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The Economic Opportunity To Irrigate Corn And Soybeans On Midwestern Claypan Soils

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TECHNICAL REPORT 93

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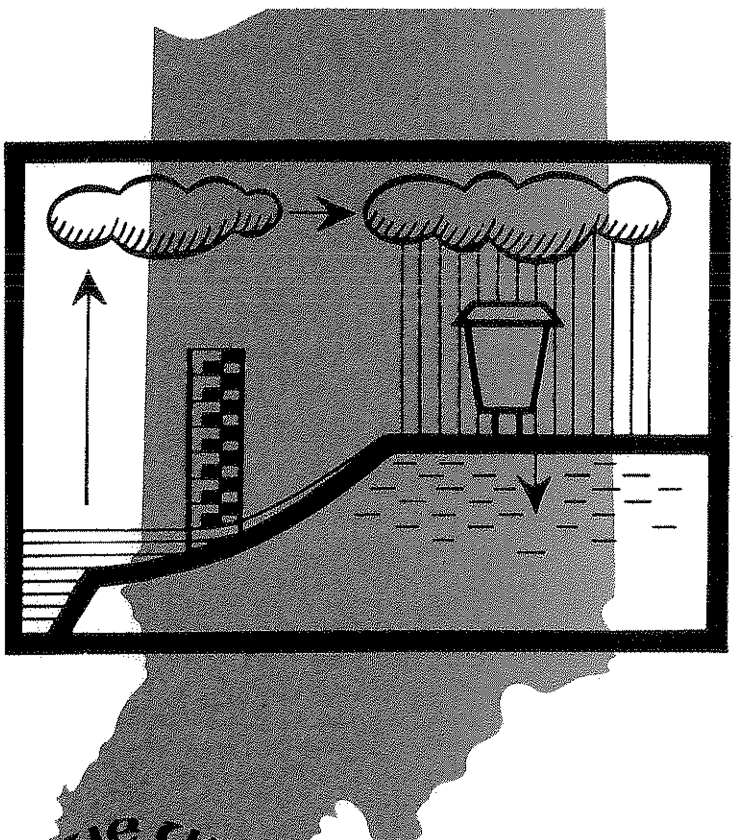

by

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June 1981

PURDUE UNIVERSITY
WATER RESOURCES RESEARCH CENTER
WEST LAFAYETTE, INDIANA

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CHAPTER I

INTRODUCTION

Earlier economic research (Clouser and Miller, 1980) has indicated that corn irrigation can be relatively profitable on claypan soils in humid areas under certain conditions. This research greatly expands the economic analysis undertaken in the earlier study. The data base for this research includes new survey information about reservoir location, reservoir cost, electric power cost, and irrigation labor requirements. The investment planning models used in this analysis permit both corn and soybeans to be irrigated and they provide for mixed crop and livestock production. In addition to examining 640 acre farm sizes, the irrigation potential for small (40, 80, 120, and 160 acre) farm operations are assessed with one investment planning model. These extensions to the earlier research provide insights on the potential relative profitability of irrigation in contrast to dryland crop production for the full range of farming conditions that occur most frequently in the claypan regions of the Midwest.

Irrigation in Indiana

The installation and operation of irrigated cropping systems have expanded rapidly in the Midwest. In Indiana, for example, in 1969 there were only 28,684 acres irrigated. By 1974 total irrigated acreage had increased to 32,540 acres, which represents an increase of 13 percent. During the next four years irrigated crop acreage increased at a much more rapid rate to 76,009 acres for a 133% increase over 1974. Similar increases have been experienced in Illinois where irrigated acreage increased from 53,777 acres in 1974 to 131,322 acres in 1978 for an increase of 144%.

Figure 1 presents the number of farms with irrigation and the number of acres irrigated in 1969. There were 26 counties which had no irrigation systems in 1969 and only six-tenths of one percent of all farms in Indiana used irrigation. The major region of the state with irrigation in 1969 was located in the northern counties of LaPorte, St. Joseph, Elkhart, Starke, Pulaski, Jasper, and Newton. Nearly all the irrigation in this area of Indiana has been on sandy soils which exhibit low water holding capacity.

Figure 2 presents similar information concerning irrigation by county for 1974. The number of acres irrigated had increased to 32,540 acres. Only 18 counties had no irrigation system in 1974, a decline of 8 counties between 1969 and 1974. The northern section of the state still represented the largest concentration of irrigated land in the state.

Figure 3 presents the most recent census data of irrigated acreage available by county for Indiana. The total irrigated acres had increased to 76,009 on 1,043 farms in 1978. Irrigated acreage in the northern counties continued to increase most rapidly with the largest irrigated acreage in LaPorte County, i.e. 5,648 acres. However rapid growth of irrigation also was occurring in Sullivan and Knox Counties in southwestern Indiana.

The rapid growth of irrigation in Indiana suggests the economic potential exists on the sandy soils where groundwater supplies are abundant at shallow depths, e.g. LaPorte County. Irrigation of claypan soils is still a rare situation in Indiana. Census data show that more claypan soils are irrigated in Missouri than in any other Midwestern state. Another area where claypan irrigation is increasing is in southern Illinois. Similarity of the claypan soils in Missouri, Illinois and Indiana suggest that the

