GROWER DECISION SUPPORT TOOL FOR CONVERSION TO A HIGH-EFFICIENCY TART CHERRY ORCHARD SYSTEM

By

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ABSTRACT

GROWER DECISION SUPPORT TOOL FOR CONVERSION TO A HIGH-EFFICIENCY TART CHERRY ORCHARD SYSTEM

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This thesis utilizes an asset replacement model to determine the optimal time period to transition from an existing standard orchard to a proposed high-density orchard system. The tart cherry industry in Michigan is the foundation for an empirical example, allowing for estimation of variables essential to the asset replacement model. The marginal net revenue approach is used to determine the optimal time period for asset replacement by comparing anticipated marginal net returns of the existing orchard to the expected discounted net returns of the proposed orchard system. Given the innate uncertainty of parameters inherent in tart cherry production, yield is stochastically estimated to evaluate the economic returns.

Results indicate that asset replacement of an existing tart cherry orchard with a high-density orchard system should occur before the traditional orchard removal time period. The anticipated returns of an existing orchard are less than that of the expected net returns of the proposed high-density orchard. This model is the first asset replacement approach developed for an individual tart cherry grower to determine if, and when, to replace existing orchards with a high-density orchard system.

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CHAPTER ONE

INTRODUCTION AND RESEARCH CONTEXT

1.1 Introduction

Asset replacement due to deterioration, advancement in technology, or changes in government policy occurs across all industries. In some cases asset replacement is as simple as substituting one piece of equipment for another, in other cases a complete system redesign is required. When an asset is replaced due to an evolution in technology there is often a considerable amount of uncertainty surrounding the new system. If there are large sunk costs in the existing asset and the economic life-cycle is long-term, the replacement decision becomes increasingly complex. However, when new technology provides better economies of scale from higher production and, in turn, reduces the unit cost of production, an industry must critically consider the replacement decision.

The tart cherry industry in Michigan is currently contemplating such a decision with respect to asset replacement and new technology. Previously, a multi-period dynamic programming model was used to evaluate asset replacement in the tart cherry industry to determine optimal replacement timing for an existing orchard with no changes in technology (Black and Nyambane, 2004). The current study evaluates optimal replacement timing for an existing orchard system with a proposed new technology that includes orchard redesign as well as equipment changes. The challenge of such research originates in the variation of crucial parameters present in the existing orchard system in addition to the underlying uncertainty of multiple components in the proposed orchard system, due to the lack of known outcomes.

As with all perennial tree fruit production, tart cherry yields fluctuate significantly from year-to-year. Incorporating an economic tool that models the yield variation in tart cherry production is critical to solving the replacement problem. To properly model yield variation, it is necessary to determine the probability density function of the yield distribution curve. Although the premise that yield varies from year-to-year is widely accepted, previous research applied a deterministic yield trajectory to estimate economic returns of a tart cherry orchard (Wright, 2005). Stochastic estimation of yield outcome is critical to accurately determine the economic return of each orchard system.

The cost of production per pound for tart cherries in the largest growing region of the United States (Northwest Michigan) is estimated to be approximately $0.05 higher ($0.32 per pound) than the 27 year average grower price of $0.262 per pound (Black et al., 2010; National Agricultural Statistic Service, 2011). Such statistics beg the critical economic question, how can an individual tart cherry grower bring his or her cost of production down? Yet, there remains significantly more complexity to this problem than simply producing more tart cherries per acre.

The long horticultural life-cycle of an existing orchard creates elevated sunk costs that are difficult to recoup; initial investment is high and estimated annual returns are low. In the existing orchard system, the annual cost of production continues to increase as input prices rise. Additionally, yield per acre fluctuates drastically creating a lower margin per pound over the life of the orchard. Without a fundamental shift in production techniques the average cost of production per pound for tart cherries will continue to increase. Better economies of scale could be realized from a higher yield per acre as fewer acres are required to maintain existing production levels. If a grower is able to produce the same quantity of tart cherries on fewer acres, the cost of production per pound would decrease, thus providing a grower with higher returns, assuming that the average price per pound also remained constant.

Currently, there are no known high-density tart cherry orchards in commercial production in Michigan. Though, within the tart cherry grower and research community, interest and enthusiasm for the proposed high-density orchard system continues to increase. Uncertainty inherent in yield outcome and cost of production has limited the ability of growers to consider a replacement plan to convert existing orchards to the new high-density orchard technology. These unknown variables can be theoretically projected through the use of data simulation, stochastic estimation, and economic valuation. While uncertainty in specific parameters remains, the economic tools available can bring insight and clarity to growers interested in replacing existing orchards with the proposed high-density orchard system.

1.2 Objectives

The primary objective of this research is to utilize an asset replacement model to determine the optimal replacement period to transition from an existing orchard system to a high-density orchard system. This replacement model incorporates constraints confronted by growers in their decision framework. There are three supporting objectives that assist in the development of the asset replacement model.

1. Determine a method to stochastically estimate yield outcome. As described above, this study seeks to provide the most accurate approximation of yield per acre over the life-cycle of each orchard. Stochastic estimation of yield variation facilitates precision in projection of yields for both orchard systems.
2. Develop accurate cost of production tables that estimate costs associated with the innate features of each orchard system; to establish an orchard as well as the annual cost per acre during peak production.

3. Compare the economic returns of each orchard system to determine if, and when, an existing orchard system should be replaced with the proposed orchard system. Evaluating the sensitivity of results to changes in specific variables under different scenarios provides an in-depth analysis of several of the possible net returns expected from each orchard system and evaluates robustness of outcomes with respect to changes in model parameters.

1.3 Procedures

Although there are several methods for developing an asset replacement model, the two primary techniques for agricultural asset replacement are marginal net revenue (MNR) and dynamic programming (DP). Previous research on asset replacement in tart cherry production used dynamic programming to determine optimal replacement policy. Dynamic programming provides useful information for asset replacement because it accounts for the variation in expected performances of both present and subsequent replacement periods (Groenendall, Galligan, and Mulder, 2004). Although the dynamic programming model has many other positive characteristics for application to optimal replacement problems, the model can become overly complex depending on the number of state variables defined (Smith et al., 1993).

One goal of this research is to provide a straightforward and accurate estimation of the optimal time period of asset replacement for an individual tart cherry grower. The MNR approach not only provides an accurate approximation of replacement, but also is a more simplified approach making it both familiar and easily accessible to users. A criticism of the MNR approach is that it does not account for variation in the expected performance of the asset (Groenendall, Galligan, and Mulder, 2004). In this research, variation in production performance is accounted for through the use of stochastic estimation of yield. This research uses the MNR technique to determine the optimal replacement period of the new orchard technology, given the constraints of investment in the existing orchard.

1.4 Implications

The direct output of this research is a method for determining the optimal time for asset replacement in perennial tree fruit production. This study also provides an approach for modeling the actual production performance of perennial tree fruit. The stochastic estimation used in this study will address the shortcomings of previous academic research that utilized a deterministic production performance for the economic comparison of expected return. Specifically, this study provides a tart cherry decision framework to evaluate if, and when, to replace an existing standard orchard with a high-density orchard system. Such analysis will generate insight for policy-makers in the tart cherry agricultural subsector who impact supply and price decisions. Finally, this study is comprehensive in that it considers the dynamics of a long-term investment decision with high sunk costs, while providing an individual participant with a model that estimates the specific constraints in transferring an existing asset to a proposed new asset.

CHAPTER TWO

INDUSTRY PRACTICES

This chapter presents a brief introduction to the tart cherry industry in Michigan, a description of the existing orchard and technology, and an explanation of the proposed high-density orchard system and anticipated technology.

2.1 The Tart Cherry Industry

The State of Michigan produces approximately 70 percent of tart cherries grown in the United States (National Agricultural Statistic Service, 2011). Tart cherry production can be divided into three regions in Michigan, northwest, west central, and southwest. Michigan produces approximately 189 million pounds from northwest, 60 million pounds from west central, and approximately 19 million pounds from the southwest region each year (Rothwell, Personal Communication, 2011). The vast difference in expected production between regions is due in large part to the Grand Traverse Bay, which provides the northwest region with a relatively warmer winter and cooler summer, an optimal scenario for the growth of a horticultural crop. Therefore, this study has focused primarily on data collected from the northwest region of Michigan.

Over the last 27 years nominal grower tart cherry prices in Michigan have varied from $0.055 per pound in 1995 to $0.479 in 2002. In those same years yield per acre also varied from an average of 10,300 pounds per acre in 1995 to 545 pounds per acre in 2002. In Michigan, total bearing acres have decreased 24 percent from 34,400 in 1997 to 26,200 in 2010. Additionally, in recent years the number of growers in Michigan has decreased from 705 in 1997 to 540 in 2006 (National Agricultural Statistic Service, 2011). Such a decrease in total bearing acreage and tart cherry growers is due in part to the expansion of real estate development on ideal tart cherry orchard sites. With a relatively low grower price per pound and elevated land values, the tart cherry industry must identify a production technique to maintain market supply with less acreage.

2.2 The Existing Orchard System

In the existing production system, an orchard is planted at a density of 20 feet between rows and 16 feet within rows, or approximately 136 trees per acre (Figure A1). Tart cherries are mechanically harvested and tree density varies from 120 to 170 trees per acre.[1] The tree density and orchard life-cycle is almost entirely related to the type of mechanical harvester used. Given that the only mechanical harvesting technology available is a trunk harvester, the desire has always been to increase trunk size as quickly as possible, thus increasing the size of the trees.

In the standard Michigan tart cherry orchard, harvesting begins around year six after planting, and trees reach peak production in year 12, lasting until around year 23 when productivity declines. Trees are typically removed after harvest around year 25. However, this type of orchard limits a grower's ability to increase production and gain economic efficiencies. This study challenges the status quo orchard design and proposes a new orchard system that provides a grower with the opportunity to increase production and gain economic efficiencies.

2.3 The Proposed Orchard System

The high-density orchard system considered for this research is defined as an orchard planted at a density of 16 feet between rows and six feet within rows, or approximately 453 trees per acre (Figure A2). In this study a high-density orchard is defined as an orchard with less than 600 trees per acre, but greater than 300 trees per acre.[2] A high-density orchard with an increased

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[1] Average tree density has historically increased with the adoption of mechanical harvesting technology.

[2] There are some fruit tree industries, such as the apple industry, that are planting more than 1,000 trees per acre, which this study would define as super high-density orchard.

number of trees per acre is expected to have a significant impact on the returns a grower receives. In the proposed high-density orchard system the existing harvesting technology (a conventional trunk harvester) is no longer a viable option.

The high-density orchard system will utilize a harvesting technology such as an over-the-row or continuous harvesting system that omits shaking the trunk of the trees. Without the need for large tree trunks, harvest may begin in a high-density orchard system as soon as sufficient production is available, in this case around year four after planting. Peak production will begin in year nine, lasting until around year 20 when productivity is expected to decline. It is assumed that the orchard will be removed after harvest in year 23. From a grower's perspective the benefits of the high-density system include an earlier return on investment and the potential for an increased yield per acre. Thus, the expectation is that a high-density orchard will decrease per unit costs from better economies of scale related to the increased yield per acre and the fewer acres required to maintain overall production.

CHAPTER THREE

METHODS

This chapter derives the empirical models used to evaluate the asset replacement decision. The first section explains the method used to stochastically estimate the yield outcome of both orchard systems. In the second section, the cost of production equation is estimated to determine the potential gain in economic efficiency from the proposed high-density orchard system. The third section explains the net present value (NPV) formula as well as how both the real price per pound and discount rate are derived. The final section describes the retention pay-off equation used to determine the optimal asset replacement time period.

3.1 Stochastic Estimation

Tart cherry yield varies from year to year due to site selection, orchard management, and weather (most often related to frost damage during the blossoming cycle). The variability in yield creates a high level of complexity in the estimation of yield outcome for both the standard and high-density orchard systems. Stochastic estimation is used to approximate the probability distribution of potential outcomes by allowing for random variation in peak production (i.e. how much an acre is capable of producing at optimum tree age) and year-to-year yield variation (i.e. how much yield is realized in a given year). Yield outcome, defined as the varied or random yield per acre over the life-cycle of the orchard, may be simulated for both a standard and high-density orchard system using stochastic estimation. In contrast, yield trajectory is defined as the set yield per acre over the life-cycle of the orchard before the simulated estimation of yield outcome.

The simulated yield outcome is based on models developed for tart cherry growers in Michigan (Beedy, Nyambane, and Black, 2005). The yield trajectory of a tart cherry orchard follows the distribution of a normal probability density function. This was determined by conducting two hypothesis tests for normality in Stata (Intercooled Stata for Windows, Version 11.0, Stata Corporation, College Station, TX, 2011) on a data set of yields per acre from a standard tart cherry orchard at the Northwest Horticultural Research Station between 1981 and 2003 (Rothwell; Northwest Horticultural Research Station Personal Communication, 2011). The null hypothesis was that yield trajectory of a tart cherry orchard was normal and the alterative hypothesis was that it was non-normal. Through the use of both a Shapiro-Wilk and Shapiro-Francia test for normality, the null hypothesis was not rejected, thus implying normality (Park, H., 2008).

The first stochastic estimate of yield per acre for the standard orchard system is the peak production level. Average yield during peak production can vary considerably from one orchard site to the next, even on the same farm operation. Through the use of Microsoft @Risk, a random simulated draw from a normal distribution was used to estimate peak production (Palisade Corp., Newfield, NY, 2010) (Table B1). The random normal distribution draw of average yield at peak production is described in equation (1):

$$ayap_t = RO + (\bar{x} + s * rv) \tag{1}$$

where:

$ayap_t$ = average yield at peak production for the standard orchard system,

RO = the risk output draw of average yield at peak production,

$\bar{x}$ = the mean yield per acre during peak production,

s = the standard deviation per acre during peak production,

rv = the random variable of the normal distribution draw.

The standard orchard system will begin harvestable production in year six, reach peak production in year 12 and have diminishing production returns starting in year 23. It is assumed that trees will be pulled after harvest in year 25 for a harvestable life-cycle of 20 years. Between years six and 12 and 23 and 25, expected yield follows a first increasing and then decreasing linear path based on the estimated yield at peak production.

To adjust for weather and other related yield variations between years, a second stochastic estimation was used for the standard orchard. A coefficient of variation was calculated by dividing the standard deviation by the mean yield per acre. The coefficient of variation was then multiplied by the yield per acre distribution to calculate year-to-year variation. These values were then multiplied by another normal random variable generated by Microsoft @Risk for each year of production (Palisade Corp., Newfield, NY, 2010). The calculated variation was then used to estimate annual expected yield outcome per acre over the life-cycle of the standard orchard (Table B2). This calculation of expected yield per acre is illustrated by equation (2).

$$EY_t = max\left(\left(ayap_{t-1,} ayap_t, ayap_{t+1}\right) + rv_t * s_t, 0\right), t = 1,2, \dots T \tag{2}$$

where:

EY_t = the expected yield per acre in period t,

$ayap_{t-1}$ = the adjusted average yield per acre before peak production,

$ayap_t$ = the average yield at peak production in period t,

$ayap_{t+1}$ = the adjusted average yield per acre after peak production,

rv_t = the random variable of the normal distribution draw in period t,

s_t = the standard deviation per acre in period t,

t = time periods in the life-cycle of the orchard.

With limited empirical data available, the high-density orchard system creates additional levels of uncertainty for yield estimation. Two uncertain parameters for the proposed tart cherry high-density orchard system include the critical age points along the distribution curve and the peak production level.

The critical age points that must be estimated for this model include first harvest, peak production, decline, and removal. It is estimated that harvest will begin as early as year three, as late as year five, and most likely in year four. Peak production will begin as early as year seven, as late as year nine, and most likely in year eight. It is expected that production will be remain at peak until it begins to decline as late as year 21, as early as year 19, and most likely in year 20 (Michigan Grower Interviews and Northwest Research Station Personal Communication, 2011). A grower will remove the orchard as early as year 22, as late as year 24, and most likely in year 23.

Triangular distribution was considered to account for the uncertainty and parameterize the critical age points for the high-density orchard system. Triangular distribution is frequently used in a situation where limited sample data is available because only the minimum, maximum, and most likely values are necessary to parameterize the model. However, given the close proximity of the years around each critical age point, the model estimation provided no variation in net returns between holding the year constant and allowing the critical age point year to vary.

Thus, the proposed high-density tart cherry orchard system is assumed to begin harvestable production in year four, reach peak production in year nine and begin to have diminishing production returns in year 21. It is assumed that the trees will be pulled after harvest in year 23 for a harvestable life-cycle of 20 years. As with the standard orchard system, the yield trajectory before and after peak production is also defined for the high-density orchard system based on specific percentage adjustments. The stochastic estimation for this model follows a linear increase to peak production and a decline from peak production until the trees are pulled, similar to the standard orchard yield trajectory.

Although triangular distribution is not used in the determination of critical age points, it is used for estimating yield at peak production. Yield parameters considered for this research are maximum value of 25,000 pounds per acre (Robinson, Andersen, and Hoying, 2007), minimum value of 15,000 pounds per acre (Seavert, Long, and Freeborn, 2008), and most likely value of 20,000 pounds per acre based on a high-density orchard system with 453 trees per acre (Michigan Grower Interview, 2011). If the tree density per acre is increased to levels of 600 or even 1200 trees per acre, the parameters would require modification to reflect this situation. The calculated mean of the minimum, maximum, and mostly likely values forms the average yield per acre at peak production, before introducing annual variability, for the estimated stochastic yield outcome (Table B3), described by equation (3):

$$ayap_t = RO + \left(RT(min, ml, max)\right) \tag{3}$$

where:

$ayap_t$ = average yield at peak production for the high-density orchard system,

RO = the risk output draw of average yield at peak production,

RT = the risk triangular distribution of average yield at peak production,

min = the minimum expected value of average yield at peak production,

ml = the most likely expected value of average yield at peak production,

max = the maximum expected value of average yield at peak production.

