A BIOECONOMIC SIMULATION ANALYSIS OF IRRIGATION INVESTMENTS

W. G Boggess and C. B. Amerling

Agriculture is unique with respect to the importance of weather variability on output and profits. Irrigation has long been recognized as a means of increasing yields and profits in the arid west, and recently interest in investments in supplemental irrigation in humid areas has accelerated (Brown and Skinner; Hewitt et al.; Levins; Clouser et al., Worm et al.; Schoney and Massie).[1] A critical component of the irrigation investment decision in humid areas, however, is the variability in weather patterns over the economic life of the investment. Previous irrigation investment studies typically ignored this problem, by assuming average yield responses and irrigation applications each year. This assumption may be relatively innocuous in arid areas, but quite misleading in humid areas. Two studies, however, have addressed the problem of variability in weather patterns. Levins analyzed the variability in yield responses by randomly selecting rainfall observations from 20 years of historical weather and using a transcendental production function to estimate annual yield responses. The simulations were repeated 100 times to allow calculation of the expected net present value (NPV) and variance of the NPV of the investments. Clouser et al. attempted to deal with the weather sequence problem by using historical yields from an 8-year span. They calculated the NPV of the investment 15 times, using a different starting year for each calculation but maintaining the historical order of years in the remainder of the sequence. The average of the 15 sequences was considered to be the expected net present value.

In this study a bioeconomic simulation model is used to analyze the risks and returns of irrigation investments. Previous applications of bioeconomic simulation techniques in the economic irrigation literature have been limited to irrigation-scheduling and optimum-cropping-pattern analyses (Anderson; Anderson and Maass; Boggess et al., Mapp and Eidman; Moore; Zavaleta et al.).

Particular attention is paid in this analysis to the impact of variations in weather patterns on the profitability of irrigation investments in humid regions. Biological crop-growth simulation models are used to generate dry-land and irrigated-crop yields based on a time series of historical weather data. These results are then incorporated into a net present value analysis, and Monte Carlo simulation techniques are used to generate probability distributions of the net present values.

The bioeconomic simulation model is applied to the analysis of investments in center-pivot and traveling-gun irrigation systems in the coastal plains regions of northern Florida. Irrigated and dry-land production of corn, soybeans, and peanuts is simulated for two major coastal plains soil groups—sands and sandy loams.[2]

PROCEDURES

An irrigation-cost generator program (d'Almada et al.) was used to generate the investment and operating costs for (1) a 132-acre, low-pressure (40 psi) center-pivot irrigation system (LPCP), (2) a 132-acre, medium-pressure (75 psi) center-pivot irrigation system (MPCP), (3) a 90-acre, cable-tow traveling-gun system (CTTG), and (4) a 90-acre, hose-tow traveling-gun system (HTTG). Total initial investment costs by component are reported in Table 1. These costs reflect representative values; actual costs may vary by location, dealer, brand, component specifications, and optional attachments. Irrigation operating costs were calculated based on labor costs of $4.00 per hour, fuel costs of $1.20 per gallon, and lubricants at $7.00 per gallon. Variable costs per acre-inch of water applied by the four systems are reported in Table 2.

Crop-growth simulation models are used to estimate the yield response to irrigation for corn, soybeans, and peanuts for 17 years of historical weather (Table 3). The crop models are mathematical representations of the biological, chemical, and physiological processes determining crop growth. The functional forms of the

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[1] Several factors have contributed to this increased interest in irrigation in the Southeast: (1) the larger area of cropland in the coastal plains characterized by deep, porous, well-drained to excessively well-drained sandy soils, (2) the highly erratic distribution of rainfall despite seemingly adequate annual precipitation, (3) recent developments in chemigation that allow chemicals to be used more effectively and applied more cheaply through the irrigation system, (4) the development of new varieties of wheat (e.g., Florida 301) suited to the Southeast, which has stimulated a rapid growth in double cropping (irrigation facilitates double cropping by ensuring adequate soil moisture to keep crops on schedule), and (5) the availability in the Southeast of large amounts of high quality, easily accessible ground-water.

