Risk, Research, and Returns: Valuation of the Potential of Improved Citrus Cultivars

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The U.S. citrus industry faces potentially devastating losses due to diseases currently infecting or threatening citrus groves. Potential exists in the development of genetically modified citrus trees that are resistant to disease. Growers face risk not only from losses attributable to disease, but also in their decisions to invest in establishing groves. Scenarios including hypothetical disease resistant citrus cultivars as well as forecasted tree losses, fruit prices, and costs are modeled and evaluated with risk ranking to identify the potential benefit of adopting improved citrus cultivars. Returns to the grower are the primary focus, however, returns to organizations producing disease resistant cultivars are also modeled.

Introduction and Problem

Faced with the potential for devastating disease losses, the $2.7 billion US citrus industry (ERS 2007) has a vested interest in the development of citrus cultivars resistant to disease. Though this paper does not focus on a specific disease, two diseases are currently very important to the industry and exemplify the potential consequences to the citrus industry. Citrus greening (Huanglongbing) and citrus canker are diseases caused by bacteria. These diseases have been found in the U.S. (USDA/APHIS 2007, Schubert and Sun 2003). Both result in reduced tree life and fruit quality.

Neither of these diseases is curable in infected trees. Management and control programs, including the destruction of trees, have been established to diminish the impact these diseases have on the citrus industry but at great effort and expense. Estimated decreased revenue and increased costs attributable to the control of citrus canker in Florida, if it were to become endemic in grapefruit, are approximately $157 million annually (Spreen, Zansler, and Muraro 2005). Though citrus greening has not been found in Texas, the insect that spreads the disease has been. Should the disease occur in the Texas citrus industry and become widespread, it has been estimated that total business activity would decrease by approximately $69 million (Niemeyer et al 2007).

Disease resistance can be introduced to plants through genetic modification. No genetically modified disease resistant citrus cultivars are currently known to exist in the market. The innovation of disease resistant trees may be efficacious in addressing disease concerns in the citrus industry. By increasing disease resistance it is possible to increase the productive life of citrus trees. Adoption of such cultivars would increase the economic efficacy in the citrus industry.

Objective

The primary objective of this paper is to quantify the economic benefits to growers of hypothetical, disease resistant citrus cultivars. Benefits are noted in terms of changes in the probability of tree survival (decreased tree loss), net present value, and net cash income of a grapefruit grove. The secondary objective is to quantify the potential economic rents that will likely accrue to research for developing disease resistant citrus cultivars. Grapefruit is a significant citrus crop in Florida and Texas. Modeling a Florida grapefruit grove will exemplify the benefits of improved, disease resistant citrus cultivars. Florida is the number one producer of grapefruit, followed by Texas. Because diseases currently threaten the Florida citrus industry and are not generally an immediate problem in Texas, this study provides the opportunity to represent the current potential (Florida) and the future potential (Texas) for improved cultivars. The methodology will be generalizable to other citrus fruits in other parts of the country by changing crop and production variables to meet the specific conditions.

Methodology

This study stochastically models a production-based investment feasibility simulation (Richardson 2006) of a 15 acre[1] grapefruit grove over 11 years of establishment, maintenance and production. Establishment and maintenance costs for land clearing and tree setting are included in the initial year set and for trees reset annually to replace those that die in the previous year. The first three years of tree growth are non-bearing while trees bearing fruit are included for the fourth through eleventh year after being set.

The analysis focuses on citrus in Florida due to the vast amount of data readily available. Historical tree numbers, yields, and prices available from the USDA and weather data from the

[1] According to the 2006 FASS *Commercial Citrus Inventory*, the average parcel size for a citrus grove in Florida is approximately 15 acres.

NOAA will be utilized to stochastically model and forecast the citrus industry at the grove level. Annual citrus industry reports from the state of Florida (FCLRS 1965-1984, FASS 1986, FASS 1988-2006) will be utilized to estimate annual tree loss rates. Citrus prices will be modeled using historical data. Additionally, based on previous occurrences of hurricanes and freezes, probabilistic occurrence of these events will be incorporated into the model.

