied to irrigation savings and prices were applied to this increased production. The cost of applying one acre inch of irrigation water was calculated to be $2.62 per acre inch according to the Texas Agricultural Extension Service Crop Enterprise Budgets (Johnson, 2000). The seven year historical average prices received by Texas farmers/ranchers were calculated from Texas Crop Statistics yearbooks (TASS, 1992-1998). These prices were reported to be: $0.635 per pound for cotton lint, $115 per ton for cottonseed, $4.35 per c.w.t. for sorghum, $3.50 per bushel for wheat, and $287 per beef cow. Stocker cattle producers typically contract grazing based on weight gain during the period. For this analysis, stocker cattle gain was valued at $0.30 per pound, on the low end of the $0.30 to $0.35 per pound range typically received in the region.

Table 2 shows the value of additional agricultural production by county and cumulatively for the region as it relates to the typical cropping and livestock inventories (shown in table 1), agronomic and grazing responses previously described, and the historical prices received by Texas farmers/ranchers. The average county stands to receive over $558,300 in estimated direct benefits accruing to agricultural producers, with estimated direct benefits ranging from $148,597 (in Coke County) to $1,828,013 (in Runnels County). Differences in the extent of county-level estimates can be entirely explained by the intensity to which cotton, sorghum, wheat, and beef cattle were prevalent in the county. Regionally, these benefits to agricultural producers total $7,262,380.

These estimates represent the most direct and immediate benefit from increased agricultural production. However, there are secondary effects from this increased production as the raw products require processing, transportation, etc.. and as this money circulates throughout the general economies of the region. These secondary impacts can be viewed as a proxy for increased economic stability and growth; benefits that are not confined to the agricultural community. In order to estimate these secondary impacts, a unique multiplier is applied to quantify these effects. These multipliers were taken from research which addressed these secondary impacts on the general economy from agricultural production (Jones, 1997). For irrigation savings, a multiplier of 1.0 was used as savings do not require additional economic expenditures. Economic multipliers of 1.57, 1.42, and 1.46 were applied to cotton lint and cottonseed production, feed grain production, and beef cattle production, respectively. This implies (for cotton) that an every dollar of raw cotton lint production generates an additional 57 cents of economic activity which permeates throughout the general economy.

While these estimates quantify the direct and indirect benefits accruing from increased agricultural production by county, they do not recognize the possibility that much of the secondary effects may migrate to other adjacent areas. In other words, it could be expected that much of the secondary effects from increased agricultural production in the more rural counties would find their way to the more urban counties. As these dollars circulate and are exchanged for goods and services, they will naturally find their way to the places where these goods and services are offered. While the overall regional estimate is fairly accurate, these county level estimates likely over-estimate the economic impact on rural counties, while under-estimating the economic impact on urban counties.

PROPOSED PROGRAM COSTS

Table 3 presents the benefits accruing to agriculture, economic stability and growth, overall economic impact, and brings in the proposed cost of a weather modification program by county. The cost estimate allocations are based on a funding formula which takes into account three county-level metrics: available acreage, retail sales activity, and population. Specifically, this formula involves a cost of $0.06 per acre plus $0.53 for every $10,000 of retail sales plus $1.20 per person. This produces a total of $513,049 annually which would fund a rainfall enhancement program costing roughly $0.11 per acre to administer. The Texas Department of Agriculture typically refunds counties in the amount of $0.045 per acre to assist in these efforts. For this region, this rebate would amount to $222,159 leaving $290,890 annually to be procured from the 9 participating counties.

BENEFIT-COST RATIOS AND MINIMUM LEVEL OF CONFIDENCE

One common technique used to evaluate a proposed expenditure is to examine the benefit-cost ratio, which is simply the dollar value of the expected benefits divided by the dollar costs of the project. Table 4 shows the benefit-cost ratios for each county and for the regional project as a whole. It should be noted that in this analysis, the estimate of benefits include only dollar estimates of economic impacts from increased production of cotton, sorghum, wheat and beef cattle. Not included are dollar estimates for the other positive results from the program: enhanced landscape appearance, increased lake and river levels, etc.. The cost component comes from the estimates reported in table 3. Regionally, the benefit-cost ratio for a weather modification program is 33.98, which can be interpreted as a $33.98 return for every $1 invested. On a county-level basis, this ranges from 7.04 (for Taylor County) to $99.65 (for Runnels County). Again, these benefit-cost ratios quantify benefits from a 5% increase in rainfall. If you wanted to look at the benefit-cost ratio of a 10% increase in rainfall, you can simply double the benefit-cost ratios which are presented.