Upper Numbers = numbers of irrigated farms

Lower Numbers = acres irrigated in county

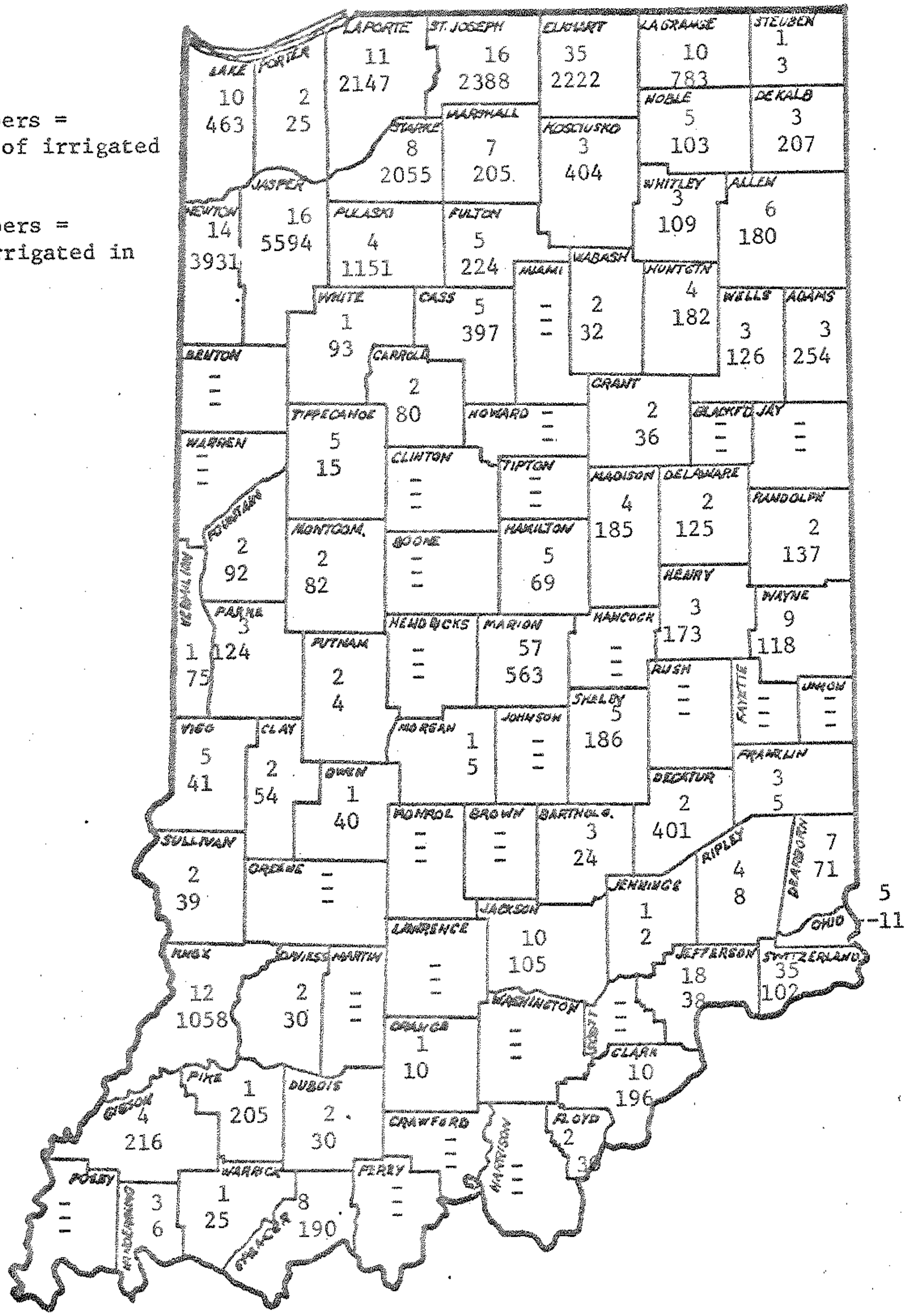

Figure 1

Irrigated Farm Numbers and Acreage by County, Indiana, 1969

Upper Numbers = numbers of irrigated farms

Lower Numbers = acres irrigated in county

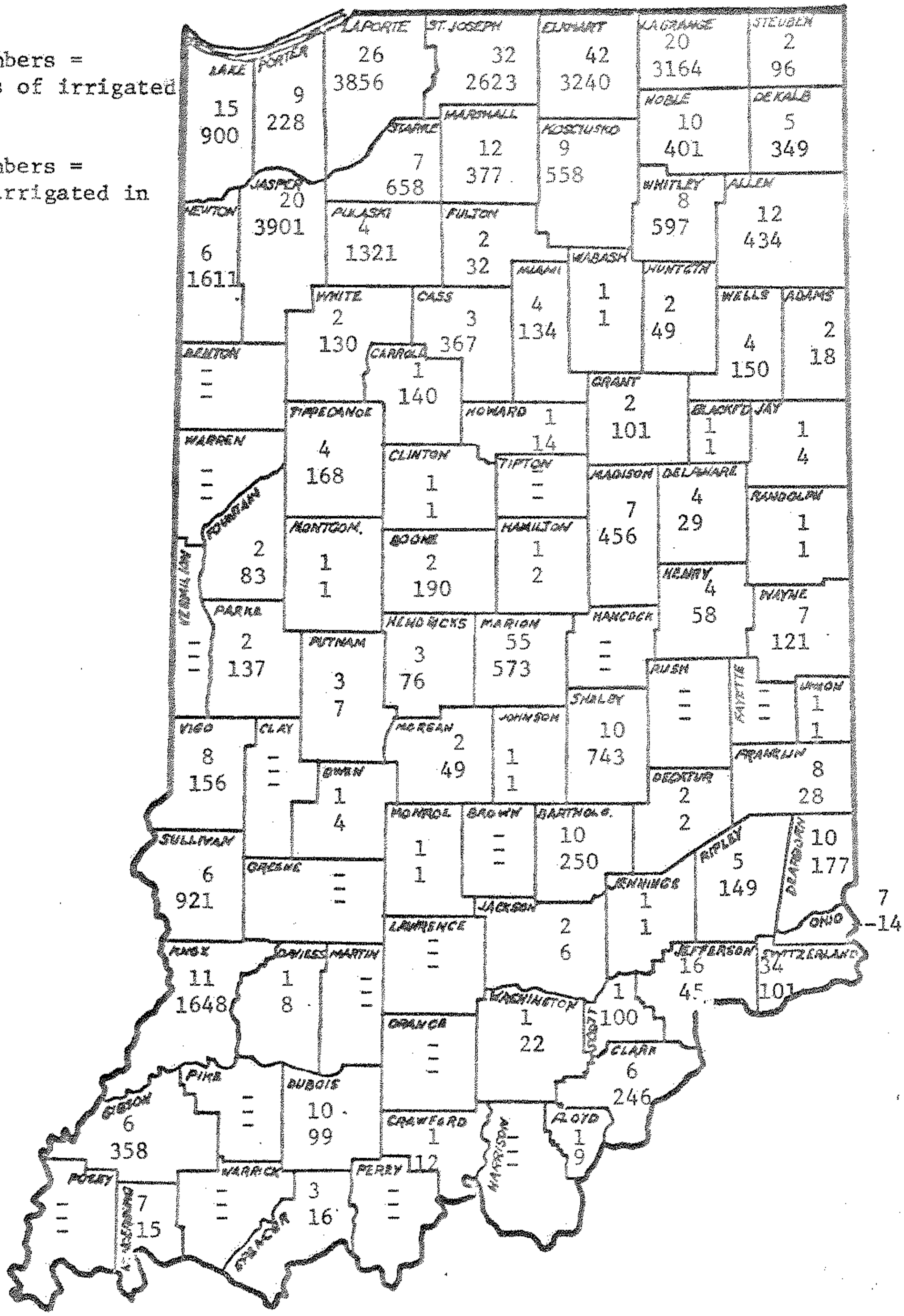

Figure 2

Irrigated Farm Numbers and Acreage by County, Indiana, 1974

Upper Numbers = numbers of irrigated farms

Lower Numbers = acres irrigated in county

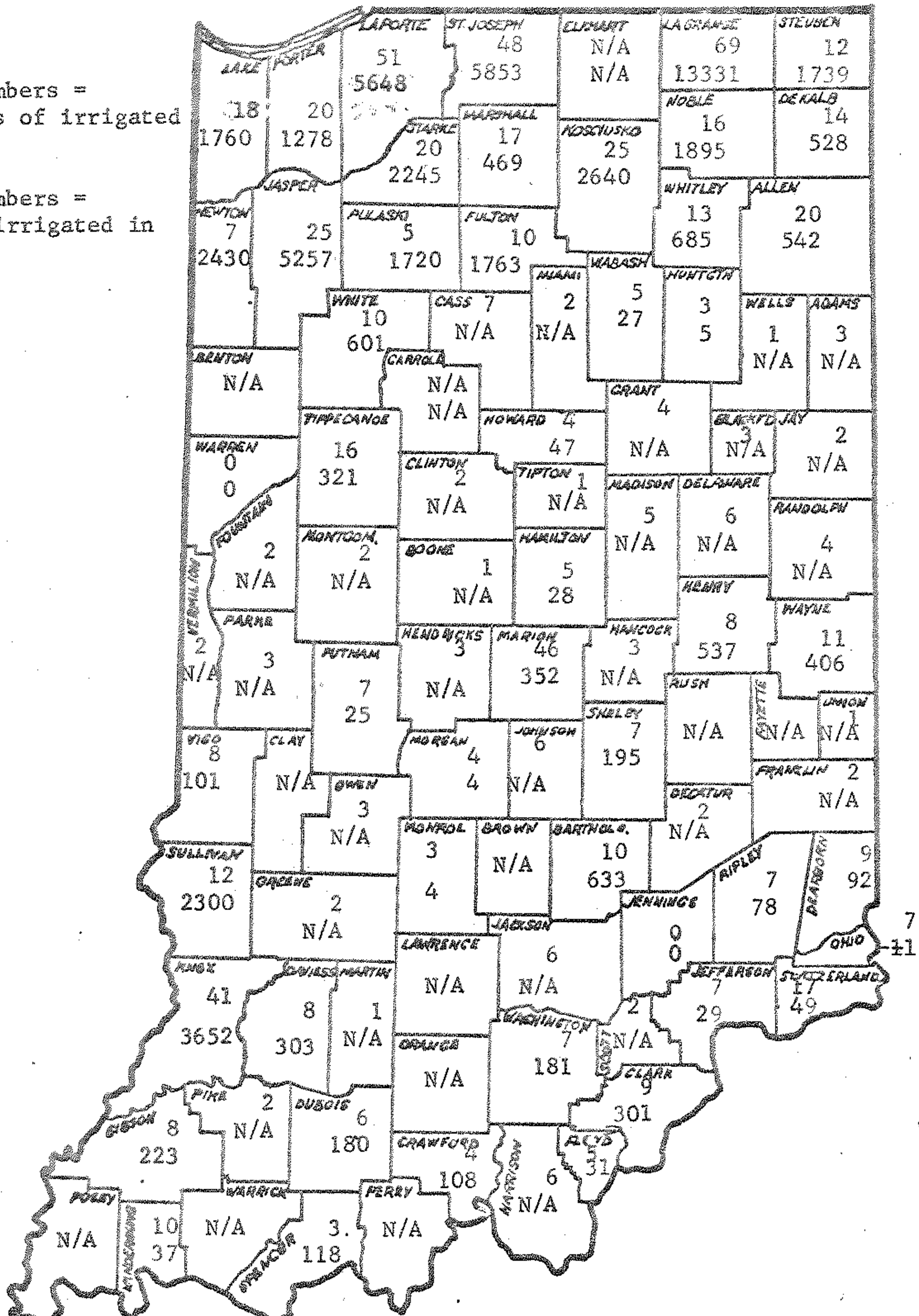

Figure 3

Irrigated Farm Numbers and Acreage by County for Indiana in 1978 potential exists for an expansion of irrigated acreage on these soils in Indiana during the 1980's. This research examines the current economic returns to irrigation on claypan soils to determine whether irrigation has an economic incentive to expand further in claypan regions in the future.

Objectives

(1) This research will examine the relative profitabilities of dryland corn, dryland soybeans, irrigated corn, and irrigated soybeans on claypan soils.

(2) This research will examine irrigation profitability on farm systems of several sizes, i.e. 640 acres, 160 acres, 120 acres, 80 acres, and 40 acres.

(3) This research will assess the relatively profitability of farms with mixed grain and livestock (hogs or cattle) as well as, cash grain operations.

CHAPTER II

THE MODEL

Mathematical programming models of a micro farm unit, producing grain and livestock were used in this study. The models used are similar to Purdue University's B-10 Farm Management model and the model formulated in a previous irrigation study by Clouser and Miller [1980]. The math programming models determine the crop mix and irrigation investment that maximizes net farm revenue. The irrigation investment alternatives are modeled as described by Apland (1977). In addition, a fixed level of livestock has been determined exogenous to the model but labor and feed activities for the livestock enterprise are endogenously deducted from available resources.

The complete model is:

$$\text{Maximize } C_1'X_1 + C_2'X_2 + Z$$

$$\text{subject to } A_1X_1 + A_2X_2 \leq b$$

$$X_1, X_2 \geq 0$$

$$X_1 \text{ integer}$$

where:

C_1 is an n_1 x 1 vector of investment cost,

C_2 is an n_2 x 1 vector of net revenues,

Z is a level of livestock enterprise established exogenously,

A_1 is an M x N_1 matrix of technical coefficients for the alternative investment decisions,

A_2 is an M x N_2 matrix of technical coefficients for production activities,

X_1 is an n_1 x 1 vector of discrete investment activites, and

X_2 is an n_2 x 1 vector of production activities.

All assumptions of the Purdue University B-10 model are retained and for the reader concerned with these assumptions it is suggested they review McCarl (1975) and Clouser and Miller (1980).

Cropping activities included in the model variation for the 640 acre farm are dryland corn or soybeans and irrigated corn or soybeans. Livestock enterprises consisted of a farrow to finish swine operation and a cow-calf operation. Details of estimated production cost and labor requirements can be obtained from "Farm Planning and Financial Management" (1978).

More cropping activities but no livestock activities were included in the model variation specified for the small farms. The optimum production activities were chosen from among continuous dryland corn, rotation dryland corn, rotation dryland soybeans, double cropped dryland wheat and soybeans, dryland wheat, irrigated continuous corn, irrigated rotation corn, irrigated rotation soybeans, and irrigated double crop wheat and soybeans for all acreage sizes.

Results from the annual math programming model were inserted into a multiperiod decision framework. The net present values of annual cash flows after income taxes (representing the returns to the operator's management and labor) were compared for alternative solutions to determine the optimum production investment. (See Appendix A).

The present value model used was $P.V = (R_n - C_n)\ (1 + i)$ where P.V is the present value of the annual cash flow after income taxes, $R_n - C_n$ is the revenue minus costs including income taxes for the n time periods, i is the discount rate and n is the number of years of life for the project. A 15 year period was used for n in this analysis because the expected life of the irrigation equipment is 15 years.