Expertise from industry representatives and academia will be utilized in estimating the potential productive life enhancements of improved citrus cultivars. Researchers at Texas AgriLife Research are investigating citrus cultivars, and their input will provide estimates of improvements in tree life. Florida Extension publications provide information regarding production practices and costs associated with grapefruit groves.

The base model for the current industry will be augmented to incorporate production cost, price, yield, and tree number forecasts and the estimated costs of improved cultivars. Scenarios from this model will be compared to models using hypothetical tree-life improvement rates.

Citrus producers face risk from current diseases and the choices they make in addressing disease concerns. Investment is required in adopting new cultivars and the risk associated with the choices growers have affects their decisions. Alternative royalty rates will be tested for the improved cultivars with varying degrees of tree-life improvement. Risk ranking will be carried out using stochastic efficiency with respect to a function (SERF) to evaluate the benefits of new cultivars to citrus growers. SERF allows for ranking the decision makers’ preferences among alternatives and at differing risk aversion coefficients (Hardaker et al 2004).

Data

Florida Agricultural Statistics Service (FASS)[2] *Commercial Citrus Inventory*[3] reports from 1965 through 2006 provide grapefruit tree numbers. Tree numbers were compiled as the number of trees by the year they were set to determine tree life. Tree censuses in these reports were performed biannually, so annual tree numbers were not available. Simple linear interpolation between existing data was used estimate the tree numbers for the missing years.

Inconsistencies in tree numbers were observed in both the actual and interpolated data. In some years, tree numbers for an age cohort increase. It is expected that as trees for a cohort age, the number of trees living will likely decrease over time or may remain unchanged. Adjustments were made to remove these types of inconsistencies in the data[4].

The resulting data set of trees by year set was utilized to calculate the percent decrease in trees per year of life. Because censuses were performed biannually, only one half of the census data had tree numbers available from the original year the trees were set while the other half reported trees at one year of age as the base. The tree loss percentage between tree ages was calculated rather than the proportion of trees surviving at each year of age. This provides the tree loss rate between the year set and age one, age one and age two, age two and age three, age three and age four, etc. The year-to-year death losses were used to calculate the survival/decline of the grove.

Freezes and hurricanes in Florida impact tree losses, thus historical information on the occurrence of these events was used to separate the tree loss data into two groups, "Normal Year" is defined as years in which neither a hurricane or freeze occurred. "Event Year" is used

[2] Reports from 1965 through 1986 were referenced as published by the Florida Crop and Livestock Reporting Service; further references will be made as "FASS" for either agency name.
[3] Prior to 1988, published as "Inventory of Commercial Citrus Acreage"; further references will be to both titles as "Commercial Citrus Inventory."
[4] For details, contact the authors.

to define years in which a hurricane or freeze occurred. Freezes occurred in January of 1971, 1977, 1981, 1983, 1985, and 1986 and in December of 1983, 1985, and 1989 (FASS 2006). Hurricanes occurred within a ten nautical mile radius of Florida grapefruit producing counties in 15 years between 1960 and 2005 (U.S. Dept. of Commerce 2007).

Historical price and yield data for grapefruit were obtained from the USDA ERS Fruit and Tree Nuts Situation and Outlook Yearbook (Pollack and Perez 2007). Historical prices (equivalent on-tree prices) were obtained for fruit sold as fresh and processed.

Grove establishment and maintenance costs were obtained from the University of Florida, Institute of Food and Agricultural Sciences report, "Budgeting Costs and Returns for Indian River Citrus Production, 2004-05" (Muraro and Hebb 2005). Data were excerpted regarding production costs including variable costs for land preparation, tree planting, and maintenance for the first three years of life. Muraro and Hebb (2005) data was used to estimate management and irrigation equipment costs as well as property taxes used in the model. Tree prices have increased dramatically since the implementation of new budwood regulations, and a price of $8.00 per tree is used (Kesinger 2007).

