Evaluating the Potential for Robotic Technology in California Table Grape Production

Dean A. McCorkle[1], Rebekka M. Dudensing[1], Dan D. Hanselka [1], and Ed W. Hellman[2]

Texas A&M AgriLife Extension Service, [1]Department of Agricultural Economics, [2]Department of Horticultural Sciences

The Texas A&M University System

Problem Statement

In 2015, the U.S. produced an estimated 1.13 million tons of table grapes valued at $1.7 billion, all of which was grown in California (NASS, 2015).

Grapes are among the most intensively managed fruit crops, requiring a deal of manual labor to complete many production tasks including vine training, canopy management, selective trimming of grapes from clusters, and harvesting and packing the grapes. Scarcity of skilled labor has been identified as an increasing challenge for the grape industry and has constrained continued expansion (MFK Research, 2007). With a push for stricter border reform in the U.S., there is cause for vineyards to be concerned about skilled labor availability and rising production and harvesting costs.

Consumers demand unblemished, undamaged fruit. Robotic technology has made significant contributions over the last decade and offers the potential to duplicate the efficacy of skilled human labor for vineyard tasks requiring selective activity. Today's industrial robots have dexterity, strength, reliability, speed, and precision that is unparalleled by human workers. Table grape production is primed for robotic technology as it faces a variety of production and labor issues that could affect long-term competitiveness.

Data and Methods

This project used a grower panel to develop a representative table grape vineyard budget for the southern San Joaquin Valley area of California. Using a consensus building process, the panel provided information for the size of the vineyard (100 acres), cost of production, fixed costs, yield, price, equipment complement, other assets, and loan terms and balances. Labor costs for various production tasks were of particular interest. A follow-up conference call was held to allow the panel to review the budget, validate the financial statements, and recommend further clarifications regarding production tasks and the potential for new technology. A summary of the production cost budget for the representative table grape vineyard is presented in Table 1, which includes subtotals for the various production tasks by budget category.

To evaluate the economic viability of the representative vineyard using current production methods and technology, data from the representative budget was used to develop a projected income statement, cash flow statement, and balance sheet to estimate a range of financial outcomes over a 10-year projection period (2015-2024). These baseline scenarios reflect the representative vineyards' current production and operating practices, projected over a 10-year planning horizon. Long-range, annual projections of inflation rate indices for input prices, labor costs, equipment, prices, and interest rates by the Food and Agricultural Policy Research Institute form the basis for vineyard expense projections (FAPRI, 2015).

A stochastic simulation model was developed to evaluate the viability of the representative table grape vineyard. The model consists of equations necessary to develop the projected financial statements for the period 2015-2024 and includes two risk variables – yield (boxes/acre) and price ($.box). The model was developed using Simetar© (2011), a simulation add-in program designed for risk analysis in Microsoft Excel ®.

Stochastic variables in a Monte Carlo simulation model are variables the decision maker is unable to forecast with certainty. They include a deterministic component and a stochastic component (Richardson et al., 2007). The deterministic price and yield were held constant throughout the 10-year planning horizon. To simulate stochastic yields and prices, probability distributions were developed for prices and yields based on panel input.

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Data and Methods, continued

An empirical probability distribution was developed for table grape prices using regional mean annual prices for 2005-2014 (California Table Grape Commission, 2014). Due to the lack of historical yield data, the panel provided a minimum (950 boxes/acre), midpoint (1,250), and a maximum (1,500) yield which were used to estimate a continuous probability distribution. The stochastic variables were simulated using these two distributions.

Table 1. Production Budget for CA Table Grapes ($/ac.)