The coefficient i, rate of discount, is utilized at two different levels in the analysis, i.e. 4 percent and 12 percent. Since no inflation factors were included in either R or C over the 15 year life for which the analysis was conducted, the appropriate discount rate to use would be one that reflected the time preference and risk associated with investments, but not the rate of inflation. The 4 percent rate was selected as an inflationless rate which should reflect the true rate of interest.

A reasonable alternative approach if different rates of inflation are expected in the cost or revenue streams would be to include an inflation factor in calculating these rates and then to use a rate of discount which included inflation as well as time preference and risk. In this case there is no reason to argue for different rates of inflation in the revenue and cost streams.

In addition to using the 4 percent rate of discount, the analysis presents results using a 12 percent rate of discount. This was presented to illustrate that the ranking of the most profitable investment alternatives in the analysis are not affected by discount rates above 4 percent. It should be noted also that the level of fixed costs common to all activities e.g., land rent, does not influence the relative ranking of systems. Consequently, the main issue discussed in the following chapters involves a comparison of irrigated to dryland systems rather than the question of the absolute level of profits associated with each system.

The costs (C) were influenced by depreciation schedules and interest paid on the irrigation equipment loan because it represents an after tax C, and tax payments depend in part on the depreciation schedule utilized for capital equipment. Alternative depreciation schedules were compared to see which schedule resulted in the maximum net present value of the annual cash flow after taxes. Accelerated depreciation schedules were often helpful in maximizing the net present value in contrast to straight line schedules. It is assumed that the irrigation equipment was purchased, not leased, by the farmer and that he repaid the money borrowed to purchase it in equal annual installments for 15 years.

The changes in income from year to year reflected particularly in R and C of the dryland operations probably result in some overstatement of the taxes that would normally be paid by a family of four. In managing taxable income the farmer would probably average income, carefully time sales and purchases if on a cash basis, make other capital investments to obtain capital gain besides the irrigation equipment and generally manage to smooth out some of the year to year variability in taxable income.

If outside income of the farmer or other family members had been allowed in R, the after tax income would change because the family would have had the impact of both higher R and a higher marginal income tax bracket. No outside income has a major impact on the results for the small 40 and 50 acre farms with restriced labor available in crop production. Economic superiority of center pivot irrigation systems (Apland, 1980) eliminated consideration of alternative irrigation systems. The model variation for 640 acre farms was designed to introduce center pivot irrigation systems in units of 160 acres. The model variation for small farms examined 40 acre center pivot systems for 40 acre, 80 acre, 120 acre and 160 acre farm systems.

CHAPTER III

INPUT DATA BASE

This chapter focuses upon the data unique to the irrigation systems which are compared to the dryland systems. General input characteristics which are common to both dryland and irrigated systems are described in detail in Clouser and Miller, (1980). Since the thrust of this research is to compare dryland and irrigated production systems, input data that are identical between systems will be only briefly discussed.

This chapter is divided into five sections. They include the capital investment associated with center pivot irrigation systems that draw water from a surface storage source. Particular emphasis is given to information about the cost of water impoundment. Operating costs of labor and electric power are considered and the last section discusses the livestock systems that were added to the basic crop farm systems.