Model

The citrus model in this paper is for analyzing a new 15 acre grove from establishment through eleven years (2007 through 2017) of maintenance and production. In the model, trees are reset annually and tree density is maintained at 117 trees per acre. Accounting equations to calculate receipts, expenses, cash flows, and balance sheet variables use the stochastic values from the probability distributions of the risky variables (tree loss rates, hurricanes and freezes, yields, prices, and percentage of harvest to processing).

The modeled tree-loss rates, receipts, expenses, cash flows and balance sheet produce three key output variables (KOVs) of interest in the model. The first KOV is annual tree-life improvement from improved grapefruit cultivars. This KOV is modeled as probability distributions for tree survival using assumptions about the new culitvars. The second KOV is net present value (NPV) and is used to rank the scenarios to determine which is preferred by risk averse decision makers. The third KOV, annual net cash income (NCI) is total cash receipts minus total cash expenses.

Using historic tree numbers (FASS 1965 through 2006), stochastic tree loss rates for a ten year period were modeled as ten stochastic variables distributed univariate empirical. An empirical distribution was utilized because it assigns probabilities of occurrence (proportion of tree losses) from the actual data, much like a frequency chart. Separate tree loss probability distributions were calculated for Normal and Event Years. The probability of a hurricane or freeze occurring was calculated to be 32.61 percent (FASS 2006, U.S. Dept. of Commerce 2007) and was simulated as a Bernoulli distribution in the model to forecast tree losses in Event Years.

Projected means for the stochastic prices, yield, and the fraction of the harvest to processing were calculated from the USDA ERS Fruit and Tree Nuts Situation and Outlook Yearbook (Pollack and Perez 2007). A multivariate empirical (MVE) distribution was used to simulate stochastic prices, yield, and the fraction of harvest for processing in the model. The MVE distribution accounts for correlation among the variables (Richardson, Klose, and Gray 2000). A trend was observed in much of the historical data, so the MVE distribution was calculated using percentage deviations from trend.

Three production scenarios (Muraro and Hebb 2005) were simulated using a GRKS distribution (Richardson 2006) and are used for annual grove costs in the model, less the tree, irrigation, and reset costs (which are included separately).

Forecasts from the Food and Agriculture Policy Research Institute (FAPRI 2007) were used to include inflation factors for inputs and costs in the model. The model includes tables for depreciation, income tax, and loan amortization. The rents, in the form of royalties, which accrue to research organizations that develop genetically modified, disease resistant citrus cultivars were specified for each scenario in the model. Table 1 provides a summary of the model assumptions.

The base scenario assumes use of traditional cultivars with no royalties per tree (table 2). This scenario provides the base against which to compare alternative scenarios of grapefruit cultivars with improved tree-life (reduced annual tree losses) and varying royalty rates for the improved cultivars.

Scenario two estimates the grove’s performance based on a 25% reduction in annual tree losses and a $0.50 one-time, per tree royalty. This effectively increases the cost by $0.50 per tree, but this value is not inflated over the forecasted years in the model.

Scenario three differs from scenario two only in that instead of a one-time, per tree royalty, the royalty rate is set at $0.055 per tree annually. The rationale for this rate was that rather than charge a one-time royalty, the institution or organization receiving the royalty may desire to charge a lower royalty up front, but recoup the royalty over the life of the tree. The royalty per tree per year is based on a 10 year period to recover a return equivalent to a per tree royalty ($0.50 per tree) and includes a 10% premium to cover administration costs borne by the royalty receiver. Producers may find such an annual royalty scenario enticing as it reduces initial tree purchase expenses and they pay royalties only while the tree is alive. Research organizations earning royalties may find an annual royalty desirable for generating revenue over a longer period of time, even beyond the 11 years in this model.