Vineyard Practice	California
Number of Acres	100
Budgeted Yield (boxes/acre)	1,250 boxes
Budgeted Price ($/box)	$18.30/box
TOTAL GROSS RECEIPTS	$22,875
OPERATING COSTS	
Pruning	$407.89
Canopy Management	$1,270.26
Fruit Management	$898.39
Floor Management – Growing Season	$28.58
Weed Management	$88.22
Irrigation	$649.41
Chemical/Pest Control	$1,162.33
Harvest	$9,410.18
Miscellaneous Costs	$198.50
Cash Overhead Costs	$709.90
TOTAL CASH COSTS	$14,823.66
Non-Cash Overhead Costs	$1,425.61
TOTAL COSTS	$16,249.27
NET RETURNS ABOVE CASH COSTS	$8,051.34
NET RETURNS ABOVE TOTAL COSTS	$6,625.73

Simulation Results

Results for the stochastic simulation analysis include the annual mean values (2015-2024) for the following key output variables (KOV): price, yield, total cash receipts, net cash vineyard income (NCVI), net vineyard income, ending cash reserves, and real net worth (Table 2).

Table 2. Mean Stochastic KOVs of Representative Table Grape Vineyard, 2015-2024

Key Output Variable	Mean	SD	Min	Max
Price	$18.30	1.39	$16.28	$20.23
Yield	1,240	138	728	1,679
Total Cash Receipts	$2,269,009	303,185	$1,304,096	$3,280,991
Net Cash Vineyard Income	$471,689	331,369	-$638,024	$1,556,370
Net Vineyard Income	$364,808	324,222	-$673,458	$1,485,547
Ending Cash Reserves	$999,776	593,316	$0	$3,316,473
Real Net Worth	$1,908,371	565,827	$367,185	$3,901,997

Figure 1 presents the range of NCVI and the probability of having a cash flow deficit each year. Following the work of Richardson et al. (2015), the representative vineyard is considered to be in good financial position if its probability of having a cash flow deficit is less than 25%. Vineyards are considered to be in marginal financial position if the probability is between 25% and 50%, and poor financial position if the probability is greater than 50%. The probability of the representative table grapes vineyard having a cash flow deficit ranges between 0.1% and 8.8% over the 10-year planning horizon, and indicates the vineyard is in good financial condition. (Figure 1).

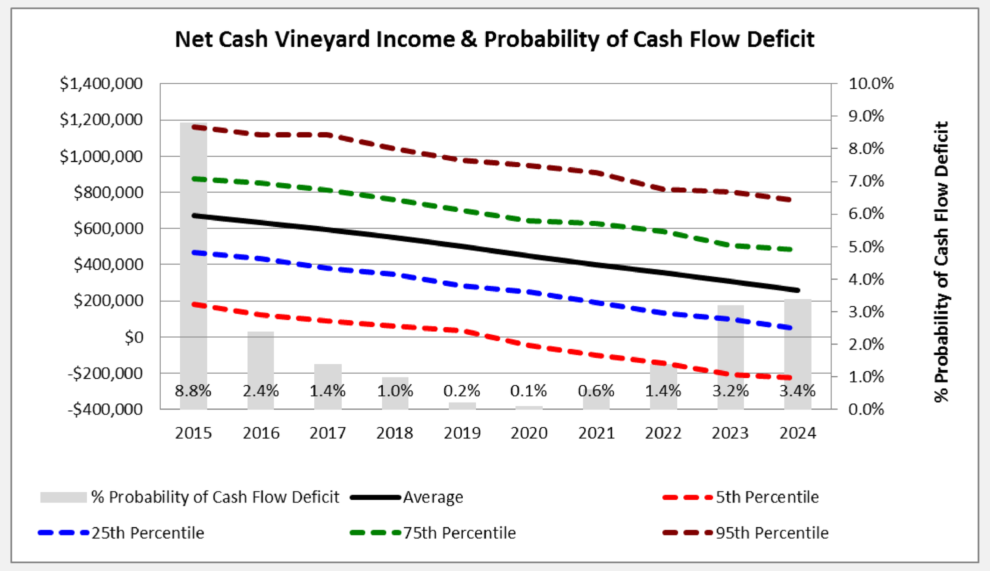

Figure 1. Representative CA Table Grapes Vineyard

Results for Labor Costs and Technology Price

To evaluate the potential for robotic technology development, the net present value (NPV) of the labor cost for each field task was calculated over seven years using a discount rate of 5.0%. The goal was to determine the price for new robotic technology that would make the NPV of purchasing new technology equal to the NPV of the labor cost. The assumptions for calculating the NPV of purchasing new technology are described in Table 3.