Center Pivot Irrigation Systems

Forty acre and 160 acre center pivot systems were utilized in this analysis because previous research (Apland, 1977) has indicated they are the most economical type of distribution system for corn when multiple pivot points are possible for the system. Application rates with this system are more consistent with the infiltration rates of the claypan soils than are the application rates with big gun systems. The center pivot system require less labor per acre irrigated than does the other irrigation distribution systems. New modifications are being developed for the center pivot systems to permit lower pressure application which will make them more cost effective relative to the big gun systems as the energy costs for pumping continue to rise. Five 1-1/4" irrigation applications were assumed to be applied with these center pivot irrigation water distribution systems during July and August.

Table 3.1 presents the capital cost levels for irrigation equipment used in analysis of the different farm sizes. Multiple pivot points reduce capital costs per acre significantly over a single pivot point system. The increasing cost of reservoir storage and underground pipe are more than offset by reductions in capital cost per acre of the distribution system motor and pump as more pivot points are used for the 40 acre center pivot system. The per acre capital cost declined from $1,023 per acre with one pivot on a 40 acre farm to $426 per acre with a four pivot point system on a 160 acre farm.

Water Impoundment Costs

In previous research it was indicated that most claypan soil regions have inadequate groundwater supplies to provide wells for irrigation. Therefore water impoundment, although more costly than shallow wells in the humid midwest, must be considered the most likely source of water for irrigation in claypan areas. The 3:1 ratio of cubic yards of water stored in the reservoir to the cubic yards of earth moved for construction used in this study is supported by data collected on pond construction in the claypan region.

Data were obtained to assess the cost of pond construction in the claypan area. Information obtained for 26 ponds constructed in 1978, 1979 and 1980 are reported in Table 3.2. Ponds were constructed that ranged in size from 0.4A to 3.6A with an average size of 1.44 A. The cost of pond

Table 3.1. Irrigation System Capital Costs

Item	Farm Size				
	40A	80A	120A	160A	640A
Acres Irrigated	36	70	105	140	524
Number of Center Pivot Distribution Systems	1	1	1	1	2
Number of Pivot Points	1	2	3	4	4
Capital Cost of Distribution Systems	$16,161	$16,161	$16,161	$16,161	$62,000
Cost of Underground Pipe from Reservoir to Pivot Points	$1,650	$3,300	$4,950	$6,600	$26,400
Water Storage Reservoir Capital Cost	$9,000	$16,000	$22,000	$27,000	$94,400
Motor and Pump	$10,000	$10,000	$10,000	$10,000	$60,800
Total Capital Cost	$36,811	$45,461	$53,111	$59,761	$243,200
Cost Per Acre Irrigated	$1,023	$649	$505	$426	$464

Table 3.2. Claypan Region Pond Construction Costs, 1978, 1979 and 1980

Cost of Pond	Size of Pond	Amount of Earthmoving	Cost per Cubic Yard	Cubic Yard Water ÷ Cubic Yard Earth
$1758.00	.7 ac	1661 cu. yds.	$1.05	3
2422.40	.8 ac	4958 cu. yds.	.48	1.2
1402.86	.4 ac.	1535 cu. yds.	.91	1.9
1887.95	.5 ac.	2800 cu. yds.	.67	1.3
2939.85	3.6 ac.	4100 cu. yds.	.71	6.4
5000.00	.5 ac.	4336 cu. yds.	1.15	0.8
3836.00	1.7 ac.	4171 cu. yds.	.91	2.95
3901.76	1.2 ac.	5391 cu. yds.	.72	1.6
4042.60	1.0 ac.	3150 cu. yds.	1.28	2.3
6500.00	1.7 ac.	6163 cu. yds.	1.05	2.0
2950.00	.8 ac.	1750 cu. yds.	1.68	3.3
4546.34	.6 ac.	4100 cu. yds.	1.10	1.1
3812.96	1.5 ac.	3200 cu. yds.	1.19	3.4
7948.80	3.1 ac.	6885 cu. yds.	1.15	3.3
4936.93	1.3 ac.	7116 cu. yds.	.69	1.3
8125.60	2.0 ac.	9100 cu. yds.	.89	1.6
2404.80	.8 ac.	2760 cu. yds.	.87	2.1
3044.96	1.2 ac.	3806 cu. yds.	.80	2.3
4536.20	3.2 ac.	5904 cu. yds.	.76	3.9
5448.29	3.5 ac.	7200 cu. yds.	.76	3.5
2212.30	.6 ac.	1563 cu. yds.	1.41	2.8
1758.21	1.5 ac.	1410 cu. yds.	1.25	7.7
1911.34	2.1 ac.	3100 cu. yds.	.61	4.9
4338.57	3.2 ac.	5844 cu. yds.	.74	4.0
1960.00	.7 ac.	1800 cu. yds.	1.03	2.8
1652.97	.4 ac.	1530 cu. yds.	1.07	1.9
Average	1.44 ac.		.965	2.87

construction per cubic yard of earth moved ranged from \$0.48 to \$1.68. The average cost per cubic yard of earth moved was \$0.965. Although the average was between \$0.90 and \$1.00 there were only two ponds that had construction costs within that range indicating that the cost of construction is not normally distributed. The cost per cubic yard has a distinctly bimodal distribution with the construction costs for eleven ponds clustered between \$0.60 and \$0.90 per cubic yard and ten ponds clustered between \$1.00 and \$1.30 per cubic yard. The cost differences might be associated with different methods of construction or different contractors bidding on the work.

The hypotheses that the cost per cubic yard was related to the size of pond was not supported by a regression analysis of the data. Cost does not decline as the cubic yards of earth moved increases because the data is best described by the linear functions: Cost = \$572.85 + \$0.904 x cubic yards. This simple two variable function results in the cubic yards of earth explaining 76 percent of the variation in cost of construction. In all probability the amount of earth moved is so small relative to larger construction jobs such as roads, bridges and buildings that no economies of scale occur within the narrow range considered.

The cubic yards of water impounded per cubic yard of earth moved was quite variable for the 26 sites examined. The rates varied from a high of 7.7:1 to a low of 0.8:1. The average ratio was 2.87 cubic yards of water stored for every cubic yard of earth moved. The ponds with lower ratios were in topographic areas where pit type pond construction was necessary while those with higher ratios were built where topographic characteristics permitted large water impoundments with a small dam.

Additional information was obtained on eight ponds designed recently by the Soil Conservation Service in the claypan region. These data are

Table 3.3. Pond Construction Data for Claypan Regions

Cubic Yards Earth in Dam	Water Depth at Dam	Acres Surface Area	Cubic Yards Water Stored	Cubic Yard Water ÷ Cubic Yard Earth
8687	11.7 ft.	3.7	27868	3.2
1220	9.1 ft.	0.8	4682	3.8
8615	16.0 ft.	1.5	15446	1.8
1087	8.0 ft.	0.3	1545	1.4
4587	11.6 ft.	2.4	17924	3.9
4687	16.0 ft.	0.7	7208	1.5
4862	16.0 ft.	0.5	5149	1.06
630	8.0 ft.	1.4	7208	11.4

presented in Table 3.3. Note the high variability in the ratio of cubic yards of water stored for cubic yards of earth moved. It ranges from 1.06:1 to 11.4:1 with an average of 4.89:1.

The average storage ratio is not of major importance in either data set because both sets of data indicate high variability in this ratio which requires each farmer to evaluate the topographic conditions for his particular irrigation system. The data do indicate, however, that a substantial number of ponds are being constructed in claypan areas with attractive impoundment ratios and hence economical water supplies for irrigation systems. In the first set of data, the 26 ponds (38 percent) had ratios greater than 3:1 and 65 percent had ratios greater than 2:1. In the second data set 50 percent of the eight ponds had ratios greater than 3:1.