A second stochastic estimation adjusts for weather and other related annual variations in yield on a given site. A coefficient of variation was calculated for the high-density orchard system by dividing the standard deviation by the mean yield per acre. The coefficient of variation for the high-density orchard is higher than the coefficient of variation for the standard orchard system. This is due to the higher expected mean and standard deviation yield per acre for the high-density orchard system. A higher coefficient of variation for the high-density orchard system not only accounts for the weather variation, but also the probability of catastrophic crop failure of the high-density orchard, given the level of uncertainty. A catastrophic crop failure may be more probable with a high-density orchard system due to the fact that more of the production potential is derived from fewer acres. The expected yield per acre for each time period in the life-cycle of the high-density orchard system was calculated using equation (2) (Table B4).

3.2 Cost of Production

One of the critical economic questions posed by this research is whether or not per unit cost of production will decrease with a high-density orchard system and provide growers with better economies of scale. By adjusting certain parameters, yet following the basic Black et al. (2010) method, cost of production per pound is calculated for both orchard systems based on annual expenditures and land values in the northwest Michigan growing region. Total cost to establish an orchard as well as the land control cost[3] during establishment is amortized over the 20 year bearing life of each orchard. Land is valued based on the average farmland price for fruit tree sites in the northwest lower peninsula of Michigan (Wittenberg and Harsh, 2011). Cost per pound of production is calculated by equation (4):

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[3] Land control cost is defined as the cost associated with maintaining a piece of property in agricultural production over the long-term life of the asset. Land invested for twenty-five years in tart cherry production cannot be used for any other type of investment opportunity without removing the orchard. Land control costs are estimated by calculating an opportunity cost of what capital invested in land could earn in another investment minus the expected annual land appreciation.

$$cpp = \frac{\alpha ec + \alpha elcc + cpa + lcc}{\bar{x}EY_t} \tag{4}$$

where:

cpp = cost of production per pound,

αec = annual amortized establishment cost during the bearing years,

$\alpha elcc$ = annual amortized establishment land control cost during the bearing years,

cpa = annual total cost per acre during peak production,

lcc = annual land control cost during the bearing years,

$\bar{x}EY_t$ = average expected yield per acre during the bearing years.

3.3 Net Present Value

Capital budgeting is the decision-making process for accepting or rejecting investment projects (Ross, Westerfield, and Jaffe, 2008). Tart cherry growers face a difficult capital budgeting decision when making the decision to plant the standard orchard or replant with a high-density orchard system. To complicate this capital budgeting decision, a limited amount of data is available for planting high-density tart cherry orchards in Michigan. However, considerable evidence suggests that perennial fruit production in a high-density orchard system creates economic advantages for a grower. For example, an Oregon State University research project indicates that the break-even point in a high-density (340 trees per acre) sweet cherry orchard occurred in almost half the time of a standard sweet cherry orchard (Seavert, Long, and Freeborn, 2008).

Several capital budgeting methods can be used to evaluate investment decisions. The net present value (NPV) method is one approach that is useful when valuing two investment projects. The formula for NPV is described in equation (5) (Skinner, 1999):

$$NPV = \frac{x_0}{(1+k)^0} + \frac{x_1}{(1+k)^1} + \frac{x_2}{(1+k)^2} + \cdots + \frac{x_t}{(1+k)^t} \quad (5)$$

where:

NPV = the net present value per acre for all time periods,

x_t = net cash flow in time period t,

t = time periods in the orchard life − cycle,

k = the discount rate.

The NPV of any project is calculated by summing the present value of future cash flows and subtracting the initial investment amount. Net cash flows (NCF) are determined by equation (6):

$$x_t = ((App * EY_t) - cpa_t) \quad (6)$$

where:

x_t = net cash flow in time period t,

App = real historical average price per pound,

EY_t = the expected yield per acre in period t,

cpa_t = the cost per acre in period t,

t = time periods in the life − cycle of the orchard.

The grower price per pound used for the calculation of NPV is held constant at \$0.262 per pound; the average real historical U.S. price per pound between 1984 and 2010 (National Agricultural Statistic Service, 2011). Average nominal price per pound for tart cherries is converted to real average price per pound by the gross domestic product deflator (GDP) (U.S. Department of Commerce, Bureau of Economic Analysis, 2011) as shown in equation (7):

$$App_t = \frac{nhpp_t}{gdp\ deflator_t} \quad (7)$$

where:

App_t = real historical average price per pound,

$nhpp_t$ = nominal historical price per pound (1984-2010),

$gdp\ deflator_t$ = gross domestic product deflator.

Actual historical tart cherry price per pound varies significantly from year-to-year depending on several different factors, including the number of pounds held in the reserve by the federal marketing order,[4] the prior year's yield, and the expected yield of the current year. Tart cherry price per pound is held constant based on the fact that price is not only set by supply and demand, but also by a noticeable influence of institutions within the tart cherry industry.

A discount rate can be used to discount the future cash flows of investment projects to the present value. The discount rate for this project represents the risk-free rate of return a grower would expect from an investment with no risk plus a risk premium for agricultural production on Michigan farmland as described by equation (8):

$$k = rf + rp \tag{8}$$

where:

k = the discount rate,

rf = the risk-free rate of another investment with no risk,

rp = the risk premium of agriculture on Michigan farmland.

Included in this discount rate is the recent five-year (2007-2011) average annual risk-free rate of 4.30 percent for a 30 year treasury-bill (Federal Reserve Board, 2012), plus a risk-premium of six percent based on an estimate of the historical risk premium for Michigan

[4] The Tart Cherry Federal Marketing Order 930, through the guidance of the Cherry Industry Administrative Board (CIAB), is charged with determining the amount of tart cherries available to the market by an optimal supply formula to provide price stabilization (White and Kesecker, 2007).

farmland (Hanson, 1999). The risk free-rate provides the required rate of return of an investment with no risk of financial loss, while the risk premium provides the required rate of return from farm assets. Hanson's estimate of the risk premium for Michigan farmland was used because of a lack of information on tart cherry historical rate of return and cost of equity.

For the standard orchard system, NCF are discounted to their present value from year six through year 25. The discounted initial investment, orchard establishment cost from year zero through year five, is then subtracted. For the high-density orchard system, the NCF are discounted from year four through year 23. The discounted initial investment amount, orchard establishment cost from year zero through year three, is then subtracted. These calculations allow the return of both orchard systems to be compared at their present value. In addition, the internal rate of return (IRR) is evaluated for each NPV calculation. IRR is the rate of return of an investment when the NPV of all cash flows is equal to zero (Skinner, 1999). This rate identifies the maximum percentage return a grower could expect from each orchard investment.

3.4 Asset Replacement

This study uses the marginal net revenue (MNR) technique to determine optimal timing of asset replacement, given investments in the current technology. In previous research the MNR approach has been used to evaluate asset replacement decisions in a dairy cattle breeding and asset replacement program (Groenendall, Galligan, and Mulder, 2004). Inputs for specific farm conditions are entered in the MNR model to determine the retention pay-off (RPO) value. For example, the RPO value of a cow is equal to the total additional profits that a producer could expect from trying to keep the cow until her optimal age, taking into account the probability of involuntary removal due to, most likely, the death of the cow, and ultimately, asset replacement (Groenendall, Galligan, and Mulder, 2004).

Similarly, the RPO value for an existing tart cherry orchard is equal to the total additional profits that a grower can expect from trying to keep the orchard until its optimal age, taking into account variation in yields. In this study all net revenues were calculated as an annuity per year based on the economic life-cycle of each orchard system (Harsh, Connor, and Schwab, 1981). Utilizing the MNR framework, the RPO value for each orchard system is calculated by equation (9).

$$rpo_t = \sum_{t=1...d}^{T} \left(\frac{k}{(1-(1+k)^{-t}} \right) (mnr_t - npv_{max} * m_t) \tag{9}$$

where:

rpo_t = annualized retention pay-off in decision period t,

d = optimal time period t for replacement (when $mnr_t < npv_{max}$),

t = period, at the end of which the orchard can be replaced,

m_t = length of period t (years), orchard life-cycle,

mnr_t = anticipated marginal net revenue in period t,

npv_{max} = expected maximum net present value of replacement system,

k = the discount rate.

The RPO value assumes that the only opportunity, other than keeping the existing orchard, is replacement with the high-density orchard system. Optimal time period for replacement is determined by comparison of the anticipated annual MNR from the present orchard with the expected annual discounted NPV from the proposed high-density orchard system. This asset replacement model is used to compare (1) annualized anticipated returns from the remaining life of an existing orchard (i.e. from the evaluation year to tree removal) and (2) the present value of expected annualized returns from the proposed high-density orchard system.

CHAPTER FOUR

DATA COLLECTION

This chapter is divided into three separate sections. The first section provides a discussion of the data collected from primary sources; fruit growers, academic researchers, and industry participants. The second section presents the data collected from secondary sources of information, including agricultural economic reports, extension bulletins, and academic journals. The final section illustrates the collective results of the data assembled from both primary and secondary sources.

4.1 Primary Data Collection

Primary data was collected in 2011 and 2012 in order to approximate net returns from each orchard system and evaluate the asset replacement decision. This data was collected from grower interviews with tart cherry growers in Michigan, sour cherry growers in Canada, and citrus growers in Florida. Horticultural specialists, academic researchers, and industry members were also interviewed. The information gathered from these interviews was used to develop cost of production tables and the stochastic estimation of yield outcome for each orchard system.

4.1.1 Michigan Interviews

Grower interviews included three tart cherry operations in the northwest, two in west central, and one in the southwest region of Michigan. As much as possible, interviews included both the current and future decision makers of an operation. Knowledge shared by the individual tart cherry growers was used (1) to verify parameters for the existing orchard system, (2) to determine the constraints for orchard redesign, and (3) to provide cost and yield expectations for the proposed high-density orchard system. Although this study is primarily concerned with the economic decision on the conversion of one orchard system to the next, understanding the critical components of horticulture and agricultural engineering is critical to the analysis. Therefore, interviews also took place with academic specialists from Michigan State University.

A key component derived from these interviews was an estimate of yield per acre for the existing orchard system as well as the expected planting density for the proposed high-density orchard system. The average historical yield per acre in Michigan from 1984 to 2010 was 6,760 pounds per acre (National Agricultural Statistical Service, 2011). Average yield per acre in the U.S. during the same 27 year period was 6,475 pounds per acre (National Agricultural Statistical Service, 2011). Preliminary analysis indicates negative net returns to tart cherry production, given historical average yields per acre.

Grower interviews indicated that the reported historical yield per acre published is lower than yields actually received in many cases. Several Michigan growers claimed that an average of 10,000 pounds per acre during peak production is actually a closer estimate of the actual yield per acre received (Michigan Grower Interviews, 2011). With an average yield per acre during peak production of 10,000 pounds, average yield per acre over the life of the orchard (before, during, and after peak production) is approximately 8,200 pounds. An average of 8,200 pound per acre is only 18 percent higher than the reported State yield in Michigan of 6,760 pounds.

Michigan yields can vary drastically from one orchard site to the next based on localized weather and site selection. Two different orchards owned by the same grower may produce a different average yield per acre over the life of each orchard. It is assumed that the first adopters of the high-density orchard system will be those growers with more favorable orchard sites and a historically higher average yield per acre. This assumption is based on the idea that these growers may be in better financial positions to make the increased capital investments required by the high-density orchard system.

Additional data collected from tart cherry growers in Michigan provided support for the estimate of yield per acre and expected planting density for the proposed high-density orchard system. Though in the early trial stages, the concept of a high-density tart cherry orchard in Michigan has been tested by a few growers. One grower had previously tested a higher density tart cherry orchard system by increasing the number of trees per acre to 240; approximately double that of the standard orchard system. During the orchard trial, yield per acre doubled between years six and 12, compared to that of a standard orchard on a similar site. However, the vigor of the Mahaleb rootstock was not controlled and during peak production, yield per acre was less than that of a comparable standard orchard (Michigan Grower Interviews, 2011). This decrease in yield per acre was due in part to the fact that the trees grew together, limiting light distribution essential for fruit production. Without proper light distribution a tart cherry orchard will not reach its peak yield per acre, thus limiting the economic return to the grower. Another grower is currently testing a high-density tart cherry orchard using a bush like system, instead of the traditional central leader tree system used in Michigan. This grower is testing the dwarfing sour cherry variety, Carmine Jewel, from the University of Saskatchewan in Canada. Similarly, another grower is planting Montmorency tart cherry on Mahaleb rootstock at approximately 350 trees per acre. This grower plans to maintain a bush-like or fruiting wall system by utilizing a variety of pruning techniques (Michigan Grower Interviews, 2011).

Interviews with horticultural specialists from Michigan State University provided the basis to approximate the critical age points of the proposed high-density orchard system. Consensus was that with the proposed high-density orchard system harvest would begin between years three and five, the orchard would reach peak production between years eight and 10, and the orchard would start to decline around year 20 (Northwest Horticultural Research Station, Personal Communication, 2011). These critical age points were consistent with results from the Michigan grower interviews.

There was greater disagreement over the year in which a high-density orchard would be removed. Some believed that the orchard would be removed later on in the life-cycle based on the level of care expected from a grower made a larger initial investment. Others held the belief that the orchard would be removed in an earlier time period based on the stress inflicted from a grower who pushed the orchard to capacity earlier in its life-cycle. (Michigan Grower Interviews, Northwest Horticultural Research Station, Personal Communication, 2011). It is important to note that the current study assumes a 20 year bearing life-cycle for the high-density orchard.

In 2010, at the Northwest Horticultural Research Station, the dwarfing rootstock Gisela, grafted with Montmorency tart cherry, was planted at a high-density. Additional varieties on Michigan State University dwarfing rootstocks and a few of the University of Saskatchewan sour cherry dwarfing varieties were planted in 2011. Although these high-density plantings are too early in their life-cycle to provide substantial evidence on cost of production or potential yield trajectory, the trials do provide some information on establishment costs including an irrigation cost of approximately $2,000 per acre and a dwarfing and standard tree cost of approximately $11 and $7 per tree, respectively (Rothwell, N., Northwest Horticultural Research Station, Personal Communication, 2011).

Interviews also took place with horticultural specialists at the Michigan State University Clarksville Horticultural Research Center where several tart cherry rootstock trials are currently underway, including dwarfing rootstocks that could eventually be planted in high-density orchards in Michigan. A dwarfing rootstock is usually less vigorous and more precocious than a standard orchard rootstock, such as Mahaleb. Precocious, when defining the nature of a tree, identifies a tree that will develop and produce fruit earlier than expected. Early experiments indicate that Montmorency on Mahaleb rootstock could be used in a high-density orchard system with proper pruning. For example, renewal pruning is one approach that removes any limbs that are over three years old. This allows the trees to maintain their space in a dense planting while simultaneously maintaining the willowing nature of fruiting limbs that is desirable for continuous mechanical harvesting (Clarksville Research Center Personal Communication, 2011).

Once a high-density orchard is planted the existing trunk harvesting technology, currently in use, is no longer a viable mechanical harvesting option in the orchard because it requires more space to maneuver the equipment and harvest the trees. However, there are alternative harvesting technologies available for closely planted fruit systems.

A recent Michigan State University project examined an over-the-row harvester, designed for blueberries, for use in high-density tart cherry orchards. Results from a trial in 2010 indicate that the rotary tower harvesting mechanism on an over-the-row harvester was efficient and effective in fruit removal and recovery with an average of approximately 80 percent of the fruit harvested (Perry et al., 2010). Tart cherries harvested during these trials were USDA tested for quality and graded at 94 out of a possible score of 100.[5] While using the rotary tine over-the-row harvester, harvest speed was limited to one mile per hour in this orchard of four-year-old Montmorency tart cherry trees (Perry, R. Personal Communication, 2011). In contrast to the existing harvesting technology, discussions with tart cherry growers in Michigan estimated that the trunk harvester operates at a maximum speed of four-tenths of a mile per hour, less than half the speed of the over-the-row rotary tine harvester (Michigan Grower Interviews, 2011). It

[5] These results were from a single observation. However, it appears from this observation and others that the over-the-row harvester, utilizing a rotary tine harvest mechanism, can achieve efficient fruit removal and deliver high quality fruit (without extensive mechanical damage).

appears possible that speeds could be increased to two or three miles per hour resulting in additional economic efficiencies. If the speed per acre of harvest was to increase, it is assumed that cost of production per acre would have somewhat of a corresponding decrease providing additional economic return to the grower.

4.1.2 Canada Interviews

A super high-density, dwarf, bush-like sour[6] cherry orchard system has been developed by researchers at the University of Saskatchewan. This orchard system in Saskatchewan may be the only sour cherry high-density orchard system in North America used for commercial production. These sour cherry bushes only grow six to eight feet tall allowing mechanical over-the-row or side-row harvesting. Interviews focused on planting density, yield trajectory, and harvesting technology. Within-row spacing ranged from three to six feet and between-row spacing ranged from 12 to 16 feet, or approximately 800 bushes per acre. A rotary tine side-row harvester was tested on a 60-foot row of 18 Carmine Jewel sour cherry bushes to harvest 135.6 pounds, or approximately seven and a half pounds per bush. Extrapolated results indicate that a five-year-old high-density sour cherry orchard could produce approximately 6,000 pounds per acre. Some fruit growers in Saskatchewan are reported to be producing yields, during full production, as great as 20 to 30 pounds per bush or approximately 16,000 to 24,000 pounds per acre (Bors, Personal Communication, 2011).

4.1.3 Florida Interviews

Florida citrus growers are also considering conversion from the traditional grove system to a high-density grove system and a transition in harvesting technology from hand harvest to

[6] There is no significant difference between a sour and tart cherry. In the United States the term “tart” is used, while in other cherry producing regions of the World the term “sour” is used. Here the term sour is used to distinguish between the cherry variety in Canada and the cherry variety in Michigan.

continuous mechanical harvest of juice oranges (Florida Grower Interviews, 2011). The standard juice orange grove includes approximately 150 trees per acre. Compared with the proposed high-density grove system with an estimated 1,500 trees per acre (Florida Grower Interviews, 2011). Several operations are experimenting with continuous mechanical harvest on a percentage of their acreage using a continuous rotary tine harvester developed for harvesting existing groves (Roka, Personal Communication, 2011).

