Impact of Energy Cost on Irrigated Production: High Plains of Texas

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Irrigation water cost data and the value of water in production for the four principal crops grown in the Texas High Plains, at a wide range of product prices, were used to estimate the price per kilowatt-hour of electricity needed to equate net returns from current irrigation practices and dryland production over time. Results indicate that rising energy prices without corresponding rises in product prices could result in energy, rather than water, being the limiting factor in High Plains irrigation.

High Plains irrigators have become increasingly alarmed at rising energy prices over the past five years. In 1970, producers were paying $0.30 per MCF for natural gas and $0.01 per KWH for electricity. Prices in 1977 were $1.25 and $0.035, respectively. Indications are that energy prices will continue to climb. Growing interest in the energy crisis will affect U. S. agriculture and food production through: 1) higher commodcost on irrigated production. Dvoskin and Heady provide some insight as to how the energy cirsis will affect U. S. agriculture and food production through: 1) higher commodity prices, 2) a shift eastward in crop production from irrigated to dryland farming regions, 3) redistribution of farm income away from irrigated regions, and 4) the impact on income and employment in rural communities. Mapp and Dobbins discuss the implications of rising natural gas prices on irrigated production as they affect pumping cost, pattern of irrigated production, level of water use and the shift from irrigated to dryland crop production.

In the Texas High Plains, the effects of rising energy prices on irrigated production will vary among producers due to differences in their total and variable costs per unit of water. Costs per acre-foot of water pumped vary widely among irrigation wells, depending primarily upon pumping capacity, pumping lift, and efficiency of the pumping system. Underground water is pumped from the Ogallala formation, which contains a nonrenewable water supply. The water-bearing strata is not homogeneous in the High Plains region, with regard to depth to bedrock, zone of saturated thickness, and depth to static water level. The annual decline in the water level from pumping varies from area to area and from year to year but averages 2 to 5 feet per year [Hughes and Harmon]. Consequently, a wide variety of pumping plants are used to provide irrigation water.

At present, about 6.4 million acres are being irrigated on the Texas High Plains. Irrigated land has increased by about a million acres during the past decade. Underground water is supplied by approximately 71,000 irrigation wells scattered over a 40 county area. Natural gas and electricity provide energy for 64 and 34 percent of the wells, respectively. The acreage ratio of surface to sprinkler irrigation is about 3 to 1. Pumping capacity is extremely variable, with about 70 percent of

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Technical article no. 13572 of the Texas Agricultural Experiment Station.

the wells pumping less than 700 gallons per minute, and 90 percent having a lift greater than 125 feet [New]. Although natural gas provides energy for most irrigation wells, projections for price increases are estimated at an annual rate of 15 to 20 percent. Natural gas reserves are being depleted and, studies have shown that by 1985, Texas may not be able to meet its own energy needs [LePori, *et al.*]. Threats of natural gas curtailment and the possibility of lowering the priority of natural gas for agricultural production have caused many irrigators to consider electricity as a more reliable energy source.

This paper will not attempt to compare the economic advantages of the two principal energy sources but will concentrate on the effects of rising electrical energy prices on production of those crops currently irrigated on the Texas High Plains. The impact of rising electrical energy prices is analyzed by using an irrigation well cost model designed for High Plains water-well conditions [Goss and Shipley] and a water value for crops established from Texas Agricultural Extension Service budgets for High Plains crops. A cost of electricity that produces a break-even net profit for irrigated and dryland crops at specific commodity prices is determined. Break-even product prices at current energy costs are then determined and compared to current product prices to assess the economic feasibility of continued irrigation.

Irrigation Well Cost Model

An irrigation well cost model, similar to that developed by Feldman and Whittlesey, was designed for steadily declining, unconfined aquifers comparable to the Ogallala of the High Plains. The computer model is sufficiently flexible to simulate any of the electrically powered well-pumping plants currently used for irrigation. Inputs into the model are the physical well and aquifer characteristics, determinants of pumping plant specifications, and economic variables.

