Evaluation of Risk Management Methods for Satsuma Mandarin

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ABSTRACT

Simulation of production budgets were used to compare net discounted returns and the distribution of returns under alternative risk-mitigation scenarios. Results indicate that the combination of freeze protection and crop insurance increases expected net discounted 20-year returns while decreasing the downside risk. Break-even prices ranged from \$.257 to \$.289 per pound. Crop insurance returns were constant across price.

Key words: Satsuma oranges, freeze protection, crop insurance, production budget, simulation

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Satsuma Mandarins are a type of citrus that is grown in the United States in the northern Gulf Coast area, from Texas to Florida, and in Arizona and California. The Gulf Coast area of the United States is desirable for production because the warm temperate-zone growing conditions allow for good tree growth and the relatively cool fall temperatures allow for good fruit quality development. Satsuma fruits mature between mid-October and mid-December. While fruit may be held on the tree beyond late December, prices are highest during the holiday season and hence most harvesting is completed then.

Planting a Satsuma orchard requires a considerable monetary investment. Because trees do not bear fruit for several years, the long-term profitability of the enterprise depends critically on the expected life of the investment. The greatest production risk to citrus crops in the United States is damage caused by freezes (Elmer, et al., 2001). For a Satsuma orchard, a moderate freeze can cause producers to lose a year of fruit production. If the freeze damage is severe enough, however, tree death can ensue, destroying the investment value of the grove and requiring replanting. Methods of risk protection can include physical means to protect trees against damage or they can involve financial protection, such as insurance. An important question for producers is how the use of risk protection methods will affect both expected net returns and the downside risk.

The introduction of random processes into a decision-making process means that standard budgeting techniques will be inadequate for a thorough assessment of a potential investment. Various techniques have been employed to evaluate investments under conditions of risk or uncertainty, including both mathematical programming techniques that account for mean and variance of returns (e.g. Featherstone and Moss, 1990) and Monte Carlo simulation (e.g. Richardson and Mapp, 1976). Unlike mathematical programming, simulation models generally do not have an objective function to optimize. Rather, either an objective or subjective probability distribution is specified for key random variables affecting the likely profitability of the investment (Jones, 1972). Using the specified distribution function, pseudo-random numbers are drawn and entered into the calculations of the expected net present value for that iteration. Through repeating the process, a probability distribution for the net present value of the investment can be calculated, allowing the potential investor to assess both the expected profitability of the investment and its risk.

The purpose of this paper is to evaluate risk management techniques for freeze risk in Satsuma mandarin (*Citrus unshiu* Marc.). The economic benefit of micro-jet sprinklers will be evaluated, with and without the availability of a hypothetical crop-insurance program. Simulation techniques will be used to compare net discounted returns and the distribution of returns (minimum, maximum, standard deviation) under alternative risk-mitigation scenarios. Break-even prices, or the price at which mean, discounted 20-year returns equal 0, will also be calculated for each scenario.

Background

Satsumas have been produced in southern Alabama since the early 1900's (Ebel, et al., 2004). Several years of severe freezes in the 1930s and 1940s, however, all but wiped out the industry (Winberg, 1948a, 1948b, 1948c). More recently, micro-sprinkler freeze protection has somewhat mitigated the risks from freeze loss (Nesbitt, et al., 2000), resulting in renewed interest in Satsuma production in southern Alabama (Ebel, et al., 2005).

The use of micro-sprinklers within a tree canopy reduces tree loss from freezes (Ebel, et al., 2004). During a freeze, micro-sprinklers protect the trunk and major scaffold branches through the release of the latent heat of fusion as the water spray freezes (Nesbitt, et al., 2000). In the south Alabama region, freeze protected trees that experienced extensive canopy damage were able to return to full production the year following the freeze event (Nesbitt, et al., 2000). The protected trees will thus miss a year of production while canopy re-growth occurs, but the grove will not need to be replanted (Bourgeois and Adams, 1987; Bourgeois, Adams, and Stipe, 1990; Nesbitt, et al., 2000). Because micro-sprinkler freeze protection does not extend to the outer canopy, freeze events that cause damage to leaves, or leaves and stems, will have the same effect on both protected and unprotected mature trees.