Scenario four has the same structure as scenario two, except the improvement in tree life used in this scenario is a 50% reduction in annual tree losses from the base. The royalty rate is set at $1.00 per tree.

Scenario five follows the structure of scenario three. The annual per tree royalty is $0.11, or $1.00 royalty per tree recoverable over 10 years plus a 10% premium for the royalty receiver. As with scenario four, the tree-life improvement is 50%.

Results

Tree loss rate distributions for three scenarios (no improvement, 25% improvement, and 50% improvement) were calculated empirically as the decrease in trees from year to year. Figure 1 provides the probability distributions for each of these scenarios by tree age (after being set). As the tree-life improvement rate increases, the right-hand tail and mean tree-loss rate of the probability distribution decreases.

Net present value (NPV) provides the present value of returns to the investment over the modeled life of the grapefruit grove. Table 3 provides a summary of NPV simulation results. Analysis of NPV across the royalty and tree-life improvement rates was performed using SERF analysis assuming a power utility function (see figure 2). Relative risk aversion coefficient (RRAC) upper and lower limits were set at 0.00 and 4.0 respectively to capture the effects of the scenario analysis for growers who range from risk neutral to very risk averse. Based on the SERF rankings, the most preferred scenario with respect to NPV was Scenario 5 ($0.11 per tree per year, 50% tree-life improvement) followed by scenario 4 ($1.00 per tree, 50% tree-life improvement), scenario 3 ($0.055 per tree per year, 25% tree-life improvement), then by scenario 2 ($.50 per tree, 25% tree-life improvement). Scenario 1 (no royalty, no tree-life improvement) was the least preferred scenario. These rankings are constant across all levels of risk aversion so the results are robust for all risk averse decision makers.

As expected, the scenario offering the greatest tree-life improvement was most preferred. Although the royalty rate for this scenario ($0.11 annually) was greater than the alternative scenario 3 ($0.055 annually), the tree-life improvement was twice that of scenario 3. This indicates that doubling the improvement rate more than offset doubling the royalty rate.

Figure 3 is a StopLight Chart that shows the probabilities of NPV for each scenario being greater than the base scenario's mean NPV (- $119,481). The probability that NPV will exceed scenario 1's mean NPV increases for each scenario from scenarios 2 to 5. For the most preferred scenario (scenario 5) there is a 63 percent probability of NPV being greater than the base scenario's mean NPV, indicating a 16 percentage point improvement over the base scenario.

Net cash income (NCI) represents cash income which exceeds cash expenses. The model simulates a grove's NCI for an eleven year period: establishment and 10 subsequent years of management and production. The first three years after establishment are assumed to be non-bearing, meaning no fruit is produced as the trees mature.

Annual NCI is used to determine the annual flow of returns to the grove. The likelihood of positive NCI over the period is low; however of interest is comparing the improvement attainable by new cultivars. Improved NCI was observed for each alternative scenario with scenario 5 having the highest probability of positive NCI over the seven years of fruit production.

A fan graph was also created to visually represent the NCI for the least and most preferred scenarios (scenarios 1 and 5 respectively). The average, and confidence intervals about the average, NCI for scenario 5 have a higher probability of positive NCI and lower probabilities of negative NCI than scenario 1 (figure 4).

Research organizations invest resources to develop disease resistant cultivars, license rights to cultivars developed from their research, and collect royalties on licensed cultivars. For growers, results indicated that an annual royalty was preferred to one-time royalties.

