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Introduction

The Texas High Plains is a fairly level semi-arid region located on the Southern Great Plains and encompassing about 35,000 square miles. The region is underlain by the Ogallala aquifer from which groundwater is pumped for irrigated crop production, however, pumpage rates have greatly exceeded recharge to the aquifer and groundwater supplies are being steadily depleted.

Groundwater pumping costs will increase over time as well yields decline and depth from which water is pumped increases. Further, natural gas, the primary fuel used in pumping on the High Plains, is in short supply and producers are faced with certain price increases and possible curtailments.

These factors coupled with a high degree of uncertainty regarding product prices have created a situation on the High Plains which has implications reaching far beyond the individual producer. Changes in the quantity of water pumped will have regional effects in terms of levels of crop production and income. There are also possible national effects in the case of cotton and feed grains. Therefore, the question of irrigation water demand may be shown to have relevance not only to the producer, but likewise to consumers, and policy-makers.

The objectives of this study were as follows:

1. To estimate the effect of alternative product and input price levels on the demand for irrigation water for the Texas High Plains.
2. To estimate the level of crop output associated with quantities of water demanded under alternative product and input price levels in objective 1.

Methodology

Linear programming (LP) was selected as the analytical technique since it provides an effective tool for allocating land, water, and other inputs. Basically the LP model developed in this study maximizes producer net returns[1] subject to resource restraints. The cost of water was varied parametrically to generate a derived demand schedule for irrigation water at alternative product price levels. This technique has been used extensively in past studies for other regions (e.g., Moore and Hedges; Shumway; Flinn; Yaron; Gray and Trock). The study area encompasses the "hardlands" or Pullman clay soils area south of the Canadian River in the Texas High Plains, defined as Subregion II in the Texas Crop Budgets (Extension Economists - Management). The area includes about 14 thousand square miles or 9 million acres. The growing season is about 200 days and annual rainfall ranges from 16 to 20 inches (Texas Almanac). Approximately 4.5 million acres are currently in cultivation with 2.8 million acres under irrigation (New).

The major crops of the area (corn, cotton, grain sorghum, soybeans, and wheat) were incorporated into the model. These crop enterprises were restrained by upper and lower flexibility restraints. These restraints reflect the maximum 'expected' increase or decrease in the acreage of a particular crop in a given year. The level of a given restraint was jointly determined by base acreage and the flexibility coefficient of increase or decrease.

Crop acreage flexibility coefficients were estimated from historical planted acreages (Texas Crop and Livestock Reporting Service) using linear regression analysis (Condra and Lacewell). Base acreages were specified as the past three years' average acreage for each crop except corn and soybeans.[2] The base was established as a three year average to minimize distortion of results due to the effects of atypical weather conditions and product prices in 1973 and 1974.

To obtain model flexibility, purchasing activities were included for natural gas, nitrogen fertilizer, diesel fuel, herbicide, direct water charges, and non-fuel groundwater pumping costs. This means prices for these items can be specified at alternative levels or varied parametrically.

Similarly, a selling activity for each crop was incorporated to allow efficient analysis of the effects of alternative product price levels on the demand for water and other inputs.

All resources were assumed to be unrestricted in supply except irrigated and total cropland, which were restricted to current levels. Groundwater supplies were not explicitly limited except through the irrigated land restriction.

Input Data

Per acre production input-output coefficients for crop enterprises were taken from the Texas Crop Budgets (Extension Economists - Management). Only single-level irrigated enterprises were considered for corn and soybeans, however, alternatives for the other three crops include dryland production and different levels of irrigation (Sartin). It has been assumed that all irrigated enterprises are under furrow irrigation and typical management applies to all crop enterprises.

Current 1975 input prices were used (Sartin; Osborn; Grubb) unless specified otherwise in the particular application. These prices are as follows:

Water - $23.88 per acre-foot = current pumping cost of groundwater.

Natural Gas - $.88 per thousand cubic feet.

Diesel - $.40 per gallon.

Nitrogen fertilizer - $.20 per pound[3]

A land charge of $15 per acre was levied against both dryland and irrigated crop enterprises, based on the typical rent for dryland cotton of one-third of production (Extension Economists - Management). This procedure was followed in order to allow residual returns to water to remain as net returns to the producer. A management charge assumed to be 5 percent of gross revenue was also assessed against all production activities.

Three levels of product prices, high, average, and low, were selected for application of the model. Data were furnished by the Texas Crop and Livestock Reporting Service and represent prices received by producers in the High Plains during the period 1971 through 1974. Average prices[4] are simple unweighted averages of monthly prices. These prices were assumed to be representative of prices which may be 'expected' over the next few years. Low[5] and high[6] crop prices were selected as the extremes for the period and represent the improbable but 'possible' range of crop prices.