Well and aquifer characteristics include size of borehole, depth to bedrock, saturated thickness, hydraulic conductivity, static water level, and annual water table decline. Determinants of pumping plant include pumping rate, surface head, and efficiency of motor and pump. Economic variables are annual interest rate, tax and insurance rate, cost of electricity, days of pumping, and for each equipment item purchased (including the hole), the annual maintenance ratio, depreciable life, and salvage value at the end of the depreciation period.

The simulation model provides estimates of total dynamic head and horsepower requirements, selects motor and pump, establishes drawdown and sets the depth of pump, determines water pumped, initial investment, and segregates annual costs.

The example of an irrigation well selected for this analysis sustained an above-average pumping rate for the Texas High Plains. Variable inputs could have simulated any of the wells currently in use.

Example well specifications include: 1) Diameter of borehole - 2 feet, 2) Depth to bedrock - 440 feet, 3) Saturated thickness - 240 feet, 4) Hydraulic conductivity - 20 feet/day, 5) Annual water table decline - 2.5 feet/yr, 6) Pumping rate 800 gpm maximum - 600 gpm minimum, 7) Surface head - 20 feet and 150 feet (sprinkler), 8) Initial efficiency - motor - 90 percent and pump - 75 percent, 9) Annual interest rate - 10 percent, 10) Annual tax and insurance rate - 2 percent, 11) Cost of electricity - $0.035 per KWH, 12) Pumping days per year - 140, and 13) Pumping life of designed well - until yield is limited by minimum saturated thickness of aquifer.

Table 1 shows a breakdown of annual well costs, averaged in 5-year increments, with average total and variable costs per acre-foot of water. The model well terminates pumping after 50 years when minimum saturated thickness made the system inefficient to operate under the specified design. Continued operation would have required a reduction in pumping rate and a redesigned pumping plant.

The lower part of Table 1 shows a comparison of surface and sprinkler irrigation costs by changing the surface head from 20 to 150 feet

TABLE 1. Annual well costs, averaged in 5-year increments, and comparable average annual costs using 20 and 150 foot surface head.

Pumping period (years)	Deprec.	Interest, Tax, Ins.	Energy	Maint.	Total	Water pumped	Average total cost-Ac/ft	Average variable cost-Ac/ft
	dollars					Ac/ft	dollars	
1 - 5	1485	2686	6163	383	10,717	443	24.19	14.78
6 - 10	1194	1882	6163	383	9,622	417	23.07	15.70
11 - 15	957	1318	6163	826	9,264	395	23.45	17.69
16 - 20	662	848	6163	399	8,072	373	21.64	17.59
21 - 25	933	1151	7449	685	10,218	430	23.76	18.92
26 - 30	887	760	7771	471	9,889	426	23.21	19.35
31 - 35	366	449	7771	983	9,569	404	23.68	21.67
36 - 40	225	305	7771	487	8,788	383	22.94	21.56
41 - 45	316	532	7754	788	9,390	371	25.31	23.02
46 - 50	449	677	7754	523	9,393	355	26.46	23.29
Surface Irrigation (20' hd)								
Total	37,367	53,044	354,591	29,641	474,643	20,007	--	--
Average	747	1,061	7,092	593	9,493	400	23.73	19.21
Sprinkler Irrigation (150' hd)								
Total	38,749	55,803	498,625	33,890	618,067	19,984	--	--
Average	775	1,116	9,792	678	12,361	400	30.90	26.17

in the example well. The average annual total and variable costs were $7.17 and $6.96 per acre-foot of water higher for the sprinkler system than for surface irrigation.

Value of Water by Crops

The ability-to-pay for (value of) irrigation water was estimated for the four principal crops produced in the central region (Region II) of the Texas High Plains, using a procedure similar to that of Lacewell *et al.* Crop enterprise budgets developed by the area economist of the Texas Agricultural Extension Service for the 1977 crop year were used in the analysis. Cost and returns of dryland and irrigated production at specified water input levels were compared, both under data specifications for high-level management. The irrigation level selected for each crop represents the quantity of irrigation water currently used by the "best" farm managers. The analyses included both fixed and variable costs and the basic principle involved allocating a return to all factors of production except irrigation water. The average water distribution costs shown in Table 2 were used in the crop budgets. With the exception of irrigation pumping costs, all other water costs were included. The residual net return was assigned to water and would be available to pay for irrigation pumping costs.

