ECONOMIC INVESTIGATIONS OF SHORT ROTATION INTENSIVELY CULTURED HYBRID POPLARS

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Abstract.--The history of the economic analyses is summarized for short rotation intensively cultured hybrid poplar at the North Central Forest Experiment Station. Early break-even analyses with limited data indicated that at a price of $25-30 per dry ton for fiber and low to medium production costs, several systems looked profitable. Later cash flow analyses indicated that two systems without irrigation and fertilization could achieve internal rates of return of 8 percent with a 5 percent inflation rate. However, two systems with irrigation and fertilization had negative internal rates of return. All systems had negative net present values when a 10 percent discount rate was used. We are currently incorporating risk analysis into our financial investigation to directly account for uncertainty in the performance calculations.

During the last several years interest has increased remarkably in intensive agronomic techniques to produce high yields of woody biomass for energy and fiber. And our knowledge and experience through many studies and field trials has been increasingly encouraging. Land managers and scientists in both the public and private sectors are facing several important decisions.

For the land manager few tasks are more challenging than developing a production plan to meet future mill requirements. Options include: investing in intensive culture short-rotation (SRIC) forest plantations, investing in conventional less-intensive longer rotation forest plantations, or purchasing the wood as needed on the open market. If a decision is made to invest in SRIC forest plantations, how intensively should these plantations be managed and which of numerous management perscriptions should be followed?

For the scientist it takes time to develop information about specific management alternatives and the number of possible management alternatives is enormous. Scientists must decide which aspects--site preparation, planting, post-planting release, etc.--of the overall management system merit further study in order to improve performance.

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The economist can aid both. He can aid the manager with financial analysis models that describe cost and return relations, determine capital requirements, and calculate financial performances of alternative projects. He can aid both manager and scientist by pointing out the importance of the various activities to the overall financial performance. And, finally, he can suggest the most fruitful areas for future research from a financial perspective.

In this paper I will summarize past intensive culture economic research sponsored by the North Central Station, discuss present ongoing work, and make some general conclusions.

BREAK-EVEN ANALYSIS

When early research efforts began, SRIC systems were believed to have several advantages over conventional silviculture systems. SRIC systems could produce more biomass from the same acreage or the same quantity of biomass from less acreage. SRIC systems could also produce this biomass much sooner--5 to 15 years after establishment rather than the 30 to 80 years of conventional silviculture. Finally, the plantations could be regenerated by coppicing every 5 to 10 years from the same root stock, thus eliminating the need for periodic replanting.

A major disadvantage was that SRIC systems require large capital expenditures for higher quality, accessible land as well as for all the machines and installations required to perform the intensive management. This is particularly true for irrigated plantations.

Thus, the economic potential of alternative SRIC systems generated much discussion as the research program began and break-even analysis was selected to make preliminary economic evaluations (Rose 1976, Rose and Kallstrom 1976, and Rose 1977). With break even analysis, the compounded cost of growing and harvesting biomass is calculated under alternative management strategies. This in turn is compared to: (1) the physical yield (e.g., dry tons/acre/year) at a specified price, or (2) the price (e.g., dollars/dry ton) at a specified physical yield. The break-even point is the dollar value of the yield that just covers all compounded production costs.

Several different production systems were evaluated using this technique. The major variables were spacing, rotation length, number of coppices, cultural practices (e.g., replanting), and project length (table 1). Estimating production cost is extremely important in a break-even analysis. However, little actual data were available when the early analyses began, complicating the situation. Thus, each of the production systems was evaluated under low, medium, and high cost assumptions for two different initial site conditions: forest and pasture.

These early break-even results estimating the cost per dry ton of fiber produced are shown in table 2. Alternatives 5, 6, 7, 8, and 10 would be profitable assuming both a price of $25-$30 per ton for dry fiber and production costs at a low to medium level. Alternative 3 would be profitable only when the same prices are assumed and costs are low.