Total cropland and irrigated cropland were set at 3.686 and 2.570 million acres respectively (New). These levels were developed from data for 1973. This year was chosen because governmental acreage controls had been relaxed and 1973 was not as atypical as 1974 in terms of prices and weather conditions.

Results

The cost of water on the High Plains may be expected to increase due to the influence of four factors; (1) increasing lift and decreasing well yields associated with exhaustion of groundwater supplies, (2) price increases for natural gas which is the predominate fuel used in irrigation (Osborn), (3) an increase in maintenance expenses and acquisition costs of pumping units, and (4) assessment of a direct charge on water pumpage. There are many institutional constraints which probably will prevent the direct charge on water withdrawals from occurring. For this analysis, effect of crop prices and natural gas price on irrigation and agricultural output on the Texas High Plains were investigated.

Effect of Crop Prices

Demand schedules for irrigation water were developed under alternative assumptions of average, high, and low crop prices (Figure 1). It was assumed that crop prices would tend to move together over time based on analysis of historical data.[7]

The range of irrigation water demand at average crop prices (curve 'b', Figure 1) is 3.4 million acre-feet at the current pumping cost of $23.88 per acre-foot to none at $48.35 per acre-foot. 'High' crop prices (curve 'c', Figure 1) yield a range of 3.7 million acre-feet of water at the current pumping cost of $23.88 per acre-foot to none at a cost of $153.67 per acre-foot. Under conditions of 'low' crop prices (point d, Figure 1) no water is demanded for irrigation.

The demand for water at average crop prices is relatively insensitive to changes in water cost up to $34.96 per acre-foot, at which point the quantity of water demanded falls to about 2.0 million acre feet. This represents a reduction of over 40 percent from the quantity of water demanded at current pumping costs. The insensitive range in water demanded goes from current pumping costs up to $114.93 per acre-foot of water with high crop prices. At a water cost of $114.93 per acre foot, quantity of water demanded declines about 50 percent. These results indicate the degree to which demand for water is affected by the level of crop prices. If low crop prices should prevail, then rapid phasing out of irrigation on the Texas High Plains would be expected. With current crop and