In Michigan there are currently no active high-density tart cherry orchards that are harvested with continuous or over-the-row equipment, other than the aforementioned orchards used solely for research. Grower interviews in Florida focused on the actual constraints a grower faces in a system redesign. Results identified expected yield per acre, projected cost of production, and anticipated economic return as critical parameters of the asset replacement decision.

4.2 Secondary Data Collection

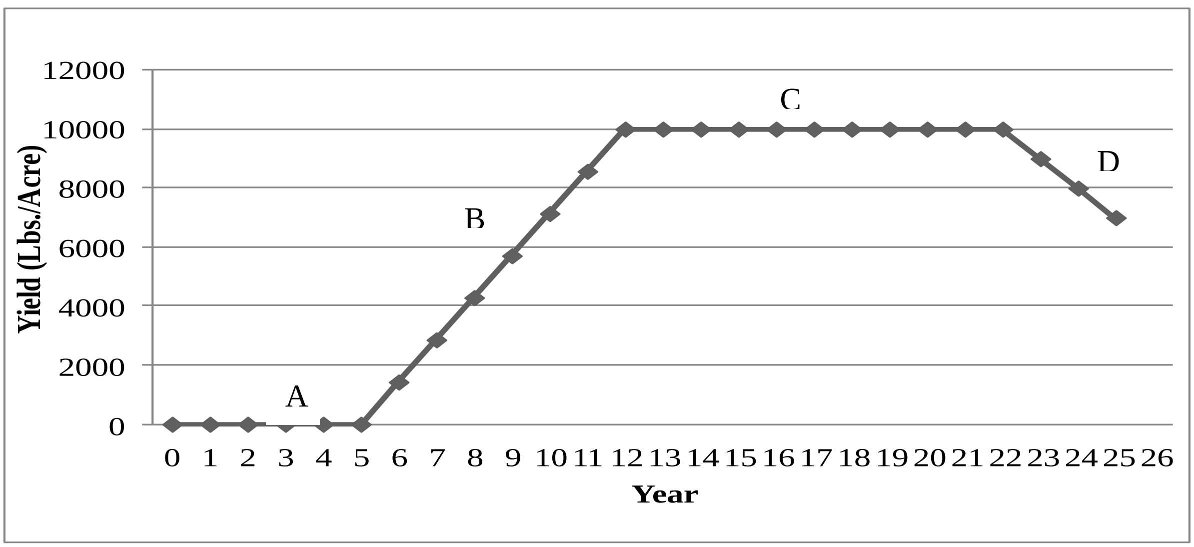
Past research and on-going research provided additional data for the comparative valuation of the standard and high-density orchard systems. A significant amount of information related to the existing standard orchard system is available in these publications. In contrast, little information is available on the proposed high-density tart cherry orchard system. Data collected from other fruit industries, including past academic research trials, provided valuable insight into the parameter estimates of the proposed high-density orchard system.

4.2.1 Cost of Production

Recent cost of production data, including critical information on labor, material, and equipment costs for the standard orchard system in three regions of Michigan is reported in a Michigan State University agricultural economics report (Black et al., 2010). The northwest region is used as a basis to construct establishment and annual costs for both orchard systems. In northwest Michigan there is a higher population of specialized tart cherry operations, generally higher annual yields, and a potential higher probability of adoption of a high-density orchard.

A tart cherry life-cycle, like other perennial tree crops, includes an establishment stage, ramping up to peak production stage, peak production stage, and a declining production stage (Black et al., 2011). Each one of these production stages is associated with a cash outflow. In Figure 1, stage A indicates the establishment cost, stage B the ramping up to peak production cost, stage C the peak production cost, and stage D reflects the decline in production cost. Cost of production must be adjusted during periods when yield is not at peak production.

Figure 1: Life-Cycle of a Tart Cherry Orchard[7]



Source: Authors calculation, 2012

In 2012, tart cherry costs were updated as part of a USDA Risk Avoidance Mitigation Program (RAMP) [8] (Dartt, 2012). Updated production, labor, equipment, and material costs from

[7] This figure identifies the cost stages in the life-cycle of a tart cherry orchard; the establishment years, the pre-peak production years, peak production years, and post-peak production years.
[8] This RAMP project was designed to develop, implement, and evaluate reduced-risk and alternative pest management strategies for U.S. tart cherry producers.

the 2012 report were included in the development of the cost of production tables for both the standard and high-density orchard system.

Cost of production data was also obtained from an earlier Michigan State University Extension Bulletin (Nugent et al., 2003). Production costs were collected from focus group discussions with tart cherry growers in the three major producing counties of northwest Michigan. Cost of production data collected from this extension bulletin provided unit cost information for the standard orchard system, transferrable to the proposed high-density orchard system. The unit cost information that was transferrable to the high-density orchard system had been calculated on a per tree basis.

The cost of production per acre in years six through 11 is adjusted to account for the reduced yield per acre as the trees develop. Cost per acre is also reduced for years 23 through 25, when yield per acre decline has begun. An early comparative economic analysis of the Michigan standard tart cherry industry and the high-density sour cherry industry in Poland provided detailed percentage adjustments to cost per acre for the years before and after peak production (Wright, 2005). The percentage adjustments in cost per acre before and after peak production for the standard orchard system are shown in Table 1.

	Table 1: Estimated Percentage Reduction in Production Costs Due to Less than Full Production in a Standard Orchard System.								
Year	6	7	8	9	10	11	23	24	25
Percent	12.5%	11.1%	8.3%	5.5%	3.3%	1.67%	1.167%	2.3%	3.5%

Source: Wright, 2005

Similarly, the percentage adjustments in cost per acre before and after peak production for a high-density orchard system are shown in Table 2.

	Table 2: Estimated Percentage Reduction in Cost per Acre Due to Less than Full Production in a High-Density Orchard System.							
Year	4	5	6	7	8	21	22	23
Percent	18.2%	14.5%	10.9%	7.2%	3.6%	2.1%	4.3%	6.5%

Source: Wright, 2005

4.2.2 Yield Trajectory

Other perennial fruit industries, including apple and sweet cherry, have designed high-density orchard systems. A motivation for moving to higher density orchards is evidence that yield per acre in perennial fruit orchards is strongly linked to tree planting density. Often lower yields from traditional apple and sweet cherry orchards can be significantly improved by planting high-density orchard systems (Robinson et al., 2007). Research studies have shown increased competitive advantages of higher density fruit orchards, from an increased yield per acre, even after considering the constraints a grower must overcome to convert from a lower density orchard system.

In a study at Cornell University, six sweet cherry orchard systems were tested using a range of different tree densities over eight years (Robinson, Andersen, and Hoying, 2007). Five high-density production systems on both standard and dwarfing rootstocks for sweet cherries were compared to determine the highest cumulative yield per acre. Results indicate that there was a three-fold difference in total crop yield between the highest density system (i.e. vertical axis) and the traditional low-density central leader system. Researchers concluded that, with current rootstocks, new sweet cherry orchards should be planted at densities of at least 300 trees per acre and possibly up to 800 trees per acre with new advances in dwarfing rootstocks.

Researchers at Oregon State University conducted a comparative economic analysis of both a standard and high-density sweet cherry orchard (Seavert, Long, and Freeborn, 2008). Yield per acre in the standard orchard was less than the yield of 14,000 pounds per acre at full production for the high-density sweet cherry orchard, although establishment cost of the high-density orchard was higher. Results indicate that the break-even in a high-density orchard occurs in almost half the time of the standard sweet cherry orchard, given expected yields.

Conclusions of a recent horticultural and economic analysis on high-density apple orchard systems are that the optimal tree density for New York apple growers is around 1,000 to 1,200 trees per acre (Robinson et al., 2007). In the past, apple orchards were planted at densities as low as 35 trees per acre; however, in recent years tree density has increased, in some cases to upwards of 2,500 trees per acre. In addition to the increased yield, high-density apple orchards increase fruit quality as well as reduce per unit costs of production (Robinson et al., 2007). New high-density orchard systems have also assisted in the partial mechanization of pruning, tree training, and harvesting in the apple orchard, providing growers with additional economic efficiencies.

4.3 Data Results

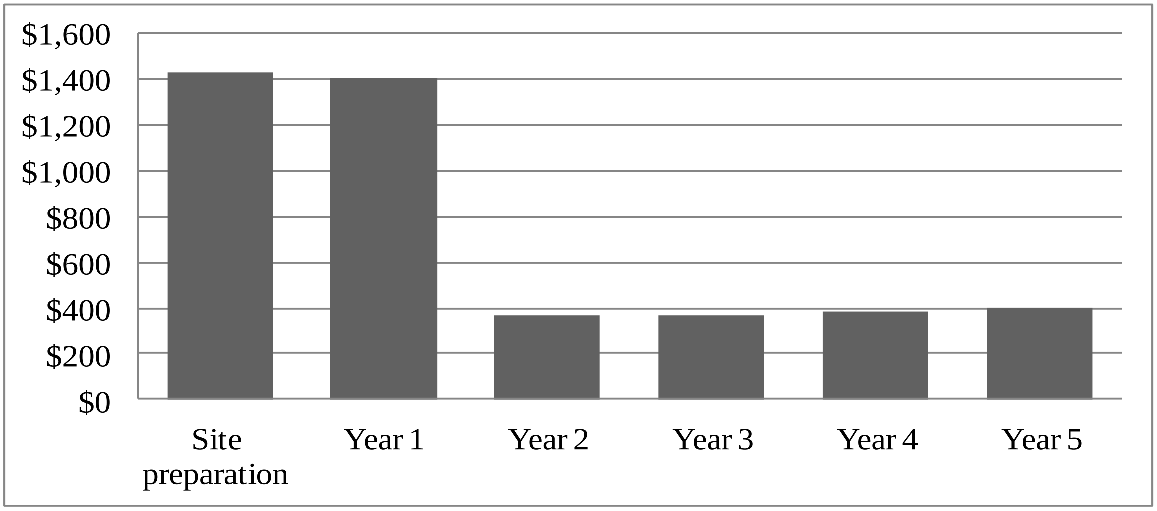
Primary and secondary data are used to develop cost of production tables and estimate the yield trajectory for both orchard systems. The following information describes the data used in the capital budgeting evaluation and asset replacement decision.

4.3.1 Standard Cost of Production

Cost of production, discounted establishment cost, and annual cost per acre values for a standard orchard system were developed by updating published budgets (Nugent et al., 2003; Black et al., 2010) using numbers gathered from interviews with tart cherry industry participants. Costs represent a standard orchard with 16 feet by 20 feet spacing, or approximately 136 trees per acre. The following information provides an overview of the cost of production for the standard orchard system (Table C1 a & b).

The total discounted cost to establish a standard orchard system is estimated as $4,354 per acre. This cost includes a site preparation year and five additional growing years prior to first harvest. Total establishment cost is the initial investment amount for the NPV calculation, in the capital budgeting model as the first six years of net cash outflows. Figure 2 illustrates the estimated cost to establish a standard orchard by year.

Figure 2: Standard Orchard Establishment Cost[9,10]



Source: Nugent et al., 2003, Black et al., 2010, Author Calculation, 2012

Total annual nominal cost per acre during peak production for a standard orchard is $1,426. Cost per acre is adjusted for years before and after peak production based on the percentage adjustments described in the previous section. Total cost of production includes both cash and non-cash (capital or depreciation costs) associated with tart cherry operating, harvest, and production. Total cost per acre is comprised of time, machinery costs, labor costs, and material costs for each operational task. Some costs, such as borer control, applied every fourth

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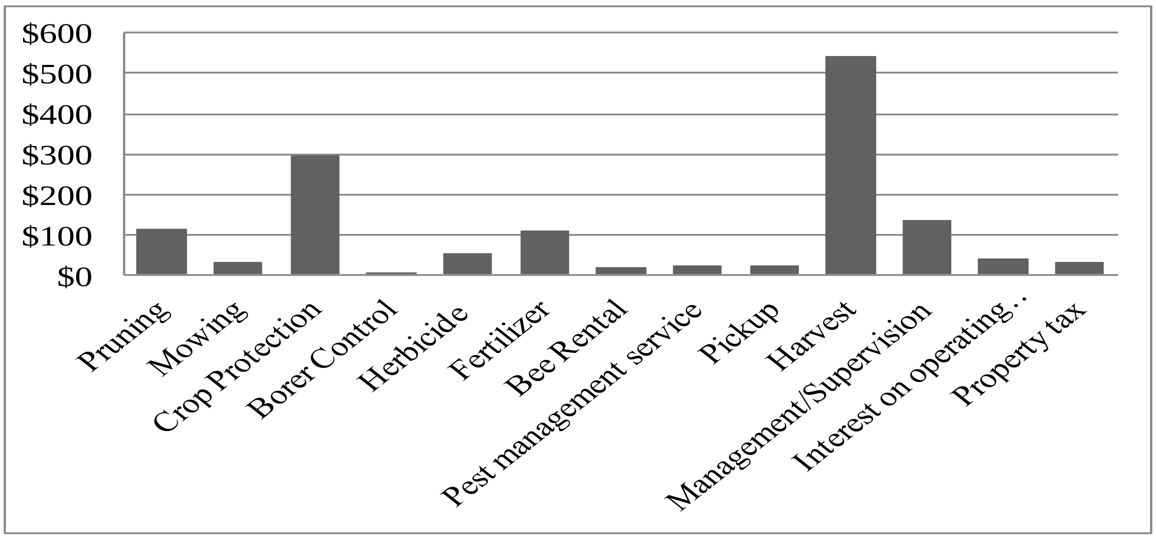
[9] Site preparation costs include (1) removing an existing orchard and (2) preparing the land to be replanted.

[10] Years 1 through 5 include the costs associated with planting and growing the tart cherry orchard up to the point of first harvest, in year 6.

year, are accounted for on an annual basis. Three harvest costs, shipping, cooling pad operations, and the tart cherry assessment, are calculated by multiplying the average yield per acre of the orchard, or 8,200 pounds per acre, by set annual cost rates. Additionally, the cost of interest on operating capital is calculated at eight percent on the operating and harvest cash outflow (Dartt, 2012). Figure 3 identifies the allocation of the costs per acre for each operation of a standard orchard.

Figure 3: Standard Orchard Annual Cost per Acre[11]



Source: Nugent et al., 2003, Black et al., 2010, Author Calculation, 2012

Harvest and crop protection costs make up the majority of the total annual cost per acre for the standard orchard system. Total annual cost per acre is subtracted from the revenue per acre to calculate the NCF each year of the orchards life.

4.3.2 Standard Yield Trajectory

The standard orchard will reach first harvest in year six, reach peak production in year 12 and have diminishing production returns from years 23 to 25 (Beedy, Nyambane, and Black,

[11] Pruning, mowing, crop protection, and so on, is the cost categories that make up the total annual cost per acre. These costs are all included at the nominal annual value.

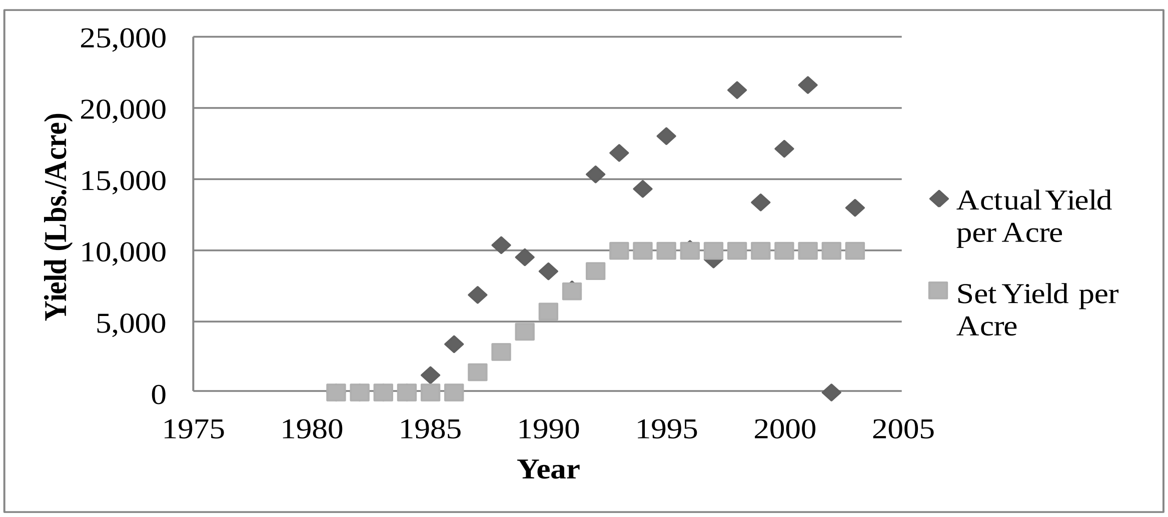
2005). Table 3 identifies the percentage yield adjustments from peak production for years six through 11 and years 23 through 25 for the standard orchard system.

	Table 3: Estimated Percentage Adjustment in Production Yield for Years Before and After Peak Production for the Standard Orchard System:								
Year	6	7	8	9	10	11	23	24	25
Percent	14.30%	28.30%	42.90%	57.10%	71.40%	85.70%	90.00%	80.00%	70.00%

Source: Beedy, Nyambane, Black, 2005

However, tart cherry growers in Michigan cannot rely on yields following this deterministic path over the life-cycle of the orchard. It is for this reason that yields are varied to account for annual uncertainty in economic returns to a standard orchard for the NPV calculation. The actual yield per acre of a standard tart cherry orchard between 1981 and 2004 is illustrated in Figure 4, where the diamond character is realized yield per acre from an existing tart cherry orchard at the Northwest Horticultural Research Station. The square character represents the set yield per acre trajectory based on a deterministic life-cycle over the same time period.