Methods

A Monte Carlo simulation was performed for each of four production scenarios for a 20-year period. The scenarios were: No crop insurance and no freeze-protection (NP_NI), no insurance and freeze protection (P_NI), insurance with no freeze protection (NP_I), and both insurance and freeze protection (P_I). A discount rate of 6 percent was used in the analysis.

A one-acre Satsuma grove was the unit of study. The orchard was assumed to be planted in March of the first year or in March of any year requiring replanting because of a freeze. Basic assumptions used in the simulations are presented in table 1. A planting density of 116 trees per acre with Satsuma 'Owari' on 'Rubidoux' trifoliate orange rootstock was assumed, based on typical practices in South Alabama. Because there will be some expected tree death, even in years with no adverse weather events, 12 trees are assumed to be replanted in year 2.

Yields used in the simulation were based on data for an 'Owari' Satsuma mandarin grove, collected by the Alabama Agricultural Experiment Station Gulf Coast Research and Extension Center at Fairhope, Alabama. Yield data used to form the yield assumptions used in this study span 16 years, from initial planting in 1990 through crop harvest 2005-06. Trees bear no fruit during the first two years of growth, and afterwards, yields increase each year until reaching a maximum average of 400 lbs per tree in the 9th and subsequent years of production (table 1). The base price used in the simulations is $10.00 per bushel or $0.25 per pound.

Production costs were derived from a Satsuma enterprise budget developed by Hinson and Boudreaux (2006) for Louisiana producers. Land preparation is assumed to cost $100 per acre and trees are assumed to cost $8.00 each. Labor for planting and layout is assumed to require 24 hours per acre in year 1, and 3 hours per acre in year 2 for the required replanting. An hourly rate of $9.60 for the labor is assumed. In the second year, one hour of labor is required to remove the small amount of unmarketable fruit from the trees.

The assumed annual direct costs are also reported in table 1 and include such items as pest control costs, fertilizer, fuel, repair and maintenance, and labor. These direct costs also vary with the age of the grove, generally becoming stable in year 5.

In addition to the costs listed in table 1, there will also be harvest costs in the years that the trees bear marketable fruit. These costs include labor for harvesting, grading, and packing, packing line electricity, field boxes, packing boxes, and packing line repairs. Field boxes require an initial outlay of $600 per acre (50 boxes costing $12.00 each). In subsequent years, it is assumed that 10 replacement boxes are purchased at $12 each. Packing line repairs are assumed to cost $50 per acre for all groves aged 3 years or more. Other harvest costs vary with yield. Harvest labor is assumed to cost $2.25 per bushel. Packing boxes are assumed to cost $1.25 per bushel. Grading and packing line labor needs, as well as packing line electricity, are also assumed to increase as yield increases. Electricity is assumed to cost $.12 per kwh, and the packing line is assumed to need 175 kwh/ac in years 3 and 4, and 210 kwh thereafter. Each bushel of fruit requires approximately 0.3 hours of grading and packing labor, which costs $9.60 per hour.

The freeze protection system modeled, developed from information supplied by the Fairhope Experiment Station, is a micro-sprinkler irrigation system with one emitter per tree situated in the canopy 5-feet above ground. The emitter delivery rate assumed is 30-gph. The study is modeled using one 4" well system with a 60-gpm capacity for each acre. During a freeze, the systems must operate continuously for all acreage to be protected. The cost of freeze protection includes a well and below ground costs of $6,350 per acre amortized at 6-percent over the 20-year period, above ground costs of $185 that are replaced every 4 years (amortized at 6-percent over each 4 year period), and a $25 per year maintenance charge. With these assumptions, the total cost of micro-jet freeze protection charge is $632 per acre per year, whether or not there is a freeze event. Variable costs of $35 are added to freeze protection in years when a freeze occurs.

Freeze Events

The random variable in the analysis is the probability of a freeze event and its severity. Based on historical levels of tree acclimation to cold in this region, the threshold for economically important injury is between 18 and 22 ^{o}F (-7 to -5 ^{o}C) (Ebel, et al., 2005; Nesbitt, et al., 2000; Nesbitt, et al., 2002). At 14 ^{o}F (-10 ^{o}C), stem dieback will occur and whole trees are susceptible to death if they are not fully hardened off. Temperatures below 12 ^{o}F (-11 ^{o}C) have historically resulted in tree death for unprotected trees.