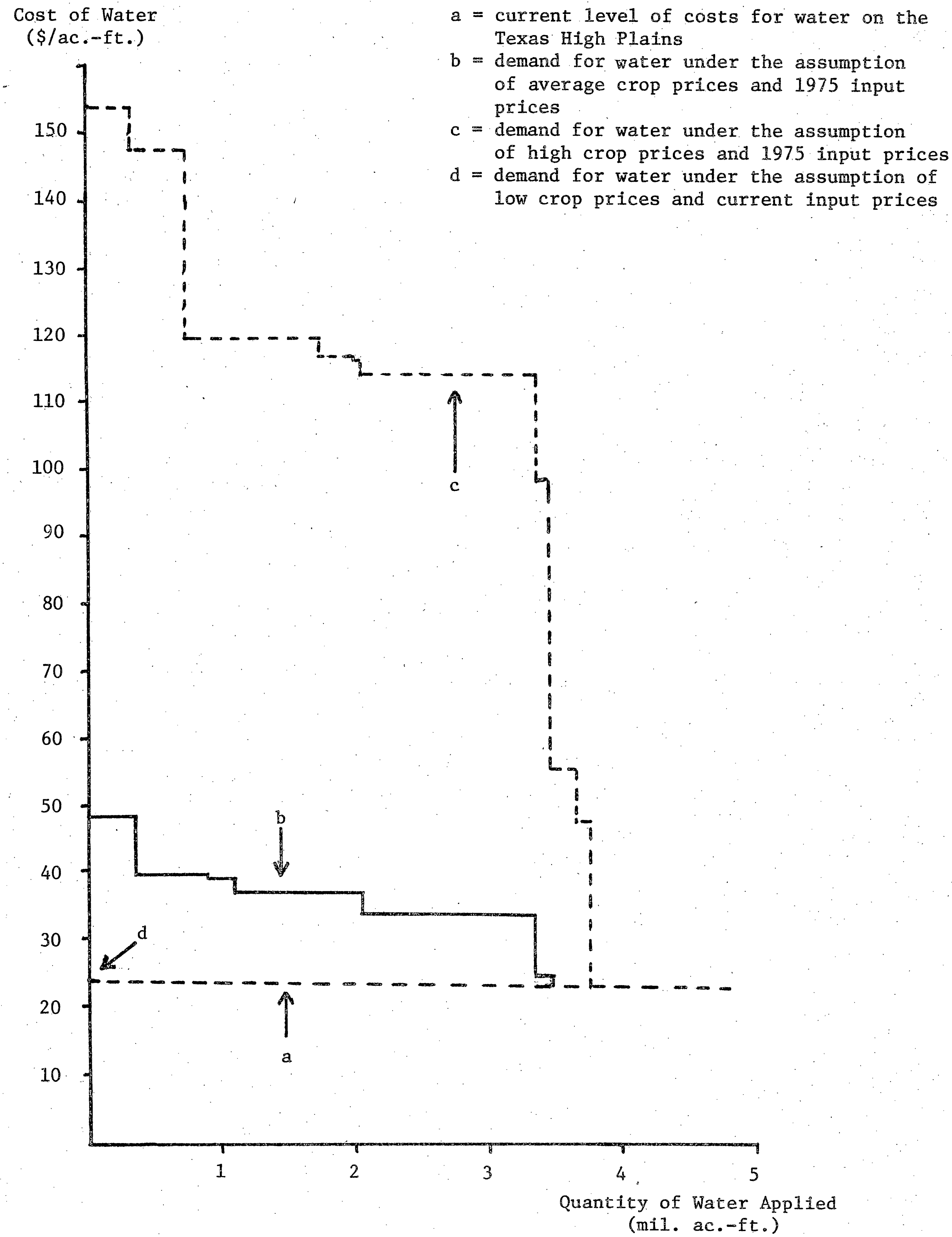

Figure 1. Demand for irrigation water at alternative crop and natural gas prices, Texas High Plains.

input prices, irrigation will remain near current levels until pumping costs increase about 50 percent above the current $23.88 per acre foot.

Increasing costs of water and fluctuations in the level of crop prices will have associated changes in the level and mix of crop output. These changes for average crop prices are shown in Table 1.

With average crop prices, corn output is reduced sharply as the cost of water approaches $34.96 per acre-foot and drops to zero when water cost reaches $40.00 per acre-foot. Grain sorghum production increases up to a cost of $34.96 per acre-foot of water, replacing corn; however, it declines at higher costs of water as production shifts toward dryland. Cotton production decreases sharply with the shift to dryland production at a water cost of $40.48 per acre-foot.

Soybean production remains at the maximum allowed in the analysis up to a water cost of $48.35 per acre-foot and then shifts out of production. The production of wheat increases as the cost of water increases because it is the most profitable dryland alternative.

Crop output shifts due to increasing water costs that were estimated with the assumed set of high crop prices (Table 2) are similar to those developed at average crop prices. Notable exceptions are (1) cotton production increases to the maximum allowable at a water cost of $48.18 per acre-foot and is sustained at this level until the cost of water reaches $117.11 and (2) soybean production remains at zero throughout the range of water demand.

With low crop prices assumed, there was no irrigation, hence no cropping pattern shifts due to changes in demand for water. Regional output under dryland production and low crop prices was estimated to be 61 million bales of cotton, 12 million hundredweight of grain sorghum and 12 million bushels of wheat.

Table 1. Expected Long Run Schedule of Crop Output at Alternative Levels of Costs for Irrigation Water, Texas High Plains[a]

Item	Units	Cost per acre-foot of water applied						
		$23.88[b]	$24.17	$34.96	$38.00	$40.00	$40.48	$48.35
		1,000,000						
Crops								
Corn	bu.	148.94	115.18	15.84	15.84	-0-	-0-	-0-
Cotton	lb.	203.50	203.50	203.50	203.50	203.50	61.05	61.05
Grain Sorghum	cwt.	29.25	40.01	40.01	12.00	14.16	14.16	18.90
Soybeans	bu.	11.06	11.06	11.06	11.06	11.06	11.06	-0-
Wheat	bu.	12.14	16.74	30.28	30.28	30.28	30.28	30.28

[a]Based on assumptions of average crop prices and 1975 prices for inputs.

[b]Current cost to pump one acre-foot of water.

Table 2. Expected Long Run Schedule of Crop Output at Alternative Levels of Costs for Irrigation Water, High Crop Prices, Texas High Plains[a]

Item	Units	Cost per acre-foot of water applied									
		$23.88[b]	$48.18	$57.10	$98.77	$114.93	$116.92	$117.11	$119.48	$147.78	$153.67
		1,000,000									
Crops											
Corn	bu.	183.70	139.50	139.59	105.82	6.49	-0-	-0-	-0-	-0-	-0-
Cotton	lb.	203.50	404.00	404.00	404.00	404.00	404.00	343.40	343.40	172.98	61.05
Grain Sorghum	cwt.	32.70	32.70	29.25	40.01	40.01	42.95	42.95	12.88	18.90	18.90
Soybeans	bu.	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Wheat	bu.	12.14	12.14	12.14	16.74	30.28	30.28	30.28	30.28	30.28	30.28

[a]Based on assumptions of high crop prices and 1975 prices for inputs.

[b]Current cost to pump one acre-foot of water.

