ECONOMIC EFFECTS OF AN EXHAUSTIBLE* IRRIGATION WATER SUPPLY: TEXAS HIGH PLAINS

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INTRODUCTION

Specialization by a region is determined primarily by resources available and the available markets for the products. In addition, specialization in the production of a product or in an industry is an initial stage of regional development but may not be sufficient. As firms locate in a region to produce with the available resources, a derived demand will develop for substitute and complementary resources.

Input supply firms will locate in the region to satisfy the derived demand for resources. In addition, other firms will locate in the region to process some of the output of the emerging industry. As associated industries locate in the area, an interdependency will develop between the industry's supply requirements and/or markets for their products. Consequently, regional development has a tendency to include firms that are interdependent.

The next stage of development in a region generally includes formation of a more diversified economic base. Expansion occurs as new firms are attracted to the region by additional benefits from an expanding industrial economy. This stage generally results from concentration of economic activity.

Groundwater from an exhaustible aquifer is being used by agricultural producers in the Texas High Plains for irrigation of crops. Extensive economic growth has occurred in recent years in the regional economy as associated industries have located in the region. However, the alternatives that are available to the industries in the area are limited without groundwater to support irrigated agriculture.

Texas High Plains

The Texas High Plains economy has developed rapidly in recent years. However, one of the industries, irrigated agriculture, is using a resource which is exhaustible and non-renewable: groundwater. The estimated total value of irrigated crops was $633 million (82 percent of the value of total crop production) in 1967. The number of irrigated acres increased from 3.0 million acres in 1954; to 4.1 million in 1959; to 4.5 million in 1965; and to 4.8 million in 1969 [7, 8].

Groundwater is the primary source of irrigation water. The source of groundwater is an aquifer called the Ogallala. The Ogallala does not receive a significant volume of recharge when compared to the withdrawal by pumping for irrigation. As irrigation has expanded to practically all parts of the Texas High Plains, the water table has declined at a fairly rapid rate (3 to 4 feet per year). Natural recharge has been estimated to range from 10 to 15 percent of the annual withdrawal. The formation can be recharged from surface sources, but technological and environmental problems have not made artificial recharge feasible on a large scale. The quantities of rechargeable water are less than the amount pumped. Although the aquifer underlies large portions of the Texas High Plains, it is relatively thin (75 to 100 feet) in many areas.

Studies have indicated that development of irrigation and associated benefits will increase until approximately 1980 and then decline as the groundwater supplies are exhausted. Grubb has estimated that benefits from irrigation will increase to $517 million by 1980 and decline to $195 million by 2020 [1, p. 21]. The production of crops will revert to dryland production when the groundwater supply is exhausted. Hughes and Harman have estimated that cotton and grain sorghum output in the Southern High Plains will decrease by 65 and 90 percent in

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2015, respectively, from the 1966 levels for the most developed portion (2.8 million acres) of the Ogallala formation [2, p. 23].

The purposes of this paper are (1) to indicate the estimated declines in total output for agriculture with an exhaustible supply of irrigation water, and (2) to estimate aggregate regional economic effects in terms of income and employment.

STUDY AREA

The study area included 56 contiguous counties in west and northwest Texas which was called the Texas High Plains. Total land area in the region has been reported to be 38.3 million acres which is approximately 21.6 percent of the land area in the state of Texas [8]. Approximately 92.7 percent of the land is included in farms.

There was a population of 960,479 in 1970 in the study area which was a decline of 3.4 percent from 1960 [9]. The population in the region was 8.2 percent of the population of the state of Texas in 1970. There are four Standard Metropolitan Statistical Areas which included over 50 percent of the population in the study area.

The number of people employed in 1970 was 361,400 with 65.1 percent in the agricultural, trade and service industries [9]. Although the population decreased by 3.4 percent from 1960 to 1970, employment increased by one percent in the same period. Agriculture included 11.1 percent of total employment.

The average size of farm in the study area was 1,342 acres in 1969 [8]. Farms in the intensive irrigated areas averaged 708 acres in 1969. The total value of crop and livestock production in the study area was $1.3 billion in 1970 which included 59.3 percent from crops [6]. Cotton, grain sorghum, and wheat were the major crops. Feedlot production was a major source of livestock income.

Agricultural production is predominant throughout the study area. However, rainfall is a major restricting element in crop production. Average annual rainfall varies from eight inches in the southern counties to 21 inches in some of the northern counties in the study area. In addition, the amount of annual rainfall varies widely from year to year.

PROCEDURES

The technique of input-output analysis as developed by Wassily Leontief was used to determine the interindustry effects of an exhaustible irrigation water supply on income and employment in the Texas High Plains economy. Benefits and effects were estimated for each decade from 1970 through 2020. Projected irrigated acres were available from results of a study completed by Grubb [1]. Interindustry relationships have been determined in a report of a study of the region [5].