Daily temperature data from 1948 through 2006 were obtained from the weather station located at the Fairhope Experiment Station. Economically important freezes were determined through a prediction formula developed by Ebel, et al. (2005) and compared to field observations for severity rating. These ratings were used to calculate probabilities of economically damaging freeze occurrence in the Fairhope, Alabama area. Freeze severity ratings are: 1) Slight – some injury to leaves, 2) Moderate – extensive leaf damage and some stem dieback and 3) Severe – widespread tree death. Only moderate and severe freeze events are considered economically important in this study.

Based on this information, annual freeze probabilities used in this study were 14-percent for a severe freeze and 11-percent for a moderate freeze. If both a severe and moderate freeze event occurred in the same growing period, only the severe freeze was counted for probability calculation purposes. Without freeze protection, trees were assumed to lose one crop year if a moderate freeze occurs, and were assumed to die and to be replanted if a severe freeze occurs. With freeze protection, trees were assumed to respond to both severe and moderate freezes with the loss of the fruit crop in that year. Although it is possible that two severe freezes could occur in one year, these events are not likely and variable costs for freeze protection are thus assumed to be incurred only once per season. Because producers may not have perfect knowledge in advance of the severity of a freeze, the variable costs of freeze protection ($35 per acre) are incurred in years with either a moderate or a severe freeze.

Crop Insurance

Federal crop insurance is not currently available for Satsumas in Alabama. Development of insurance policies for specialty crops is a priority for the USDA Risk Management Agency (USDA, Risk Management Agency, 2004), however, and it is therefore possible that such policies will be available in the future.

Policies for tree crops are of two types, those that insure the trees and those that insure the fruit. The hypothetical crop insurance policy for tree coverage used in this study was modeled after an existing policy and actuarial tables for early to mid-season orange trees in Cameron County, Texas (USDA-RMA, 2008b, and 2008c). Base indemnities were taken from the Texas Citrus I policy actuarial tables. The tree policy has a fixed liability per acre with a graduated indemnity rate that reaches its maximum if loss occurs during the fifth and subsequent growing seasons. This graduated indemnity schedule reflects both a decreasing risk of tree damage due to freeze injury and an increasing value of the tree as the tree matures. The model uses a 65-percent coverage level for the tree crop insurance policy.

The fruit policy was modeled on the existing policy for mandarin fruit in Riverside County, California (USDA-RMA, 2008a, and 2008c). The fruit crop insurance policy uses a 65-percent coverage level. The grove cannot be insured against fruit loss until the sixth growing season, because of low fruit production in the early years. The fruit policy indemnity is based on the grove's actual production history (APH) with a minimum of four building to ten years of yield history. Yields for loss years were replaced with a yield adjustment value equal to 60-percent of the transitional yield of 430 25-pound cartons per acre. In the first year of insurance coverage (sixth growing season), there were three actual or replacement yields and one transitional yield. Transitional yields were not used in APH calculations for subsequent years. Total liability per acre was calculated by multiplying the APH by the price election of $5.70 per 25-pound carton by the 65-percent coverage level.

Premium rates for the Texas Citrus I crop insurance policies could not be used for these scenarios because of differences in freeze risk exposure (Elmer, et al., 2001). The Risk Management Agency rate setting procedures are normally based on county/state indemnity experience for a particular crop (Schnapp, et al., 2000). Without any indemnity history, different methods need to be employed to determine a rate. In this study, base insurance premiums were calculated to produce a 1.00 premium to loss ratio based on the simulated loss experience with the given freeze probabilities. A catastrophic load was added to the base premium by dividing it by .88. The insured grove was assumed to have only one basic unit. With these assumptions, and the deduction of the government premium subsidy of 59 percent for the 65-percent coverage level, a producer premium of $155 per acre was used for the tree policy and a producer premium rate of $0.128 per dollar of liability per acre was used for the fruit policy.