There may be a potential for reducing pond storage costs further by developing pump storage ponds which have high water stored to earth moved ratios. The lower storage cost would have to be compared with the increased cost of pumping water up into the pond rather than having it flow by gravity to determine whether that system would be economically preferable. That analysis was not completed in this study.

Operating Cost of Labor

Operating labor information for irrigation systems is information that is not generally available. Although manufacturing specification and engineering estimates are available for most systems, little information has been obtained about the labor used by farmers who operate center pivot irrigation systems with multiple pivot points. Operating labor data were collected from farmers with 160 acre and 40 acre center pivot systems in July and August of 1980.

Table 3.4. Labor Utilization for 160 Acre Multipivot Point Center Pivot Irrigation Systems, Indiana, 1980.

	Start up	Store	Move	Monitor, Repair & Chemical Application	Annual Application	Water Applied	Acres Irrigated
	(Annual Hours)	(Annual Hours)	(Hours per Application)	(Hours per Application)	(Number)	(Inches per Irrigation)	
	3	3	5	3	4	1.3	320
	2	3	5	5	10	1.0	165
	4	4	4	4	4	1.0	120
	30	16	6.2	3.3	5	1.3	360
	6	3	6	3.1	6	1.3	300
	3	1	2	1.5	4	1.5	160
	8	4	3	3.5	9	1.0	220
	15	5	5	6.5	6	.8	215
	3	2	2.5	2.9	6	1.5	175
Mode	3	3	5		4.6	1.0-1.3	
Mean	8.2	4.6	4.3	3.6	6	1.2	226

Information about 9 multiple pivot 160 acre center pivot systems was obtained in this survey. The multipivot 160 acre system required an average of 8.2 labor hours to start in the summer and 4.6 hours to store. (See Table 3.4.) Each application required an average of 3.6 hours of labor to monitor, repair, service, apply fertilizer, and apply herbicide. An average of 4.3 hours was required to move the system between pivot points. An average of 1.2 inches of water was applied in each of six applications during the irrigation season. Total labor requirements for the season were 84.1 hours or .372 hours per acre. It should be noted that some of these farmers irrigated only partial circles from the multiple pivot setting, e.g. the 120 acres irrigated by one farmer.

Labor data were obtained through a survey of 19 multipivot point 40 acre center pivot irrigation distribution systems. (See Table 3.5) The average annual start-up time was 3.8 hours and the storage time was 3.1 hours. An average of 3.7 hours was utilized to monitor, repair, service, and apply chemicals for each irrigation application. Movement of this smaller system between pivot points only required an average of 2.2 hours in contrast to the 4.3 hours required for 160 acre center pivot systems. Approximately seven applications of water were made during the irrigation season with 1.3 inches of water applied during each application. The total hours required annually for the 40 acre center pivot systems was 76.8 or .709 hours per acre irrigated. The operating labor requirements determined from these surveys are used in the models presented in Chapter IV.

Operating Cost: Electric Power

The cost for electric energy to operate center pivot irrigation systems varies greatly among individual power companies. The cost per KWH in some

Table 3.5. Labor Utilization for 40 Acre Multipivot Point Irrigation Systems, Indiana, 1980.

	Start up	Store	Move	Monitor, Repair & Chemical Application	Annual Application	Water Applied	Acres Irrigated
	(Annual Hours)	(Annual Hours)	(Hours per Application)	(Hours per Application)	(Number)	(Inches per Irrigation)	
	6	8	5	11.5	9	1.0	80
	3	3	4	1.1	25	1.0	160
	6	6	6	6.0	10	1.5	40
	5	2	1.5	2.5	6	1.0	80
	2	2	2	1.6	5	1.2	42
	1	1	1	1.3	4	1.5	150
	2	2	1	1.4	7	1.6	80
	2	2	1	1.6	7	1.6	80
	1	2	1	11.0	6	1.0	140
	2	4	3	1.0	6	1.0	80
	1	2	1	1.1	7	1.5	160
	2	2	1	0.6	5	0.8	145
	2	1	1.5	1.9	6	1.5	102
	4	3	3	5.0	3	1.0	110
	5	5	4.5	1.5	5	1.2	100
	3	3	1.5	3.0	4	1.3	144
	15	8	1.0	3.0	6	1.5	150
	10	2	.8	2.0	5	1.3	120
	1	1	1.0	0.5	3	1.5	144
Mode	2	2	1.0	1.1-3.0	6	1-1.5	80
Mean	3.8	3.1	2.15	3.7	6.79	1.26	108.3

areas of Indiana is twice as high as in other areas. Data were obtained in July 1980 from power companies in Indiana on the rates for center pivot irrigation systems using 3-phase power. These data are presented in Table 3.6. The cost of power ranged from .024 per KWH to .049 per KWH with an average cost of .037 per KWH. With six applications annually of 1.3 inches per application, the 160 acre center pivot systems would incur and average cost of $762.74 for electricity used during the two month irrigation period. However, this would vary from a low of $470.66 for a utility in one area to a high of $1228.27 in another. If the center pivot system was the only power unit on the electric system, minimum monthly billing for the remaining 10 months of the year would increase the annual power cost to an $857.71 average with a range from $515.76 to $1293.24.

If electric power is purchased for the irrigation system, the particular location of the farm becomes important to access the cost of that electricity. The current variation among rates charged by power companies will decline during the 1980's. As long term contracts for power expire new higher cost contracts will be integrated into the rate structure for the Rural Electrical Cooperatives that usually buy all of the power they use. In addition if electric power requirements expand for these systems (as might occur if several irrigation systems were installed in the same area) the additional power required above current contracts would have to be purchased at higher rates.

In addition to power variation by location, the type of power and electric motor selected influences the cost of power for irrigation. The data in Table 3.6 assumed three phase power was available at commercial rates and the lines did not have to be brought onto the farm. Other scenarios are equally likely. Single phase power might be available at commercial rates

Table 3.6. Electric Power Cost for Irrigation, 1980, in Indiana

Utility	Cost per KWH	Total 2-Month Cost	Annual Cost
	(dollars)	(dollars)	(dollars)
1	.044	836.14	1272.24
2	.049	1228.27	1228.27
3	.040	756.016	781.016
4	.042	808.928	872.728
5	.042	800.994	835.994
6	.045	856.14	1293.24
7	.038	723.59	775.79
8	.029	555.00	675.00
9	.0435	890.392	1038.392
10	.046	875.17	1188.97
11	.039	737.968	774.768
12	.024	569.28	925.78
13	.035	815.444	899.244
14	.041	785.296	854.296
15	.029	548.08	603.08
16	.030	565.64	618.64
17	.045	851.104	1051.104
18	.039	750.736	801.936
19	.036	684.176	1049.476
20	.030	710.788	748.888
21	.045	863.08	1230.78
22	.043	812.416	962.416
23	.030	567.056	607.056
24	.031	837.5544	1176.1544
25	.033	635.692	690.692
26	.0415	868.468	1051.368
27	.033	620.164	663.864
28	.040	752.48	852.48
29	.039	737.312	789.812
30	.037	698.36	1048.36
31	.030	575.50	623.50
32	.034	800.442	854.142
33	.025	474.78	571.68
34	.039	735.28	801.78
35	.025	470.66	515.76
36	.045	859.68	959.68
37	.043	825.28	884.88
38	.037	699.90	919.90
Range	.024-.049	470.66-1228.27	515.76-1293.24
Mean	.037	762.74	857.71

Table 3.7. Annual Irrigation System Power Cost for 160 Acre Center Pivot[a]

Motor Options	Three Phase Commercial Rate	Single Phase Commercial Rate	Single Phase Residential Rate
3-Phase Motor on 3-Phase Direct Lines	$1771		
3-Phase Motor on Rotor Phase Converter - Single Phase Lines[b]		$2264	$1914
Single Phase Motor on Tractor Start Clutch - Single Phase Lines[b]		$2820	$2448

[a] The rates used here are based on utility number 2 in Table 3.6.