[2] The sands consist of 80 percent sand, 12 percent silt, and 8 percent clay particles and hold 5.5 inches of available water in the top 5 feet of soil. The sandy loams consist of 65 percent sand, 20 percent silt, and 15 percent clay particles and hold 8.9 inches of available water in the top 5 feet of soil.

Table 1. Initial Investment Costs for Four Irrigation Systems in Florida (1981 prices)

Component	System[a]			
	MPCP	LPCP	CTTG	HTTG
Well[b]	$ 5,500	$5,500	$ 5,500	$5,500
Pump and Gearhead	6,562	5,904	8,062	8,722
Power Unit	9,500	6,148	6,148	7,108
Distribution System	31,843	31,843	18,581	24,426
TOTAL	$53,405	$49,395	$38,293	$45,756
Acres Covered	132	132	90	90
Per Acre Investment	$405	$374	$425	$508

[a] Medium pressure center-pivot (MPCP), low pressure center-pivot (LPCP), cable-tow traveling gun (CTTG), and hose-tow traveling gun (HTTG).
[b] The traveling gun systems might get by with a smaller well. The cost saving however, would not affect the relative per acre investment costs.

models are derived from theories about the underlying processes, and the coefficients are empirically determined. For soybean, a simulation model developed by Swaney et al. and a soil-water balance model developed by Jones and Smajstrala are used. For corn and peanuts, models developed by Duncan are used.

The NPV method of financial analysis was used because of the unconventional cash flows of the investments considered and its generally recognized theoretical superiority to internal rate of return, payback period, and average rate of return methods. The basic input for this analysis is incremental after-tax cash flows over the planning horizon. As in Robertson et al.'s study, the complete NPV formula for the purchase of a capital asset can be specified as

$$(1) \quad NPV_s = -(1-d)C_0 + \sum_{t=1}^{n} [P_tY_t(1+f_o)^t - (IVC_t - VPC_t - 0_t)(1+f_i)^t - A_t - D_t - i_s d(IVC_t + VPC_t + 0_t)(1+f_i)] (1-I_t) \Big/ (1+k_e)^t + \sum_{t=1}^{n} \frac{[-N_t + D_t]}{(1+k_e)^t} + \sum_{t=1}^{n} \frac{ITC_t}{(1+k_e)^t} + \frac{S_n}{(1+k_e)^n} + .4\left[\frac{S_n - (C_0 - \sum_{t=1}^{n} D_t)}{(1+k_e)^n}\right] I_t$$

where

d = debt to assets or leverage ratio for the firm,
C_o = initial cost of the irrigation system,
P_t = price of output in year t,
Y_t = incremental yield due to irrigation in year t,
IVC_t = irrigation variable costs in year t,
f_o = annual rate of inflation in output prices,

Table 2. Variable Costs per Acre-Inch of Water Applied for Four Alternative Irrigation Systems

Crops[a]	System[b]			
	LPCP	MPCP	CTTG	HTTG
Soybean	$4.98	$6.87	$8.54	$8.85
Corn	$4.91	$6.80	$8.24	$8.78
Peanuts	$4.91	$6.80	$8.24	$8.78

[a] The variable costs of applying an acre-inch of water in a single application with a particular system do not vary across crops. However, the variable costs are a function of the amount of water applied per application. Thus, since the recommended application rates differ across crops the variable cost per acre-inch of water applied varies across crops.
[b] Low pressure center-pivot (LPCP), medium pressure center-pivot (MPCP), cable-tow traveling gun (CTTG), and hose-tow traveling gun (HTTG).

f_i = annual rate of inflation in input prices,
VPC_t = increases in other production costs (e.g. fertilizer and pesticides) in year t as a result of irrigation,
O_t = ownership costs, such as taxes and insurance associated with the irrigation system in year t,
A_t = interest paid on the irrigation loan in year t,
D_t = tax-related depreciation charged against the irrigation system in year t,
i_s = interest rate charged on operating capital,
I_t = investor's marginal income tax rate in year t,
k_e = investor's after-tax minimum acceptable nominal rate of return,
N_t = principal payment on the irrigation loan in year t,
ITC_t = investment tax credit taken in year t,
S_n = net salvage value of the irrigation system in year n, and
n = life of the system in years.

