THE BENEFITS OF IRRIGATION IN MITIGATING THE IMPACTS OF DROUGHT

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ABSTRACT

A few comments regarding the economic impacts of drought are made, then a model of a livestock ranch with and without irrigation is presented. The hypothesis is that irrigation reduces risk and stabilizes production of roughage, consequently there is better utilization of the cow herd and associated production factors. A dynamic linear programming model was constructed which captured the variations in yields and prices over time. Results verified that irrigation has a positive impact on income for ranchers, and a dynamic model more accurately simulates these impacts than a static model.

INTRODUCTION

All of the crop producing areas of the United States are subject to recurring droughts. The West may seem to be more subject to them, but the East and Northeast have had their share. However, production of most of the major commodities is widely disbursed, and consequently the whole country is virtually never totally impacted by drought. Droughts cause economic hardship for producers in local areas, but supplies are generally not reduced enough to cause consumer shortages. Lack of knowledge concerning appropriate production practices early in our history gave rise to misuse of resources which exacerbated the impacts of weather. Governmental support for research and education since the 1930's has mitigated these impacts to a large extent.

Severe or extreme drought can result in complete loss of crops in the worst affected areas, lack of water and feed for livestock, impacts on transportation, and increases in forest and range fires. Continued dry conditions, often coupled with poor management, leads to desertification, as has been occurring in parts of Africa. Although we cannot exercise much control over the weather, we have the knowledge and technology for proper management, consequently desertification is not likely to occur over the shorter term. However, considerable concern is being expressed over global warming, and the

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long term impacts of this phenomenon are indeterminate at this time.

The economic manifestations of drought are fairly well known, therefore it is not necessary to spend a lot of time on the obvious. More time will be spent discussing the economic benefits of irrigation citing a specific research study recently completed. In the most severe of drought circumstances, the consequences make news. Production is reduced and prices rise. However, the economy is very complex and the direct results cannot always be identified. It may seem to be heresy, but drought can have some advantages in economies with surplus productive capacity. In economic terms, most agricultural production is inelastic. That is, a small change in production can make a larger percentage change in prices.

The consequences in 1988 are a case in point. Reductions in production due to the drought caused farm product prices to rise considerably. The stable production levels on irrigated areas coupled with the increasing prices resulted in large increases in gross income. This was certainly true on Bureau of Reclamation projects in 1988. Price levels rose 27 index points (based on 1977=100) while overall production and irrigated acreage declined slightly, consequently gross income rose by 15 index points.

Drought can also lead to inefficient use of resources. Labor is underutilized because of lower production levels. Ranches, in particular, can incur severe problems because of poor grass conditions, and if they are unable to obtain hay or forage, they are often forced to liquidate part or all of the herd. This additional beef coming onto the market often forces prices lower, and a downward spiral of prices and income ensues.

IRRIGATION BENEFITS FOR LIVESTOCK RANCHES

Having talked some about these general consequences of drought, a specific example of the economic impacts of drought on livestock ranchers and how irrigation can serve to mitigate those consequences will be discussed. A stable feed supply and associated stability in herd size are often cited as benefits of supplemental irrigation for forage-based livestock ranchers. However, the traditional comparison of average ranch returns with and without irrigation fails to include these economic benefits. Recognizing that this might be the case, the Bureau of Reclamation contracted with North Dakota State University to investigate this particular benefit of irrigation in drought mitigation.

The study developed a dynamic model that traces the effects of drought cycles on ranch profitability. The model is demonstrated for a ranch in the Lake Andes-Wagner Irrigation Project in southeastern South Dakota. The working hypothesis is that the calculated benefits of irrigation of a western beef cow ranch are underestimated by comparing average net returns with and without irrigation. A model that includes changes in ranch organization due to drought will more accurately reflect the benefits of irrigation over time. Higher irrigation benefits are due to better use of forage and increased efficiency in the operation of the cow herd. Increased year-to-year income stability is another benefit demonstrated in a dynamic model.