[b] The 60 HP electric motor and the Rotor Phase connections or Tractor Start Clutch Systems are assumed to be purchased at a 12% rate of interest and have an expected life of 15 years.

or at residential rates where three phase was unavailable or prohibitively expensive to bring onto the farm. The alternative scenarios that might occur and the resulting cost for irrigation are compared in Table 3.7.

It is clear that direct line 3-phase power would be preferable at $1771 annually if these lines were already on the farm. With either commercial rates or residential rates the use of a three phase motor with a Roto Phase converter based on single phase lines is less costly than the tractor start clutch system with a single phase motor, e.g. $1914 vs. $2445. Although the rates among utilities in Indiana will vary, the relative superiority of the alternative electrical systems is expected to remain the same as demonstrated in Table 3.7.

Livestock

Hog and cattle operations were incorporated into the analysis because census data indicate many farms in the claypan regions of Indiana, Illinois and Missouri have mixed crop and livestock systems. The scale of livestock operations on these farms is small in most cases. Information on the hog operation in selected counties located in claypan areas of Indiana and Illinois are presented in Table 3.8. Thirty-seven percent of the farms had swine operations in 1974. These farms marketed an average of 161 hogs annually. Fifty-nine percent of the farms in these counties had cattle and calf operations. In 1974 they sold an average of 17 head per farm. Information is presented in Table 3.9 on the cattle and calf numbers in selected counties.

In those models where mixed crop and livestock systems were analyzed, two alternative production levels of hog and cattle operations are assessed. Sixty-six unit and 198 unit cattle and calf enterprises were examined in the

Table 3.8. Hogs and Pigs in Selected Counties in Claypan Regions in 1974.

County/State	Number of Farms Selling	Number of Head Sold	Average Sold Per Farm
Clay/Indiana	209	48488	232
Owen/Indiana	200	29746	149
Putnam/Indiana	392	92871	237
Vigo/Indiana	150	25906	173
Clay/Illinois	287	44640	156
Crawford/Illinois	253	57155	226
Edwards/Illinois	396	82213	208
Franklin/Illinois	229	37016	162
Hamilton/Illinois	324	43118	133
Jackson/Illinois	264	36289	137
Jefferson/Illinois	382	50240	132
Lawrence/Illinois	175	27921	160
Marion/Illinois	304	42360	139
Perry/Illinois	280	43527	155
Randolph/Illinois	482	73388	152
Richland/Illinois	213	37447	176
Saline/Illinois	178	17682	99
Wayne/Illinois	496	75269	152
White/Illinois	263	47909	182
Williamson/Illinois	141	17056	121

Table 3.9. Cattle and Calves in Selected Counties in Claypan Regions in 1974.

County/State	Number of Farms Selling	Number of Head Sold	Average Sold Per Farm
Clay/Indiana	381	5858	15
Owen/Indiana	473	6363	13
Putnam/Indiana	710	14647	21
Vigo/Indiana	307	3906	13
Clay/Illinois	397	5411	14
Crawford/Illinois	319	7254	23
Edwards/Illinois	329	7565	23
Franklin/Illinois	362	5814	16
Hamilton/Illinois	340	4838	14
Jackson/Illinois	489	7952	16
Jefferson/Illinois	609	9462	16
Lawrence/Illinois	278	4688	17
Marion/Illinois	619	9593	16
Perry/Illinois	459	10731	23
Randolph/Illinois	743	14846	20
Richland/Illinois	351	6471	18
Saline/Illinois	315	5498	17
Wayne/Illinois	751	14181	19
White/Illinois	375	7034	19
Williamson/Illinois	382	6177	16

models. Each unit is equivalent to 1.8 head of livestock. Seventeen unit and 51 unit hog and pig operations where evaluated with each unit equal to 15 pigs. The smaller unit for each type of livestock represents the current average levels of livestock scale and the larger unit represents larger livestock operations in the region. The larger scale operations are more consistent with the 640 acre farm size modeled with the livestock operations.

CHAPTER IV

ANALYSIS

The analysis of alternative farming systems that incorporate irrigation is described in the section below. The first section examines dryland corn and soybean production on claypan soils as a basis for comparison of systems with irrigation. The second section presents the 640 acre irrigated corn and soybean crop farms and the mixed irrigated crop and livestock systems. The third section examines the opportunity for irrigation on overall crop farms.

Dryland Crop Production

Table 4.1 presents crop yields on dryland soils in a claypan region of Missouri for an 8 year period. The average yield of corn was 71 bushels per acre, but the annual yields varied from 46 percent above average to 37 percent below average. The average dryland soybean yield was 29 bushel per acre but annual yields varied from 48 percent above average to 34 percent below average. These percentage changes in yield for corn and soybeans were used to adjust the yield data in the model over the 15 year period of analysis considered for the irrigation systems.

The net cash flow after taxes is presented in Table 4.2 for a 640 acre dryland farm with 320 acres of corn and 320 acres of soybeans. Since the present value of this cash flow depends upon the arbitrary sequence of high and low years, it was recalculated assuming each of the fifteen years was the first period and following through the other years in order. The average of these 15 sequences ($112,955 at 12% rate of discount) is considered to be net present value of revenue for dryland corn and soybean production.

Table 4.1. Dryland Corn and Soybean Yields in Missouri on Claypan Soils[a]

Year	Dryland Corn		Dryland Soybeans	
	Yield[b]	Variation[c]	Yield	Variation[c]
1972	44	-30	22	-24
1973	98	+38	34	+17
1974	52	-27	23	-20
1975	58	-18	30	+3
1976	45	-37	19	-34
1977	94	+32	43	+48
1978	104	+46	34	+17
1979	72	+1	28	-3
Average	71 Bu.		29 Bu.	

[a]Hein (1980).
[b]The yield is in bushels per acre.
[c]Variation is the percentage annual yield is above or below average.

Table 4.2. The Annual Cash Flow After Taxes for Production on 640 Acre Farm System

Year	Dryland Corn and Soybeans[a]	Irrigated Corn[b]	Irrigated Corn and Soybeans[c]
1	− $ 22,794	$ 23,793	$ 26,817
2	+ 53,017	23,793	26,817
3	− 12,743	23,793	26,817
4	+ 6,836	23,793	26,817
5	− 27,558	23,793	26,817
6	+ 65,067	23,793	26,817
7	+ 56,368	23,793	26,817
8	+ 15,858	22,373	24,767
9	− 22,794	22,006	24,378
10	+ 53,017	21,596	23,910
11	− 12,743	21,090	23,355
12	+ 6,836	20,499	22,669
13	− 27,558	19,729	21,840
14	+ 65,067	18,800	20,864
15	+ 56,368	17,712	19,626
NPV @ 12%	$112,955[d]	$155,530	$173,971
NPV @ 4%	$187,569[d]	$248,308	$261, 505

[a]Dryland corn 320 acres, dryland soybeans 320 acres.
[b]Irrigated corn 524 acres, dryland corn (field corner) 112 acres, lanes 4 acres.
[c]131 acres irrigated corn, 28 acres dryland corn (field corners), 393 acres irrigated soybeans, 84 acres dryland soybeans (field corners), 4 acres lanes.
[d]This is the average net present value of the cash flow after taxes calculated by averaging 15 net present value coefficients developed by utilizing each of the 15 years as the first year in the sequence.

Large Farms

Several comparisons can be made among the economic returns to dryland and irrigated systems presented in Tables 4.2 and 4.3. The major conclusion is that the net present value of the annual cash flow is greater for the irrigated than the dryland systems. The fifty percent yield increases for corn and soybeans (about a 50 bushel per acre increase for corn and a 15 bushel per acre increase for soybeans) covers the cost of the irrigation investment and provides some increase in profits over cost. The average dryland yields were 110 bushel per acre for corn and 30 bushel per acre for soybeans. For example dryland corn and soybean production yields $112,955 of annual cash flow after taxes when discounted at 12 percent, but irrigated corn and soybean production yields $173,971 when discounted at 12 percent.