The first term on the right side of equation (1) represents the initial cash outlay from equity for the system. The larger the debt-equity ratio the smaller the actual initial cash outlay.[3] The second term represents the discounted sum of nominal after-tax income, calculated by subtracting all deductible expenses (including depreciation) from gross income and multiplying by $(1-I_t)$. However, since the NPV is based on nominal after-tax cash flows rather than net income flows, the third term in equation (1) is needed to adjust the net income stream to a net cash flow stream. Depreciation expenses are subtracted from gross revenue in the calculation of after-tax income. Depreciation, however, is not a cash expense and thus must be added back in to accurately reflect the net cash flows. Likewise, the cash outflow associated with principal payments on the irrigation loan must be subtracted. The fourth term in equation (1) represents the cash inflow associated with the investment tax credit available to the investor. Generally the entire credit would be available at the end of the first year, unless the investor is in a low tax

[3] In corporate finance theory, the debt-to-asset ratio d represents the overall leverage position of the firm. This approach explicitly treats all investments equally, regardless of the specific financing arrangements available for a particular investment. It should be recognized that investment in irrigation may reduce production risk (Boggess et al.). If production risk is reduced by an investment, the firm will be able to increase financial leverage without increasing the overall risk facing the firm.

Table 3. Simulated Yield Response and Irrigation Water Applied for Corn, Soybean and Peanuts Grown on Sands and Sandy Loam Soils Over 17 Years of Historical Weather Data in North Florida

	Soybeans				Corn				Peanuts			
	Sandy Loams		Sands		Sandy Loams		Sands		Sandy Loams		Sands	
Year	Yield Response (bu)	Irrigation Applied (in)	Yield Response (bu)	Irrigation Applied (in)	Yield Response (bu)	Irrigation Applied (in)	Yield Response (bu)	Irrigation Applied (in)	Yield Response (bu)	Irrigation Applied (in)	Yield Response (bu)	Irrigation Applied (in)
1955	12	9.0	19	12.2	69	13.3	81	15.0	317	5.3	876	13.0
1956	35	9.4	36	12.6	78	13.3	94	16.0	274	5.3	695	12.0
1957	21	7.9	25	11.0	34	9.3	51	10.0	349	5.3	504	8.0
1958	34	10.6	39	13.0	52	12.0	61	14.0	1186	12.0	1907	17.0
1959	12	6.7	23	9.0	29	9.3	45	9.0	1246	8.0	1903	16.0
1960	8	5.5	11	8.7	70	13.3	104	16.0	369	6.7	1522	13.0
1961	11	8.7	19	10.2	48	13.3	68	15.0	495	6.7	1123	12.0
1962	29	7.9	38	9.8	75	12.0	97	15.0	1618	9.3	1813	17.0
1963	27	9.4	35	11.8	39	12.0	29	13.0	518	8.0	906	12.0
1964	9	6.7	18	8.3	105	13.3	123	16.0	23	4.0	332	11.0
1965	19	7.9	26	10.2	95	12.0	116	12.0	429	6.7	1457	12.0
1966	29	7.9	35	9.8	96	14.7	90	15.0	476	10.7	1268	15.0
1967	17	9.8	26	13.0	92	16.0	97	17.0	635	9.3	1265	14.0
1968	19	7.9	28	10.6	36	12.0	44	14.0	728	6.7	1459	14.0
1969	2	2.4	10	5.5	81	12.0	104	14.0	159	4.0	164	9.0
1970	30	9.0	40	12.2	76	10.7	94	12.0	780	10.7	1788	17.0
1971	3	5.9	11	9.4	62	12.0	56	14.0	36	2.7	761	7.0
Average	19	7.8	26	10.5	67	12.4	80	14.0	570	7.1	1162	12.9
Std. Dev.	10.1	1.8	9.9	1.9	23.1	1.6	27.0	2.1	423	2.5	536	3.3