Some budget cost items were adjusted to reflect differences in two basic tenure groups: farm owner-operators and tenant farmers. Owner-operator fixed land cost was calculated at an 8 percent annual interest rate on land values of $600 and $200 dollars per acre for irrigated and dryland, respectively. Tenant annual rent was based on paying one-third of grain crops and one-fourth of cotton production, with the landlord sharing a comparable percentage of fertilizer, hauling, drying (corn) and ginning costs for cotton.

A water value equation was developed by using crop enterprise budgets of both farm owner-operators and tenants, at current irrigation levels as specified in Tables 3 and 4. Equations are shown as follows:

Owner-operators

$$1) \quad V_i = [(Y_i - Y_{ik})\, P_i - (C_i - C_{ik})]/w_i$$

Where:

V_i = irrigation water value per acre foot in producing crop i; Y_i = yield per acre of

TABLE 2. Irrigation Distribution Cost per Acre for Center Pivot Sprinkler and Surface Irrigation Systems, Texas High Plains, 1977.

Item	Sprinkler[a]	Surface
	dollars	
Investment per acre	111.	55.
Distribution Costs		
Annual Depreciation[b]	7.40	2.75
Annual Opportunity Costs[c]	5.55	2.75
Annual Tax, Risk, and Ins.[d]	2.22	.55
Repairs	1.57	.55
Labor — $4.00/hr.	3.76	8.00
Total Cost per Acre	20.50	14.60

[a]Based on 270 acres.
[b]15 years for center pivot; 20 years for surface.
[c]Average investment times 10 percent.
[d]Initial investment times 2 percent (sprinkler) 1 percent (surface).

crop i at specified irrigation level; Y_{ik} = yield per acre of crop i under dryland production; P_i = price per unit of crop i; C_i = total cost per acre of producing crop i at specified irrigation level (excluding all water costs except water distribution costs); C_{ik} = total cost per acre of producing crop i under dryland production; and W_i = acre feet of irrigation water used in producing crop i.

Tenants

$$2) \quad V_i = [(S_i - S_{ik}) P_i - (X_i - X_{ik})]/w_i$$

Where:

S_i = tenants share of per acre yield of crop i at specified irrigation level; S_{ik} = tenants share of per acre yield of crop i under dryland production; X_i = tenants share of total cost per acre of producing crop i at specified irrigation level (excluding all water costs except water distribution costs; and X_{ik} = tenants share of total cost per acre of producing crop i under dryland production.

Tables 3 and 4 show the value per acre-foot of irrigation water used in producing wheat, grain sorghum, corn and cotton under both sprinkler and surface irrigation, at specified irrigation levels and three product prices, for owner-operators and tenant farmers, respectively. These values represent the ability-to-pay for water at the farm gate; thus, all costs associated with pumping groundwater must be deducted.

Water values and pumping costs both differ between owner-operators and tenant farmers. Differences in water values are associated with the operator's share of the product produced and increase as product prices rise. Variable (out-of-pocket) pumping costs are the same for both groups of farm operators and total pumping costs differ only in proportion to their share of the fixed investment in the irrigation well. Although rental agreements vary between landlord and tenant, it was assumed that the tenant provides the irrigation motor. The well cost model was used to determine the average cost of water per acre-foot for the owner-operator and tenant at different electricity prices, with all other input variables held constant. For the example well, the average energy cost for surface irrigation was $5.07 per acre-foot per ¢/KWH. The total of all other costs were $5.95 per acre-foot of irrigation water for the owner-operator and $1.48 per acre-foot for the tenant. The additional surface head (pressure) required for the sprinkler system increased the average energy cost to $7.00 per acre-foot per ¢/KWH and other costs were increased to $6.38 and $1.69 per acre-foot of water for the owner-operator and tenant, respectively. Other well costs were not allowed to increase

TABLE 3. Value per acre foot of irrigation water for farm owner-operators, using surface and sprinkler irrigation, by crops at specified product prices, Texas High Plains, 1977.