Since these irrigation systems include the higher cost pond water supplies, a well source of water supplies would show even a greater advantage of irrigated systems over dryland than shown in these tables. These results for corn and soybean production are similar to those found when only irrigated corn systems were examined in the previous publications by Clouser and Miller.

The particular price ratios and yield responses utilized in this analysis resulted in the production of more irrigated soybeans than corn on the 640 acre farm. One-fourth of the land was planted to corn and three-fourths to soybeans in the optimum (most profitable) model solution. Table 4.2 indicates that combination is more profitable than irrigated corn alone at either the 4 percent or 12 percent rate of discount. This aspect of the results should not be overemphasized because the model is sensitive to relatively small shifts in the corn/soybean price ratio. Of interest, however, is the fact that soybeans appear to be an attractive alternative for

Table 4.3. The Annual Cash Flow After Taxes for Irrigated Crop Production or Mixed 640 Acre Crop and Livestock Farms.[a]

Year	Small Hog Enterprise[b]	Large Hog Enterprise[c]	Small Cattle Enterprise[d]	Large Cattle Enterprise[e]
1	$ 29,843	$ 36,555	$ 41,085	$ 70,005
2	29,843	36,555	41,085	70,005
3	29,843	36,555	41,085	70,005
4	29,843	36,555	41,085	70,005
5	29,843	36,555	41,085	70,005
6	29,843	36,555	41,085	68,484
7	29,843	36,555	41,085	51,982
8	27,092	32,010	35,084	51,219
9	26,672	31,450	34,468	50,366
10	26,143	30,826	33,746	49,317
11	25,541	30,086	32,951	48,137
12	24,786	29,179	31,898	46,815
13	23,906	28,146	30,720	45,335
14	22,800	26,817	29,400	43,677
15	21,520	25,340	27,859	41,821
PV @ 4%	$306,916	$370,031	$411,565	$647,733
PV @ 12%	$192,954	$233,718	$260,752	$418,112

[a]All livestock systems include 131 acres irrigated corn, 393 acres irrigated soybeans, 28 acres dryland corn and 84 acres of dryland soybeans.
[b]A 255 head hog enterprise plus crops.
[c]A 765 head hog enterprise plus crops.
[d]A 119 head cattle and calve enterprise plus crops.
[e]A 356 head cattle and calve enterprise plus crops.

irrigation. Although the soybean plant has a longer flowering period than the corn plant suggesting they can handle short periods of moisture stress better than corn, the claypan agronomic data indicates a strong yield response to irrigation. Apparently the moisture stress reduces yield through smaller soybeans or fewer soybeans per pod even though the plant may respond by flowering and setting pods when moisture stress is relieved. Alternatively perhaps the claypan soil has such a severely restricted rooting zone that moisture stress is persistent even shortly after rainfall throughout the flowering season. Whatever the explanation for the yield response of soybeans it is clear that because they are an economically attractive alternative farmers can take advantage of the yield increases which result from crop rotations of corn and soybeans in contrast to continuous corn on irrigated land.

When livestock enterprises are added to the farm operation the net present value of the annual cash flow exceeds that of the crop farming operations. This occurs for several reasons. The livestock enterprise was not designed to be directly competitive to crop field labor time. The livestock enterprises were not developed at a scale which would require full time labor for this operation. The fertilizer value of manure returned to the field reduced crop fertilizer costs. As long as the livestock operations covered all of their costs of production (including home produced feed priced at market opportunity cost) they would permit a farmer to increase net present value without expanding crop acreage. While the corn-soybean land use pattern is compatable with the hog operations, beef production requires the purchase of hay to supplement roughage available from corn production for the cattle operation.

The annual cash flow after taxes illustrates some of the impacts of tax structure on the returns as income expands when livestock systems are added to the crop production. No taxes are paid due to loss carryover, investment credit, and accelerated depreciation during the first seven years after the irrigation system is purchased on the grain farms, i.e. the annual cash flow is constant at $26,817 (see Table 4.2). In contrast, the higher income larger cattle operation uses up the tax advantages of the irrigation investment by the end of the fifth year when annual cash flow begins to drop from $70,005 to $68,484. It should be noted that the higher marginal tax rates due to higher incomes of the crop and livestock operation mitigate the rate of increase of the net present value of the annual cash flow after taxes.

Small Farms

The result of the small farm analysis is presented in Tables 4.4 and 4.5. these results should not be compared with the 640A analysis presented above because there are several differences in the data base. For example, in the small farm analysis farm prices, crop yields, variable costs, income tax tables, machinery complements and the size of center pivot systems differ from those in 640 acre farms. Comparison will be made in the following sections among the different small farm scenarios examined, i.e. comparisons among dryland, irrigated and labor constrained irrigated crop production systems.

In Table 4.4 for 160 acre farms, the irrigated system with a full time operator is shown to be more profitable than dryland production with a full time operator. If the operator works part time and has only 20 hours per week to devote to farming the present value of the net revenue falls dramatically to $75,197 from $174,062. This result is due to the labor

Table 4.4. The Annual Cash Flow After Taxes for Irrigated Crop Production on 160 Acre Cash Grain Farms.

Year	Dryland[a]	Irrigated[b]	Irrigated[c] (labor constraint)
1	$ -5,824	$ 16,623	$ 6,881
2	+20,904	16,623	6,881
3	-2,300	16,623	6,881
4	+4,108	16,623	6,881
5	-7,358	16,623	6,881
6	+24,914	16,623	6,881
7	+22,946	16,623	6,881
8	+7,886	14,962	6,881
9	-5,824	14,867	6,821
10	+20,904	14,773	6,751
11	-2,300	14,657	6,681
12	+4,108	14,531	6,597
13	-7,358	14,395	6,487
14	+24,914	14,220	6,367
15	+22,946	14,016	6,237
NPV @ 4%	$ 90,734	$174,062	$ 75,197
NPV @ 12%	$ 54,866	$108,738	$ 46,359

[a]Eighty acres dryland corn, 80 acres dryland soybeans, full-time operator.
[b]Seventy acres irrigated rotation corn, 70 acres irrigated rotation soybeans, 8 acres dryland corn, 9 acres dryland soybeans, 3 acres lanes, full-time operator.
[c]Forty-nine acres irrigated rotation corn, 49 acres irrigated rotation soybeans, 48 acres wheat, six acres dryland corn, 6 acres dryland soybeans, and 2 acres lanes, part-time operator.

Table 4.5. The Annual Cash Flow After Taxes for Irrigated Crop Production on 80 Acre Cash Grain Farms.

Year	Dryland[a]	Irrigated[b]	Irrigated[c] (labor constraint)
1	$-6,412	$ 2,233	$ 1,998
2	+6,952	2,233	1,998
3	-4,650	2,233	1,998
4	-1,446	2,233	1,998
5	-7,179	2,233	1,998
6	+8,957	2,233	1,998
7	+7,973	2,233	1,998
8	+443	2,233	1,998
9	-6,412	2,233	1,998
10	+6,952	2,233	1,998
11	-4,650	2,233	1,998
12	-1,446	2,233	1,998
13	-7,179	2,233	1,998
14	+8,957	2,233	1,998
15	+7,973	2,233	1,998
NPV @ 4%	$+5,983	$24,833	$ 22,220
NPV @ 12%	$+3,591	$15,208	$ 13,608

[a]Forty acres dryland corn, 40 acres dryland soybeans, full-time operator.
[b]Thirty-five acres irrigated rotation corn, 35 acres irrigated rotation soybeans, 4 acres dryland corn, 4 acres dryland soybeans, 2 acres lanes, full-time operator.
[c]Thirty-four acres irrigated rotation corn, 35 acres irrigated rotation soybeans, 4 acrs dryland corn, 4 acres dryland soybeans, 2 acres lanes, part-time operator.

constraint which changes some acreage to wheat and forces less timely planting and harvesting of the two major crop enterprises.