Figure 4: Standard Tart Cherry Orchard Actual Yield per Acre Outcome[12]

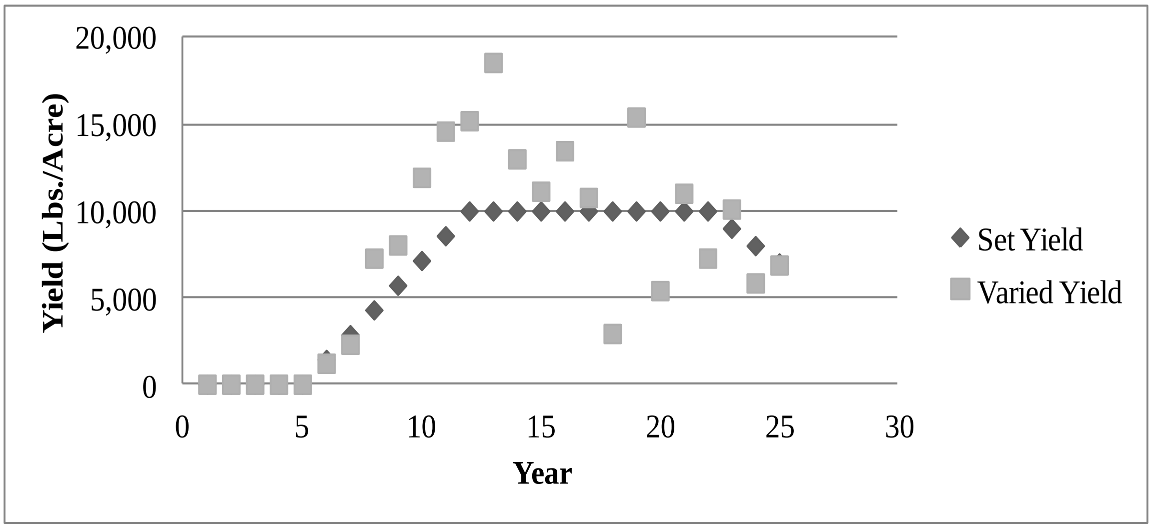


Source: Rothwell, 2011

12 In 1981 a tart cherry orchard was planted at the Michigan State University Northwest Horticultural Research Station. This figure illustrates an actual yield outcome compared to the yield trajectory discussed by this study.

Yield outcome for the standard orchard system, used in this study, was developed to capture the realized year-to-year variation in yield illustrated by Figure 4. This stochastic estimation of yield per acre captures the true nature of a yield outcome for the standard orchard. Multiple standard orchard yield outcomes are drawn using Microsoft @Risk (Palisade Corp., Newfield, NY, 2010) (Table C5). Each distribution could represent a different orchard site, manager's performance, or climate scenario. Figure 5 identifies both the set yield distribution and an example stochastic yield outcome for the life-cycle of the orchard. The stochastic estimation of yield outcome is used to calculate the NPV for the standard orchard system.

Figure 5: Standard Orchard Yield Trajectory and Outcome[13]



Source: Authors Calculation, 2012

4.3.3 High-Density Cost of Production

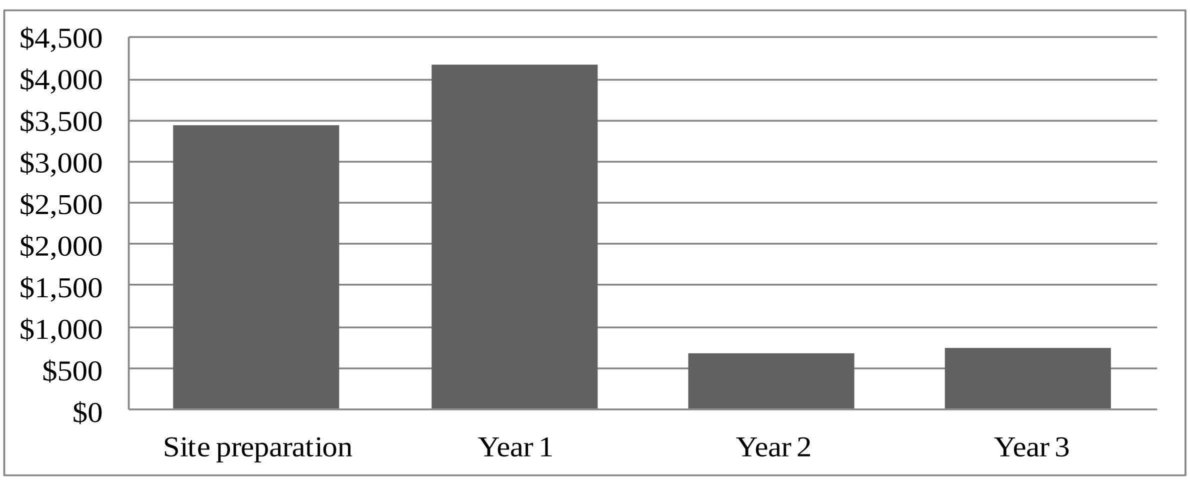
Cost of production for the proposed high-density orchard was developed by adapting each item in cost of production for the standard orchard. Grower and researcher interviews and publications on the costs of production from other high-density perennial fruit systems provide

[13] Years 0 through 5 represent the establishment period with no harvestable production, while years 6 through 25 identify both the estimated varied yield outcome and set yield trajectory.

adjustments to cost of production based on tree density per acre. Discounted establishment cost and annual costs per acre values were developed for a high-density orchard system with six feet by 16 feet row spacing, or approximately 453 trees per acre (Table C6 a & b). Estimated average yield per acre is 20,000 pounds during peak production.

Total discounted cost to establish the proposed high-density orchard system is $9,024 per acre including a site preparation year and three years of growing costs prior to first harvest. An irrigation system is included for the high-density orchard system at a cost of $2,000 per acre. Planting almost three times as many trees per acre will likely mandate an irrigation[14] system as the tree roots draw more moisture from the soil. Costs that vary with tree numbers, such as pruning and management hours, are increased to reflect the necessary hours for managing a high-density orchard system. Figure 6 illustrates the cost to establish a high-density orchard by year. Estimated costs represent the initial investment amount for the NPV calculation and are included in the capital budgeting model as the first four years of production costs.

Figure 6: High-Density Orchard Establishment Cost[15]



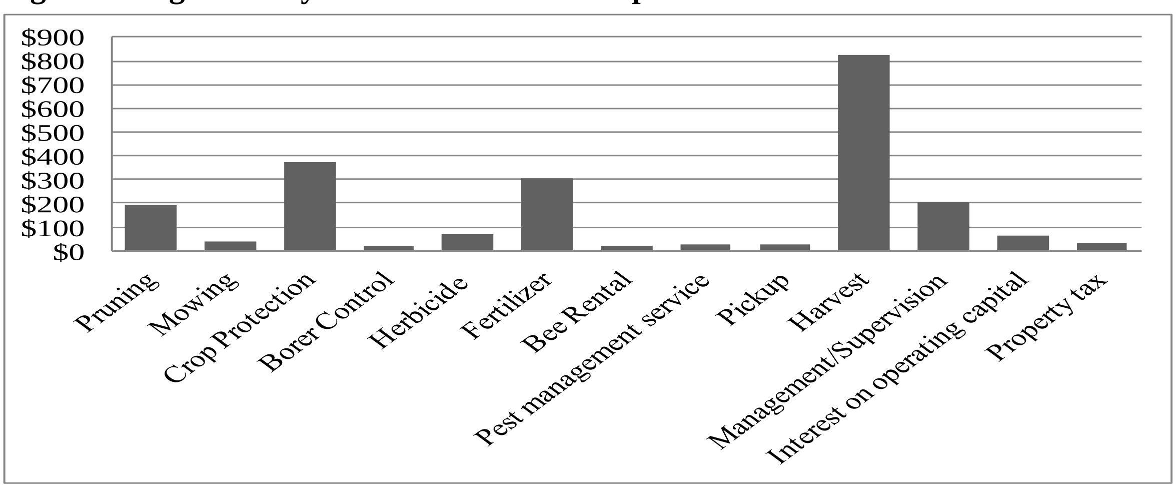
Source: Nugent et al., 2003, Black et al., 2010, Author Calculation, 2012

[14] An irrigation system could also be used in a high-density orchard as frost protection.

[15] Years 1 through 3 include the costs associated with planting and growing the tart cherry orchard up to the point of first harvest, in year 4.

Total annual nominal cost during peak production for a high-density orchard is estimated to be $2,185 per acre. Modifications are made for the years before and after peak production based on the percentage adjustments described in the previous sections. Annual cost includes both cash and non-cash costs associated with tart cherry operating, harvesting, and production (Figure 7). For the proposed high-density orchard system, time, equipment costs, and material costs are adjusted for the increased number of rows and trees planted per acre. The machinery cost is altered to reflect new equipment for harvesting the closely planted orchard. However, the labor costs and base material costs were not adjusted. Total cost per acre is still comprised of time, equipment costs, labor costs, and material costs for each operation. The three harvest costs of shipping, cooling pad operations, and the tart cherry assessment, are calculated by multiplying the average yield per acre, or 16,900 pounds per acre, by set annual cost rates. Interest is calculated at eight percent on the operating and harvest cash outflows (Dartt, 2012). In Figure 7 harvest and crop protection costs are again the two largest cost components of the total annual cost per acre.

Figure 7: High-Density Orchard Annual Cost per Acre[16]



Source: Nugent et al., 2003, Black et al., 2010, Author Calculation, 2012

[16] Pruning, mowing, crop protection, and so on, is the cost categories that make up the total annual cost per acre. These costs are all included at the nominal annual value.

4.3.4 High-Density Yield Trajectory

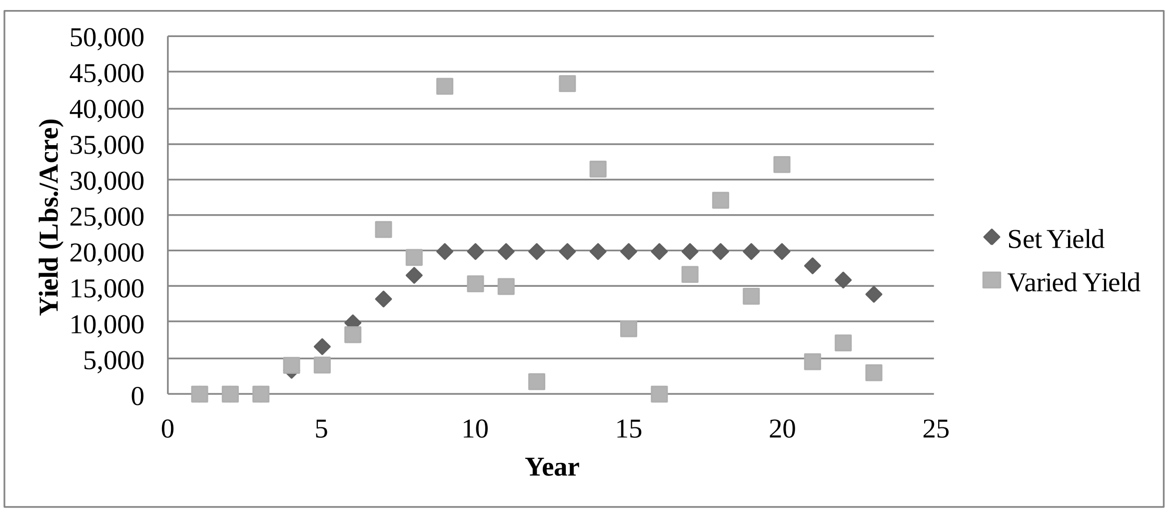
Like the standard orchard system, the yield outcomes for the high-density orchard system reflect variability from year-to-year. Again, yield trajectory values are positioned along a normal distribution curve. This trajectory follows the yield pattern of steady increase to peak production, 12 years of peak production, and decline for three years until the orchard is removed (Table 4).

	Table 4: Estimated Percentage Adjustment in Production Yield for Years Before and After Peak Production for the High-Density Orchard System:							
Year	4	5	6	7	8	21	22	23
Percent	16.70%	33.30%	50.00%	66.70%	83.30%	90.00%	80.00%	70.00%

Source: Beedy, Nyambane, Black, 2005

Historically, perennial fruit production yield does not maintain this deterministic path but instead includes variations for conditions in individual years as well as tree age. Figure 8 identifies both the set yield trajectory and an example stochastic yield for the high-density orchard system that is used as one component in the calculation of the NPV for the high-density orchard system (Table C8).

Figure 8: High-Density Orchard Yield Trajectory and Outcome[17]



Source: Authors Calculation, 2012

[17] Years 0 through 3 represent the establishment period with no harvestable production, while years 4 through 23 identify both the estimated varied yield outcome and set yield trajectory.

CHAPTER FIVE

RESULTS

This chapter presents the results of the calculations of cost of production, NPV, and asset replacement. Through the use of a sensitivity analysis the yield, price, and discount rate were adjusted to consider different scenarios that an individual tart cherry grower could encounter. The results obtained for both the standard and high-density orchard, under each scenario, are discussed for their economic relevance.

5.1 Cost of Production

One of the crucial economic questions posed by this research is whether or not the proposed high-density orchard system is likely to generate better economies of scale than the existing orchard system. To answer this question, the expected cost of production per pound was calculated for both orchard systems. Table 5 provides a detailed description of the calculation of cost per pound for the standard and high-density orchard system.

Table 5: Cost of production per pound for both the standard and high-density orchard system

	Standard Orchard ($/Acre)	High-density Orchard ($/Acre)
Amortized Establishment Cost		
Establishment cost	$437	$905
Establishment land control cost	$184	$122
Annual Bearing Cost		
Cost per acre	$1,426	$2,185
Land cost	$306	$306
Total Cost	$2,447	$3,616
Yield per acre	8,200	16,900
Average Cost per Pound	$0.29	$0.21

Source: Black et al., 2010, Author Calculation, 2012

The annual amortized cost to establish a standard orchard was $437 per acre, while the annual amortized cost to establish a high-density orchard was $905 per acre. A standard orchard’s amortized cost to establish was lower than the amortized cost to establish a high-density orchard based on the previously discussed factors influencing the lower establishment cost of a standard orchard. The annual amortized land control cost for a standard orchard for the six year orchard establishment was $184 per acre, while the annual amortized land control cost of a high-density for the four year orchard establishment was $122 per acre. A grower with a high-density orchard system gains economic efficiencies, with a lower land control cost during establishment, by entering the orchard for harvest in year four instead of year six. The cost per acre during peak production was $1,426 for the standard orchard and $2,185 for the high-density orchard. The annual land control cost during the bearing years of both orchards was $306 per acre. With an average yield per acre of 8,200 pounds, the standard orchard cost of production per pound was approximately $0.29. The cost of production per pound for a high-density orchard was approximately $0.21 with an average yield per acre of 16,900 pounds.

The estimated cost of production per pound indicates that a grower would receive approximately $0.05 per pound above the adjusted 27 year average price per pound with a high-density orchard system. If a tart cherry grower continues to operate a standard orchard system and the production costs and yield per acre are similar to those discussed above, it is possible that, on average, a grower will lose approximately $0.03 per pound.

5.2 Net Present Value

For each orchard system a capital budgeting model was developed to calculate NPV. Price per pound was multiplied by yield per acre to determine revenue per acre. Revenue per acre was subtracted from the cost per acre to estimate a NCF for each year in the life-cycle of the orchard. The stream of NCFs for the production years were discounted at a rate of 10.30 percent and the discounted establishment costs were subtracted to calculate NPV for each orchard system.

A tax rate is not assessed on the revenue per acre in this calculation. Growers, even within the northwest Michigan region, pay significantly different tax rates. The economic question in this study is whether or not growers should invest in one orchard system or the other, not whether or not growers should invest in tart cherry production. Tax rate it is not an important component in the decision on which orchard system to choose once the production decision has been made.

The base NPV for the standard orchard system, with an average yield per acre of 8,200 pounds, was -$247 per acre (Table D1). At an IRR of 6.76 percent the NPV was equal to zero for all cash flows. This estimation of NPV was calculated before including the stochastic estimation of yield and thus is not representative of any specific tart cherry grower in Michigan, but rather an average of the many possible scenarios that exist.

With an average yield per acre of 16,900 pounds, the base NPV for the proposed high-density orchard system was $6,477 per acre (Table D2). The NPV was equal to zero for all cash flows at an IRR of 12.53 percent. This estimated return is representative of expected performance of the proposed high-density orchard system before yield was stochastically estimated.

The comparison of these two base scenarios suggests that a tart cherry grower in Michigan should replant all new orchard sites with the proposed high-density orchard system. The NPV rule states, if the NPV of an investment project is positive, accept and if negative, reject. Therefore, the results obtained from these base scenarios answers the first question posed by this study, should a high-density orchard be planted in place of the existing standard orchard? As a result, it is clear economically, that a tart cherry grower, who is confronted with the decision to plant either orchard, should choose the high-density orchard system.

In addition to stochastically estimating the yield outcome, Microsoft @Risk has the capability to evaluate 10,000 iterations of the NPV calculation for each orchard system (Palisade Corp., Newfield, NY, 2010). This allows an analysis of certain statistics, including the mean, median, mode, maximum, minimum, and standard deviation of the NPV for both orchard systems (Table 6). These iterations analyze different yield trajectories, costs of production, and resulting NCF. The resulting cash flows are used to calculate 10,000 different NPV iterations that are used to evaluate the statistics described.

Table 6: Analytical statistics of the NPV calculation for both the standard and high-density orchard system

	Standard Orchard ($/Acre)	High-density Orchard ($/Acre)
Minimum	-$13,966	-$11,032
Maximum	$18,879	$31,116
Mean	-$217	$7,351
Mode	-$1,398	$6,752
Median	-$301	$7,066
Standard Deviation	$4,528	$5,326
Values	10,000	10,000

Source: Palisade Corp., Newfield, NY, 2010, Author Calculation, 2012

These results indicate that although there is more variation from the mean NPV for the high-density orchard system, there is a statistically significant advantage from a high-density orchard system when compared to a standard orchard system. This is related to a much higher expected maximum return from the high-density orchard system as well as a smaller potential minimum return. On average, across all 10,000 iterations, the high-density orchard system has the potential to provide better returns to the grower than the existing standard orchard system.

5.3 Sensitivity Analysis

The set parameters described in the previous NPV calculation provide the closest approximation of these values. However, certain components of the capital budgeting model may be adjusted, using a sensitivity analysis, to consider how a change in these parameters affects the results obtained. Several parameters, including the yield per acre, price per pound, and the discount rate, have a significant impact on the economic outcome. These parameters were altered to realistically provide the most accurate information on the possible scenarios these orchard systems could encounter. These adjustments are just a few of the many possible alternative solutions available for the existing standard orchard and proposed high-density orchard system.