	Irrigated net yield increase (units)	Product price (dollars)	Water used (Ac-Ft)	Value of water per acre-foot[a] Sprinkler[b]	Surface
				— — dollars — —	
Wheat	34 bu	3.10/bu	1.3	5	10
		3.60/bu		18	23
		4.10/bu		31	36
Gr. Sorghum	60 cwt	3.10/cwt	1.8	22	25
		3.60/cwt		39	42
		4.10/cwt		56	59
Corn	71.4 cwt	4.00/cwt	2.0	35	38
		4.50/cwt		53	56
		5.00/cwt		71	74
Cotton	400 lb	.43/lb	1.2	59	64
		.50/lb		86	91
		.60/lb		123	128

[a]Excludes all water costs, except distribution costs.
[b]Center pivot sprinkler w/135 acre coverage.

with rising energy prices, as would likely occur.

The price limit which irrigators can afford to pay for energy will be the price which equates water cost with the value of water in production. As an example, the maximum price that an owner-operator surface irrigator can afford to pay for energy for irrigating a specific crop can be derived from the above cost data of the model well and shown as:

$$3) \quad V_i = 5.95 + 5.07X$$

or

$$X = (V_i - 5.95)/5.07$$

Where:

V_i = irrigation water value per acre foot in

TABLE 4. Value per acre foot of irrigation water for tenant farmers, using surface and sprinkler irrigation, by crops at specified product prices, Texas High Plains, 1977.

	Irrigated net yield increase (units)	Product price (dollars)	Water used (Ac-Ft)	Value of water per acre-foot[a] Sprinkler[b]	Surface
				— — dollars — —	
Wheat	22.6 bu	3.10/bu	1.3	8	12
		3.60/bu		17	21
		4.10/bu		26	30
Gr. Sorghum	40 cwt	3.10/cwt	1.8	10	13
		3.60/cwt		21	24
		4.10/cwt		32	35
Corn	47.6 cwt	4.00/cwt	2.0	10	13
		4.50/cwt		22	25
		5.00/cwt		34	37
Cotton	300 lb	.43/lb	1.2	50	55
		.50/lb		70	75
		.60/lb		99	104

[a]Excludes all water costs, except distribution costs.
[b]Center pivot sprinkler w/135 acre coverage.

producing crop i and X = cost per KWH electricity, cents.

The solution of equation (3) represents the price per KWH of electricity which would negate any economic advantage from irrigation, and would yield the same net returns as dryland production. Justification of continued irrigation would then be based on factors other than increased profits, such as reducing production risk and improving availability of financing.

Discussion

In these analyses, water values were computed at current irrigation levels, as shown by the quantity of water used in production of each crop reported in Tables 3 and 4. We have not attempted to establish a value for water under a reduced or limited irrigation program where emphasis is placed on maximizing efficiency of water-use. A lesser quantity of water applied at critical periods of plant development could prove profitable; whereas, net returns from a full irrigation level, at the same energy price, could be less than that of dryland production [Shipley and Regier]. For any given irrigation yield and product price, there is an energy price which will equate net returns of irrigated and dryland production. We are examining current irrigation levels that predominate in the area for the major crops and the price of energy that would negate any economic advantage in support of continued irrigation. Under an assumption of high-level management, the same quantity of water is assumed to be applied by both surface and sprinkler irrigators. The quantity of water applied by sprinklers may be reduced slightly without affecting yield due to increased irrigation application efficiency.

The value of increased yield due to irrigation is extremely sensitive to product prices, as shown in Tables 3 and 4. Consequently, water values have been expanded to cover a wide range in product prices for these four principal crops for both tenure groups under surface and sprinkler irrigation in Figures 1 and 2, respectively.