Table 1.--Specifications for intensive cultural alternatives

Alternative	Spacing (feet)	Rotations (number/ years)	Stand Origin	Project Length (years)	Regeneration Planting (age)
1	4x4	(1) 4 (4) 4	cuttings coppice	20	none
2	4x4	(2) 4 (2) 4	cuttings coppice	24	13
3	4x4	(1) 5 (3) 5	cuttings coppice	20	none
4	2x4	(2) 2 (4) 2	cuttings coppice	20	11
5	12x12	(1) 10 (1) 10	cuttings coppice	20	none
6	12x12	(2) 10	cuttings	20	11
7	12x12	(1) 15 (1) 15	cuttings coppice	30	none
8	4x4	(1) 15 (1) 15	cuttings coppice	30	none
9	4x4	(1) 5 (3) 5	cuttings coppice	20	none
10	12x12	(1) 15	cuttings	15	none

Table 2.--Break-even results of ten intensive culture alternatives

Alternative	Initial Site Condition	Cost Range/Ton of Fiber Produced (low) (high)
1	Forest	$ 53.48-$ 97.21
	Pasture	43.82- 84.71
2	Forest	54.89- 100.59
	Pasture	45.73- 68.75
3	Forest	29.82- 58.74
	Pasture	24.26- 51.56
4	Forest	512.78- 739.46
	Pasture	436.54- 652.02
5	Forest	21.68- 44.88
	Pasture	17.30- 39.18
6	Forest	22.23- 45.58
	Pasture	17.82- 39.88
7	Forest	27.11
	Pasture	22.65
8	Forest	26.86
	Pasture	22.67
9	-------	35.34- 60.64
10	-------	18.23- 42.08

Production cost per dry ton differs greatly depending upon the general cost level assumed. Also, these production costs were calculated from harvest yield assumptions based on experimental plots that were irrigated and fertilized annually (Ek and Dawson 1976). In contrast, most of the alternatives shown in table 2 assumed no irrigation and only periodic fertilization. If the management alternatives were carried out on sites where water and nutrients were limiting factors, the costs would be higher. Thus, these first analyses were crude and only roughly approximated the economic potentials of alternative production systems. Further investigations would be necessary using more sophisticated models when better production cost and yield information became available.

CASH FLOW ANALYSIS

As research on SRIC progressed, more realistic information became available on production costs and biological growth and yield, and land managers wanted more specific economic information about short-rotation systems, we chose to analyze them with a cash flow model (Lothner et al. 1981, Rose et al. 1981, and Ferguson et al. 1981).

We evaluated a few specific hybrid poplar plantations representing a likely range of spacings (4 by 4 feet and 8 by 8 feet), rotations (5, 10 and 15 years), and cultural practices (including irrigation and fertilization). Four alternative systems combined these variables (table 3). Each system consisted of 1,000 acres of cleared marginal agricultural land arranged in 10 tracts of 80 to 120 acres each.

Table 3.--Four alternative SRIC systems

Alternatives	Rotations		Dry Yields	
	Length	Stand Origin	Per Acre/ Year	Total Yield at End of Rotation
	(years)		(tons)	(tons)
4 by 4 foot spacing irrigated and fertilized	10	cuttings	6.3	63
	5	coppice	7.2	36
	5	coppice	7.2	36
	5	coppice	7.2	36
	5	coppice	7.2	36
4 by 4 foot spacing not irrigated or fertilized	10	cuttings	3.2	32
	5	coppice	3.6	18
	5	coppice	3.6	18
	5	coppice	3.6	18
	5	coppice	3.6	18
8 by 8 foot spacing irrigated and fertilized	15	cuttings	6.3	95
	15	coppice	6.3	95
8 by 8 foot spacing not irrigated or fertilized	15	cuttings	3.2	47
	15	coppice	3.2	47

The important production and management activities of each system were identified by North Central scientists and the forester in charge of the only large-scale industrial SRIC plantation in the Lake States. Physical and dollar estimates were made for each of the production factors and yields as well as the relative uncertainty of each. Using a cash flow model, the financial performance of each system was evaluated by an internal rate of return (IRR) and present net value (PNV) criteria for a 30-year period. We also evaluated the sensitivity of the IRR and the PNV to both relative and absolute changes in the production factors and yields due to uncertainties.