Insurance premiums were assumed not to be due for the tree policy in the initial year of the simulation because the policy period is from November 21 to November 20 and trees were not planted until March. In all scenarios, freezes were assumed to occur between December and March of the policy year. There was no premium due nor indemnity calculated during the first 5 years in the P_I scenario. If micro-jet freeze protection is in place, producers will not need the tree insurance policy and will elect only the fruit insurance. If no micro-jet freeze protection is in place, producers are assumed to opt only for the tree insurance. Thus, the two scenarios with insurance (P_I and NP_I) employ different assumptions about the type of insurance in place.

Simulation Models

The simulation models were developed in Microsoft Excel. A 20 (years in the planning horizon) by 500 (number of iterations) array of pseudo-random numbers was generated using the RAND function. The array of pseudo-random numbers was held constant across all four scenarios. If the value was above the threshold value for a severe freeze, a severe freeze was indicated by an integer value. If the number fell between the threshold for moderate and severe freezes, a moderate freeze was indicated using a different integer value. In scenarios without freeze protection, trees were assumed killed and replanted in the event of a severe freeze. For both protected and unprotected trees, a moderate or severe freeze would result in no fruit to sell. In the absence of a freeze event, age of the tree determined the yield, using the values in table 1.

The discounted total net returns equation for the base scenario NP_NI is:

$$(1) \qquad NR_d = \sum_{j=1}^{20} [(PY_j(f, t) - C_j(t) - X_j(y)) / (1+r)^j]$$

where NR_d = total discounted net returns, j = the simulation year, f = freeze event, t = tree age, P = market price for fruit, $Y_j(f, t)$ = yield in the jth year as a function of freeze event and tree age, $C_j(t)$= fixed and direct costs in the jth year as a function of tree age, and $X_j(y)$ = variable costs as a function of yield in the jth year, and r = the discount rate. This equation is modified for the different scenarios as follows:

$$\text{(2)} \quad \text{P\_NI:} \quad NR_d = \sum_{j=1}^{20} [(PY_j(f(cp), t) - C_j(t) - CP - X_j(y)) / (1+r)^j]$$

$$\text{(3)} \quad \text{NP\_I:} \quad NR_d = \sum_{j=1}^{20} [(PY_j(f, t) + I_j(f, t) - C_j(t) - CI_j - X_j(y)) / (1+r)^j]$$

$$\text{(4)} \quad \text{P\_I:} \quad NR_d = \sum_{j=1}^{20} [(PY_j(f(cp), t) + I_j(f) - C_j(t) - CP - CI_j - X_j(y)) / (1+r)^j]$$

where the terms described above are applicable and CP = the fixed cost of freeze protection, f(cp) = freeze event as a function of freeze protection, $I_j(f, t)$ = the insurance indemnity in the jth year as a function of freeze event and tree age, CI_j = cost of crop insurance policy in the jth year, and $I_j(f)$ = insurance indemnity in the jth year as a function of freeze event. For each scenario, results of the 500 iterations were summarized using mean, standard deviation, range, and the percentage of times that the 20-year discounted returns fell below zero.

Results

Summary statistics for the simulations are presented in table 2. At a price of $.25/pound, no scenario resulted in a positive mean, discounted 20-year return. Returns ranged from -$1,889 (P_I) to -$6,235 (NP_NI). The lowest standard deviation of returns occurred when both freeze protection and crop insurance were in use, while the highest standard deviation occurred when neither insurance nor freeze protection was used. In all scenarios, the bulk of the iterations resulted in negative 20-year discounted returns, ranging from 84 percent (NP_I and NP_NI) to 97 percent (P_NI and P_I). The pattern of results was not sensitive to choice of the discount rate except for the P_I scenario. When a discount rate of 3 percent was tested, the mean, discounted net returns remained negative for all other scenarios; the outcome became positive, however, with both freeze protection and crop insurance.

Results for the simulation using a price of $0.30/pound are also presented in table 2. At this price, mean, discounted net returns are positive in all scenarios, with the highest net returns accruing to the grove that has both crop insurance and freeze protection. This scenario also has the lowest standard deviation and zero percentage of iterations with negative returns. Hence, results of this study indicate that the combination of freeze protection and crop insurance boosts expected net returns while decreasing the downside risk.