bracket. The final term in equation (1) represents the discounted nominal after-tax net salvage value of the investment at the end of the useful life.

The net cash flows in equation (1) are expressed in nominal dollars, and therefore a nominal discount rate is used. Equation (1) allows output prices and input prices to inflate at different rates. Many of the cash flow items (e.g., C_o, A_t, D_t, N_t, and ITC) are fixed in nominal dollars once the investment is made and thus are not inflated.

In most cases acquisition of a center-pivot irrigation system will require drilling a well. In this case the farmer needs to jointly consider the NPV's of the system and the well. The NPV of drilling a well can be specified as:

$$(2)\quad NPV_w = -(1-d)C_w + \sum_{t=1}^{n} \frac{(D_{wt} + A_{wt})I_t}{(1+k_e)^t} - \sum_{t=1}^{n} \frac{N_{wt}}{(1+k_e)^t} + \frac{ITC_{wt}}{(1+k_e)^t}$$

where

NPV_w = net present value of the well investment,
C_w = initial cost of the well,
D_{wt} = for related depreciation charged against the well in year t,
A_{wt} = interest paid on the well loan in year t,
N_{wt} = principal paid on the well loan in year t,
ITC_{wt} = investment credit claimed in year t, and all other variables are defined in equation (1).

The first term in equation (2) represents the initial outflow of equity. The second term represents the discounted sum of tax savings associated with the depreciation and interest expenses on the well. The third term is the discounted sum of principal payments on the well loan. The final term in equation (3) is the discounted sum of investment tax credit claimed for the well investment.

In humid regions, the expected NPV of irrigation investments is quite sensitive to the particular sequence of growing seasons that occur over the life of the system. A Monte Carlo simulation model written in Basic on a Radio Shack Model II computer was developed to evaluate the impact of variations in weather sequences on the NPV of irrigation investments. The basic logic underlying the simulation model is as follows.

1. Crop simulation models were used to generate dry-land yield, irrigated yield, and irrigation water applied for 17 years of daily historical weather data recorded at Chipley, Florida. The weather data was obtained from the Hydrologic Information Storage and Retrieval System (HISARS).
2. A particular yield response to irrigation and amount of irrigation water applied is selected by randomly drawing an observation from the uniform distribution of simulated results.
3. The incremental after-tax cash flow for the year is computed.
4. Steps 2 and 3 are repeated 15 times. At the end of 15 simulated years, the net present value of the irrigation investment is computed.
5. Steps 2, 3, and 4 are repeated 100 times to generate the probability distribution of the net present value of the irrigation system.
6. Steps 1–6 are repeated for each combination of the three crops, four systems, and two soil types.

A base scenario for each crop that reflects typical purchase conditions was constructed for the financial analysis. A 15-year system life was assumed. The buyer finances 80 percent of the initial cost of the well and system with a 7-year loan at 15 percent effective annual interest. Depreciation on the well and the system are calculated using the Accelerated Cost Recovery System (U.S. Department of Treasury). The well is depreciated over 15 years and the system over the first five years.

A 10 percent investment tax credit is available after the first year, subject to the restriction that the tax credit may not exceed the tax obligation in any one year. A marginal tax rate of 30 percent, reflecting a taxable income of $24,600 (U.S. Department of Treasury), is assumed.[4] By assumption, the after-tax required rate of return is 15 percent.