5.3.1 Yield Adjustment

Through the use of Microsoft @Risk, many different yield trajectories for both the standard and high-density orchard system can be projected. It was in this analysis that yield per acre was varied to capture the true economic returns of each orchard system (Palisade Corp., Newfield, NY, 2010). In the first yield adjusted scenarios, for both orchard systems, the average yield per acre draw was approximately one standard deviation (σ) greater than the average yield per acre estimated by the base scenarios. The second yield per acre draw was approximately one (σ) lower than the average yield per acre evaluated in the base scenarios of both orchard systems. A one (σ) increase or decrease in average yield per acre was greater for the high-density orchard system based on its higher average yield per acre. The one (σ) increase and decrease represents an accurate unit movement between the base scenario and the yield adjusted scenarios analyzed. A one unit adjustment in yield was designed to provide a precise comparative illustration. The stochastic estimation of yield outcome within the NPV calculation allows this study to analyze realistic yield outcomes in representative scenarios for both orchard systems.

The NPV was $3,901 per acre for a standard orchard with a one (σ) increase in average yield per acre from 8,200 to 10,857 pounds (Table D3). With an IRR of 11.38% the NPV was equal to zero for all cash flows. As described by Table 7, the NPV with a one (σ) increase in average yield per acre and variability was positive and significantly higher than the NPV in the base scenario. This increased yield per acre could describe a very good orchard site, manager's performance, or climate scenario.

Table 7: NPV Results of Sensitivity Analysis Compared to Base Scenario		
	Standard Orchard ($/Acre)	High-density Orchard ($/Acre)
Base Scenario	-$247	$6,477
1 σ average yield increase with variability	$3,901	$12,836
1 σ average yield decrease with variability	-$3,748	-$2,236
25 percent price increase	$3,635	$14,725
25 percent price decrease	-$4,130	-$1,645
Risk-free discount rate	$3,901	$18,864

Source: Authors Calculation, 2012

With a one (σ) increase in average yield per acre to 21,862 pounds, the NPV for the proposed high-density orchard system was $12,836 per acre (Table D4). The NPV was equal to zero for all cash flows at an IRR of 15.13 percent. In this simulated scenario, there were actually two crop failures, one in year six and one in year 12. This was due to the higher coefficient of variation for the high-density orchard system that creates the potential for a higher yield as well as a higher chance of crop failure. A higher coefficient of variation was included for the high-density orchard system to account for some of the potential variation created by this new orchard system.

Results suggest that a tart cherry grower in Michigan should replant any new orchard sites with the proposed high-density orchard system. These results support the conclusion from the base NPV calculation that a high-density tart cherry orchard should be planted in place of the existing standard orchard system. Both orchard systems have a positive NPV, however, the NPV for the high-density orchard system is significantly higher. A grower should replant with a high-density system due to the higher return over the life of the orchard.

The NPV was -$3,748 per acre for a standard orchard with a one (σ) decrease in average yield per acre from 8,200 to 5,525 pounds (Table D5). In this situation the IRR was negative.

This scenario may describe a poor orchard site, manager's performance, or climate scenario. The average yield per acre was less than the historical average yield per acre in Michigan from 1984 to 2010 of 6,760 pounds per acre (National Agricultural Statistical Service, 2011). In this scenario NPV was significantly influenced by the decrease in average yield per acre as NPV decreased by over $3,000 per acre.

With a one (σ) decrease in average yield per acre to 11,979 pounds, the NPV for the proposed high-density orchard system was -$2,236 per acre (Table D6). However, the IRR was positive in this scenario at 6.05 percent. There were two crop failures, one in year four and another in year twelve. This scenario describes a situation where the high-density tart cherry orchard system did not properly function due to a possible poor orchard site, manager's performance, or other potential components that are currently unknown.

These results suggest that a tart cherry grower in Michigan should not plant either orchard system. Both the present value for the standard orchard and high-density orchard system are negative, so both investment projects should be rejected. However, a high-density orchard system should be planted if a grower's expected rate of return is less than 6.05 percent.

5.3.2 Price Adjustment

In this study, price was held constant at $0.262 per pound based on a calculated historical real average price per pound received by growers in the United States. However, price fluctuates from year-to-year depending on several factors, including those such as how much tonnage is held in the reserve by the federal marketing order, the prior year's production level, global and national demand for tart cherries, and the current year's production estimate. Tart cherry growers expect and receive different prices based on the quality of their fruit, the existing market for tart cherries, and the type of processor to whom they sell their fruit. To account for different price distributions across industry members, price per pound was increased 25 percent to $0.328 per pound and decreased by 25 percent to $0.197 per pound. The 25 percent increase and decrease reflects a realistic three year price swing in the price per pound for tart cherries, as the price in 2009 was $0.192 per pound, 2010 $0.221 per pound, and 2011 approximately[18] $0.32 per pound (National Agricultural Statistics Service, 2011).

The NPV for the standard orchard system was $3,635 per acre with an average yield per acre of 8,200 pounds and a price per pound of $0.328 (Table D7). With an IRR of 11.17 percent, the NPV was equal to zero for all cash flows. In this scenario an increase in price per pound creates a positive NPV for the standard orchard with the same yield, cost of production, and discount rate parameters used in the base scenario.

With an average yield per acre of 16,900 pounds and price per pound of $0.328, the NPV for the proposed high-density orchard system was $14,725 per acre (Table D8). The NPV was equal to zero for all cash flows at an IRR of 16.96 percent. Again, price was a significant factor in the expected return by increasing the present value from the base NPV calculation.

These results suggest that a tart cherry grower in Michigan should replant any new orchard sites with the proposed high-density orchard system. The results support the conclusion from the base NPV calculation that a high-density tart cherry orchard should be planted in place of the existing standard orchard system. Again, both orchard systems have a positive NPV however, the NPV for the high-density orchard system was significantly higher. In this scenario, a grower should replant with a high-density system due to the higher expected return over the life of the orchard.

[18] At the time of this thesis defense, U.S. price per pound had not yet been released by the National Agricultural Statistics Service. The $0.32 per pound is an approximate price paid to some Michigan tart cherry growers in 2011.

The NPV for the standard orchard system with an average yield per acre of 8,200 pounds and a price per pound of $0.197 per pound was -$4,130 per acre (Table D9). In this scenario, the IRR was negative. The decrease price per pound significantly lowers the present value in this scenario from the base NPV.

With an average yield per acre of 16,900 pounds and a price per pound of $0.197 per pound, the NPV for the proposed high-density orchard system was -$1,645 per acre (Table D10). The NPV was equal to zero for all cash flows at an IRR of 6.48 percent. Once more, the price per pound distribution has a significant impact on the present value of this orchard scenario.

These results suggest that a tart cherry grower in Michigan should not plant either orchard system. Both the present value for the standard orchard and high-density orchard system are negative, so both investment projects should be rejected. However, a high-density orchard system should be planted if a grower's expected rate of return is less than 6.48 percent.

5.3.3 Discount Rate Adjustment

For both orchard systems a discount rate of 10.30 percent was used to discount the NCF flows to their present value. The discount rate represents the risk-free rate of return, expected by a grower from an investment with no risk, plus a risk premium for planting the trees and waiting on a return over the life of the orchard. However, it is possible that some growers do not consider the risk premium of Michigan farmland in their investment decision. For this reason, the following NPV calculations use a discount rate of 4.30 percent, the risk-free rate to discount the NCFs to their present value.

The NPV for the standard orchard system with an average yield per acre of 8,200 pounds and a discount rate of 4.30 percent was $3,901 per acre (Table D11). The IRR remains at 6.76

percent. In this situation with a lower discount rate, the NPV was positive when compared with the negative base NPV calculation with a discount rate of 10.30 percent.

With an average yield per acre of 16,900 pounds and a discount rate of 4.30 percent, the NPV for the proposed high-density orchard system was $18,864 per acre (Tables D12). The IRR remains at 12.53%. In this situation the lower discount rate increased the NPV drastically from the base present value calculation.

Once more results suggest that a tart cherry grower in Michigan should replant any new orchard sites with the proposed high-density orchard system. These results support the conclusion from the base NPV calculation that a high-density tart cherry orchard should be planted in place of the existing standard orchard system. Though, both orchard systems have a positive NPV, the NPV for the high-density orchard system is considerably higher. This NPV result and all previous NPV results are used to determine the optimal asset replacement decision for an individual tart cherry grower.

5.4 Asset Replacement

The optimal time period for orchard replacement was determined by comparison of the annualized RPO value anticipated from the existing orchard with the annualized RPO value expected from the proposed high-density orchard system.[19] The following information provides an asset replacement decision for each NPV scenario evaluated between the existing orchard and proposed high-density orchard system.

When comparing the first two base scenarios, the optimal replacement period to transition an existing orchard with a yield of 8,200 pounds per acre to a high-density orchard system with an expected yield per acre of 16,900 pounds (Tables D1 & D2) was after harvest in

[19] For details on this calculation, please see the section on asset replacement in the methods chapter.

year 22 (Table D13). After harvest in year 22 the anticipated annual MNR of $716 from the existing orchard was less than the expected annual discounted NPV of $737 from the proposed high-density orchard system (Table 8). In this situation a grower should forgo the anticipated net returns from years 23 through 25 in pursuit of the higher expected NPV of the proposed orchard system.

Table 8: Asset Replacement Results Compared to Base Scenario			
	Replacement Year	Standard Orchard rpo_t	High-density Orchard rpo_t
Base Scenario	22	$716	$737
1 σ average yield increase with variability	21	$1,318	$1,461
25 percent price increase	18	$1,643	$1,676
Risk-free discount rate	Immediate	$1,115	$1,275

Source: Authors Calculation, 2012

The optimal replacement period to transition an existing orchard with a yield of 10,857 pounds per acre to a high-density orchard system with an expected yield per acre of 21,862 pounds (Tables D3 & D4) was after harvest in year 21 (Table D14). After harvest in year 21 the anticipated annual MNR of $1,318 from the existing orchard is less than the expected annual discounted NPV of $1,461 from the proposed high-density orchard system. Therefore, a grower should forgo the anticipated net return from years 22 through 25 in pursuit of the higher expected return from the proposed orchard system. With the stochastic estimation of yield outcome, the results indicate that asset replacement should occur one year before the optimal replacement period under the base scenario.

When average yield per acre decreases from the base approximation to 5,525 pounds per acre for the standard orchard and 11,979 pounds per acre for the high-density orchard system (Tables D4 & D5), there is no[20] optimal time period for asset replacement. As discussed, with

[20] This study did not calculate an asset replacement decision for the two scenarios where the NPV was negative for both orchard systems.

these negative NPVs, there should not be an investment in either the standard or high-density orchard system. A grower with anticipated low yields in the existing orchard and an expectation for a continuation of lower than average yields in the high-density orchard should reconsider the investment decision in tart cherry production. This scenario also provides information for growers who expect to plant the proposed high-density orchard system on their poorest orchard sites. A grower may not have a positive return from the high-density orchard system based solely on the site disadvantage the orchard encounters before it is even planted.

In scenarios where price increased 25 percent to $0.328 per pound (Tables D7 & D8), the optimal time period to replace the existing orchard with the high-density orchard system was after harvest in year 18 (Table D15). After harvest in year 18 the anticipated annual MNR of $1,643 from the existing orchard was less than the expected annual discounted NPV of $1,676 from the proposed high-density orchard system. In this asset replacement decision price has a significant influence on the decision of when to replace an existing orchard system. A grower should forgo the returns from years 19 through 25 to pursue the opportunity of a higher return from the high-density orchard system.

If a grower received a price per pound of $0.197 with an average yield per acre of 8,200 pounds from the standard orchard and 16,900 pounds from the high-density orchard (Tables D9 & D10), there would again, be no asset replacement decision. In these two situations the NPV for both orchard systems are negative. Growers must seriously consider their ability to generate positive returns based not only on higher yields and a lower cost of production per unit, but also on a realistic price per pound estimate.

In the final two scenarios where the discount rate was reduced to 4.30 percent (Tables D11 & D12) the optimal time period for a grower to replace the existing orchard system was recommended to be immediately (Table 16). The anticipated annual MNR from the existing orchard was less in every period when compared to the expected annual discounted NPV from the proposed high-density orchard system. Therefore, in whatever time period the orchard is in, if the orchard characteristics are similar to the base parameters described, except for a lower discount rate of 4.30 percent, a tart cherry grower should remove the existing orchard immediately and replant with a high-density orchard system.

The pattern of results in this section is driven by the change in critical economic parameters. As average yield per acre for both orchard systems increased one σ, or approximately 23 percent, the asset replacement decision changed from year 22 to year 21. In the scenario where price increased 25 percent, optimal orchard replacement changed from year 22 in the base scenario to year 18. As economic returns increased from a lower discount rate, the asset replacement decision changed drastically from year 22 to whichever year the orchard currently resides. These results appear to indicate that as economic returns increase for both orchard systems the asset replacement decision occurs in a year that is earlier than the traditional orchard removal time period.

CHAPTER SIX

CONCLUSION

This chapter is divided into three sections. The first section presents a summary of the asset replacement, stochastic estimation, cost of production, and NPV results from this study. In the second section specific variables that require some solidifying data are discussed. Finally, the third section offers a few general recommendations for future research on this topic.

6.1 Summary

The primary objective of this research was to utilize an asset replacement model to determine the optimal replacement period to transition the existing orchard system to the proposed high-density orchard system. A replacement model was designed to consider the constraints faced by an individual tart cherry grower in his or her decision framework. Six comparative scenarios were discussed in this study. In four of the six scenarios, asset replacement was optimal before the traditional removal time period for the standard orchard system. The optimal replacement time period was determined for each orchard scenario by comparing the annualized anticipated MNR of the existing orchard with the annualized expected NPV of the proposed high-density orchard system. The orchard scenarios analyzed in this study portray a few of the many possible situations that could exist for an individual tart cherry grower. The replacement model designed for this project has the ability to bring insight and clarity to the asset replacement decision for each individual grower's orchard characteristics.

One of the crucial components of this research was to determine a method to stochastically estimate yield outcome to provide the most accurate approximation of yield per acre for both orchard systems. In addition, with the limited amount of primary data available for the proposed high-density orchard system, the stochastic estimation of yield outcome provided an approximation of variability in the projection of yield per acre for the proposed orchard system. Stochastic estimation also accounted for some of the variation in production performance of the asset. A criticism of the MNR approach is that it does not easily take into account the variation in the expected performance of the asset. Therefore, stochastic estimation was used to account for this criticism and provide the most accurate yield outcome for the evaluation of the asset replacement decision.

Within the tart cherry industry a great deal of uncertainty remains around the expected yield per acre and price per pound of any system in any given year. When two of the primary components for determining profitability are highly uncertain, growers often look to a variable they can control, in most cases, cost of production. Cost of production tables were developed to approximate the costs associated with the inherent features of each orchard system. Although costs do increase with the proposed high-density orchard system, these costs are spread over a higher level of production. Results indicate that there was a significantly lower unit cost of production for the high-density orchard system when compared to the cost of production per pound for the standard orchard system.

The NPV was estimated to compare the economic returns of each orchard system to determine if an existing orchard system should be replaced with the proposed high-density orchard system. Furthermore, by evaluating specific variables under different scenarios, this study provides an in-depth analysis of the possible net returns from each orchard system. In four of the six scenarios analyzed, results indicated that an orchard site should be replanted with a high-density orchard system. The NPVs for both orchard systems were also used to determine the optimal replacement time period as one of the variables in the asset replacement model. This

NPV analysis represents the first component in the evaluation of asset replacement between the standard orchard system and the proposed high-density orchard system.

6.2 Variable Consideration

The results of this research indicate that an individual tart cherry grower should, in most situations, replant with a high-density orchard system, given the returns from the standard orchard and expected returns from the high-density orchard system. In addition, the optimal replacement time period for an existing orchard is often before the traditional removal period. However, there are still several variables that must be seriously considered by the grower before the decision is made to replace an existing orchard.

There is uncertainty related to the expected yield of the proposed high-density orchard system. The available primary and secondary data was collected and applied to approximate the expected yield trajectory of the high-density orchard system. Additionally, the expected yield outcome was estimated through stochastic estimation to account for some of the uncertainty present with the proposed high-density orchard system. In spite of this economic analysis there remains a level of uncertainty in the projection of yield per acre for the proposed high-density orchard system. In addition to the yield per acre, there are other variables in this study that are also supported by a limited amount of available data. To verify these variables, the research results would need to be obtained from fully developed research trials or active producing orchards. Currently, some of this necessary research is underway to define these variables and bring clarity to the uncertain parameters. When the primary data is available for the proposed high-density orchard system, the asset replacement model developed by this study will be able to be used to solidify the results obtained. Although these results appear conclusive on if, and when to replace an existing orchard, growers should carefully consider their ability to handle the risk associated with some of these variables before replacing any existing orchards.

6.3 Future Research

This research project is just one component of a large on-going effort to evaluate the feasibility of a comprehensive redesign of the tart cherry orchards in Michigan. There are currently some trial high-density tart cherry orchards being planted across Michigan. By 2020, the primary data collected from these and other possible high-density plantings will provide clarity to the uncertain parameters discussed throughout this study. When the primary data from research and grower trials is collected, there will be several opportunities to continue the economic research on this topic. A few of the potential research initiatives available for transition towards a high-density tart cherry orchard system are outlined below.

1. Analyze the asset replacement decision with a dynamic programming model. At the point at which a number of the state variables are less uncertain, use a dynamic programming model to sequence through the life-cycle of each orchard system and determine again the optimal time period for asset replacement.
2. Determine the optimal life-cycle of the high-density orchard system. One may discover that the optimal life-cycle of the high-density orchard is shorter or longer than expected, depending on the actual economic returns.
3. Conduct an economic price analysis to determine the impact a high-density tart cherry orchard has on average grower price-per-pound for tart cherries. Similarly, consider the impact, on price, of a high-density orchard at both the market and processor level.