A wide range of commodity prices, by tenure groups, with corresponding water values for surface irrigation, and cost per KWH of electricity that would equate net returns (break-even) for irrigated and dryland production, at 1977 input prices, are presented in Figure 1. Similar data for sprinkler irrigation are shown in Figure 2. Water values at current irrigation levels and production practices were established as a function of commodity prices and the long run average total water costs were established as a function of the price of electricity. When water cost is equated with water value (Figures 1 and 2), the product price and cost per KWH of electricity that equates net returns from irrigated and dryland production can be read directly from the chart. For example in Figure 1, if an owner-operator surface irrigator is paying 3.5 cents/KWH for electricity, his average total water cost is $23.78/Ac ft. A straight edge across Figure 1 at $23.78, under the two columns labeled water cost and water value, will show product prices corresponding to a water value of $23.78, i.e., $3.64/bu for wheat, $3.05/cwt for grain sorghums and $3.59/cwt for corn. At these product prices, the value of water in production equals the cost of water with electricity selling for 3.5 cents/KWH. These data represent a long run analyses, which include total costs, and farm irrigators could make various adjustments during the short run or intermediate periods; for example, irrigation and other input levels could be reduced and irrigation continued as long as returns exceed variable production costs.

Surface Irrigation

For owner-operators at the current price of 3.5 cents per KWH of electricity, the irrigated-dryland "break-even" prices are $3.64/bu for wheat, $3.05/cwt for grain sorghum and $3.59/cwt for corn (Figure 1). The long run profitability of surface irrigating these crops at present input levels is in serious jeopardy at current market prices. Texas Market News Service (Nov. 1977) price quotations are $2.38/bu for wheat, $3.25/cwt for grain sorghum, and $3.57/cwt for corn. Of