The price of corn, soybeans, and peanuts in the initial year of the base scenario is $2.50 per bushel, $6.50 per bushel, and $0.24 per pound, respectively. These values are based on 1981 prices received by farmers in Florida. Diesel fuel prices of $1.20/gal. are used in the initial year of the base scenario case, based on the 1981 average price paid by farmers in Florida (USDA, SRS). Annual inflation rates in the base case are assumed to be 7 percent for output prices and 10 percent for input prices. These rates reflect moderate to high overall inflation and allow costs to increase faster than product prices. These rates are based on the USDA indexes of prices paid and received by farmers. The annual rate of increase in the Index of Prices Paid by farmers in April for all commodities, services, and wages (1970–81) was 9.5 percent. The annual rate of increase in the Index of Prices Received by Farmers for all crops in October (1970–81) was 7.5 percent.

The sensitivity of the NPV results to variation in parameter values is analyzed by calculating a sensitivity index (interval elasticity). The sensitivity index (SI) is defined as:

$$SI = \frac{\dfrac{\text{change in net present value}}{\text{initial present value}}}{\dfrac{\text{change in parameter value}}{\text{initial parameter value}}}$$

The SI provides an estimate of the relative impact of variations in individual parameters on the NPV of the irrigation investment.

EXPECTED VALUE AND SENSITIVITY RESULTS

The expected NPV's and standard deviations of investing in the four systems for growing corn, soybeans, and peanuts on sands are reported in Table 4.[5] The values reported in Table 4 reflect the additional benefits of investing in irrigation as compared to dryland production of the same crop. It was assumed in the analysis that the irrigation efficiencies, and thus the yield response to irrigation, are identical across systems. Thus, the relative attractiveness of the four systems, based on their expected NPV's, mimics their relative per acre investment costs (Table 1) and their relative variable costs per acre-inch of water applied (Table 2).[6] Under the base scenario conditions, the LPCP system was the only system with a positive expected NPV for all three crops, and peanuts was the only crop for which all four irrigation systems had positive expected NPV's.

Table 4. Expected Net Present Values and Standard Deviations (in parentheses) of Investing in Four Alternative Irrigation Systems for Irrigating Corn, Soybeans and Peanuts on Sands in North Florida

	System[a]			
Crops	LPCP	MPCP	CTTG	HTTG
Corn	$25,663 (14,323)	$-5,111 (13,881)	$-18,964 (9,263)	$-29,275 ((9,196)
Soybeans	$8,143 (10,573)	$-15,296 (10,110)	$-23,738 (6,657)	$-30,955 (6,618)
Peanut	$69,329 (26,334)	$40,969 (25,138)	$13,721 (16,530)	$3,876 (16,310)

[a] Low pressure center-pivot (LPCP), medium pressure center-pivot (MPCP), cable-tow traveling gun (CTTG), and hose-tow traveling gun (HTTG).

The values reported in Table 4 reflect base scenario parameter values, some of which are highly variable. Sensitivity analyses were performed on soil type, marginal tax rate, inflation rate, product price, and yield response to evaluate their impact on the expected value of the LPCP system. The expected NPV's standard deviations, and sensitivity index values are reported in Table 5. The expected NPV's indicate that irrigation investment in a LPCP system is profitable on the more droughty sands, but not on the sandy loams, except in the case of corn production.

The sensitivity indexes reported in Table 5 indicate that the expected NPV of investing in irrigation is more sensitive to the yield response to irrigation and the prices received for the crops. These parameters reflect the production and price risk elements of the overall expected NPV's. Yield response is partially a function of irrigation-scheduling decisions and the farmer's management skills. Corn is far more sensitive to yield response than either soybeans or peanuts on sands because corn has the lowest value per unit of the three crops, and thus net returns to irrigating corn are more dependent on the yield response obtained. This suggests that farmers need to be particularly careful in scheduling irrigation for corn. However, weather will still play a major role in determining yield response to irrigation.