APPENDIX A

Figure A1: Existing Orchard System[21]

Source: Authors Photo, 2012

Figure A2: High-Density Orchard System

Source: Clarksville Research Center, Michigan State University, Authors Photo, 2011

[21] "For interpretation of the reference to color in this and all other figures, the reader is referred to the electronic version of this thesis."

APPENDIX B

Table B1: Standard orchard parameters describing yield trajectory							
	Age	Yield	Percentage Adjustment	Yield RV	N(0,1)	Expected Mean: (Lbs./Acre)	Expected SD: (Lbs./Acre)
Before harvest	5	0					
1st crop	6	1,430	14.30%				
2nd crop	7	2,860	28.60%				
3rd crop	8	4,290	42.90%				
4th crop	9	5,710	57.10%				
5th crop	10	7,140	71.40%				
6th crop	11	8,570	85.70%				
Peak Production	12	10,000	100.00%	10,000	0.00	10,000	3147
1st crop decline	23	9,000	90.00%				
2nd crop decline	24	8,000	80.00%				
Rapid crop decline	25	7,000	70.00%				
Pull trees							
				CV of yield trajectory			0.384
				Annual yield is I.I.D			

Source: Black, 2011, Authors Calculation, 2012

Table B2: Standard orchard base yield trajectory									
Age	Expected Yield Lbs./A	Expected Yield Lbs./Tree	Expected Total Yield	Avg. Yield	N(0,1)	SD		Estimated Yield Lbs./A	Estimated Total Yield
1	0	0	0					0	0
2	0	0	0					0	0
3	0	0	0					0	0
4	0	0	0					0	0
5	0	0	0					0	0
6	1,430	11	1,430	1,430	0	549		1,430	1,430
7	2,860	21	4,290	2,145	0	1098		2,860	4,290
8	4,290	32	8,580	2,860	0	1647		4,290	8,580
9	5,710	42	14,290	3.573	0	2193		5,710	14,290
10	7,140	53	21,430	4,286	0	2742		7,140	21,430
11	8,570	63	30,000	5,000	0	3291		8,570	30,000
12	10,000	74	40,000	5,714	0	3840		10,000	40,000
13	10,000	74	50,000	6,250	0	3840		10,000	50,000
14	10,000	74	60,000	6,667	0	3840		10,000	60,000
15	10,000	74	70,000	7,000	0	3840		10,000	70,000
16	10,000	74	80,000	7,273	0	3840		10,000	80,000
17	10,000	74	90,000	7,500	0	3840		10,000	90,000
18	10,000	74	100,000	7,692	0	3840		10,000	100,000
19	10,000	74	110,000	7,857	0	3840		10,000	110,000
20	10,000	74	120,000	8,000	0	3840		10,000	120,000
21	10,000	74	130,000	8,125	0	3840		10,000	130,000
22	10,000	74	140,000	8,235	0	3840		10,000	140,000
23	9,000	66	149,000	8,278	0	3456		9,000	149,000
24	8,000	59	157,000	8,263	0	3072		8,000	157,000
25	7,000	51	164,000	8,200	0	2688		7,000	164,000

Source: Black, 2011, Authors Calculation, 2012

Table B3: High-Density orchard parameters describing yield trajectory							
	Age	Yield	Percentage Adjustment	Yield RV		Expected Yield Peak Production	
Before harvest	3	0				Minimum	15,000
1st crop	4	3,340	16.70%			Most Likely	20,000
2nd crop	5	6,660	33.30%			Maximum	25,000
3rd crop	6	10,000	50.00%				
4th crop	7	13,340	66.70%				
5th crop	8	16,660	83.30%				
Peak Production	9	20,000	100.00%	20,000			
1st crop decline	21	18,000	90.00%				
2nd crop decline	22	16,000	80.00%				
Rapid crop decline	23	14,000	70.00%				
Pull trees							
				CV of yield trajectory			0.652
				Annual yield is I.I.D			

Source: Black, 2011, Authors Calculation, 2012

Table B4: High-Density orchard base yield trajectory									
Age	Expected Yield Lbs./A	Expected Yield Lbs./Tree	Expected Total Yield	Avg. Yield	N(0,1)	SD		Estimated Yield Lbs./A	Estimated Total Yield
1	0	0	0					0	0
2	0	0	0					0	0
3	0	0	0					0	0
4	3,340	7	3,340	3,340	0	2,178		3,340	3,340
5	6,660	14	10,000	5,000	0	4,342		6,660	10,000
6	10,000	22	20,000	6,667	0	6,520		10,000	20,000
7	13,340	29	33,340	8,335	0	8,698		13,340	33,340
8	16,660	36	50,000	10,000	0	10,862		16,660	50,000
9	20,000	44	70,000	11,667	0	13,040		20,000	70,000
10	20,000	44	90,000	12,857	0	13,040		20,000	90,000
11	20,000	44	110,000	13,750	0	13,040		20,000	110,000
12	20,000	44	130,000	14,444	0	13,040		20,000	130,000
13	20,000	44	150,000	15,000	0	13,040		20,000	150,000
14	20,000	44	170,000	15,454	0	13,040		20,000	170,000
15	20,000	44	190,000	15,833	0	13,040		20,000	190,000
16	20,000	44	210,000	16,154	0	13,040		20,000	210,000
17	20,000	44	230,000	16,429	0	13,040		20,000	230,000
18	20,000	44	250,000	16,667	0	13,040		20,000	250,000
19	20,000	44	270,000	16,875	0	13,040		20,000	270,000
20	20,000	44	290,000	17,058	0	13,040		20,000	290,000
21	18,000	39	308,000	17,111	0	11,736		18,000	308,000
22	16,000	35	324,000	17,052	0	10,432		16,000	324,000
23	14,000	30	338,000	16,900	0	9,128		14,000	338,000

Source: Black, 2011, Authors Calculation, 2012

APPENDIX C

Table C1 (a): Standard orchard establishment cost			
Site preparation prior to year 1	**Cost/Acre($)**	Growing cost (year 3)	**Cost/Acre($)**
Orchard removal and clean-up	$600.00	Pruning	$28.18
Plowing and cover crop	$300.00	Tree replacement	$32.76
Custom nematicide application	$500.00	Pest control sprays	$88.68
Property tax	$30.00	Herbicide sprays	$55.74
Total	$1,430.00	Mowing	$20.37
Planting year (year 1)		Fertilizer	$109.70
Ground preparation	$27.22	Mouse control	$10.22
Marking and surveying	$13.24	Deer control	$68.00
Tree cost	$1,030.88	Management	$50.66
Tree planting	$61.20	Property tax	$30.00
Mulch application	$102.00	Total	$494.30
Pest control sprays	$88.68	Growing Cost (year 4)	
Herbicide sprays	$55.74	Pruning	$42.27
Mouse control	$10.22	Tree replacement	$6.31
Deer control	$68.00	Pest control sprays	$110.85
Management	$67.54	Herbicide sprays	$55.74
Property tax	$30.00	Mowing	$30.55
Total	$1,554.72	Fertilizer	$164.54
Growing cost (year 2)		Mouse control	$10.22
Pruning	$14.09	Deer control	$68.00
Tree replacement	$54.60	Management	$50.66
Pest control sprays	$88.64	Property tax	$30.00
Herbicide sprays	$55.74	Total	$569.14
Mowing	$20.37	Growing cost (year 5)	
Fertilizer	$51.93	Pruning	$56.36
Mouse control	$10.22	Pest control sprays	$110.85
Deer control	$68.00	Herbicide sprays	$55.74
Management	$50.66	Mowing	$30.55
Property tax	$30.00	Fertilizer	$219.39
Total	$444.28	Mouse control	$10.22
		Deer control	$68.00
		Management	$67.54
		Property tax	$30.00
		Total	$648.65
		Total Establishment Cost	$5,141.10

Source: Nugent et al., 2003, Black et al., 2010, Author Calculation, 2012

Table C1 (b): Standard orchard cost per acre							
	Time	Labor	Material	Equipment		Total	
Operation	Cash (Hrs/ Acre)	Cash ($/Hr)	Cash ($/Hr)	Cash ($/Hr)	Non-Cash ($/Hr)	Cash ($/Hr)	Non-Cash ($/Hr)
Pruning (every 2 years)						$97.39	$16.87
Pruning: chain saw	4	$14		$0.25		$57.34	$0.00
Brush disposal: 85 HP tractor	0.50	$14		$21.03	$9.88	$17.56	$4.94
Flail chopper	0.50			$4.37	$4.84	$2.18	$2.42
Summer hedge: 85 HP tractor	0.50	$14		$21.03	$9.88	$17.56	$4.94
Summer hedging: sickle bar	0.50			$5.51	$9.13	$2.76	$4.57
Mowing (3 times)						$19.82	$10.73
60 HP tractor	0.60	$14		$15.14	$6.42	$17.54	$3.85
Rotary mower	0.60			$3.80	$11.46	$2.28	$6.88
Crop Protection (4 times)						$279.91	$16.95
85 HP tractor	0.80	$26		$21.03	$9.88	$38.01	$7.90
Orchard sprayer	0.80			$9.65	$11.31	$7.72	$9.05
Insecticide			$83.60			$83.60	$0.00
Fungicide			$140.26			$140.26	$0.00
Plant growth regulator			$10.32			$10.32	$0.00
Borer control (every 4th year)						$1.34	$0.53
85 HP tractor	0.03	$14		$21.03	$9.88	$0.60	$0.25
Orchard sprayer	0.03			$9.65	$11.31	$0.24	$0.28
Insecticide			$0.50			$0.50	$0.00
Herbicide (2 times 50% of land)						$49.74	$6.01
60 HP used tractor	0.80	$26		$21.26	$2.03	$38.20	$1.63
Weed sprayer	0.80			$0.84	$5.47	$0.67	$4.38
Herbicide			$10.87			$10.87	$0.00
Fertilizer						$107.73	$3.21
60 HP tractor: Nitrogen	0.15	$26		$15.14	$6.42	$6.24	$0.96
Spin spreader	0.15			$0.90	$3.32	$0.13	$0.50
60 HP tractor: Potash	0.15	$26		$15.14	$6.42	$6.24	$0.96
Spin spreader	0.15			$0.90	$3.32	$0.13	$0.50
Nitrogen			$63.70			$63.70	$0.00
Potash			$20.00			$20.00	$0.00
60 HP tractor: Lime	0.03	$26		$15.14	$6.42	$1.25	$0.19
Spin spreader	0.03			$0.90	$3.32	$0.03	$0.10
Lime			$10.00			$10.00	$0.00
Bee rental			$18.15			$18.15	$0.00
Pest management service			$25.00			$25.00	$0.00
Pickup (40 miles/A @ 0.60/mile)				$20.00	$4.00	$20.00	$4.00
Total Operating Cost						$619.08	$58.29

Source: Nugent et al., 2003, Black et al., 2010, Author Calculation, 2012

Table C1 (b): Standard orchard cost per acre cont.							
	Time	Labor	Material	Equipment		Total	
Operation	Cash (Hrs/ Acre)	Cash ($/Hr)	Cash ($/Hr)	Cash ($/Hr)	Non-Cash ($/Hr)	Cash ($/Hr)	Non-Cash ($/Hr)
Harvest						$485.91	$58.76
85 HP tractor	0.20	$26		$21.03	$9.88	$9.50	$1.98
Orchard sprayer	0.20			$9.65	$11.31	$1.93	$2.26
Ethrel			$4.20			$4.20	$0.00
Double incline shaker 1	1.1	$33		$40.97	$30.31	$84.70	$34.36
Double incline shaker 2	1.1	$26				$30.02	$0.00
85 HP tractor	1.1	$14		$21.03	$9.88	$38.63	$10.87
60 HP tractor	1.1	$14		$15.14	$6.42	$32.16	$7.06
60 HP used tractor	1.1	$14		$21.26	$2.03	$38.88	$2.24
Skimmer (Misc. labor)	2	$12				$24.50	$0.00
Shipping						$131.20	$0.00
Cooling pad operation						$49.20	$0.00
Tart cherry assessment						$41.00	$0.00
Management & Labor Supervision	4	$33				$135.08	$0.00
Interest on operating capital @ 8%						$39.50	$0.00
Property tax						$30.00	$0.00
Production costs/acre						$1,309.57	$117.05
Total cost/acre						$1,426.62	

Source: Nugent et al., 2003, Black et al., 2010, Author Calculation, 2012

Table C2: Standard orchard estimated yield outcomes per acre						
Year	Set Yield	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	1,430	2,365	1,211	1,823	1,805	2,524
7	2,860	2,525	2,304	4,339	5,280	3,361
8	4,290	7,515	7,277	3,693	7,345	6,688
9	5,710	8,213	8,038	3,619	9,700	12,564
10	7,140	5,018	11,941	4,218	8,702	7,563
11	8,570	2,356	14,609	12,638	9,961	8,299
12	10,000	11,368	15,211	8,597	0	15,703
13	10,000	11,336	18,574	3,725	16,802	16,709
14	10,000	26,171	13,009	12,749	9,737	6,846
15	10,000	4,509	11,141	10,967	6,101	10,763
16	10,000	20,131	13,478	11,760	19,200	6,933
17	10,000	23,180	10,779	9,110	8,214	27,208
18	10,000	20,178	2,927	5,876	10,780	19,772
19	10,000	19,144	15,423	12,451	9,374	21,561
20	10,000	16,621	5,401	15,780	12,136	11,510
21	10,000	23,871	11,023	9,275	8,661	19,207
22	10,000	17,551	7,280	11,342	16,570	3,155
23	9,000	5,936	10,110	14,681	11,408	15,154
24	8,000	13,302	5,846	8,374	8,431	1,769
25	7,000	9,011	6,880	9,444	7,222	11,930
Draw	10,000	13,938	14,192	10,117	11,328	15,797
Average	8,200	12,515	9,623	8,723	9,371	11,461

Source: Authors Calculation, 2012

Table C3 (a): High-Density orchard establishment cost	
Site preparation prior to year 1	**Cost/Acre($)**
Orchard removal and clean-up	$600.00
Plowing and cover crop	$300.00
Irrigation system	$2000.00
Custom nematicide application	$500.00
Property tax	$30.00
Total	$3,430.00
Planting year (year 1)	
Ground preparation	$27.22
Marking and surveying	$19.87
Tree cost	$3,433.74
Tree planting	$203.85
Mulch application	$339.75
Pest control sprays	$164.95
Herbicide sprays	$66.96
Mouse control	$10.22
Deer control	$226.50
Management	$84.43
Property tax	$30.00
Total	$4,607.48
Growing cost (year 2)	
Pruning	$49.32
Pest control sprays	$164.95
Herbicide sprays	$66.96
Mowing	$40.73
Fertilizer	$160.06
Mouse control	$10.22
Deer control	$226.50
Management	$67.54
Property tax	$30.00
Total	$816.28
Growing cost (year 3)	
Pruning	$56.36
Pest control sprays	$164.95
Herbicide sprays	$66.96
Mowing	$40.74
Fertilizer	$338.85
Mouse control	$10.22
Deer control	$226.50
Management	$67.54
Property tax	$30.00
Total	$1,002.12
Total Establishment Cost	$9,855.88

Source: Nugent et al., 2003, Black et al., 2010, Author Calculation, 2012

Table C3 (b): High-Density orchard cost per acre							
	Time	Labor	Material	Equipment		Total	
Operation	Cash (Hrs/ Acre)	Cash ($/Hr)	Cash ($/Hr)	Cash ($/Hr)	Non-Cash ($/Hr)	Cash ($/Hr)	Non-Cash ($/Hr)
Pruning						$181.36	$14.72
Pruning: hand tools	10	$14		$0.10		$141.88	$0.00
Brush disposal: 85 HP tractor	1	$14		$21.03	$9.88	$35.11	$9.88
Flail chopper	1			$4.37	$4.84	$4.37	$4.84
Summer hedging: 85 HP tractor	0.15	$14		$21.03	$9.88	$5.27	$1.48
Summer hedging: sickle bar	0.15			$5.51	$9.13	$0.83	$1.37
Mowing (3 times)						$26.43	$14.31
60 HP tractor	0.80	$14		$15.14	$6.42	$23.39	$5.13
Rotary mower	0.80			$3.80	$11.46	$3.04	$9.17
Crop Protection (4 times)						$349.89	$21.19
85 HP tractor	1	$26		$21.03	$9.88	$47.51	$9.88
Orchard sprayer	1			$9.65	$11.31	$9.65	$11.31
Insecticide			$104.50			$104.50	$0.00
Fungicide			$175.33			$175.33	$0.00
Plant growth regulator			$12.90			$12.09	$0.00
Borer control (every 4th year)						$11.00	$6.62
85 HP tractor	0.31	$14		$21.03	$9.88	$7.49	$3.09
Orchard sprayer	0.31			$9.65	$11.31	$3.02	$3.53
Insecticide			$0.50			$0.50	$0.00
Herbicide (2 times 50% of land)						$62.17	$7.51
60 HP used tractor	1	$26		$21.26	$2.03	$47.74	$2.03
Weed sprayer	1			$0.84	$5.47	$0.84	$5.47
Herbicide			$13.59			$13.59	$0.00
Fertilizer						$299.17	$6.43
60 HP tractor: Nitrogen	0.30	$26		$15.14	$6.42	$12.49	$1.93
Spin spreader	0.30			$0.90	$3.32	$0.27	$1.00
60 HP tractor: Potash	0.30	$26		$15.14	$6.42	$12.49	$1.93
Spin spreader	0.30			$0.90	$3.32	$0.27	$1.00
Nitrogen			$191.10			$191.10	$0.00
Potash			$60.00			$60.00	$0.00
60 HP tractor: Lime	0.06	$26		$15.14	$6.42	$2.50	$0.39
Spin spreader	0.06			$0.90	$3.32	$0.05	$0.20
Lime			$20.00			$20.00	$0.00
Bee rental			$18.15			$18.15	$0.00
Pest management service			$25.00			$25.00	$0.00
Pickup (40 miles/A @ 0.60/mile)				$20.00	$4.00	$20.00	$4.00
Total Operating Cost						$993.16	$74.77