The input-output model included 14 processing sectors, four final payments sectors, and five final demand sectors (Table 1). The model was:

$$X_i = \sum_{j=i}^{14} a_{ij} X_j + \sum_{r=1}^{5} V_{ir} \qquad i = 1, 2, \ldots, 14$$

$$Z_i = \sum_{j=1}^{14} Z_{ij} + \sum_{r=1}^{5} V_{ir} \qquad i = 15, 16, 17, 18$$

where X_i is the total output of sector i, a_{ij} is the direct requirement of sector j from sector i, X_j is the total output of sector j, V_{ir} is the sales to final demand sector r by sector i, Z_i is the total of the row for final payments sector i, and Z_{ij} is sales of services and resources by final payments sector i to sector j.

Data were assembled on a producer's price FOB the shipper for 1967. An establishment (individual firm) basis for collection of data with a stratified (by employment) random sample was used for all sectors except some of the agricultural and construction

Table 1. SECTORS IN INPUT-OUTPUT MODEL AND THE STANDARD INDUSTRIAL CLASSIFICATION COMPONENTS IN EACH SECTOR, TEXAS HIGH PLAINS

Sector code number	Sector name	Standard Industrial Classification components
	Processing Sectors	
1	Irrigated Crops	Irrigated part of 0112, 0113 and 0119-0123
2	Dryland Crops	Dryland part of 0112, 01.3. and 0119-0123
3	Livestock and Livestock Products	0132-0139
4	Ginning, Compressing, and Agricultural Services	0712-0731
5	Mining	1011-1499
6	Construction	1511-1799
7	Meat Products	2011-2026
8	Crop Products	2031-2399
9	Other Manufacturing	2411-3999
10	Transportation and Communication	4011-4214, 4222-4721, 4742-4899
11	Utilities	4911-4971
12	Trade	4221, 4731, 5012-5999, 7531-7539
13	Finance, Insurance and Real Estate	6011-6799
14	Services	7011-7525, 7622-8999
	Final Payments Sectors	
15	Households	
16	Government (Federal, State, and Local)	
17	Imports	
18	Depreciation	
	Final Demand Sectors	
19	Households	
20	Net Inventory Change	
21	Government (Federal, State, and Local)	
22	Exports	
23	Capital Formation	

sectors. Data were collected for major purchases by sector and location, for taxes, salaries, wages, depreciation, total sales by sector and destination, inventories, and employment. The predominant method of data collection was personal interviews with the establishments.

Economic benefits were based on increases in economic activity when irrigation water was applied to dryland. The economic benefits included direct benefits (benefits to farmers) and stemming-from benefits (benefits to processors of irrigated crop production).

Type I and Type II income and employment multipliers were estimated from the input-output model [5]. The Type I income multiplier is an estimate of the direct and indirect change in household income per dollar change in payments to households [3]. The Type II income multiplier is the same as the Type I income multiplier except induced changes from a change in the level of household are also included. Type I employment multipliers are estimates of the direct and indirect changes in employment per unit change in direct employment of a sector. Type II employment multipliers are the same as Type I employment multipliers except induced changes from a change in the level of household consumption expenditures are also included. The estimates were used to estimate employment and income effects as groundwater supplies were projected to decline.

Technology was assumed to be constant for the study. Particularly, water saving technologies in irrigation of crops were not considered in the analysis. Although several water saving techniques are being developed, it is not known how significant the developments will be in terms of water use efficiency. The relationships of production inputs (column vector of direct requirements per acre) for each agricultural sector were assumed to be constant.

RESULTS

Irrigated acreage has been estimated for a 42 contiguous county area by decades from 1970 through 2020 by Grubb [1]. The 42 county area is encompassed by the study area. In addition, the 42 county area included 96.5 percent of the irrigated acres in the study area in 1969. The irrigated acres were projected to increase from approximately 5.3 million acres in 1970 to approximately 5.8 million acres in 1980 (Table 2). The irrigated acres were estimated to decrease monotonically to 2.2 million acres in the year 2020. The absolute decline in irrigated acreage was greater between 1980 to 1990 than in following periods. This decline between 1980 and 1990 occurred from the hydrologic conditions and characteristics of the aquifer as well as the estimated number of wells during this period.

Table 2. ESTIMATED IRRIGATED ACRES, DIRECT BENEFITS, AND TOTAL ECONOMIC ACTIVITY, TEXAS HIGH PLAINS

Year	Irrigated acres[a] (thousand)	Direct benefits (million dollars)	Total economic activity (billion dollars)
1970	5,294	338.3	1.4
1980	5,816	371.6	1.6
1990	4,475	286.0	1.2
2000	3,584	229.0	1.0
2010	2,931	187.3	0.8
2020	2,191	140.0	0.6

[a]Source [1]. The projected irrigated acres of 5,294 acres for 1970 compares to 5,497 thousand acres in 1970 that was reported to be irrigated [4] that is, the projected acres were 3.8 percent less than the actual irrigated acres in 1970.