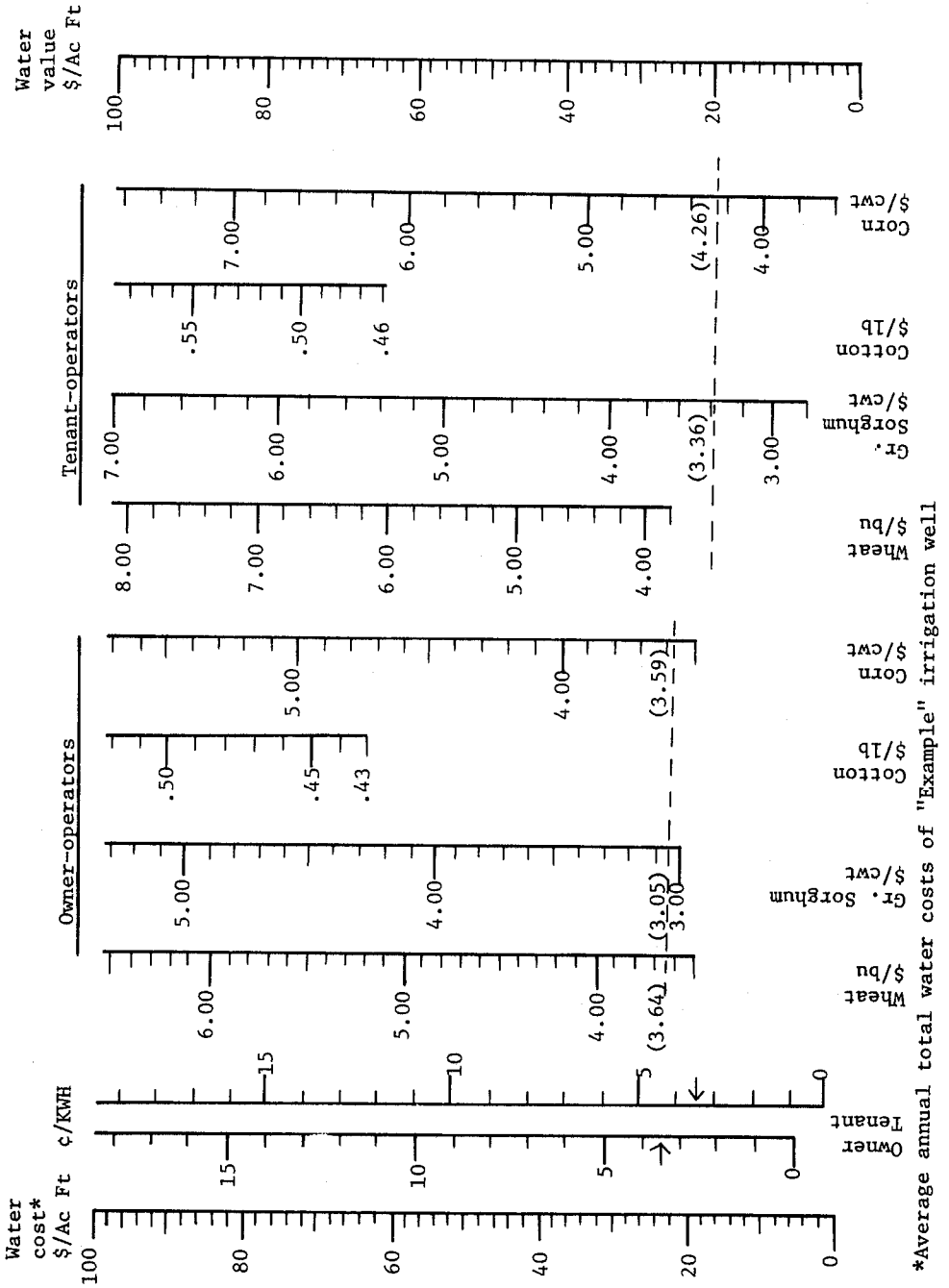

Figure 1. Commodity prices, by tenure groups, with corresponding water values for surface irrigation farmers in the Texas High Plains and cost per KWH of electricity which equates net returns (break-even) for Irrigation and Dryland production, 1977.