The sensitivity of the NPV's to product prices suggests that irrigators would benefit from effective marketing strategies. In years of relatively low crop prices, the farmer's participation in, and compliance with, government price support programs may substantially affect the price he receives. In general, however, price

[4] Obviously before tax cash flows will be positively related to crop yields (assuming yields and prices are independent at the farm level). This in turn suggests that the farmer's marginal tax rate may vary from one year to the next. As long as the farmer averages a 30 percent marginal tax rate, no systematic bias should be introduced into the expected NPV's by assuming a constant marginal tax rate. However, since years with larger before-tax cash flows are likely to be taxed at higher marginal rates and years with lower before-tax cash flows at lower marginal rates, the variance of the NPV's is biased upwards if a constant marginal tax rate is assumed.

[5] It was assumed in the analysis that each crop was grown in continuous monoculture. This allows direct comparisons of the relative profitability of irrigating the various crops. The approximate NPV of various rotations can be calculated as a weighted average of the individual crop NPV's.

[6] On heavier soils, surface runoff can be a problem with low pressure systems. Likewise, where fields are small and irregular, center-pivot systems may be impractical. The key point is that there may be physical or other considerations that will alter these rankings.

Table 5. Expected Net Present Values E(NPV), Standard Deviation (SD) and Sensitivity Analysis (SI) of Investments in a Low Pressure Center Pivot Irrigation System for Irrigating Corn, Soybeans and Peanuts on Sands in North Florida

Parameter	Corn			Soybeans			Peanuts		
	E(NPV)	S.D.	S.I.	E(NPV)	S.D.	S.I.	E(NPV)	S.D.	S.I.
Soil Type									
Sands[a]	25,663	14,323	n.a.	8,143	10,573	n.a.	69,329	26,334	n.a.
Sandy Loams	8,449	11,524	n.a.	-9,816	10,808	n.a.	-20,919	21,853	n.a.
Marginal Tax Rate									
0.0	30,598	20,462	0.14	5,568	15,105	-0.26	92,978	37,620	0.14
0.15	26,833	17,392	0.09	7,102	12,839	-0.21	81,401	31,977	0.35
0.30[a]	25,633	14,323	0.00	8,143	10,573	0.00	69,329	26,334	0.00
0.45	21,048	11,254	-0.36	7,282	8,304	-0.21	55,357	20,691	-0.40
Inflation Rate[b]									
4,7	17,506	12,359	-0.90	2,508	9,142	-1.96	53,926	22,685	-0.59
7,10[a]	25,663	14,323	0.00	8,143	10,573	0.00	69,329	26,334	0.00
10,13	35,838	16,883	1.12	15,155	12,433	2.44	88,597	31,121	0.74
Product Price[c]									
Low	-7,229	11,224	-6.40	-18,051	7,882	-14.09	36,379	22,129	-3.38
Medium[a]	25,663	14,323	0.00	8,143	10,573	0.00	69,329	26,334	0.00
High	86,844	20,128	6.41	35,222	13,382	14.10	102,279	30,480	3.38
Yield Response[d]									
Low	-18,753	10,144	-65.8	-7,731	8,741	-11.05	6,021	18,382	4.70
Medium	1,767	12,069	0.00	8,143	10,573	0.00	35,269	22,052	0.00
High	25,663	14,323	76.6	28,962	12,455	14.49	69,329	26,334	5.47

[a] Base case values.
[b] Percent increase in output prices followed by the percent increase in input prices.
[c] Corn prices of $2.00, $2.50 and $3.43 per bushel; soybean prices of $5.02, $6.50 and $8.03 per bushel; and peanut prices of 21.4, 24.9 and 28.4 cents per pound.
[d] The crop simulation models reflect Experiment Station growing conditions and management. While some of the better farmers achieve similar yields, the county average yields are normally about 15 percent lower than Experiment Station yields. Based on these relationships, high yield response reflects yields predicted by the crop models, medium yield response assumes a 15 percent reduction in predicted yields and low yield response assumes a 30 percent reduction in predicted yields.

risk will continue to be an important factor due to changing market forces.