The benefit cost ratio assumes some level of confidence in the outcomes of the program. Another way to look at this proposition is to examine the minimum level of confidence (in the program's success) one would need in order for the benefits to justify the expense. Suppose for example that you were given the opportunity to receive $10 if you successfully predicted the outcome of a coin toss. How much would you be willing to pay to take this chance? Probability of success and the resulting outcome allow you to make an educated decision. You have a 50 percent chance of winning $10 - that should be worth $5. You would also have a 50 percent chance of winning $0. The combination of these two would dictate that you should not be willing to pay more than $5 to participate in this game.

We can look at a weather modification program with the same framework. How confident would you have to be in the program to produce one additional inch of rainfall in order to justify the expense? If (for the region as a whole) the expected payoff is $10.78 million dollars and the costs to participate are $513,049, what is the minimum level of confidence you must have? In order to participate in the West Central Texas Weather Modification Association, this can be expressed as:

Probability of Success X Expected Payoff > Expected Cost

Solving for the Probability of Success, we have:

$$\text{Probability of Success} > \frac{\text{Expected Cost}}{\text{Expected Payoff}} > \frac{\$\ 513{,}049}{\$10{,}779{,}756}$$

Table 3. Total Agricultural Value, Economic Stability and Growth, Overall Economic Impact, and Proposed Program Cost, West Central Texas Region.

County	Total Agricultural Value	Economic Stability and Growth	Overall Economic Impact	Proposed Program Cost
Brown	$ 420,434	$ 182,538	$ 602,972	$ 72,073
Callahan	$ 403,274	$ 176,992	$ 580,266	$ 25,931
Coke	$ 148,597	$ 66,150	$ 214,747	$ 12,476
Coleman	$ 701,621	$ 320,611	$ 1,022,232	$ 26,438
Comanche	$ 563,361	$ 225,348	$ 788,709	$ 32,125
Eastland	$ 425,428	$ 181,721	$ 607,149	$ 38,071
Nolan	$ 1,617,463	$ 870,675	$ 2,488,138	$ 34,571
Runnels	$ 1,828,013	$ 932,948	$ 2,760,961	$ 27,706
Taylor	$ 1,154,189	$ 560,393	$ 1,714,582	$243,658
Region Total	**$7,262,380**	**$3,517,376**	**$10,779,756**	**$513,049**

Table 4. Benefit-Cost Ratios and Minimum Level of Confidence Necessary for Program Benefits to Justify Program Costs, West Central Texas Region.

County	Benefit-Cost Ratio One Additional Inch of Rainfall [1]	Minimum Level of Confidence Necessary 2
Brown	8.37	11.95%
Callahan	22.38	4.47%
Coke	17.21	5.81%
Coleman	38.67	2.59%
Comanche	24.55	4.07%
Eastland	15.95	6.27%
Nolan	71.97	1.39%
Runnels	99.65	1.00%
Taylor	7.04	14.21%
Region Average	33.98	4.75%

1 Benefits only include dollar estimates of farm value economic impacts on cotton, sorghum, wheat and beef cattle. The cost estimates by county used in this analysis were taken from preliminary project proposal. This can be interpreted as the dollar return for every $1 invested.

2 This is the minimum level of confidence (that the program could generate one additional inch of timely rainfall) needed in order to justify the expenditure based solely on the benefits accruing from increased agricultural production.

In this case, the necessary probability of success for the program benefits to justify the program costs is 4.75%. This can also be interpreted as the minimum level of confidence (that the program could generate one additional inch of timely rainfall) needed in order to justify the expenditure based solely on the benefits accruing from increased agricultural production. This minimum level of confidence needed to support the program varies by county (as county-level benefits and county-level costs differ) and are also reported in table 4. Note that this analysis incorporates expected benefits resulting from one additional inch (a 5% increase) of rainfall, where other programs have documented higher effectiveness levels. Similarly to the benefit-cost ratio, if you wanted to look at the minimum level of confidence (in program success) necessary for a 10% increase in rainfall, you would need to reduce the levels in table 4 by one half because estimated benefits (or the expected payoff) would double.