When farming only 80 acres (Table 4.5) the irrigated system continues to be more profitable than dryland for the full time operator, but the present value of the annual cash flow declines only slightly from $24,833 to $22,220 for the part time farmer. The part-time farmer still has enough time to handle the land preparation, planting, cultivation and harvesting for corn and soybeans without being forced to switch to lower profit wheat production or to the less optimum harvesting and planting periods. Another feature of the 80 acre farm is income so low that no taxes are paid in any year. The return to management and labor is so low that the farms of this scale are only found either when other sources provide a major portion of the income or when the land is owned so the operator obtains the returns to land, labor, and management.

Forty acre irrigated farms for the part time farms were evaluated but found to be unprofitable because the cost of the capital investment in a 40 acre center pivot irrigation system and machinery cannot be spread over enough acreage. Note however that both the 80 acre irrigated and 160 acre irrigated farms show a profit even with labor constrained. Once the 80 acre size is reached the machinery complement becomes more efficiently used and the minimum of two pivot points for the forty acre center pivot made it economically feasible. The results clearly indicate that irrigated crop production has a higher net present value of the annual cash flow than does dryland production on small farms as well as for the larger farms evaluated previously.

The sensitivity of the crop yields used in the model was evaluated on the small irrigated farms. When the yield increases in irrigated corn and soybean production over dryland was reduced by 21 percent the optimum model solution shifted to dryland production of corn and soybeans on all acres of cropland.

Labor Constraints

The impact of limited labor availability for the part time farmer, who has only 20 hours a week to devote to farming, is clearly illustrated when the periods of planting and harvesting are compared among the 40 acre, 80 acre, and 160 acre irrigated farms. Table 4.6 presents these data which indicate several shifts in the operations as the size of farm increases. On the 40 acre farm there is enough time to prepare the seedbed, plant, and harvest in the optimum yield periods for both corn and soybeans. The corn is planted in the last week of April and harvested during the last two weeks of October while the soybeans are planted in mid-May and harvested the first week in October.

In contrast the labor constraint results in substantial planting and harvesting during periods which result in lower yields when the farm size is increased to 80 acres. Later planting of corn in May and later harvest of some of the corn and soybean acreage result in reduced yields.

When the farm size is increased to 160 acres the penalty for limited labor becomes even more severe. The yield penalty is so great for the later planting and harvesting of corn and soybeans that dryland wheat becomes more profitable for 48 acres of the 160 than additional irrigated corn and irrigated soybean production.

Table 4.6. Acreage by Planting and Harvesting Period with Labor Constrained[a]

Farm Size/ Planting Period	Harvesting Period: June 28 - July 4	Sept. 27 - Oct. 10	Oct. 11 - Oct. 31	Nov. 1 - Nov. 21	Nov. 22 - Dec. 5
40 Acre Farm					
April 26 - May 2			20 - C		
May 3 - May 9					
May 10 - May 16		1 - Sb			
May 17 - May 23		19 - Sb			
80 Acre Farm					
April 26 - May 2			20 - C		
May 3 - May 9			7 - C	10 - C	
May 10 - May 16		16 - Sb	3 - C		
May 17 May 23		19 - Sb			
May 24 - May 30			5 - Sb		
160 Acre Farm					
April 26 - May 2		12 - C		8 - C	
May 3 - May 9				17 - C	
May 10 - May 16			8 - C	5 - C	3 - C
May 17 - May 23		16 - Sb		3 - C	
May 24 - May 30			24 - Sb		
May 31 - June 6			16 - Sb		
Sept. 13 - Oct. 10	48 - W				

[a]C = Corn, Sb = Soybeans, W = Wheat.

CHAPTER V

SUMMARY

The objectives of this research were to examine the profitability of dryland vs. irrigated corn and soybean production on claypan soils. This comparison was made for several different farm sizes and for grain farms as well as livestock and crop mixed farming situations.

The results of this analysis show irrigation on claypan soils to result in higher net values of the annual discounted cash flows for farms of different sizes. In cases where 80 acre, 160 acre, and 640 acre farms were evaluated, the irrigated systems produced higher net returns to labor and management than did the dryland operations. The results of the analysis are summarized in Table 5.1 for both the 4 percent and 12 percent rate of discount. The relative ranks among systems are the same regardless of which rate of discount is used to make the comparisons.

These results indicate a potential exists for irrigation on small and medium size farms in claypan areas. The results only indicate potential because each farm situation must be evaluated on its own merits taking into consideration factors such as the distance from a water storage pond to the fields to be irrigated, labor availability during the irrigation season and access to capital to finance irrigation investments. The results indicate it appears to be worthwhile for the individual farmer operating on claypan soils to evaluate irrigation along with other alternative capital investments.

Table 5.1. Comparison of the Alternative Types and Scales of Irrigation Systems[a]

System	Acreage	NPV @ 12%	NPV @ 4%
Dryland Corn and Soybeans	640	$ 112,955	$ 187,569
Irrigated Corn	640	155,530	248,308
Irrigated Corn and Soybeans	640	173,971	261,505
Irrigated Corn and Soybeans with Small Hog System	640	192,954	306,916
Irrigated Corn and Soybeans with Large Hog System	640	233,718	370,031
Irrigated Corn and Soybeans with Small Cattle System	640	260,752	411,565
Irrigated Corn and Soybeans with Large Cattle System	640	418,112	647,733
Dryland Corn and Soybeans	160	54,866	90,734
Dryland Corn and Soybeans	80	3,591	5,983
Irrigated Corn and Soybeans	160	174,062	108,738
Irrigated Corn and Soybeans	80	24,833	15,208
Irrigated Corn and Soybeans with Limited Labor	160	75,197	46,359
Irrigated Corn and Soybeans with Limited Labor	80	22,220	13,608

[a]These data are taken from the Tables in Chapter IV.

Although the net present value of the annual cash flows for irrigated production always exceed dryland, in a particular year dryland production could be more profitable. When rainfall is adequate during July and August for good crop production, dryland becomes more profitable than irrigated because no costs associated with irrigation are incurred. However in other years of low rainfall substantial losses are incurred by the dryland claypan farmer. This clearly illustrates the insurance nature of irrigation over a period of years.

Soybeans appear to be a profitable crop for irrigation on claypan soils. This permits an irrigator to rotate corn and soybean production which permits him to achieve the higher yields associated with crop rotations in contrast to a continuous corn alternative.

Data were collected on several aspects of the irrigation program. On claypan soils water impoundment reservoirs cost slightly less than $1.00 per cubic yard of earth moved in construction. About 3 cubic yards of water were impounded for every cubic yard of earth moved for these structures. Labor requirements for operation of a 160 acre center pivot system throughout the operating season averaged .372 hours per acre irrigated for a multiple pivot system. Labor requirements were .709 hours per irrigated acre for the multipivot 40 acre systems. Electric power costs ranged from $516 to $1293 per season with an average cost of $858 for the electric utilities in the State of Indiana. Three phase electric motors operated with Roto Phase Convertors from single phase electric lines are the most economical source of power when three phase lines are not available at the site.

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Appendix A

Net Annual Cash Flow Examples

Item	640 Acre Grain Farm with Hogs[a]	160 Acre Cash Grain Farm[b]
Revenue	$204,666	$65,728
Variable Cost	55,216	16,890
Machinery Loan Payment	23,040	7,000
Hired Labor	8,000	--
Land Rent	42,240	16,000
Livestock Loan Payment	3,519	--
Irrigation Loan Repayment	35,750	7,696
Irrigation Repairs, Tax & Insurance	7,058	1,519
Net Annual Cash Flow	$29,843	$16,623

[a]See Table 4.3 for discounted present value of the cash flow after taxes.
[b]See Table 4.4 for discounted present value of the cash flow after taxes.

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