Table 3. Assumptions for Estimating Maximum Price for New Robotics Technology

Assumptions specific to finish spur pruning		Assumptions for all vineyard tasks	
Acreage per robotic machine	100	Years of expected life	7
Vines per acre	1,000	Total annual hours of operation	varies by task
Total vine count	100,000	Hourly labor cost (1)	$17.11
Days for operating	60	Insurance (% of price)	0.50%
Acres per day	1.667	Property taxes (% of price)	0.25%
Vines per day	1,667	Repair cost per hour	$2.78
Running hours per day	18	Fuel gallons per hour	1.25
Vines per hour	92.6	U.S. regular gasoline price/gal.(2)	$2.154
Seconds per vine	38.9	Interest rate (I.T. loan)	5.5%
Hours per acre	10.80	Years financed	7
Total annual hours of operation	1,080	Down payment %	10%
		Discount rate	5.0%
Note: For all other field tasks, no improvement in efficiency (speed) is assumed. Instead, the new technology operates at the same rate per acre as is required by humans (see Table 3).		(1) One worker is assigned to oversee the robotics machine, and works 50% of the time the machine is running. (2) U.S. Energy Information Administration, 11/28/2016	

For each field task, Table 4 summarizes the manual labor hours/acre, labor cost/acre, NPV of labor costs/acre, total NPV for 100 acres, and the maximum new technology price. From an economic perspective, this is the price, ceteris paribus, where growers would be indifferent about purchasing robotics or continuing to perform a task with manual labor. Technology developers would need to determine if they could develop the technology for a price that is at or below these prices.

Table 4. Net Present Value of Labor Cost and Equivalent Price for New Technology

	Field & Tractor Labor Hours Per Acre	Wage Rate/Hour for Current Method of Performing Tasks	Total Labor Cost Per Acre	NPV of Labor Cost 7 Years Per Acre	Total NPV Labor Cost 7 Year 100 Acres	**Purchase Price of New Technology to equal Labor NPV**
Cane Cutting	0.44	17.11	$7.53	$51	$5,110	**$1,061**
Post-emergent Herbicide	0.74	17.11	$12.66	$86	$8,592	**$1,783**
Shred Brush	0.75	17.11	$12.83	$87	$8,707	**$1,806**
Fruit Management: Bloom Thin	0.75	17.11	$12.83	$87	$8,707	**$1,806**
Fruit Management: Color Enhancement	0.75	17.11	$12.83	$87	$8,707	**$1,806**
Fruit Management: Berry Size	0.76	17.11	$13.00	$88	$8,823	**$1,830**
Post-emergent Herbicide (Spot Spray)	0.80	17.11	$13.69	$93	$9,291	**$1,929**
Mowing Vineyard Floor	1.20	17.11	$20.53	$139	$13,933	**$2,891**
Insecticides Application	2.25	17.11	$38.50	$261	$26,129	**$5,424**
Sucker Removal - manual	3.00	12.90	$38.70	$263	$26,265	*
Trellis Maintenance and Repair	3.00	12.90	$38.70	$263	$26,265	*
Fungicides Application	4.56	17.11	$78.02	$530	$52,950	**$10,989**
Tie Canes	13.50	12.90	$174.15	$1,182	$118,191	*
Fruit Management: Girdling	18.00	12.90	$232.00	$1,575	$157,452	*
Finish Prune	25.95	12.90	$334.76	$2,272	$227,193	**$122,163**
Spread, Swamp and Haul	20.50	17.11	$350.76	$2,381	$238,052	**$49,412**
Fruit Management: Cluster Tipping	30.00	12.90	$387.00	$2,626	$262,647	*
Cordon/Shoot Thinning	80.00	12.90	$1,032.00	$7,004	$700,392	*
Pick and Field Pack	275.00	12.90	$3,547.50	$24,076	$2,407,598	*

* Not feasible based on current assumptions.

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