CONCLUSION

This paper was intended solely as an educational resource to provide a framework for assessing the likely benefits and costs of a weather modification program. No attempt was made to quantify many of the benefits that would intuitively evolve from additional rainfall. That responsibility has been left up to the reader to include as appropriate. While it becomes fairly evident that the benefits from increased agricultural production alone would prove to be significant, they only result from a more favorable production environment. It is the responsibility of the reader to assign value to public benefits not quantified and assess their individual level of confidence in weather modification to draw their own conclusions. For additional information related to research conducted by the Texas Department of Agriculture on weather modification programs, please obtain a copy of: "Cloud Seeding for Enhancing Rainfall in Texas," from the TDA by contacting: Jane Lee, P.O. Box 12847, Austin, Texas 78711. (512) 475-3641.

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Table 1. Average Agricultural Production Acreage and Beef Cattle Inventories, West Central Texas Region.

County	Irrigated Acres	Dryland Cotton Acres	Dryland Sorghum Acres	Dryland Wheat Acres	Beef Cows Head	Stocker Cattle Head
Brown	4,611	0	1,683	34,750	32,286	24,497
Callahan	1,020	0	1,483	49,267	22,000	33,689
Coke	485	0	467	10,700	12,857	8,100
Coleman	1,501	4,567	14,050	67,583	30,143	20,447
Comanche	25,268	417	2,117	28,300	39,571	49,859
Eastland	8,479	283	2,617	27,617	34,429	19,576
Nolan	6,845	50,017	9,600	20,133	21,286	21,667
Runnels	1,693	41,767	43,883	82,467	17,714	31,703
Taylor	1,640	17,667	9,550	111,367	22,000	49,831
TOTALS	**51,542**	**114,718**	**85,450**	**432,184**	**232,286**	**122,777**

Table 2. Value of Increased Agricultural Production from One Additional Inch of Timely Rainfall, West Central Texas Region.

County	Irrigation Savings	Added Cotton Value	Added Cottonseed Value	Added Sorghum Value	Added Wheat Value	Added Beef Cows Value	Added Stocker Value	Total Agricultural Value
Brown	$ 12,081	$ 0	$ 0	$ 10,982	$ 121,625	$ 231,652	$ 44,095	$ 420,434
Callahan	$ 2,672	$ 0	$ 0	$ 9,677	$ 172,435	$ 157,850	$ 60,640	$ 403,274
Coke	$ 1,271	$ 0	$ 0	$ 3,047	$ 37,450	$ 92,249	$ 14,580	$ 148,597
Coleman	$ 3,933	$ 101,502	$ 14,890	$ 91,676	$ 236,541	$ 216,276	$ 36,805	$ 701,621
Comanche	$ 66,202	$ 9,268	$ 1,360	$ 13,813	$ 99,050	$ 283,922	$ 89,746	$ 563,361
Eastland	$ 22,215	$ 6,290	$ 923	$ 17,076	$ 96,660	$ 247,028	$ 35,237	$ 425,428
Nolan	$ 17,934	$ 1,111,628	$ 163,068	$ 62,640	$ 70,466	$ 152,727	$ 39,001	$ 1,617,463
Runnels	$ 4,436	$ 928,272	$ 136,171	$286,337	$ 288,635	$ 127,098	$ 57,065	$ 1,828,013
Taylor	$ 4,297	$ 392,649	$ 57,599	$ 62,314	$ 389,785	$ 157,850	$ 89,696	$ 1,154,189
TOTALS	**$135,041**	**$2,549,609**	**$374,011**	**$557,562**	**$1,512,647**	**$1,666,652**	**$466,865**	**$7,262,380**
MULTIPLIER	**1.00**	**1.57**	**1.57**	**1.42**	**1.42**	**1.46**	**1.46**	
IMPACT	**$135,041**	**$4,002,886**	**$587,197**	**$791,738**	**$2,147,959**	**$2,433,312**	**$681,623**	**$10,779,756**