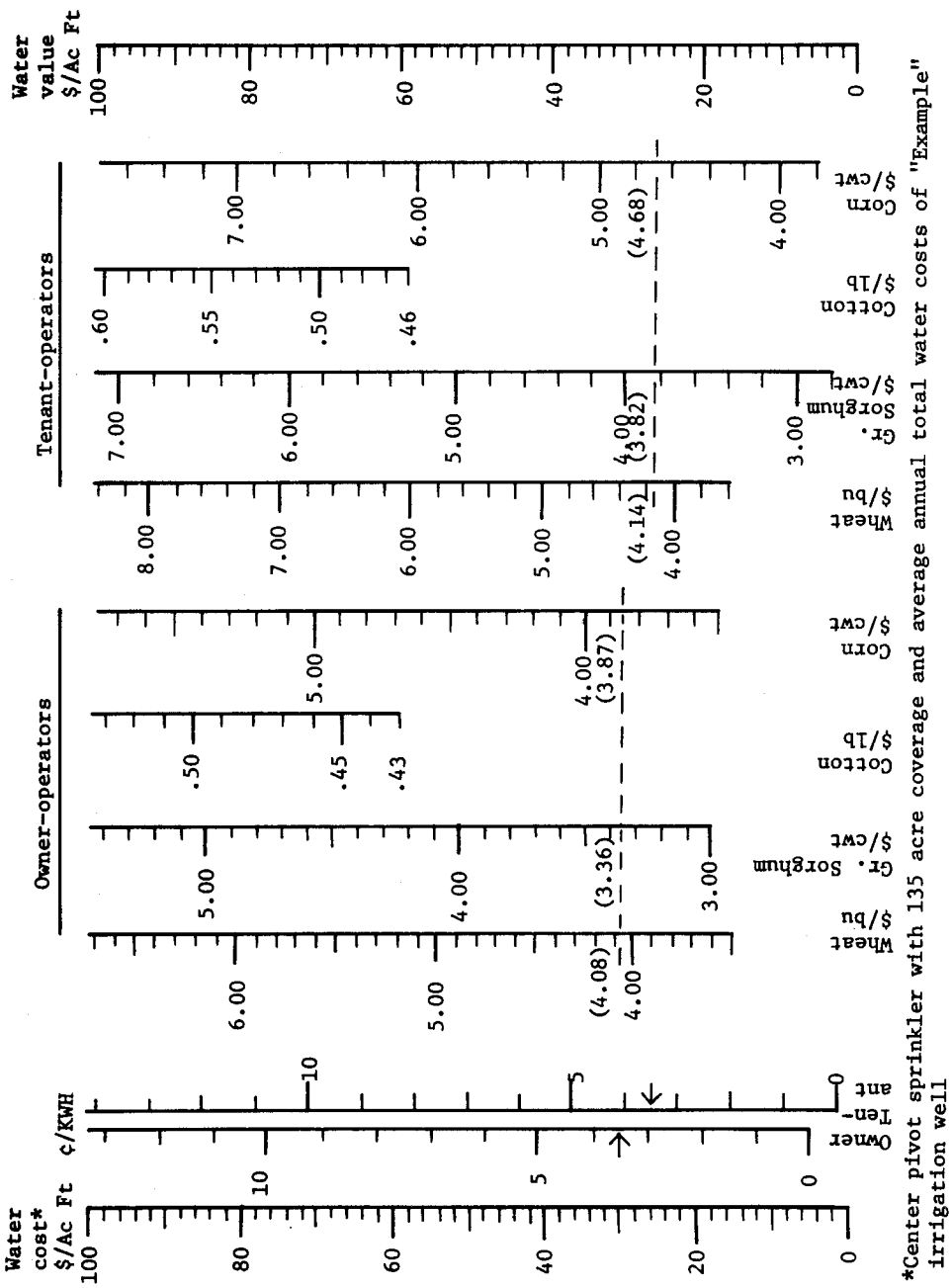

Figure 2. Commodity prices, by tenure groups, with corresponding water values for sprinkler irrigation farmers in the Texas High Plains and cost per KWH of electricity which equates net returns (break-even) for Irrigated and Dryland production, 1977.

the three crops, only grain sorghum yielded a return greater than dryland production. The current market price for wheat is considerably below the owner-operator's irrigated cost of production and the irrigated-dryland "break-even" price (Table 5). This difference would be partially off-set during some years by the grazing income which was not included in this analysis. Since the owner-operator's dryland cost of production for cotton was $0.43/lb, dryland cotton would not be an alternative enterprise until electrical energy reached 11.6 cents per KWH.

The current price of electricity establishes the tenant farmer's irrigated-dryland "break-even" product prices for grain sorghum and corn at $3.36 and $4.26/cwt, respectively. Over the long run, the market price will have to be higher than the above quoted "break-even" product prices for these two surface irrigated crops to be more profitable than dryland production.

A tenant farmer's cost of production for surface irrigated wheat is $3.58/bu and is $3.76/bu for dryland (Table 5). The present market price of wheat eliminates both enterprises as being profitable ventures. At a market price of $3.76/bu for wheat, energy prices would have to rise to 4.5 cents per KWH before the net returns from irrigation would be reduced to that of dryland wheat.

Production costs for irrigated and dryland cotton are $0.36 and $0.46/lb, respectively. At a market price of $0.46/lb for cotton, the irrigated-dryland "break-even" price of energy would be 12.3 cents per KWH for tenants.

Sprinkler Irrigation

Under the assumption that the same quantity of water is being used through sprinkler and surface irrigation systems, water costs for sprinklers will be higher due to the increased head pumped and a more costly distribution system. Consequently, the irrigated-dryland "break-even" product prices for any given energy price will be higher than for surface irrigation.

TABLE 5. Cost of Production "break-even" product prices, by farm operators, for specified crops and yields on the Texas High Plains, 1977.

Producer	Product	Net Yield/Acre		Cost of Production "Breakeven" Product Prices		
		Dryland	Irrigated	Dryland	Irrigated[a] Sprinkler[b]	Irrigated[a] Surface
		Units		dollars/unit		
Owner-Operator						
	wheat[c]	16 bu	50 bu	3.55	3.91	3.61
	gr. sorghum	15 cwt	75 cwt	3.06	3.30	3.05
	corn[d]	12.6 cwt	84 cwt	3.64	3.84	3.60
	cotton	200 lb	600 lb	.43	.38	.36
Tenant						
	wheat[c]	10.7 bu	33.3 bu	3.76	4.02	3.58
	gr. sorghum	10 cwt	50 cwt	2.81	3.62	3.25
	corn[d]	8.4 cwt	56 cwt	3.35	4.48	4.12
	cotton	150 lb	450 lb	.46	.38	.36

[a]Texas Agric. Extension Budgets, Region II, High Plains (prepared by Ray Sammons, Amarillo) and "Example" Irrigation well cost model average water costs with electricity @3.5 cents per KWH and specified distribution costs (Table 2).