Expected NPV's were also sensitive to fuel prices, especially those of soybeans and to a lesser extent corn and peanuts, although in absolute magnitude the three crops responded similarly. A difference of $0.30/gal. altered expected NPV's by $7,000–$9,000. In trials to determine the approximate switching values for fuel prices, irrigated peanuts required a diesel fuel price per gallon of $3.65 before the expected NPV turned negative, while corn and soybeans turned negative at $2.05/gal. and $1.65/gal., respectively.

Inflation rates on output and variable input prices also had substantial effects on expected NPV's. The inflation rate on output prices was kept 3 percent below that of input prices, based primarily on forecasts of oil prices keeping abreast or ahead of the overall rate of inflation. Again corn and soybeans were more sensitive than peanuts. Expected NPV's increased with increased inflation, reflecting the nominal values used in the analysis and the assumption that the nominal discount rate is unchanged. As the rate of inflation is increased, holding the nominal discount rate fixed, the real discount rate falls, and thus the NPV increases.

CUMULATIVE PROBABILITY FUNCTIONS

One of the dominant aspects of Tables 4 and 5 is the relative magnitude of the standard deviations. These values indicate that variations in weather sequences over the economic life of the investment have substantial effects on the NPV. Cumulative probability distributions of the NPV's of irrigating peanuts on sands with the four irrigation systems are presented in Figure 1. Similar distributions for corn are presented in Figure 2 and for soybeans in Figure 3. Notice that within crops, the systems exhibit first-degree stochastic dominance, based on their relative per acre investment and variable costs (e.g., LPCP dominates the other systems; MPCP dominates the two traveling-gun systems; and CTTG dominates the HTTG). This result reflects the assumption of equal irrigation efficiencies and thus identical yield responses to irrigation across systems. The dis-

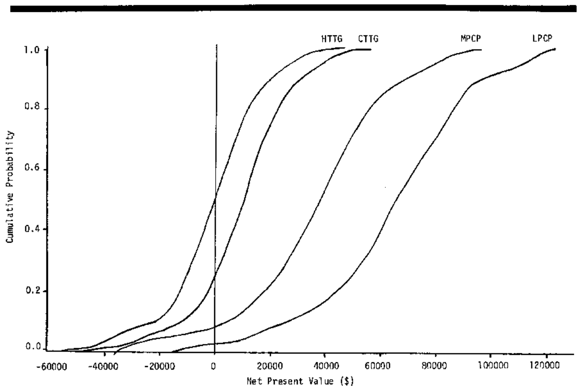

Figure 1. Cumulative Probability Functions of Net Present Values for Purchasing Four Irrigation Systems to Irrigate Peanuts, on Sands

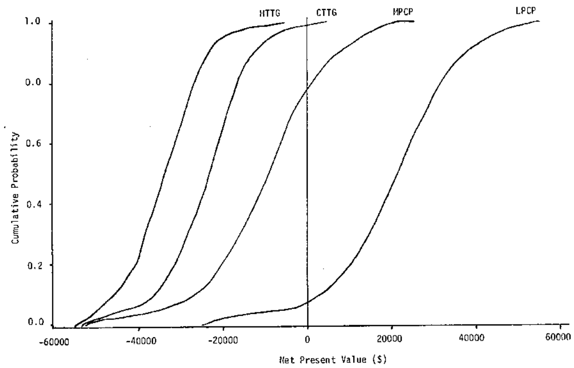

Figure 2. Cumulative Probability Functions of Net Present Values for Purchasing Four Irrigation Systems to Irrigate Corn, on Sands