Finally, break-even prices per pound of fruit for each scenario are reported. The break-even price is the price at which the mean, discounted 20-year returns is 0. For these calculations, a 6 percent discount rate was used. Break-even prices range from $.257 (P_I_) to $.289 (NP_NI).

Sensitivity Analysis

A sensitivity analysis on Satsuma price was conducted. The four scenarios were simulated using prices ranging from $.20 per pound to $.50 per pound. Results, in terms of expected discounted returns are summarized in figure 1. As prices rise, freeze protection, both with and without insurance, becomes increasingly valuable. This result occurs because of the large capital investment needed for the freeze protection system and the resulting higher total production of marketable fruit. Groves with freeze protection thus will benefit more from an increasing market price situation than unprotected groves, which will have a lower 20-year yield over the time-period because of replanting.

Without freeze protection, the use of the fruit crop insurance results in an increase in the mean discounted, 20-year net returns of about $1,915. With freeze protection, the tree policy results in an increase of about $3,413. Because the insurance indemnity was constant across price levels, the net benefit of crop insurance did not change as market price increased. A break-even producer share of tree insurance premium was found to be $337 per acre, and the break-even producer share of fruit insurance premium was found to be $0.253 per dollar of liability.

Discussion

Information obtained from this study should be useful in the decision-making process for current and potential Satsuma producers in the northern Gulf Coast region of the United States and, more generally, to all enterprises facing decisions between the use of self-insurance measures and market insurance for risk management. Installing freeze protection systems is costly, with the initial investment for the system being three times greater than the initial investment for planting the grove. However, with the freeze probabilities used in this study, producers could benefit from freeze protection investment as long as Satsuma prices remain above break-even levels.

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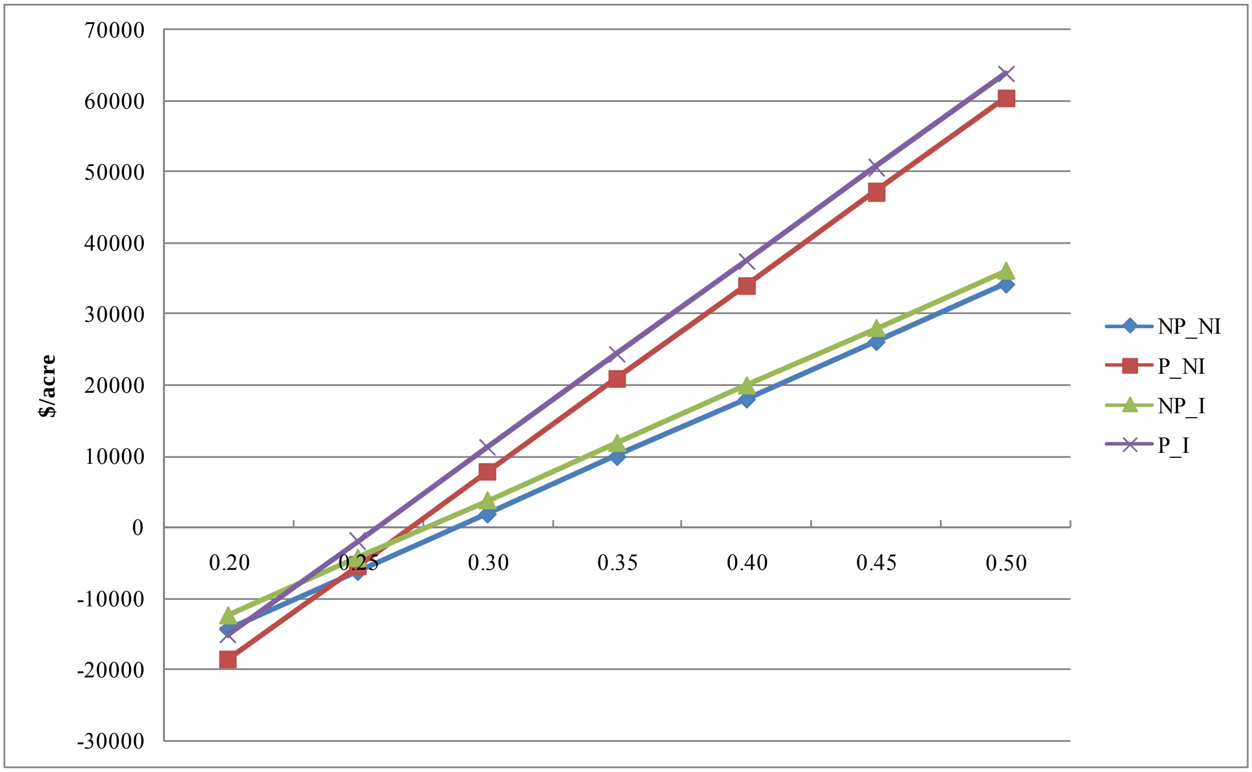
Figure 1. Discounted 20-Year Net Returns for 1 Acre of Satsuma Mandarins under Varying Prices and Risk Management Scenarios