Total royalty payments over the 11 years of the model were calculated to compare the annual and one-time royalty returns to research organizations. Because the reset interval was annual, the original number of trees each year of the model was maintained. By doing this, the annual royalty scenarios result in a constant royalty each year. The one-time royalties on trees set each year are stochastic variables based on the probabilistic tree-loss rates and vary from year to year based on that distribution. Grower royalty expenses are returns to research organizations and were used to compute probabilities of the one-time royalties being greater than the annual royalties. Scenario 2 (25% improvement, $0.50 one-time per tree royalty) had a 58.9 percent probability of total royalty payments being greater than total royalty payments for scenario 3 (25% improvement, $0.055 annual per tree royalty). Scenario 4 (50% improvement, $1.00 one-time per tree royalty) had a 27 percent probability of total royalty payments being greater than total royalty payments for scenario 5 (50% improvement, $0.11 annual per tree royalty).

Summary and Conclusions

Probabilistic annual tree loss rates were calculated and provided the base against which to compare decreases in tree loss rates achievable by the introduction of genetically modified cultivars. Five scenarios were modeled to determine the most preferred combination of tree-life improvement and royalty rate. Using relative risk aversion coefficients for growers who range from risk neutral to very risk averse, scenario 5 (50% tree-life improvement and $0.011 annual royalty) was the most preferred for all levels of risk aversion. The scenarios that incorporate an annual royalty were preferred to scenarios with the same tree life improvement rate and one-time royalties. This result is largely due to the lower up front investment required in these scenarios.

Research organizations have interest in royalties, and the greater the improvement in tree-life improvement, the greater their royalty potential. Normal royalty schemes with one-time charges as well as annual royalty schemes were modeled . Total royalties in the preferred scenario (with an annual royalty schedule) was greater than that for the second most preferred scenario (with a one-time royalty schedule).

Future research is needed to evaluate tree-life improvements of actual improved cultivars as they move from hypothesis to reality. Other research may evaluate consumer acceptance of fruit from genetically modified trees which would provide another useful tool for growers and research organizations.

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Table 1. Model Assumptions

Assumption	Value
Grove Establishment Year	2007
Grove Acreage	15
Trees Per Acre	117
Reset Interval	1 year
Tree Cost (per tree)	$ 8.00
Land Value/acre	$ 10,000
Beginning Cash	$ 100,000
Property Taxes/acre	$ 50
Management Cost/year/acre	$ 48.00
Irrigation Equipment Cost/acre	$ 600.00
Establishment Loan	
Amount borrowed	$ 45,000
Interest Rate	9.5%
Duration (years)	20
Equipment loan	
Amount borrowed	$ 9,000
Interest Rate	8%
Duration (years)	10 years
Operating Loan	
Fraction of cost	.45
Wedge	.06
Discount Rate	.09
Depreciation Schedule	MACRS
Income Tax Rate	Corporate

Table 2. Scenarios for Modeling Grove Costs and Returns

Scenario	Annual Tree-Life Improvement	Royalty Schedule
1	Base scenario – no tree-life improvement	No royalty
2	25% reduction in annual tree loss	$0.50 one-time per tree
3	25% reduction in annual tree loss	$0.055 annually per year
4	50% reduction in annual tree loss	$1.00 one-time per tree
5	50% reduction in annual tree loss	$0.11 annually per tree

Table 3. Summary of Net Present Value for Five Scenarios

	Scenario				
	1	2	3	4	5
Royalty Rate	0	$0.50 One-Time	$0.055 Annual	$1.00 One-Time	$0.11 Annual
Tree-Life Improvement	0	25%	25%	50%	50%
Mean	- $ 119,481	- $ 116,217	- $ 116,001	- $ 112,772	- $ 112,429
Min	- $ 159,787	- $ 157,076	- $ 156,869	- $ 154,285	- $ 154,001
Max	- $ 63,124	- $ 61,117	- $ 60,997	- $ 59,078	- $ 58,862
Std. Dev.	17,947.72	17,607.03	17,578.56	17422.53	17390.62