A representative acre of irrigated and dryland crops for 1967 was used to estimate the benefits associated with irrigation for each decade from 1970 through 2020. This representative acre was determined by dividing the output of the irrigated crop sector by the acres of irrigated crops. The same procedure was used for dryland crop production. Increased output above dryland production that can be associated with irrigation was called direct benefits from irrigation.

The direct benefits per acre were estimated to be

Table 3. **ESTIMATED INCOME EFFECTS FROM CROP PRODUCTION WITH DECLINING IRRIGATION WATER SUPPLY, TEXAS HIGH PLAINS**[a]

Year	Direct	Indirect	Induced	Total
		-million dollars-		
1970	203.4	118.9	110.4	432.7
1980	223.5	130.5	121.4	475.4
1990	171.9	100.4	93.4	365.7
2000	137.7	80.4	74.7	292.8
2010	112.6	65.8	61.1	239.5
2020	84.1	49.2	45.7	179.0

[a]Type I and Type II income multipliers were estimated to be 1.37 and 1.84, respectively. The direct income effect was 0.4967 of total direct benefits.

Table 4. **ESTIMATED EMPLOYMENT EFFECTS FROM CROP PRODUCTION WITH DECLINING IRRIGATION WATER SUPPLIES, TEXAS HIGH PLAINS**[a]

Year	Direct	Indirect	Induced	Total
		(number employed)		
1970	32,851	17,757	15,075	65,683
1980	36,085	19,507	16,558	72,150
1990	27,771	15,011	12,744	55,526
2000	22,237	12,021	10,196	44,454
2010	18,188	9,831	8,346	36,365
2020	13,595	7,349	6,238	27,182

[a]Type I and Type II employment multipliers were estimated to be 1.39 and 1.84, respectively. The direct employment effect was 0.0708 per $1,000 of total direct benefits.

$63.80. The projected acres of irrigated crops were multiplied by the direct benefits from irrigation per acre to determine total direct benefits for each decade. Total direct benefits increased from $338.3 million in 1970 to $371.6 million in 1980 and then decreased to $140.0 million in 2020 (Table 2).

Total economic activity associated with one dollar of direct benefits was estimated to be $4.30. The benefits include direct, indirect, and stemming-from (processing of irrigated crop production) economic activity associated with irrigation. To estimate total economic activity, the direct benefits were multiplied by 4.30. Total economic activity (direct, indirect, and stemming-from) associated with irrigation water was estimated to reach a maximum of $1.6 billion in 1980 and decline to $0.6 billion by 2020 (Table 2).

Direct income effects from production of irrigated agricultural products and the resulting processing (stemming-from benefits) of the products for final demand were estimated. Direct income effects from the net increase in production from irrigation were estimated to decrease from $223.5 million in 1980 to $84.1 million in 2020 (Table 3). The indirect income effects were estimated with the Type I multiplier. Total income effects from irrigation were estimated to reach a maximum in 1980 of $475.4 million and decline to $179.0 million in 2020.

Direct employment effects from production and processing of the products from irrigated production for final demand were estimated (Table 4). The direct effects regarding employment were that labor requirements would expand from an estimated

32,851 people in 1970 to 36,085 people in 1980 and then decrease to 13,595 people in 2020. The estimated total decline in employment from 1980 to 2020 was 44,968 people.

Total employment in 1970 was 361,460 people [9]. With employment of 65,683 people in 1970 that was associated with irrigation, 18.2 percent of the labor force was employed as a consequence of irrigation of agricultural crops.

CONCLUSIONS

The availability of groundwater for irrigation has been an important input to provide an incentive for economic growth in the Texas High Plains economy. In 1967, over 82 percent of all crop production in the study area was produced with irrigation. However, groundwater which is the major source of water for irrigation is non-renewable and exhaustible in the foreseeable future.

Total economic activity from the net increase (direct benefits) in production with irrigation was estimated to be $1.6 billion in 1980 and then decreased in each decade to $0.6 billion in 2020 or a decrease of 62.5 percent. The income effect from the decrease in irrigation water was estimated to be a decline of $296.4 million from 1980 through 2020.

It was estimated that 18.2 percent of the labor force of 361,460 in 1970 was associated with irrigation water from the exhaustible source of groundwater. Only 13,595 people were estimated to be employed as a result of irrigation in the Texas High Plains in 2020. That is, the level of employment associated with irrigation would decrease by 62.3 percent from 1980 to 2020.

It appears that a decline in the development of the region is inevitable as the irrigation water supply is exhausted. Thus, the economy is expected to encounter difficulties and is faced with the necessity to consider alternative development programs as well as alternative resource management policies. Numerous water saving technologies such as tail water return systems, skip row planting patterns, land leveling, and alternate row irrigation practices are currently being used to increase water use efficiency. Sub irrigation, trickle irrigation, water harvesting, improved varieties, and recharge techniques are being developed at experiment stations throughout the area. All of these practices will prolong the period until the formation is exhausted. It does not appear that the use of the practices will result in a balance between withdrawals and recharge from natural and artificial sources.

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