The specific irrigation benefits to a beef cow ranch that are better estimated in a dynamic than a static model are:

1. A longer cow life because the disposal of productive cows due to drought can be reduced or eliminated.

2. Fewer purchases of replacement animals because with a stable herd size all replacements are raised. This assumes raised replacements are less expensive than purchased ones because labor and facilities for replacement stock exist on the ranch.

3. Less beef sold at lower prices (or more at higher prices) to the extent that herd liquidation due to drought is widespread enough to influence market price.

4. Use of labor and facilities nearer capacity by eliminating herd reductions because of drought.

5. A larger percentage of calves backgrounded and/or finished because adequate forage is available every year.

6. Less purchase of hay at above-average prices.

7. Reduced loss of hay due to deterioration in storage from high-yield years to low-yield years. Irrigated forage production reduces the need for long-term hay storage as a precaution against drought. In addition, the irrigated forage is generally of higher quality.

8. Less supplementation of pasture with hay.

Methods of Analysis

Benefits of irrigation on ranch income are normally estimated using a static model comparing average net returns to a typical ranch with and without irrigation. Depending upon the purpose of the analysis and the irrigation project involved, a point in time is selected to make the comparison based on projected yields, normalized prices, and costs. Discounted present value of the returns over the life of the project is used to calculate agricultural benefits of the irrigation project.

The difference in benefits between the dynamic model developed in this research project and its static equivalent is illustrated for a case study ranch. For the static analysis, a 1-year model with 31-year average yields, levels of production, and prices was used to compare the irrigated and nonirrigated situation. Differences between the irrigated and nonirrigated return above variable costs are the static model's measure of the benefits of irrigation. The same comparison was made using the dynamic model. Fixed irrigation costs are unchanged between the static and dynamic models. The dynamic model calculates return above variable costs for each of 31 years, so results for both dryland and irrigation were divided by 31 to get average benefits of irrigation over the period. Comparing irrigation benefits from the 1-year model with the dynamic model tests the hypothesis as well as the usefulness of the model.

A sequential multiyear maximizing linear programming model was used in the dynamic analysis. A schematic diagram of the model is shown in figure 1.

Individual linear programming models are solved for winter and summer periods for each of the years of simulation. The modeling process is sequential because the solution values of importance from each period's model is passed to the following period. Exogenous events of yields and market prices are provided as historical data sets.

Returns above variable costs are maximized each period based upon information available to the producer at the simulated time. An accounting row in the LP model monitors the actual income and cost that would take place. Therefore, the economic decisions and actual cash impacts are separated to reflect yield and price outcomes different from those used to make decisions.

The model can run for as many years as desired or for which data are available. The Lake Andes-Wagner application was run for 31 years using data for the years 1955-1985 inclusive. Since the purpose is to show irrigation impacts in mitigating