Table 4. Total Royalties through 10 Production Years

	Scenario			
	2	3	4	5
Royalty Rate	$0.50 One-Time	$0.055 Annual	$1.00 One-Time	$0.11 Annual
Tree-Life Improvement	25%	25%	50%	50%
Mean	$ 1,096.26	$ 1,061.78	$ 2,056.71	$ 2,123.55
Min	$ 938.00	$ 1,061.78	$ 1,841.00	$ 2,123.55
Max	$ 1,418.00	$ 1,061.78	$ 2,485.00	$ 2,123.55
Std. Dev.	85.96	N/A	114.17	N/A
P(Mean One-Time > Mean Annual)	0.589	N/A	0.270	N/A

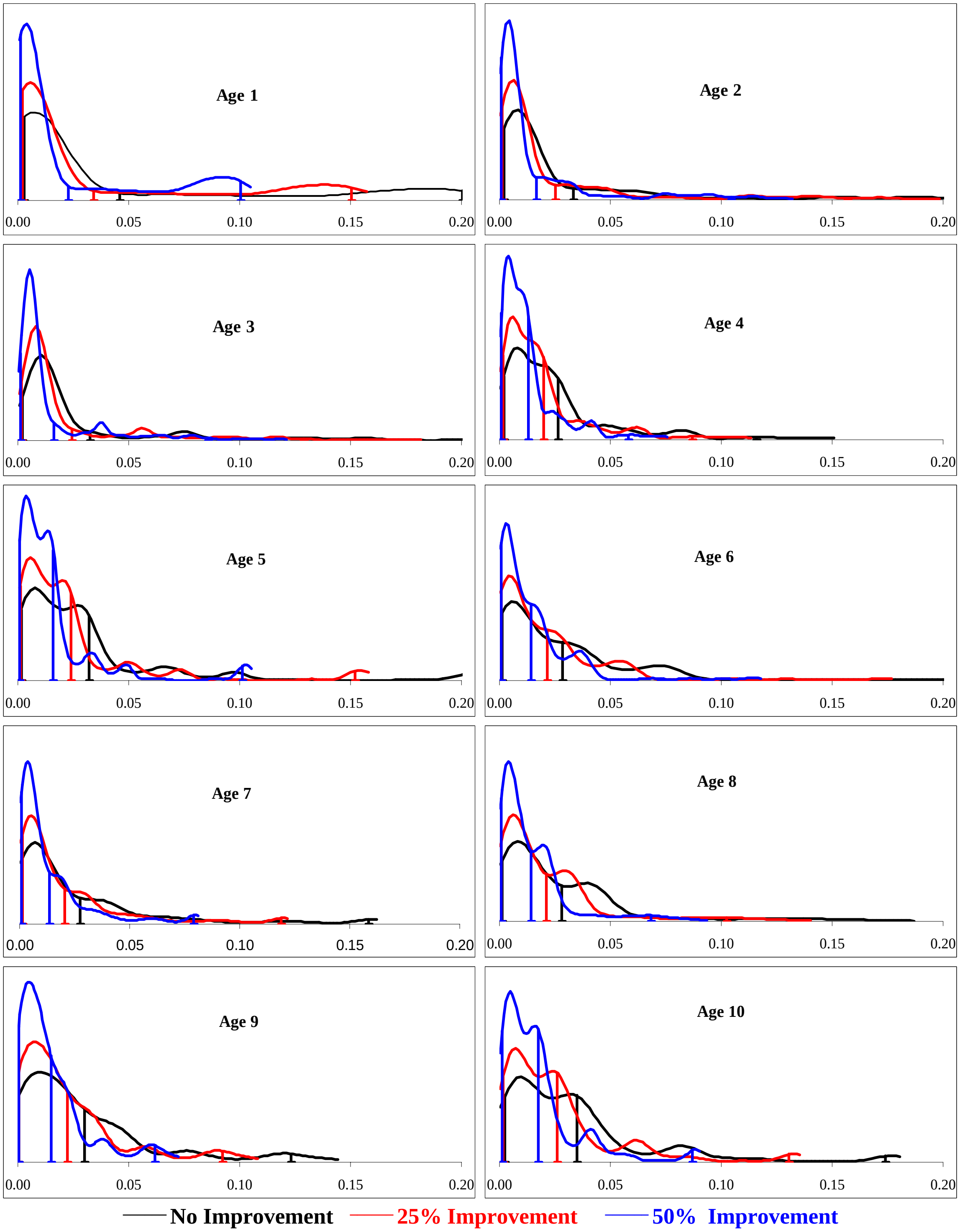

Figure 1. PDF Approximations of Tree Loss Rates by Tree Age