Effect of Natural Gas Price

The expected long run irrigated land adjustments associated with increases in natural gas prices, given "average" crop prices, (Table 3) are not significant up to a price of $2.15 per thousand cubic feet of natural gas. The major effect is a reduction in net returns to the producer. However, at a natural gas price of $2.15 per thousand cubic feet, demand for natural gas and irrigation water decreases by over 40 percent compared to levels demanded at the 1975 natural gas price of $.88 per thousand cubic feet. Irrigated acreage declines by 35 percent and output of grain is significantly relative to 1973 production levels.

Irrigated acreage, groundwater pumpage, and crop output steadily decline as the price of natural gas is increased above $2.15 and irrigation ceases at a price of $3.69 per thousand cubic feet of natural gas.

These results indicate the sensitivity of irrigation and agricultural output on the Texas High Plains to natural gas prices that could occur in the next several months. Without corresponding crop price increases, fairly rapid economic exhaustion of the groundwater used for irrigation is expected if natural gas prices rise substantially; i.e., in excess of $2.00 per 100 cubic feet.

Conclusions and Limitations

1. Irrigated agriculture on the Texas High Plains is vulnerable to crop prices. At crop price levels equal to the low over the past four years, economic exhaustion of the water supply has already occurred.

2. Increases in the natural gas price will have little or no effect on the demand for irrigation water or level of crop output until it nears $2.00 per thousand cubic feet. Previous studies indicate that immediate adjustments will

Table 3. Expected Effect of Natural Gas Price on Quantity of Natural Gas Demanded, Irrigation, and Agricultural Output, Texas High Plains[a]

Item	Unit	Price Per Thousand Cubic Feet of Natural Gas						
		$.88[b]	$.91	$2.15	$2.50	$2.73	$2.79	$3.69
		----------------------------1,000,000----------------------------						
Natural Gas	1000 cu.-ft.	30.10	29.21	17.39	9.25	7.36	3.22	-0-
Water[c]	Ac.-ft.	3.45	3.35	2.00	1.06	.85	.37	-0-
Irrigated Crops	Ac.	2.57	2.57	1.67	.87	.72	.32	-0-
Crop Output								
Corn	bu.	148.94	115.18	15.84	15.84	-0-	-0-	-0-
Cotton	lb.	203.50	203.50	203.50	203.50	203.50	61.05	61.05
Grain Sorghum	cwt.	29.25	40.01	40.01	12.00	14.16	14.16	18.90
Soybeans	bu.	11.06	11.06	11.06	11.06	11.06	11.06	-0-
Wheat	bu.	12.14	16.74	30.28	30.28	30.28	30.28	30.28

[a]Based on assumptions of average crop prices and 1975 prices for inputs (except natural gas).

[b]Current price of natural gas. Quantity of natural gas demanded, irrigation and crop output remain unchanged from a natural gas price of zero up to $.91 per thousand cubic feet.

[c]Effective quantity of water applied to crops.

not be significant (Lacewell), however, this study shows that the long run adjustments where fixed and variable costs both must be considered will be dramatic. Increases in the price of natural gas above $2.00, coupled with other factors which lead to increased pumping costs, will result in severe reductions in irrigated acreage and crop output on the Texas High Plains.

3. The conclusions from this study are subject to the following major limitations:

a. Groundwater supplies have been assumed to be homogeneous throughout the study area.

b. Crop acreage flexibility restraints have been developed using historical data from periods in which federal farm programs prevailed.

c. Risk has not been explicitly considered; nor has there been extensive investigation to identify 'relevant' product prices in the producers' crop selection decision.

d. This LP model still exhibits many of the normative characteristics of the technique based on the assumption that producers will tend to move toward 'the' optimum crop selection pattern over time.

FOOTNOTES

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[1] Net returns to producers in this study are defined as income above return to management, dryland, and other resources.

[2] Insufficient data were available for statistical analysis using average for corn and soybeans.

[3] Weighted price for anhydrous ammonia and granular nitrogen fertilizer.

[4] Corn @ $1.95/bu.; Cotton @ $.31/lb.; Grain Sorghum @ $3.10/cwt.; Soybeans @ $4.27/bu.; and Wheat @ $2.60/bu.

[5] Corn @ $1.12/bu.; Cotton @ $.18/lb.; Grain Sorghum @ $1.86/cwt.; Soybeans @ $2.30/bu.; and Wheat @ $1.34/bu.

[6] Corn @ $3.46/bu.; Cotton # $.67/lb.; Grain Sorghum @ $5.96/cwt; Soybeans @ $7.75/bu.; Wheat @ $5.35/bu.

[7] Correlations between crop prices were positive based on 1969-73 data and the least relationship found was between cotton and soybeans (.88).

[8] Lacewell reported in a previous study considering only short run adjustments (using variable production costs), that no significant adjustments would occur below a price of $2.64 per thousand cubic feet of natural gas. These findings are not contradictory since these long run adjustments include consideration of total production costs which must be covered over time.

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