Site preparation for the plantations included plowing, disking, and applying preplant herbicides. All these activities took place in late summer and fall prior to spring planting. Three cultivations and two applications of herbicide were used for postplanting weed control. Trees were irrigated by a traveling gun system that applied 10 inches of water per acre annually. Liquid nitrogen fertilizer was applied in the irrigation water at 100 pounds per acre per year. Plantations were harvested using whole-tree chippers for the 10- and 15-year rotations, and forage harvesters for the 5-year coppice rotations. Expenditures common to all alternatives included administrative costs, insurance, land purchase and sale, equipment cost, and taxes (income and property).

An annual inflation rate of 5 percent and a 10 percent discount rate were applied to all costs and returns.

Some of the cost and return assumptions follow:

Cost	Estimate (1979 dollars)
Land	$400 per acre
Planting stock	$ 80 per thousand
Fuel (diesel)	$ 1 per gallon
Labor (nonunion)	$ 4 to $ 6 per hour
Site preparation & weed control	$33.42 to $73.11 per acre
Irrigation	$99.74 per acre per year
Irrigation equipment	$387,700(initial investment for 1,000 acres)
Harvest	
Whole tree	$ 14 to $ 18 per dry ton
Forage	$ 8 per dry ton
Administration	$7,500 per year (for 1000 acres)
Property tax	$ 4 per acre per year
Income tax	28 percent of capital gains
Equipment insurance	1 percent of new price per year
Return	
Product value	$25 per dry ton

A more detailed account of the costs and returns is found in Lothner et al. (1981) and Rose et al. (1981).

With the assumed 10 percent discount rate, no alternative had a positive PNV. However, the two systems without irrigation and fertilization had positive after tax internal rates of return of 8 percent; the two irrigated and fertilized systems had negative internal rates of return (table 4). Economically, dif-

Table 4.--Initial investment and investment performance of four SRIC alternatives

Management Alternative	Initial Investment[1] (dollar/acre)	Present Net Value (dollar/acre)	Internal Rate of Return (percent)
4 by 4 foot spacing, irrigated and fertilized, short-rotations (5 to 10 years)	1,158	-2003.82	-0.4
4 by 4 foot spacing, not irrigated or fertilized, short-rotations (5 to 10 years)	770	- 236.78	8.1
8 by 8 foot spacing, irrigated and fertilized, long-rotations (15 years)	945	-2149.51	-1.6
8 by 8 foot spacing, not irrigated or fertilized, long-rotations (15 years)	557	- 200.30	8.1

[1] Includes land purchases, initial equipment purchase or lease, site preparation and planting costs, and administration cost for first two years.

ferences were small between rotation length and spacing options, but they were significant between the systems that were irrigated and fertilized and those that were not.