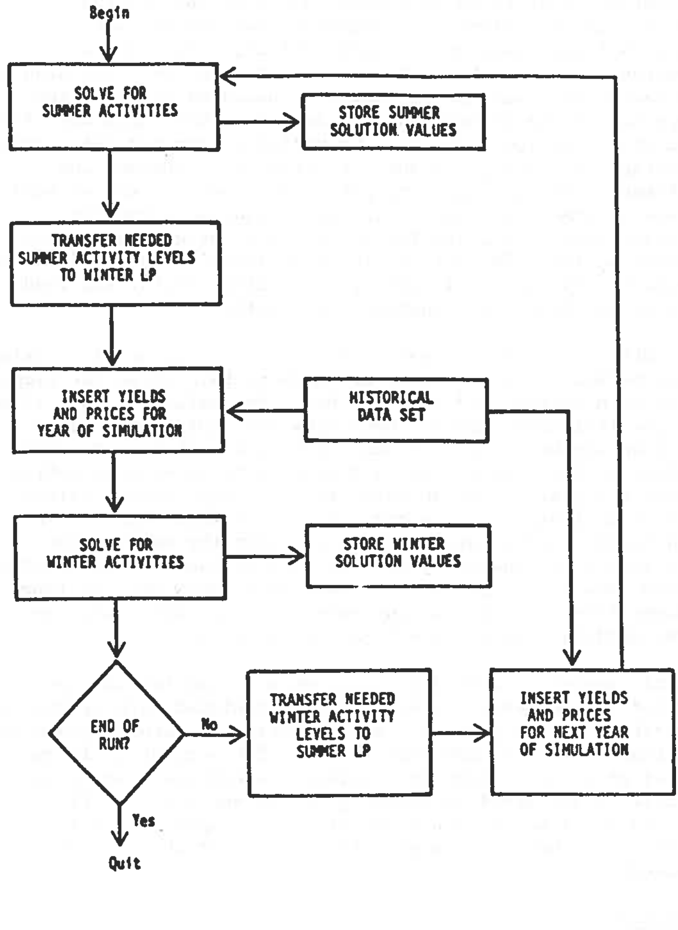

Figure 1. Schematic Diagram of Multiyear Sequential Linear Programming Model, Lake Andes-Wagner Irrigation Study

drought, a drought period should be included in the time sequence if at all possible. The summer period runs from May through October. During this period decisions are made concerning what crops to produce based on anticipated profitability subject to limitations imposed by land availability, rotational considerations, labor, and/or machinery constraints. The size of the beef herd can also be increased to a maximum or decreased based on the carrying capacity of the pasture and the amount of hay carry-over from the winter period. The grazing period is divided into early grazing (May to August) and late grazing (September and October). The late grazing period includes the use of small grain aftermath grazing. For the irrigation situation, backgrounded calves are fed to slaughter weight during the summer period. The cattle finishing decision is based on feed availability and profitability of feeding considering feed prices and expected slaughter steer prices.

The winter period encompasses November through April. During this period, crop decisions are made to bale straw for feed, make corn silage, and purchase hay. Hay sales are only allowed in the irrigation model. Decisions concerning livestock include whether to sell producing cows and whether to wean calves or feed through the winter on a backgrounding ration. Under irrigation, the decision to hold backgrounded calves into summer to finish is also made in this period. Least-cost cow and feeder rations are determined within the model. The decision to purchase hay or sell cows is based on hay purchase price relative to projected losses from early sale of cows. Losses from sale of cows increase with the number sold as progressively younger cows must be selected.

Cattle numbers and feed inventories are transferred from one period to the next. Forage losses associated with storage are specified in the program. An accounting of actual income and variable costs is made each period. The accounting income is based on actual prices and yields. In contrast, management decisions are based on planning prices and yields. Planning prices are a weighted average of prices lagged for 3 years reflecting that farmers plan based on their most recent experience.

Model Ranch

The Lake Andes-Wagner irrigation unit in southeastern South Dakota was used as a case study. The present land use is a mixture of row crops, alfalfa, small grains, and tame and native grasses. The model ranch has 1,000 acres. Dryland and irrigated land use is summarized in table 1. Labor supply consists of 2,500 hours by the ranch operator which is evenly divided between the summer and winter periods. Additional hired labor is available at $4.50 per hour. The beef cow herd has a maximum of 140 cows for dryland and 163 with irrigation. These limits are based on the carrying capacity of the pasture and aftermath grazing. Under irrigation, some supplemental feeding of hay on pasture would be required in most years. A 92-percent calf crop is assumed with a cow culling rate of 16 percent. Calves could be sold at weaning at 425 pounds for steers and 375 pounds for heifers or could be backgrounded for 150 days and sold as yearlings at 650 pounds for steers and 600 pounds for heifers. Under irrigation, the option of feeding the cattle out to market weight is also available.