Source: Nugent et al., 2003, Black et al., 2010, Author Calculation, 2012

Table C3 (b): High-Density orchard cost per acre cont.							
	Time	Labor	Material	Equipment		Total	
Operation	Cash (Hrs/ Acre)	Cash ($/Hr)	Cash ($/Hr)	Cash ($/Hr)	Non-Cash ($/Hr)	Cash ($/Hr)	Non-Cash ($/Hr)
Harvest						$742.35	$80.10
85 HP tractor	0.25	$26		$21.03	$9.88	$11.88	$2.47
Orchard sprayer	0.25			$9.65	$11.31	$2.41	$2.83
Ethrel			$4.20			$4.20	$0.00
Continuous Harvester	1.6	$26		$28.35	$29.22	$86.25	$45.97
85 HP tractor	1.6	$14				$55.23	$15.54
60 HP tractor	1.6	$14				$45.98	$10.10
60 HP used tractor	1.6	$14				$55.60	$3.20
Skimmer (Misc. Labor)	2	$12				$24.50	$0.00
Shipping						$270.40	$0.00
Cooling pad operation						$101.40	$0.00
Tart cherry assessment						$84.50	$0.00
Management & Labor Supervision	6	33				$202.62	$0.00
Interest on operating capital @ 8%						$62.87	$0.00
Property tax						$30.00	$0.00
Production costs/acre						$2,031.00	$154.87
Total cost/acre						$2,185.86	

Source: Nugent et al., 2003, Black et al., 2010, Author Calculation, 2012

Table C4: High-Density orchard estimated yield outcomes per acre						
Year	Set Yield	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	3,340	1,379	4,039	4,220	656	5,749
5	6,660	2,421	4,077	15,254	10,955	11,345
6	10,000	10,402	8,337	14,165	10,711	3,977
7	13,340	20,630	23,092	7,236	7,889	2,081
8	16,660	18,904	19,171	0	36,930	35,906
9	20,000	0	43,175	14,863	0	34,095
10	20,000	20,264	15,475	24,745	39,289	36,009
11	20,000	19,908	15,093	25,795	36,758	1,587
12	20,000	7,175	1,749	8,372	1,359	23,400
13	20,000	17,500	43,555	6,806	21,083	14,584
14	20,000	200	31,564	14,662	26,956	18,361
15	20,000	15,293	9,170	17,179	26,370	40,202
16	20,000	25,201	0	7,105	19,441	25,017
17	20,000	36,804	16,791	10,919	32,310	29,199
18	20,000	20,000	27,192	17,660	26,738	29,405
19	20,000	37,381	13,729	6,811	7,822	4,300
20	20,000	12,360	32,201	24,779	0	55,637
21	18,000	14,743	4,546	3,454	14,512	44,336
22	16,000	1,685	7,183	0	18,622	27,654
23	14,000	5,838	3,001	9,972	9,561	15,562
Draw	20,000	17,040	19,840	15,617	22,988	24,101
Average	16,900	14,404	16,157	11,700	17,398	22,920

Source: Authors Calculation, 2012

APPENDIX D

Table D1: Standard orchard base NPV calculation						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$1,430.00	10.30%	$0.262	0	$0.00	$1,430.00
1	-$1,554.72		$0.262	0	$0.00	$1,554.72
2	-$444.28		$0.262	0	$0.00	$444.28
3	-$494.30		$0.262	0	$0.00	$494.30
4	-$569.14		$0.262	0	$0.00	$569.14
5	-$648.65		$0.262	0	$0.00	$648.65
6	-$872.97		$0.262	1,430	$375.33	$1,248.30
7	-$517.62		$0.262	2,860	$750.65	$1,268.27
8	-$182.24		$0.262	4,290	$1,125.98	$1,308.21
9	$150.52		$0.262	5,710	$1,498.68	$1,348.16
10	$494.46		$0.262	7,140	$1,874.00	$1,379.54
11	$825.09		$0.262	8,570	$2,249.33	$1,424.24
12	$1,198.03		$0.262	10,000	$2,624.65	$1,426.62
13	$1,198.03		$0.262	10,000	$2,624.65	$1,426.62
14	$1,198.03		$0.262	10,000	$2,624.65	$1,426.62
15	$1,198.03		$0.262	10,000	$2,624.65	$1,426.62
16	$1,198.03		$0.262	10,000	$2,624.65	$1,426.62
17	$1,198.03		$0.262	10,000	$2,624.65	$1,426.62
18	$1,198.03		$0.262	10,000	$2,624.65	$1,426.62
19	$1,198.03		$0.262	10,000	$2,624.65	$1,426.62
20	$1,198.03		$0.262	10,000	$2,624.65	$1,426.62
21	$1,198.03		$0.262	10,000	$2,624.65	$1,426.62
22	$1,198.03		$0.262	10,000	$2,624.65	$1,426.62
23	$937.23		$0.262	9,000	$2,362.19	$1,424.96
24	$705.91		$0.262	8,000	$2,099.72	$1,393.81
25	$460.56		$0.262	7,000	$1,837.26	$1,376.69
26						
NPV	-$247.85					
IRR	6.67%					
Avg. Yield				8,200		

Source: Authors Calculation, 2012

Table D2: High-Density orchard base NPV calculation						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$3,430.00	10.30%	$0.262	0.00	$0.00	$3,430.00
1	-$4,607.48		$0.262	0.00	$0.00	$4,607.48
2	-$816.28		$0.262	0.00	$0.00	$816.28
3	-$1,002.12		$0.262	0.00	$0.00	$1,002.12
4	-$912.96		$0.262	3,340	$875.08	$1,788.03
5	-$123.99		$0.262	6,660	$1,744.92	$1,868.91
6	$672.40		$0.262	10,000	$2,620.00	$1,947.60
7	$1,466.60		$0.262	13,340	$3,495.08	$2,028.48
8	$2,257.75		$0.262	16,660	$4,364.92	$2,107.17
9	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
10	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
11	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
12	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
13	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
14	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
15	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
16	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
17	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
18	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
19	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
20	$3,054.14		$0.262	20,000	$5,240.00	$2,185.86
21	$2,576.04		$0.262	18,000	$4,716.00	$2,139.96
22	$2,100.13		$0.262	16,000	$4,192.00	$2,091.87
23	$1,624.22		$0.262	14,000	$3,668.00	$2,043.78
24						
NPV	$6,477.52					
IRR	12.53%					
Avg. Yield				16,900		

Source: Authors Calculation, 2012

Table D3: Standard Orchard NPV calculation: 1 σ average yield increase with variability						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$1,430.00	10.30%	$0.262	0	$0.00	$1,430.00
1	-$1,554.72		$0.262	0	$0.00	$1,554.72
2	-$444.28		$0.262	0	$0.00	$444.28
3	-$494.30		$0.262	0	$0.00	$494.30
4	-$569.14		$0.262	0	$0.00	$569.14
5	-$648.65		$0.262	0	$0.00	$648.65
6	-$686.50		$0.262	2,383	$625.40	$1,311.90
7	-$1,138.46		$0.262	741	$194.43	$1,332.89
8	-$328.19		$0.262	3,988	$1,046.68	$1,374.87
9	$979.16		$0.262	9,129	$2,396.01	$1,416.85
10	$2,994.25		$0.262	16,932	$4,444.09	$1,449.84
11	$1,926.12		$0.262	13,041	$3,422.93	$1,496.81
12	-$606.29		$0.262	3,402	$893.02	$1,499.31
13	$848.06		$0.262	8,944	$2,347.38	$1,499.31
14	$2,171.69		$0.262	13,987	$3,671.00	$1,499.31
15	$1,936.34		$0.262	13,090	$3,435.65	$1,499.31
16	$1,752.85		$0.262	12,391	$3,252.16	$1,499.31
17	$2,868.05		$0.262	16,640	$4,367.36	$1,499.31
18	$3,439.30		$0.262	18,816	$4,938.62	$1,499.31
19	$979.89		$0.262	9,446	$2,479.20	$1,499.31
20	$2,388.10		$0.262	14,811	$3,887.42	$1,499.31
21	$3,275.57		$0.262	18,192	$4,774.89	$1,499.31
22	$2,792.68		$0.262	16,353	$4,292.00	$1,499.31
23	$426.45		$0.262	7,331	$1,924.01	$1,497.56
24	$1,874.52		$0.262	12,723	$3,339.35	$1,464.83
25	-$187.58		$0.262	4,798	$1,259.26	$1,446.84
26						
NPV	$3,901.73					
IRR	11.38%					
Avg. Yield				10,857		

Source: Authors Calculation, 2012

Table D4: High-Density orchard NPV calculation:1 σ average yield increase with variability						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$3,430.00	10.30%	$0.262	0	$0.00	$3,430.00
1	-$4,607.48		$0.262	0	$0.00	$4,607.48
2	-$816.28		$0.262	0	$0.00	$816.28
3	-$1,002.12		$0.262	0	$0.00	$1,002.12
4	-$1,365.21		$0.262	0	$0.00	$1,365.21
5	-$1,367.16		$0.262	2,358	$617.83	$1,985.00
6	-$1,365.21		$0.262	0	$0.00	$1,365.21
7	$1,631.46		$0.262	14,450	$3,785.93	$2,154.47
8	-$622.95		$0.262	6,165	$1,615.10	$2,238.05
9	$11,568.04		$0.262	53,014	$13,889.67	$2,321.63
10	$629.32		$0.262	11,263	$2,950.95	$2,321.63
11	$8,922.14		$0.262	42,915	$11,243.77	$2,321.63
12	-$1,365.21		$0.262	0	$0.00	$1,365.21
13	$6,204.00		$0.262	32,541	$8,525.63	$2,321.63
14	$6,908.59		$0.262	35,230	$9,230.22	$2,321.63
15	$4,008.95		$0.262	24,163	$6,330.58	$2,321.63
16	$3,597.10		$0.262	22,591	$5,918.73	$2,321.63
17	$9,728.56		$0.262	45,993	$12,050.19	$2,321.63
18	$9,832.51		$0.262	46,390	$12,154.14	$2,321.63
19	$2,212.95		$0.262	17,308	$4,534.59	$2,321.63
20	$3,745.57		$0.262	23,157	$6,067.20	$2,321.63
21	$4,605.61		$0.262	26,254	$6,878.49	$2,272.88
22	$3,659.19		$0.262	22,447	$5,880.99	$2,221.80
23	$713.58		$0.262	11,009	$2,884.31	$2,170.73
24						
NPV	$12,836.39					
IRR	15.13%					
Avg. Yield				21,862		

Source: Authors Calculation, 2012

Table D5: Standard orchard NPV calculation: 1 σ average yield decrease with variability						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$1,430.00	10.30%	$0.262	0	$0.00	$1,430.00
1	-$1,554.72		$0.262	0	$0.00	$1,554.72
2	-$444.28		$0.262	0	$0.00	$444.28
3	-$494.30		$0.262	0	$0.00	$494.30
4	-$569.14		$0.262	0	$0.00	$569.14
5	-$648.65		$0.262	0	$0.00	$648.65
6	-$811.47		$0.262	1,420	$372.77	$1,184.25
7	-$31.87		$0.262	4,463	$1,171.32	$1,203.19
8	-$301.91		$0.262	3,578	$939.18	$1,241.09
9	-$673.57		$0.262	2,307	$605.42	$1,278.99
10	-$763.99		$0.262	2,076	$544.77	$1,308.76
11	$384.53		$0.262	6,613	$1,735.70	$1,351.16
12	$810.63		$0.262	8,245	$2,164.06	$1,353.42
13	$507.19		$0.262	7,089	$1,860.62	$1,353.42
14	$1,414.06		$0.262	10,544	$2,767.48	$1,353.42
15	$2,071.47		$0.262	13,049	$3,424.90	$1,353.42
16	$962.91		$0.262	8,825	$2,316.33	$1,353.42
17	-$170.88		$0.262	4,506	$1,182.54	$1,353.42
18	-$35.00		$0.262	5,023	$1,318.42	$1,353.42
19	$908.68		$0.262	8,619	$2,262.10	$1,353.42
20	-$283.79		$0.262	4,075	$1,069.63	$1,353.42
21	-$880.99		$0.262	0	$0.00	$880.99
22	$570.23		$0.262	7,329	$1,923.66	$1,353.42
23	-$880.99		$0.262	0	$0.00	$880.99
24	-$234.30		$0.262	4,145	$1,087.99	$1,322.29
25	$947.17		$0.262	8,585	$2,253.22	$1,306.05
26						
NPV	-$3,748.87					
IRR	-					
Avg. Yield				5,525		

Source: Authors Calculation, 2012

Table D6:High-Density orchard NPV calculation:1 σ average yield decrease with variability						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$3,430.00	10.30%	$0.262	0	$0.00	$3,430.00
1	-$4,607.48		$0.262	0	$0.00	$4,607.48
2	-$816.28		$0.262	0	$0.00	$816.28
3	-$1,002.12		$0.262	0	$0.00	$1,002.12
4	-$1,361.65		$0.262	0	$0.00	$1,361.65
5	$1,043.14		$0.262	10,675	$2,796.93	$1,753.79
6	-$983.98		$0.262	3,220	$843.65	$1,827.63
7	$190.87		$0.262	7,994	$2,094.39	$1,903.53
8	$2,975.11		$0.262	18,903	$4,952.48	$1,977.37
9	-$1,117.88		$0.262	3,562	$933.33	$2,051.21
10	$81.00		$0.262	8,138	$2,132.22	$2,051.21
11	$5,153.50		$0.262	27,499	$7,204.71	$2,051.21
12	-$1,361.65		$0.262	0	$0.00	$1,361.65
13	$3,634.38		$0.262	21,701	$5,685.60	$2,051.21
14	-$1,537.91		$0.262	1,959	$513.30	$2,051.21
15	$2,022.58		$0.262	15,549	$4,073.79	$2,051.21
16	$2,335.37		$0.262	16,743	$4,386.58	$2,051.21
17	$1,727.80		$0.262	14,424	$3,779.02	$2,051.21
18	$3,509.94		$0.262	21,226	$5,561.15	$2,051.21
19	$1,638.80		$0.262	14,084	$3,690.01	$2,051.21
20	$2,735.34		$0.262	18,269	$4,786.55	$2,051.21
21	$467.67		$0.262	9,450	$2,475.81	$2,008.14
22	$1,383.46		$0.262	12,773	$3,346.47	$1,963.01
23	$1,593.71		$0.262	13,403	$3,511.59	$1,917.88
24						
NPV	-$2,236.14					
IRR	6.05%					
Avg. Yield				11,979		

Source: Authors Calculation, 2012

Table D7: Standard orchard NPV calculation with 25 percent price increase						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$1,430.00	10.30%	$0.328	0.00	$0.00	$1,430.00
1	-$1,554.72		$0.328	0.00	$0.00	$1,554.72
2	-$444.28		$0.328	0.00	$0.00	$444.28
3	-$494.30		$0.328	0.00	$0.00	$494.30
4	-$569.14		$0.328	0.00	$0.00	$569.14
5	-$648.65		$0.328	0.00	$0.00	$648.65
6	-$779.14		$0.328	1,430.00	$469.16	$1,248.30
7	-$329.96		$0.328	2,860.00	$938.31	$1,268.27
8	$99.26		$0.328	4,290.00	$1,407.47	$1,308.21
9	$525.19		$0.328	5,710.00	$1,873.34	$1,348.16
10	$962.96		$0.328	7,140.00	$2,342.50	$1,379.54
11	$1,387.42		$0.328	8,570.00	$2,811.66	$1,424.24
12	$1,854.19		$0.328	10,000.00	$3,280.81	$1,426.62
13	$1,854.19		$0.328	10,000.00	$3,280.81	$1,426.62
14	$1,854.19		$0.328	10,000.00	$3,280.81	$1,426.62
15	$1,854.19		$0.328	10,000.00	$3,280.81	$1,426.62
16	$1,854.19		$0.328	10,000.00	$3,280.81	$1,426.62
17	$1,854.19		$0.328	10,000.00	$3,280.81	$1,426.62
18	$1,854.19		$0.328	10,000.00	$3,280.81	$1,426.62
19	$1,854.19		$0.328	10,000.00	$3,280.81	$1,426.62
20	$1,854.19		$0.328	10,000.00	$3,280.81	$1,426.62
21	$1,854.19		$0.328	10,000.00	$3,280.81	$1,426.62
22	$1,854.19		$0.328	10,000.00	$3,280.81	$1,426.62
23	$1,527.77		$0.328	9,000.00	$2,952.73	$1,424.96
24	$1,230.84		$0.328	8,000.00	$2,624.65	$1,393.81
25	$919.88		$0.328	7,000.00	$2,296.57	$1,376.69
26						
NPV	$3,635.26					
IRR	11.17%					
Avg. Yield				8,200		

Source: Authors Calculation, 2012

Table D8: High-Density orchard NPV calculation with 25 percent price increase						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$3,430.00	10.30%	$0.328	0.00	$0.00	$3,430.00
1	-$4,607.48		$0.328	0.00	$0.00	$4,607.48
2	-$816.28		$0.328	0.00	$0.00	$816.28
3	-$1,002.12		$0.328	0.00	$0.00	$1,002.12
4	-$692.52		$0.328	3,340.00	$1,095.52	$1,788.04
5	$315.57		$0.328	6,660.00	$2,184.48	$1,868.91
6	$1,332.40		$0.328	10,000.00	$3,280.00	$1,947.60
7	$2,347.04		$0.328	13,340.00	$4,375.52	$2,028.48
8	$3,357.31		$0.328	16,660.00	$5,464.48	$2,107.17
9	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
10	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
11	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
12	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
13	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
14	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
15	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
16	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
17	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
18	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
19	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
20	$4,374.14		$0.328	20,000.00	$6,560.00	$2,185.86
21	$3,764.04		$0.328	18,000.00	$5,904.00	$2,139.96
22	$3,156.13		$0.328	16,000.00	$5,248.00	$2,091.87
23	$2,548.22		$0.328	14,000.00	$4,592.00	$2,043.78
24						
NPV	$14,725.36					
IRR	16.96%					
Avg. Yield				16,900		