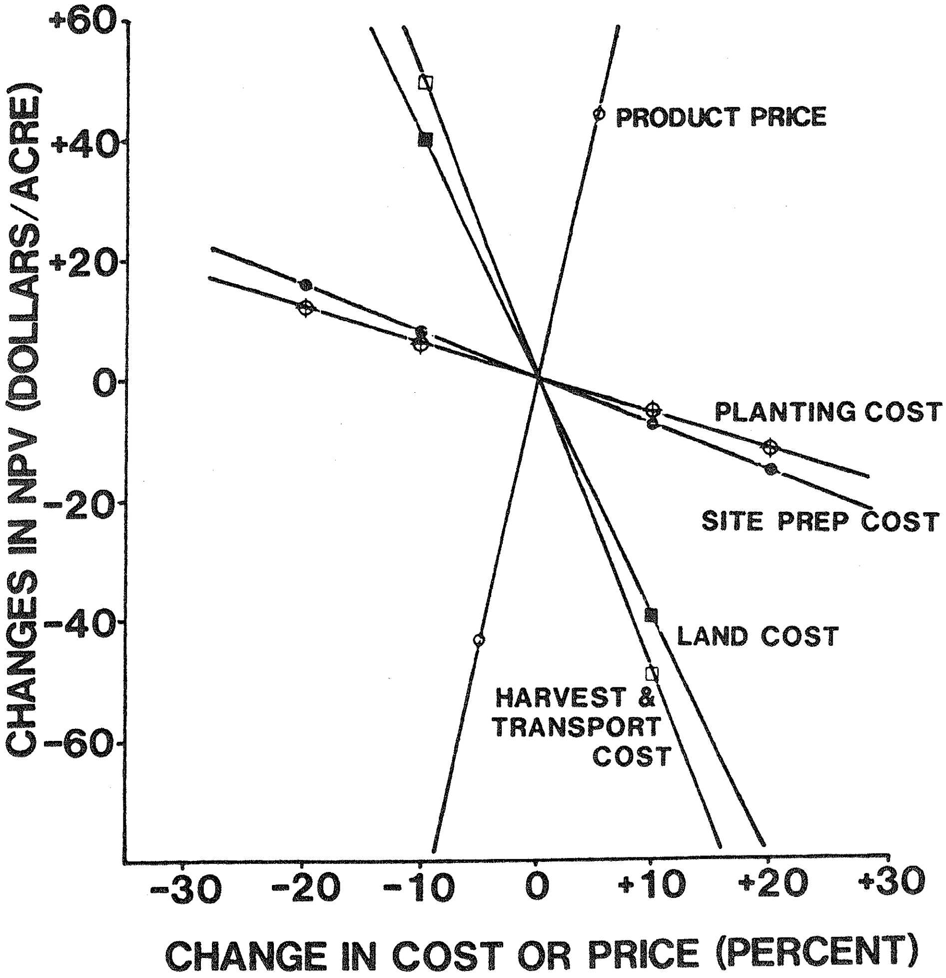
A sensitivity analysis can help identify how each cost or revenue factor affects the financial performance. In all four systems, the most important factor affecting investment performance was the product sale value. It was also one of the most uncertain factors. A change in yield, product price, or both, could substantially change the economic attractiveness of SRIC systems. For example, a 10 percent increase in mill prices from $25 to $27.50 per dry ton for chips for the 8 by 8 foot nonirrigated and nonfertilized system increased the PNV by 44 percent or $88 (fig. 1).

For systems without irrigation and fertilization, harvest and transport cost were the next important factor. For the 8 by 8 foot spacing alternative, a 10 percent change in harvesting and transport cost changed PNV by almost 25 percent or about $49 (fig. 1).

For the irrigated and fertilized systems, irrigation operating costs, primarily fuel, was the second most important factor affecting investment performance and would have to be substantially reduced for these systems to become financially attractive. Fuel costs represent 68 percent of the operating costs of the traveling gun irrigation system and a substantial fuel cost reduction with this type of irrigation system seems unlikely. However, new technology or changes in the irrigation schedule to only sporadic use (e.g., during establishment) could significantly reduce irrigation operating costs.

Site preparation costs and planting costs for any of the systems have little effect on PNV. For example, a 10 percent change in site

Figure 1.--Sensitivity of net present values (NPV) for 8 by 8 foot spacing, nonirrigated and nonfertilized system to relative changes in costs or prices.



preparation cost for the 8 by 8 foot, nonirrigated and nonfertilized system changes PNV by 4 percent or $8, while a 10 percent change in planting cost changes PNV by 3 percent or $6 (fig. 1).

The cash flow analyses suggested that nonirrigated and nonfertilized SRIC systems would be preferable to those that are irrigated and fertilized. But because the returns on investment would be low even for the nonirrigated and nonfertilized systems, these systems would be of interest only to individual users of wood biomass who can compare the potential of these systems to alternative sources of supply prior to making an investment decision.

In addition, the results indicate that the investment performance of the SRIC system is most sensitive to the product sale value (yield and product price), irrigation operating costs, and harvesting costs. Our current data concerning all these factors are inadequate. However, by pointing out their importance, we can focus our research efforts on them in the future. This may help us to reduce some of the important sources of uncertainty and make more informed future decisions. However, many of the factors depend on uncertain future events for which there will always be a limited present understanding.