Table 1. Land Use for Dryland and Irrigation Model Ranch
Lake Andes-Wagner Unit, South Dakota

Land Use	Dryland	Irrigated
	Acres	
Rangeland Pasture	493	493
Farmstead and Waste	27	27
Total Nontillable	520	520
Dryland Alfalfa	120	65
Dryland Tame Pasture	50	50
Other Dryland Crops[a]	310	220
Total Dryland Tillable	480	335
Irrigated Alfalfa	0	60
Other Irrigated Crops[b]	0	85
Total Irrigated	0	145
Total Land in Ranch	1,000	1,000

[a]Corn, sorghum, wheat, and oats
[b]Corn, soybeans, and potatoes

Results

Cow numbers (figure 2) for the dryland situation were severely reduced in 1956 and 1959 due to a lack of summer grazing and exhaustion of stored hay supplies. Smaller reductions periodically occurred during the summer in other years. Cows were also sold in the winter period in 1974 and 1976. Hay purchases were not profitable in 1976 relative to losses from selling cows, but in 1974 a combination of hay purchases and sales of cows was selected by the model. Cows were also purchased to rebuild herds as conditions improved. For example, over 30 replacements were purchased in 1957, 1960, and 1977. However, in only 1 year of major cow replacement

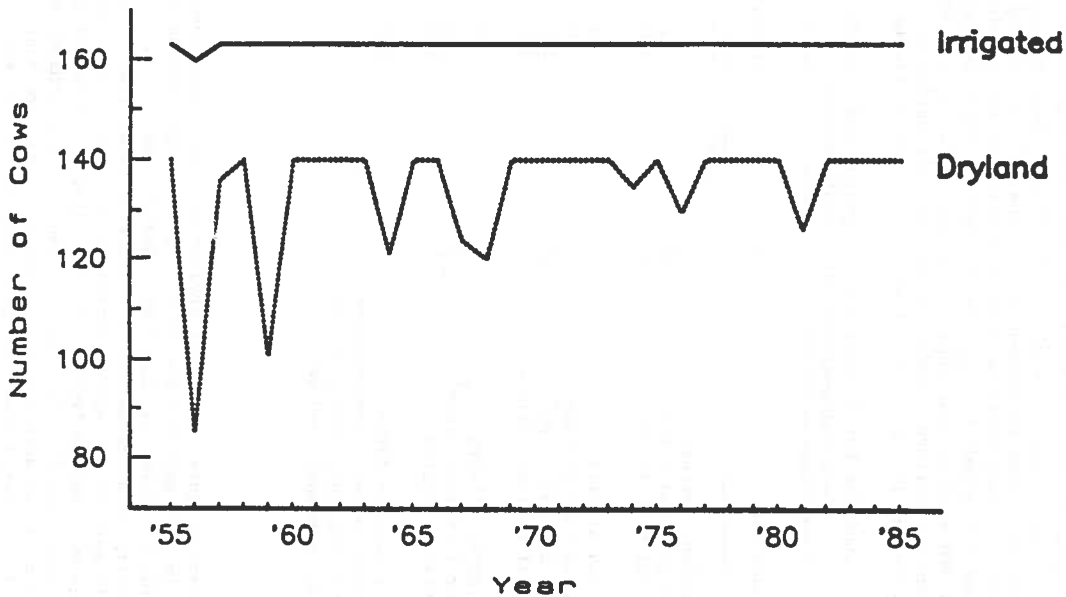

Figure 2. Comparison of Cow Numbers Under Dryland and Irrigation, Ranch Model II, Lake Andes-Wagner Unit, South Dakota, 1955-1985

purchases were cows selling at a premium over their slaughter value. This muted the negative economic impact of cow purchases on net return. The irrigated ranch, even at the higher stocking level, showed almost no variation in herd size (figure 2) because irrigated forage was available.

A comparison of the key results between dryland and irrigation is summarized in table 2. This comparison provides a test of the hypothesized advantages of ranch irrigation benefits over dryland. The following shows the results relative to the list of hypotheses on page 3.

1. The reduction in sales of productive cows between the dryland and irrigated models indicated the longer average productive cow life with irrigation.

2. The reduction in purchase of replacement cows illustrates this advantage of irrigation. The reduction in cow sale and purchased replacement cost of $366.46 annually with irrigation was due to greater herd stability. The premium paid for replacement cows in some of the years purchased plus the loss from selling some cows 1 to 2 years before the end of their normal productive life were captured by the dynamic model versus the static model.

3. Reduced calf production due to herd reduction in the dynamic dryland model occurred during periods of below-average calf prices resulting in slightly higher calf values under dryland than under irrigation. Apparently, droughts in this application were not widespread enough to significantly affect prices.