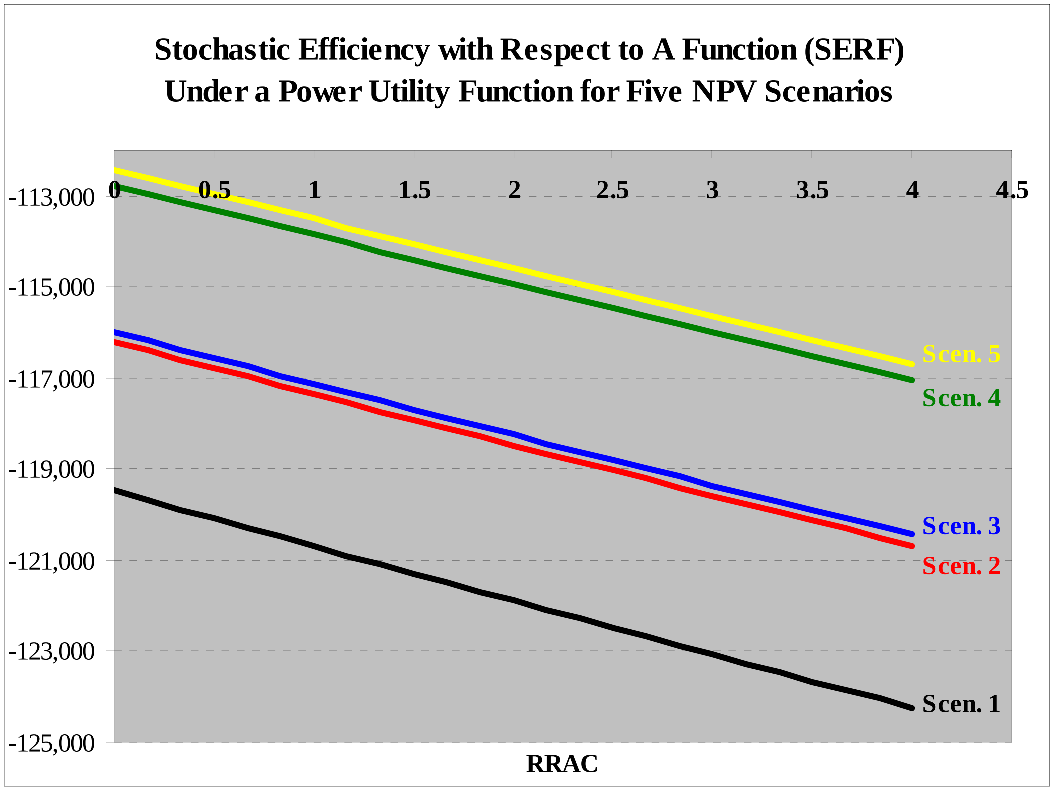

Figure 2. SERF Analysis Output Chart for NPV

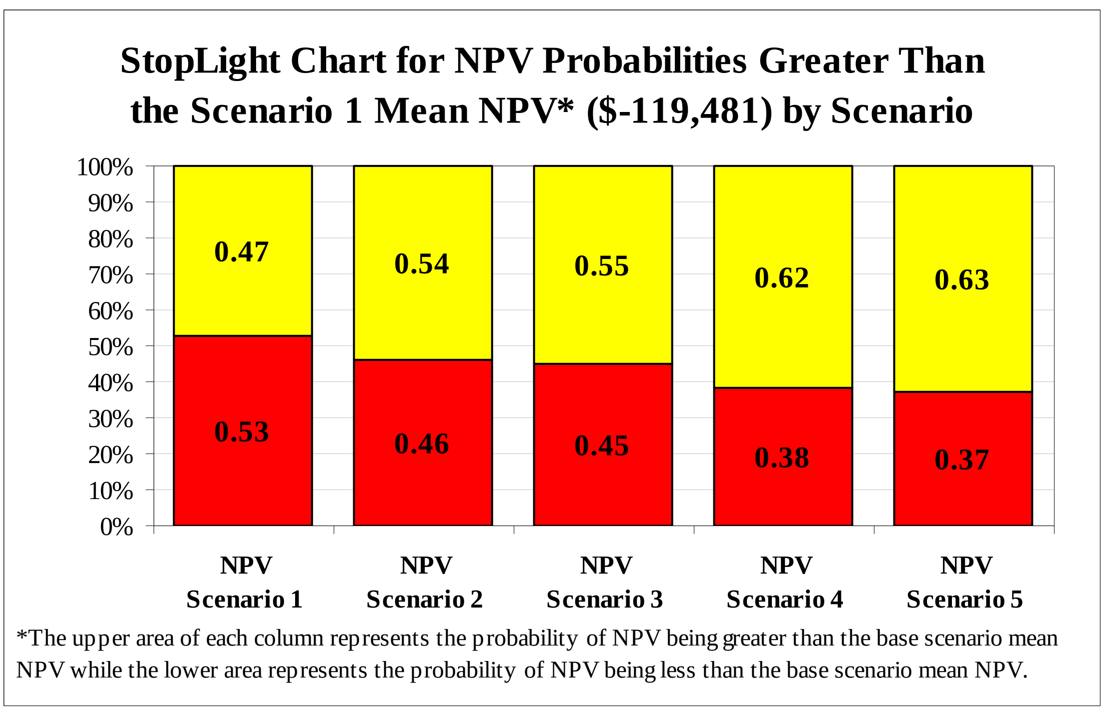

Figure 3. NPV StopLight Chart for Five Scenarios

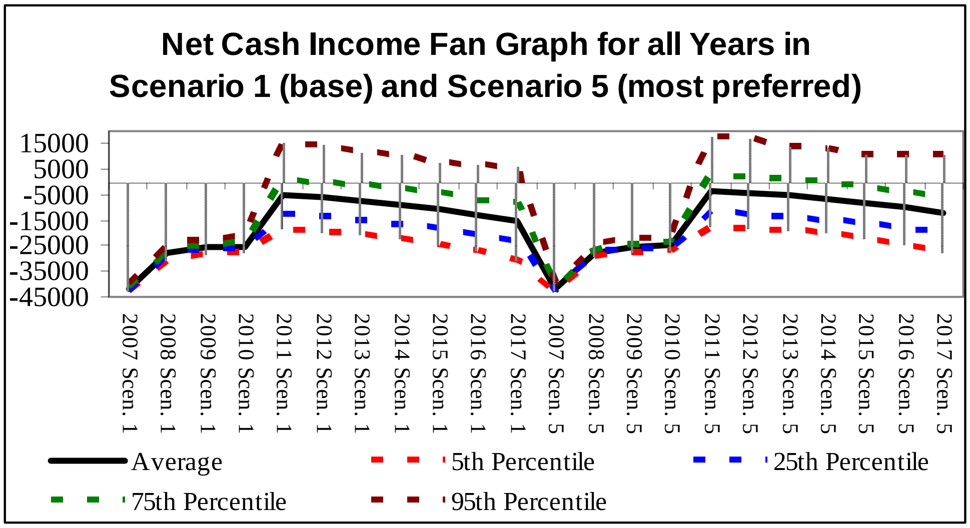

Figure 4. Fan Graph of NPV for Scenario 1 and Scenario 5