However, some additional risks were not addressed by the cash flow analysis. For example, what are the risks of insect or disease outbreaks and what impact would they have on the investment performance? Or, what is the risk of failure, in unirrigated and unfertilized plantations?

RISK ANALYSIS

In a conventional cash flow analysis, mathematical formulas are used to precisely calculate financial performance estimates for various criteria by incorporating point estimates for each relevant factor included in the analysis. However, both the analyst and the decisionmaker--manager or scientist--know that behind these precise calculations are imprecise data. A great deal of uncertainty and/or risk[2/] always surrounds the basic information that goes into the analysis. Our past cash flow calculations have not adequately measured risks nor have we been able to directly incorporate risks into investment performance calculations.

[2/] In our discussions a risk situation is where the probability of an activity or event occurring is known or can be estimated; an uncertainty situation is where the probabilities of an activity or event occurring have not been estimated or determined.

We are currently cooperating with Michigan State University[3/] to model the risk inherent in SRIC projects. This work is based on some earlier work in risk analysis by Hertz (1964) and developed and reported on by others (Davidson and Cooper 1980; Economos 1968; and Hillier 1963). Incorporating risk analysis into a basic cash flow model requires three basic steps. First, a range of values is estimated for each of the production activities (e.g., a range of site preparation costs) and the probability or likelihood of occurrence of different values within the range. This is in contrast to the previous practice of estimating only the most likely value of each factor. Second, one value from the distribution of values for each factor is selected at random. The resulting set of selected values for all factors are combined in one cash flow analysis and the financial performance (e.g., internal rate of return or present net value) is calculated. Third, the second step is repeated over and over again to develop a probability distribution for the financial performance outcomes. This distribution of financial performance outcomes thus shows the probability of achieving any specified outcome--e.g., internal rate of return.

If we use two of the hypothetical SRIC systems mentioned earlier--the 4 by 4 foot and 8 by 8 foot nonirrigated and nonfertilized systems--we can illustrate what a risk model can provide in comparison to the conventional cash flow model. Let me emphasize that the numbers found in this section using the risk analysis model have no empirical value. They have been selected only to illustrate the risk analysis method.

Using a conventional cash flow model, both the 4 by 4 foot and 8 by 8 foot nonirrigated and nonfertilized alternatives show 8 percent internal rates of return. Incorporating risk estimates provides the decisionmaker with estimates of the probabilities of achieving each possible value for the financial performance criteria--e.g., internal rate of return. Let's assume that when we incorporate risk into our analysis, the most likely outcomes for both the 4 by 4 foot and 8 by 8 foot alternatives remain the same as the conventional outcome--an 8 percent internal rate of return (fig. 2). In practice the most likely internal rates of return found using a risk analysis model would probably differ from the expected internal rates of return found under the conventional method using single point estimates. In the example above, we have