4. Herd size increase was greater with the dynamic model resulting in better use of labor and facilities.

5. Fewer calves were backgrounded, but more calves were finished giving inconclusive results.

6. Hay purchases of 3.9 tons per year were eliminated with irrigation in the dynamic model. Purchased hay was charged a transportation cost above the price received for hay sold.

7. The model ranch did not show a reduction in hay carry over with irrigation as hypothesized. Drought periods reduced hay carry over to zero in many years under dryland, while a constant but reduced hay carry over was programmed into the irrigated model. The dryland model exhibited a trade off between setting lower maximum cow numbers and more hay carry over or the converse.

8. There was more supplemental hay fed with pasture under irrigation in the dynamic model. This was due to a hay shortage under dryland necessitating the sale of cows.

Table 2. Dynamic Model Comparisons of Dryland and Irrigated Ranches

Item	Unit	Dryland Mean	Dryland Range	Irrigated Mean	Irrigated Range
Beef cows	Hd	134.1	85-140	162.9	160-163
Backgrounded Calves for Sale	Hd	22.6	0-103	17.9	0-120
Supplemental Forage on Pasture	Tons	9.0	0-84	75.0	24-108
Small Grains Aftermath Grazed	Ac	73.6	36-116	50.8	31-65
Corn or Sorghum Aftermath Grazed	Ac	83.9	13-112	79.1	22-124
Alfalfa Carried Over to Summer	Tons	6.9	0-62	33.1	12-84
Alfalfa Sold	Tons	0.0	0-0	92.6	0-461
Corn Grain	Ac	94.1	60-208	66.5	60-110
Corn Silage	Ac	25.7	0-56	26.7	0-60
Sorghum	Ac	93.4	0-148	43.6	0-50
Wheat	Ac	122.0	102-155	83.0	83-83
Alfalfa	Ac	120.0	120-120	65.0	65-65
Irrigated Crops					
Potatoes	Ac			40.0	40-40
Corn	Ac			40.8	2-45
Soybeans	Ac			4.2	0-43
Alfalfa	Ac			60.0	60-60
Hired Labor	Hr	2.0	0-63	360.7	307-729
Return above Variable Costs	Dol	35,381.	14,510-65,678	71,414.	38,601-113,573

The average return above variable costs under dryland conditions was $35,381 with a range of $14,510 to $65,678. Under irrigation, the average was $71,414 with a range of $38,601 to $113,573. It is important to note the percentage change in returns from low to high under dryland (352 percent) is much higher than under irrigation (194 percent). This would indicate that irrigation is helping to stabilize income levels over the period of analysis. Both irrigated and dryland are still subject to variations in yields and prices, therefore there is still considerable variation in income levels over the 31-year period.

It is also interesting to note the difference between the static and the dynamic model in terms of income measures. The increased returns above variable costs between dryland and irrigation were $36,518 annually from the static model and $39,831 from the dynamic model. The $3,313 higher irrigation benefit from the dynamic model was as hypothesized. This occurs because of the large reductions in cow numbers in droughts and purchases of hay, which the dynamic model captures, but the static model would average out. Under irrigation, the irrigated forages were sufficient to virtually eliminate herd size variability.

The difference between the static and dynamic model depends upon the ranch situation being modeled. Some of the hypothesized benefits of irrigation were increased under the dynamic model, but not all. Livestock number variations due to drought appear to be the most important variable modeled in a dynamic context. This would suggest the improved benefits from a dynamic model would be even greater in dryer areas.

In conclusion, this is an example of the mitigation characteristics of irrigation in recurring drought situations. This case study was perhaps unusual in some respects in that it dealt with livestock, something not often considered in discussing irrigation benefits. The results showed that there were positive impacts and that it was best to use the dynamic modeling approach to measure them.

The economic and social impacts from this are a reduction of risk, more certainty regarding production, and less anxiety. There are also community impacts that were not included in the model, but that certainly exist. These would include the stability of income and higher levels of production, which precipitate stable secondary impacts in the retail establishments in the local communities.

REFERENCES

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