Source: Authors Calculation, 2012

Table D9: Standard orchard NPV calculation with 25 percent price decrease						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$1,430.00	10.30%	$0.197	0.00	$0.00	$1,430.00
1	-$1,554.72		$0.197	0.00	$0.00	$1,554.72
2	-$444.28		$0.197	0.00	$0.00	$444.28
3	-$494.30		$0.197	0.00	$0.00	$494.30
4	-$569.14		$0.197	0.00	$0.00	$569.14
5	-$648.65		$0.197	0.00	$0.00	$648.65
6	-$966.80		$0.197	1,430.00	$281.49	$1,248.30
7	-$705.28		$0.197	2,860.00	$562.99	$1,268.27
8	-$463.73		$0.197	4,290.00	$844.48	$1,308.21
9	-$224.15		$0.197	5,710.00	$1,124.01	$1,348.16
10	$25.96		$0.197	7,140.00	$1,405.50	$1,379.54
11	$262.75		$0.197	8,570.00	$1,686.99	$1,424.24
12	$541.87		$0.197	10,000.00	$1,968.49	$1,426.62
13	$541.87		$0.197	10,000.00	$1,968.49	$1,426.62
14	$541.87		$0.197	10,000.00	$1,968.49	$1,426.62
15	$541.87		$0.197	10,000.00	$1,968.49	$1,426.62
16	$541.87		$0.197	10,000.00	$1,968.49	$1,426.62
17	$541.87		$0.197	10,000.00	$1,968.49	$1,426.62
18	$541.87		$0.197	10,000.00	$1,968.49	$1,426.62
19	$541.87		$0.197	10,000.00	$1,968.49	$1,426.62
20	$541.87		$0.197	10,000.00	$1,968.49	$1,426.62
21	$541.87		$0.197	10,000.00	$1,968.49	$1,426.62
22	$541.87		$0.197	10,000.00	$1,968.49	$1,426.62
23	$346.68		$0.197	9,000.00	$1,771.64	$1,424.96
24	$180.98		$0.197	8,000.00	$1,574.79	$1,393.81
25	$1.25		$0.197	7,000.00	$1,377.94	$1,376.69
26						
NPV	-$4,130.96					
IRR	-					
Avg. Yield				8,200		

Source: Authors Calculation, 2012

Table D10: High-Density orchard NPV calculation with 25 percent price decrease						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$3,430.00	10.30%	$0.197	0.00	$0.00	$3,430.00
1	-$4,607.48		$0.197	0.00	$0.00	$4,607.48
2	-$816.28		$0.197	0.00	$0.00	$816.28
3	-$1,002.12		$0.197	0.00	$0.00	$1,002.12
4	-$1,130.06		$0.197	3,340.00	$657.98	$1,788.04
5	-$556.89		$0.197	6,660.00	$1,312.02	$1,868.91
6	$22.40		$0.197	10,000.00	$1,970.00	$1,947.60
7	$599.50		$0.197	13,340.00	$2,627.98	$2,028.48
8	$1,174.85		$0.197	16,660.00	$3,282.02	$2,107.17
9	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
10	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
11	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
12	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
13	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
14	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
15	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
16	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
17	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
18	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
19	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
20	$1,754.14		$0.197	20,000.00	$3,940.00	$2,185.86
21	$1,406.04		$0.197	18,000.00	$3,546.00	$2,139.96
22	$1,060.13		$0.197	16,000.00	$3,152.00	$2,091.87
23	$714.22		$0.197	14,000.00	$2,758.00	$2,043.78
24						
NPV	-$1,645.36					
IRR	6.48%					
Avg. Yield				16,900		

Source: Authors Calculation, 2012

Table D11: Standard orchard NPV calculation with risk-free discount rate						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$1,430.00	4.30%	$0.262	0.00	$0.00	$1,430.00
1	-$1,554.72		$0.262	0.00	$0.00	$1,554.72
2	-$444.28		$0.262	0.00	$0.00	$444.28
3	-$494.30		$0.262	0.00	$0.00	$494.30
4	-$569.14		$0.262	0.00	$0.00	$569.14
5	-$648.65		$0.262	0.00	$0.00	$648.65
6	-$872.97		$0.262	1,430.00	$375.33	$1,248.30
7	-$517.62		$0.262	2,860.00	$750.65	$1,268.27
8	-$182.24		$0.262	4,290.00	$1,125.98	$1,308.21
9	$150.52		$0.262	5,710.00	$1,498.68	$1,348.16
10	$494.46		$0.262	7,140.00	$1,874.00	$1,379.54
11	$825.09		$0.262	8,570.00	$2,249.33	$1,424.24
12	$1,198.03		$0.262	10,000.00	$2,624.65	$1,426.62
13	$1,198.03		$0.262	10,000.00	$2,624.65	$1,426.62
14	$1,198.03		$0.262	10,000.00	$2,624.65	$1,426.62
15	$1,198.03		$0.262	10,000.00	$2,624.65	$1,426.62
16	$1,198.03		$0.262	10,000.00	$2,624.65	$1,426.62
17	$1,198.03		$0.262	10,000.00	$2,624.65	$1,426.62
18	$1,198.03		$0.262	10,000.00	$2,624.65	$1,426.62
19	$1,198.03		$0.262	10,000.00	$2,624.65	$1,426.62
20	$1,198.03		$0.262	10,000.00	$2,624.65	$1,426.62
21	$1,198.03		$0.262	10,000.00	$2,624.65	$1,426.62
22	$1,198.03		$0.262	10,000.00	$2,624.65	$1,426.62
23	$937.23		$0.262	9,000.00	$2,362.19	$1,424.96
24	$705.91		$0.262	8,000.00	$2,099.72	$1,393.81
25	$460.56		$0.262	7,000.00	$1,837.26	$1,376.69
26						
NPV	$3,901.19					
IRR	6.76%					
Avg. Yield				8,200		

Source: Authors Calculation, 2012

Table D12: High-Density orchard NPV calculation with risk-free discount rate						
Year	NCF	Discount Rate	Price/Lb.	Yield/Acre	Revenue/Acre	Cost/Acre
0	-$3,430.00	4.30%	$0.262	0.00	$0.00	$3,430.00
1	-$4,607.48		$0.262	0.00	$0.00	$4,607.48
2	-$816.28		$0.262	0.00	$0.00	$816.28
3	-$1,002.12		$0.262	0.00	$0.00	$1,002.12
4	-$912.96		$0.262	3,340.00	$875.08	$1,788.04
5	-$123.99		$0.262	6,660.00	$1,744.92	$1,868.91
6	$672.40		$0.262	10,000.00	$2,620.00	$1,947.60
7	$1,466.60		$0.262	13,340.00	$3,495.08	$2,028.48
8	$2,257.75		$0.262	16,660.00	$4,364.92	$2,107.17
9	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
10	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
11	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
12	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
13	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
14	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
15	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
16	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
17	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
18	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
19	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
20	$3,054.14		$0.262	20,000.00	$5,240.00	$2,185.86
21	$2,576.04		$0.262	18,000.00	$4,716.00	$2,139.96
22	$2,100.13		$0.262	16,000.00	$4,192.00	$2,091.87
23	$1,624.22		$0.262	14,000.00	$3,668.00	$2,043.78
24						
NPV	$18,864.74					
IRR	12.53%					
Avg. Yield				16,900		

Source: Authors Calculation, 2012

Table D13: Asset replacement base scenario							
Age	Year Left	Discount Rate	Standard RPO_t	Year	NPV	HD RPO_t	Decision
15	10	10.30%	$1,099.22	24	$6,477.52	$737.30	Maintain
16	9		$1,081.86			$737.30	Maintain
17	8		$1,059.85			$737.30	Maintain
18	7		$1,031.18			$737.30	Maintain
19	6		$992.53			$737.30	Maintain
20	5		$937.91			$737.30	Maintain
21	4		$855.32			$737.30	Maintain
22	3		$716.78			$737.30	Replace
23	2		$589.25			$737.30	Replace
24	1		$460.56			$737.30	Replace
25	0						

Source: Authors Calculation, 2012

Table D14: Asset replacement: 1 σ average yield increase with variability							
Age	Year Left	Discount Rate	Standard RPO_t	Year	NPV	HD RPO_t	Decision
15	10	10.30%	$2,103.37	24	$12,836.39	$1,461.10	Maintain
16	9		$2,164.96			$1,461.10	Maintain
17	8		$2,031.73			$1,461.10	Maintain
18	7		$1,739.74			$1,461.10	Maintain
19	6		$1,915.74			$1,461.10	Maintain
20	5		$1,790.18			$1,461.10	Maintain
21	4		$1,318.54			$1,461.10	Replace
22	3		$722.63			$1,461.10	Replace
23	2		$893.97			$1,461.10	Replace
24	1		-$187.58			$1,461.10	Replace
25	0						

Source: Authors Calculation, 2012

Table D15: Asset replacement with 25 percent price increase							
Age	Year Left	Discount Rate	Standard RPO_t	Year	NPV	HD RPO_t	Decision
15	10	10.30%	$1,729.32	24	$14,725.36	$1,676.11	Maintain
16	9		$1,707.38			$1,676.11	Maintain
17	8		$1,679.56			$1,676.11	Maintain
18	7		$1,643.33			$1,676.11	Replace
19	6		$1,594.49			$1,676.11	Replace
20	5		$1,525.45			$1,676.11	Replace
21	4		$1,421.07			$1,676.11	Replace
22	3		$1,245.99			$1,676.11	Replace
23	2		$1,082.97			$1,676.11	Replace
24	1		$919.88			$1,676.11	Replace
25	0					$1,676.11	

Source: Authors Calculation, 2012

Table D16: Asset replacement with risk-free discount rate							
Age	Year Left	Discount Rate	Standard RPO_t	Year	NPV	HD RPO_t	Decision
1	24	4.30%	$365.00	24	$18,864.74	$1,275.57	Replace
2	23		$421.11			$1,275.57	Replace
3	22		$486.28			$1,275.57	Replace
4	21		$563.60			$1,275.57	Replace
5	20		$655.19			$1,275.57	Replace
6	19		$774.53			$1,275.57	Replace
7	18		$879.10			$1,275.57	Replace
8	17		$968.38			$1,275.57	Replace
9	16		$1,040.14			$1,275.57	Replace
10	15		$1,090.25			$1,275.57	Replace
11	14		$1,115.85			$1,275.57	Replace
12	13		$1,107.47			$1,275.57	Replace
13	12		$1,097.65			$1,275.57	Replace
14	11		$1,086.01			$1,275.57	Replace
15	10		$1,071.99			$1,275.57	Replace
16	9		$1,054.81			$1,275.57	Replace
17	8		$1,033.27			$1,275.57	Replace
18	7		$1,005.51			$1,275.57	Replace
19	6		$968.43			$1,275.57	Replace
20	5		$916.42			$1,275.57	Replace
21	4		$838.29			$1,275.57	Replace
22	3		$707.92			$1,275.57	Replace
23	2		$585.82			$1,275.57	Replace
24	1		$460.56			$1,275.57	Replace
25	0						

Source: Authors Calculation, 2012

REFERENCES

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ASAE Standards. (2003). Standards engineering practices data, 50th edition. American Society of Agricultural and Biological Engineers.

Beedy, T., Nyambane, G., and Black, J. (2005). Relative Yield Worksheet, East Lansing: Michigan State University. Excel File.

Black, R., Nugent, J., Rothwell, N., Thornsbury, S.and N. Olynk (2010). "Michigan Production Costs for Tart Cherries by Production Region" Economics Report 639, Department of Agricultural, Food and Resource Economics, Michigan State University, September.

Black, R. and Nyambane, G. (2004). "The Real Options Puzzle For Michigan Tart Cherry Producers". American Agricultural Economics Association Annual Meeting [Selected Paper]. Retrieved 2 Jan. 2011, ageconsearch.umn.edu/bitstream/20011/1/sp04ny01.pdf

Board of Governors of the Federal Reserve System. (2011). U.S. 30-year treasury bill. Retrieved from the world wide web January 5, 2012. http://www.federalreserve.gov/releases/h15/data.htm.

Brealey, R. and Myers, S. (2000). Principles of Corporate Finance. 6th ed. McGraw-Hill, New York, NY.

Iezzoni, A., Perry, R. (2011). Clarksville Research Center Michigan State University. Department of Horticulture. Personal Communication.

Chen, Z. (1996). "New Technology, Subsidies, and Competitive Advantage." Southern Economic Journal. 63(1): 124-139.

Dartt, Barbara. (2012). USDA's Risk Avoidance Mitigation Program (RAMP). Excel file

Downy, R., Good, D.L., Norton, R.L., and Kearl, C.D. (1974). An economic evaluation of high-density apple planting systems in Western New York. A.E. Res. 73-26, Dept. of Agric Econ., Cornell University, Ithaca, NY, 31 pp.

Florida Grower Interviews. (2011). Personal Communication.

France, J. and Thornley, J. H. M. (1984). Mathematical models in agriculture: a quantitative approach to problems in agriculture and related sciences. London, Butterworths.

Groenendaal, H., Galligan, D., Mulder, H. (2004). An Economic Spreadsheet Model to Determine Optimal Breeding and Replacement Decisions for Dairy Cattle. J. Dairy Sci. 87:2146-2157.

Hanson, S.D. (1999) A simple Framework for Determining the Fundamental Agricultural-Use Value of Michigan Farmland. Dept. of Agr. Econ. Michigan State University, Staff Paper, 1-12.

Harsh, S. B., Connor, L. J., and Schwab, G. D. (1981). Managing the farm business. Englewood Cliffs, N.J: Prentice-Hall.

Heuser, W. (2011) Personal Communication.

Huirne, R., Dijkhuizen, A., Van Beek, P., and Renkema, J. (1997). Dynamic programming to optimize treatment and replacement decisions. Pages 85-97 in Animal Health Economics; Principles and Applications. A.A. Dijkhuizen and R. S. Morris, ed. Post Graduate Foundation in Veterinary Science, University of Sydney, Sydney Australia.

Iezzoni, A., Perry, R. (2011). Clarksville Research Center Michigan State University. Department of Horticulture. Personal Communication.

Michigan Grower Interviews. (2011). Personal Communication.

Microsoft. (2010). Microsoft Excel @Risk. Redmond, Washington: Microsoft.

National Agricultural Statistics Service. (2011). Michigan Rotational Survey, Michigan Agricultural Statistics.

Nugent, J., Kole, G., Thornton, G., & Bardenhagen, J. (2003). Cost of Producing Tart Cherries in Northwestern Michigan. Michigan State University Extension Bulletin E-1108.

Park, H. (2008). Univariate Analysis and Normality Test Using SAS, Stata, and SPSS. Indiana University, University Information Technology Service. http://www.indiana.edu/~statmath/stat/all/normality/normality.pdf

Perry, R. (2011). Personal Communication.

Perry, R., Guyer, D., Thornsbury, S., Iezzoni, A., Flore, J., Lang, G., Rothwell, N., Schwallier, P. (2010). Over-the-Row Harvest Trial Video. Michigan State University.

Peterson, D.L., Miller, S.S., Whitney, J.D. (1994). Harvesting Semidwarf Freestanding Apple Trees with an Over-the-Row Mechanical Harvester. J. Amer. Soc. Hort. SCI. 119(6): 1114-1120.

Ricks, D., Hamm, L., Chase-Lansdale, W. (1982). The Tart Cherry Subsector of U.S. Agriculture: A Review of Organization and Performance. Research Division, College Of Agriculture and Life Sciences, University of Wisconsin-Madison.

Robinson, T., Hoying, S.A., DeMaree, A., Lungerman, K. Fargione, M. (2007). The Evolution Towards More Competitive Apple Orchard Systems in New York. Volume 15, New York Fruit Quarterly.

Robinson, T.L., R.L. Andersen and S.A. Hoying. (2007). Performance of six high density cherry training systems in the northeastern United States. Acta Hort. 732:421-428.

Roka, F. (2011). Southwest Florida Research and Educational Center. University of Florida, Personal Communication.

Ross, S., Westerfield, R., Jaffe, J. (2008). Corporate Finance. New York: McGraw-Hill/Irwin.

Rothwell, N. (2011). Northwest Michigan Horticultural Research Station, Michigan State University. Personal Communication.

Schmitz, A. and Seckler, D. (1970). Mechanized agriculture and social welfare: The case of the tomato harvester. American Journal of Agricultural Economics, 52, 567-577.

Seavert, C., Long, L.E. (2004). Financial and economic comparison between establishing a standard and high-density sweet cherry orchard in Oregon, USA.

Seavert, C., Long, L.E., Freeborn, J. (2008). The Costs and Returns of Establishing and Producing High-Density Sweet Cherries in Wasco County. Oregon State University Extension Service, EM 8802-E, March 2008.

Skinner, D. (1999). Introduction to Decision Analysis: A practitioner's guide to Improving decision quality. Florida: Probabilistic Publishing, 2nd Edition.

Smith, B., Taylor, J., Walter, J., Tomaszewski, M. Woelfel, C., and Leatham, D. (1993). Seasonal effects on income over feed and replacement costs. J. Dairy Sci. 76:1678-1682

StataCorp. (2009). Stata Statistical Software: Release 11. College Station, TX: StataCorp LP.

Van Arendonk, J. (1985). Studies on the replacement policies in dairy cattle. Ph.D. Diss., Wageningen Agricultural Univ., Wageningen, The Netherlands.

White, G., Kesecker, K. (2007). Economic Analysis of the Tart Cherry Federal Marketing Orders. New York: Cornell University. http://www.cherryboard.org/TartCherryExecSummaryFINAL.pdf

Wittenberg, E., Harsh, S. (2011). 2011 Michigan Land Values and Leasing Rates. Agricultural Economic Reports Series 642.Dept. of Agricultural, Food, and Resource Economics, Michigan State University.

Wright, R. (2005). "Technological leapfrogging as a source of competitive advantage in the American and Polish tart cherry industries". Department of Agriculture, Food, and Resource Economics Michigan State University [A Plan B Paper]. Retrieved 10 November 2010, ageconsearch.umn.edu/bitstream/10954/1/pb05wr01.pdf