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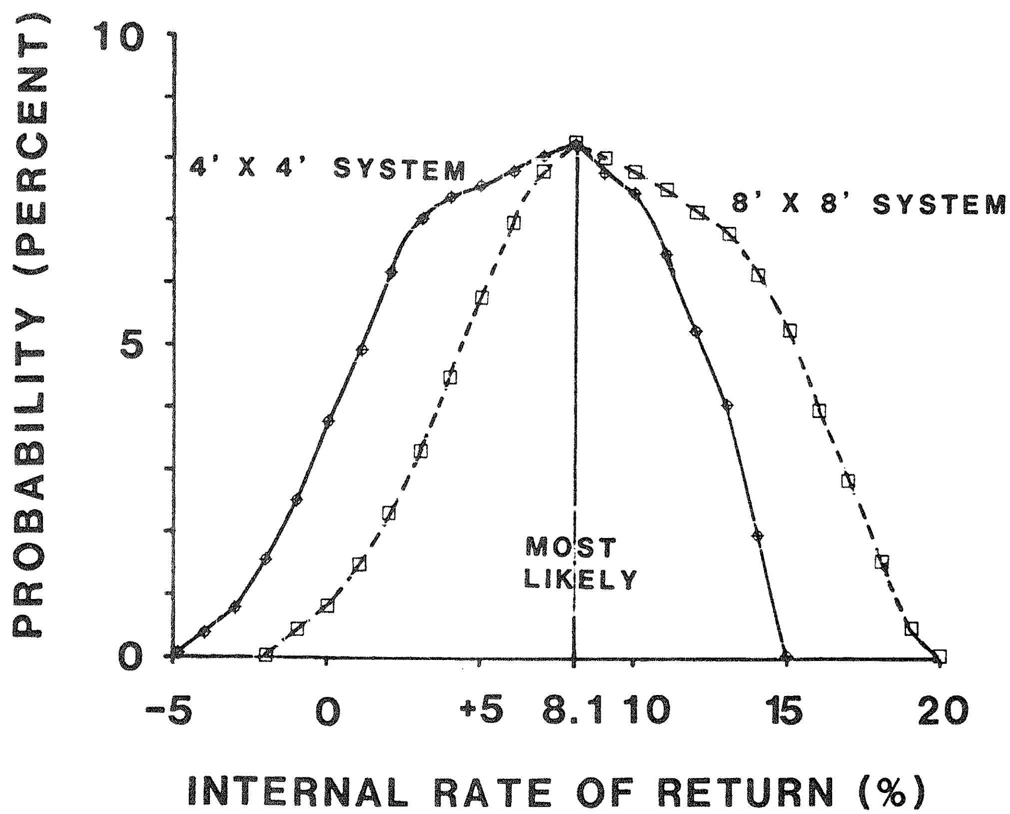
Figure 2.--Probability distributions of the internal rate of return for two hypothetical SRIC systems.



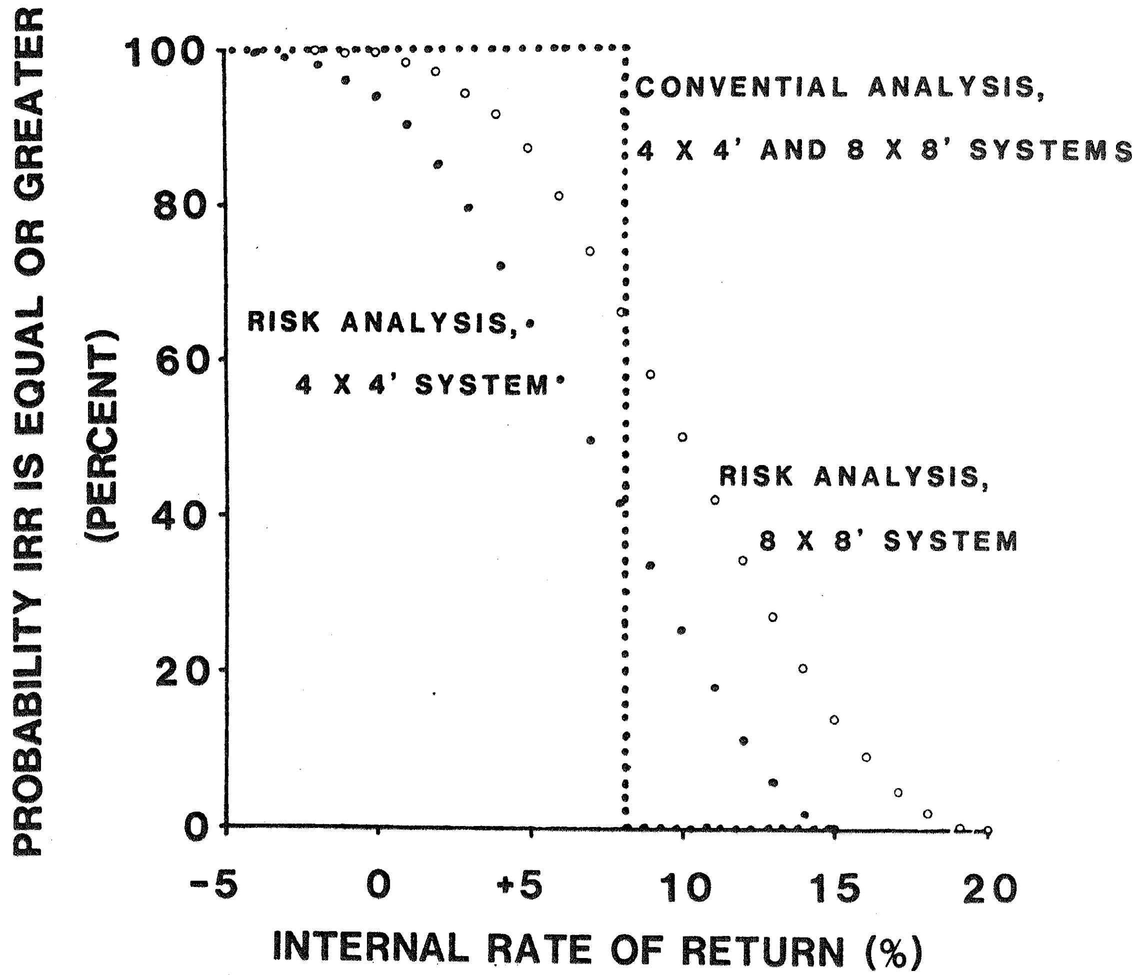
assumed both alternatives have about an 8 percent chance of achieving the 8 percent internal rate of return. The chances or probability of a zero or negative internal rate of return (no profit at all or even a loss) are much greater for the 4 by 4 foot system (fig. 2). (Remember that these numbers are for illustration purpose only and have no empirical value.)