Farmgate Price $/lb

Table 1. Basic Assumptions Used in Simulations, by Year

	Unit	Leaf Year									Rate
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**	
Yield	lb/tree	0	0	70	120	190	250	350	350	400	$0.25
Yield	bu/acre	0	0	203	348	551	725	1015	1015	1160	$10.00
Establishment Costs											
Land Preparation	$/ac	100									1
Plants	no/ac	116	12								$8.00
Labor- layout& plant	hr/ac	24	3								$9.60
Labor- strip fruit	hr/ac		1								$9.60
Direct Costs											
Pest/Disease/Weed	$/acre	91.24	260.41	368.47	542.25	555.61	555.61	555.61	555.61	555.61	1
Fertilizer (13-13-13)	cwt/ac	2	6	4	9.2	11.5	11.5	11.5	11.5	11.5	$15.50
Fuel	gal/ac	40	20.6	26.3	29.3	28.5	28.5	28.5	28.5	28.5	$2.23
Repair/maintenance	$/ac	60.00	38.00	45.00	55.00	55.00	55.00	55.00	55.00	55.00	1
Operator labor	hr/ac	16.8	10.4	13.2	11.8	11.45	11.45	11.45	11.45	11.45	$15.30
Other labor:											
Pruning	hr/ac	4.5	4	5	1.5	6.5	6.5	6.5	6.5	6.5	$9.60
Fertilizing	hr/ac	5	8	7	7	7	7	7	7	7	$9.60
Scouting	hr/ac		5	6	18	20	20	20	20	20	$9.60
Micro-jet maintenance*	hr/ac	3	3	3	3	3	3	3	3	3	$9.60
Irrigation maintenance	hr/ac	10	10	10	10	10	10	10	10	10	$9.60

* No cost incurred if grove does not have micro-jet protection

Table 2. Simulation Results for One Acre Satsuma Grove, South Alabama Area, 500 Iterations, 20-Year Horison and 6 Percent Discount Rate

	Unit	No Protection No Insurance	Protection No Insurance	No Protection Insurance	Protection Insurance
		Price = $0.25/lb			
Mean discounted 20-year returns	$/ac	-6,235	-5,301	-4,320	-1,889
Minimum discounted 20-year returns	$/ac	-17,233	-15,407	-12,056	-7,991
Maximum discounted 20-year returns	$/ac	9,504	2,255	7,872	734
Percentage of iterations with negative returns	%	84.0	97.0	84.2	97.0
Standard deviation	$/ac	5,787	3,041	4,164	1,277
		Price = $0.30/lb			
Mean discounted 20-year returns	$/ac	1,858	7,830	3,772	11,243
Minimum discounted 20-year returns	$/ac	-15,785	-8,231	-9,738	335
Maximum discounted 20-year returns	$/ac	27,069	19,820	25,438	15,701
Percentage of iterations with negative returns	%	46.4	5.8	34.8	0.0
Standard deviation	$/ac	9,310	4,818	7,656	2,618
Break-even price*		$0.289	$0.270	$0.277	$0.257

* Price at which mean discounted 20-year returns = 0.