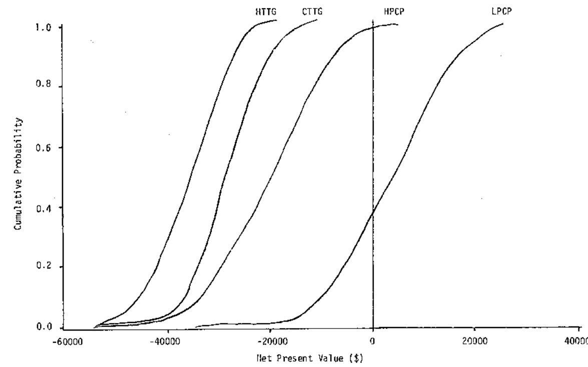

Figure 4. Cumulative Probability Functions for Net Present Values of Investing in a Low Pressure Center Pivot System for Corn, Soybeans and Peanuts on Sands and Sandy Loam Soils

tributions in Figures 1, 2, and 3 also reflect the greater profitability and variability of irrigating peanuts over either corn or soybeans under the base conditions.

Cumulative probability distributions for the NPV's of irrigating corn, soybeans, and peanuts with a LPCP system on both sands and sandy loams are presented in Figure 4. Figure 4 can be used to establish priorities of investing in irrigation for different crops and soil types. On sands, peanuts dominate corn, which in turn dominates soybeans, by first degree stochastic dominance criteria. However, on sandy loams corn dominates both soybeans and peanuts by first-degree and soybeans dominate peanuts by second-degree stochastic dominance criteria. Only systems for irrigating corn or peanuts on sands could be considered "sure bets" with probabilities of negative NPV's of only 8 and 2 percent, respectively, under base conditions. Likewise, only systems to irrigate soybeans and peanuts on sandy loams might be considered "sure losers," with probabilities of positive NPV's of only 10 and 13 percent, respectively, under base conditions. But more important is that systems for irrigating corn on sandy loams or soybeans on sands have negative NPV's 40 percent of the time, even though their expected NPV's are over $8,000. It is in these latter cases, the close calls rather than the obvious calls, where the ability to generate the probability distributions and thus provide farmers with information concerning the downside losses and associated probabilities will pay off.

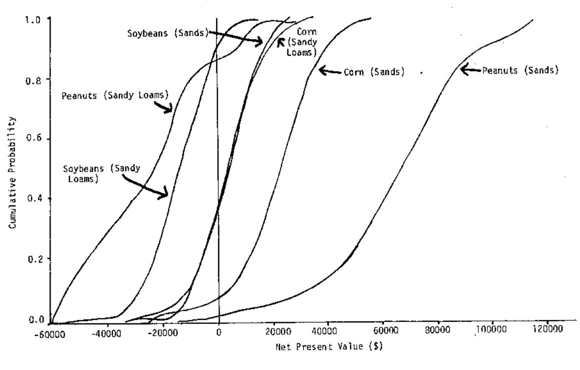

Figure 3. Cumulative Probability Functions of Net Present Values for Purchasing Four Irrigation Systems to Irrigate Soybeans, on Sands

CONCLUSIONS

The specific application of the bioeconomic simulation models in this study indicates that the profitability and risk of irrigation investments in humid regions is critically dependent upon a number of factors, including soil type, crop yield response to irrigation, future price, and financial variables. The results herein shed some light on the relative importance of these factors in evaluation of irrigation investments. Moreover, the microcomputer model allows evaluation of specific cases under any number of "what if?" situations.

Perhaps the most interesting result from the specific application of the model in this study is that, even though irrigation is normally a risk-reducing input, irrigation investments are in many cases quite risky. Even if prices, costs, financial parameters, and yield responses were known with certainty over the life of the system, uncertainty about the sequence of weather years in humid regions introduces tremendous variability in the NPV of the investment. In effect, the farmer trades a reduction in production risk for an increase in financial risk. The net effect will depend upon the specific situation and weather. The best that can be done is to present sufficient information for farmers to evaluate the probability of making a successful investment. Bioeconomic simulation models provide the capability to do just that.

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