Using a risk analysis method, the uncertainty of achieving at least a certain financial performance--i.e., internal rate of return--can be clearly displayed:

Internal Rate of Return	Probability of achieving at least the returns indicated	
Percent	Percent	
	8x8' spacing	4x4' spacing
0	99	94
2.5	96	83
5.0	87	65
7.5	69	45
8.1	66	42
10.0	50	25
12.5	29	8
15.0	14	0
17.5	3	0
20.0	0	0

We can compare the cumulative profile for the 8 by 8 foot and the 4 by 4 foot spacing systems using a risk analysis with the profile for these systems obtained under the conventional approach (fig. 3). Under the conven-

Figure 3.--Cumulative rate of return profile for two hypothetical SRIC systems using a conventional cash flow model and a risk analysis model.



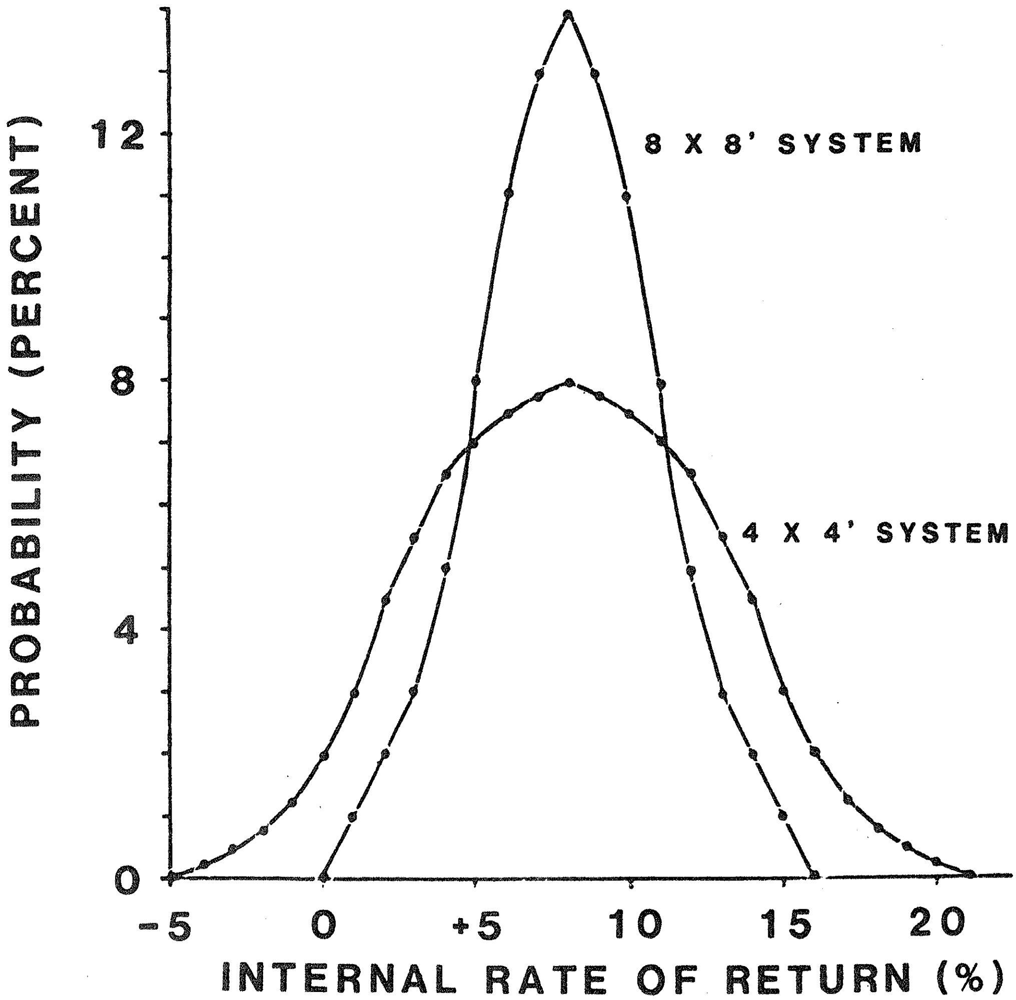
tional cash flow approach we would have no way to choose between the two systems because both produced an 8 percent internal rate of return. However, using risk analysis we can see that the 8 by 8 foot spacing would be superior to the 4 by 4 foot spacing. With the wider spacing we are 99 percent certain that we will not obtain a negative internal rate of return as compared to only a 94 percent chance with the narrower spacing alternative. In addition, we have a 66 percent probability of achieving at least an 8 percent rate of return with the wider spacing system as opposed to only a 42 percent probability with the narrower spacing. It is clear in this example that the wider spacing system is significantly better. Without accounting for risk in the model as with the conventional cash flow model, we would never know this.

This is not to say, however, that using risk analysis will always present information to the analyst for making clear choices. An analysis between two alternatives could result in one alternative being both more risky as well as having a greater opportunity for larger gains (fig. 4).

SUMMARY AND CONCLUSIONS

Economic analysis of SRIC at the North Central Forest Experiment Station has progressed during the past several years. After some early break-even analyses when basic data required for economic evaluation were almost nonexistent, we moved on to discounted cash flow analyses using sensitivity analysis to handle risks and uncertainties. Through these analyses we learned that using single estimates of production factor values, the monetary returns were fairly low. Through the sensitivity analysis we learned that financial performance was most sensitive to product price, product yields, irrigation costs, har-

Figure 4.--Alternative probability distributions of the internal rate of return for two hypothetical SRIC systems.



vesting costs, and land costs. These are all highly uncertain factors. The traditional and more certain management activities necessary to establish and grow hybrid poplars, such as site preparation and planting, were not as important as the previous factors. We also believe that considerable risk is involved in analyzing the financial performance of these systems where uncertainties are not directly accounted for within the system.

From a growing awareness of the importance of uncertainties we began to develop models to handle this problem. Work is still in progress so we do not have any real results. However, we can use hypothetical examples to show the kind of information that can be obtained by incorporating risk directly into the financial analysis.

Much work remains. If we recognize uncertainty, how do we build the model to allow managers to react to possible outcomes? And, once the model is developed, are there any real advantages for evaluating SRIC investment opportunities by this method? These will take considerable effort. Yet, the discipline of thinking through the uncertainties of the problem will perhaps in itself help the analyst assist the decisionmaker in making wise investment choices.

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