[b]Center pivot sprinkler w/135 acre coverage.

[c]Excludes any income from grazing.

[d]Dryland grain sorghum considered as alternative for dryland corn — to compensate for an assumed 1.5 price differential (bu corn vs cwt grain sorghum), a yield ratio substitution of .84 to 1 was used for dryland corn and grain sorghum with production costs assumed constant.

For owner-operators at the current energy price of 3.5 cents per KWH, product prices over the long run must exceed $4.08/bu for wheat, $3.36/cwt for grain sorghum and $3.87/cwt for corn before sprinkler irrigation will be more profitable than dryland production. Present market quotations for all three crops are below these specified prices.

Compared to other crops, cotton maintains a unique position at present. The market price for cotton is above the cost of production for both irrigated and dryland producers. Current market price for cotton is about $0.45/lb whereas, sprinkler irrigated cost of production is $0.38/lb and dryland production cost is $0.43/lb. For $0.45/lb cotton, the irrigated-dryland "break-even" price of energy is 8.7 cents per KWH.

If tenant-operators expect to recover their total production costs, with energy priced at 3.5 cents per KWH, product prices will have to exceed $4.14/bu for wheat, $3.82/cwt for grain sorghum and $4.68/cwt for corn. Current market conditions for all three crops favor dryland production.

At the current energy price, sprinkler irrigation of cotton will continue as long as market price exceeds the cost of production of $0.38/lb. Dryland cotton production would be an alternative at a market price of $0.46/lb, if the price of energy increased to 8.2 cents per KWH.

Summary and Conclusions

An irrigation well cost model was used to estimate the average annual total cost per acre-foot of water for an electrically powered well on the Texas High Plains. Water costs were estimated as a function of the price of electricity. The example well was above average in pumping rate for the High Plains area, and the model maintained a high efficiency for the pump and motor. Seventy percent of the irrigation wells have less pumping capacity, and experience would indicate that relatively few operate at the level of efficiency included in the model. Thus, water costs for the majority of electrically powered wells should equal or exceed those of the well used in the analysis.

Water cost data and the value of water in production for the four principal crops grown in the area, at a wide range of product prices, were used to estimate the price per KWH of electricity to equate net returns from current irrigation practices and dryland production over time. Total costs of production practices that predominate in the area were used in this analysis. In the short run or intermediate period, farmers will continue production as long as returns exceed variable costs; however, as in any business, total costs cannot be ignored indefinitely.

Three of the four crops included in this analysis (wheat, grain sorghum and corn), appear to be in serious jeopardy for continued irrigation at current levels of production with existing product prices. Dramatic changes in current production practices will be necessary if irrigation of these crops is to continue. Specific areas for consideration include: 1) Improved crop production systems to reduce irrigation level and other inputs; 2) More efficient water distribution systems; 3) Higher efficiency levels in irrigation pumping plant; 4) Utilize lower cost energy sources; 5) Greater use of rainfall and more careful management of crop water requirements by irrigation during critical periods of plant development; 6) Selection of drought tolerant varieties; and 7) The utilization of crop residues as an additional source of income.

Although owner-operators and tenants both are experiencing economic pressures at current product and input prices, tenants are placed in a much more vulnerable position than owner-operators. Neither owner-operators nor tenants have a management charge included in the analyses, but the owner-operators do have a land rent charge that yields a return on their investment in land. With rising energy prices, tenure arrangements between landlords and tenants need to be re-evaluated. Landlords may have to share the cost of energy for irrigation.

If irrigated agriculture is to remain a viable

industry in the Texas High Plains, drastic changes will have to be made in crop production systems because spiralling energy prices without corresponding rises in product prices could result in energy, rather than water, being the limiting factor in High Plains irrigation.

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