The Potential for Robotic Technology for Grape Production in the U.S.

Dean McCorkle, Dan Hanselka, Ed Hellman, Rebekka Dudensing, and Reeg Allen

Industry Overview

In 2015, the U.S. produced an estimated 4.2 million tons of wine grapes on 641,000 acres and 1.1 million tons of table grapes on 110,000 acres (USDA-NASS). A 2007 study estimated the economic impact of grape and wine production, and all related industries, at $162 billion (MKF Research).

Grapes are among the most intensively managed fruit crops, requiring a great deal of manual labor to complete many production tasks. The declining availability of skilled labor in some grape producing areas is an issue for many growers. Robotic technology 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. Wine and table grape production is primed for robotic technology as it faces a variety of production and labor issues that could affect long-term competitiveness.

This article looks at the economic potential of robotic technology development for vineyards, with the goal of generating interest among technology developers and investors to develop new technology for vineyards.

Labor Requirements and Maximum Technology Price for Wine and Table Grape Vineyards

Using a grower panel process, this research project includes the development of representative wine grape budgets for California, Washington, Oregon, Texas, and New York; and a representative table grape budget for California. Labor requirements and costs for individual production tasks are of particular interest.

An important factor in assessing the feasibility of robotic technology for vineyards is the cost of human labor. The cost of using human labor to accomplish each vineyard task was analyzed to evaluate the economics of potentially deploying robotic technology as a force multiplier in vineyards. The labor cost was used to estimate a maximum price that growers would be willing to pay for new technology to accomplish these same tasks. To assess the labor costs, the net present value (NPV) of the labor cost for each field task was calculated over 7 years (the expected life of new technology). NPV, a tool commonly used in investment analysis, was used to discount the annual labor cost cash outflows to account for the time value of money. A discount rate of 5% was used. To compare the labor NPV to potentially having new robotic technology developed, a labor replacement price (technology price) was calculated as the technology price that would make the NPV of purchasing robotic technology equal to the NPV of the labor cost. The hourly cost of employee compensation for each representative vineyard is outlined in Table1.

Table 1. Wine and table grape vineyard hourly employee compensation cost (2017) [2]

	Wine Grapes					Table Grapes
Type of worker	TX South Plains	NY Finger Lakes	WA Yakima Valley	OR Willamette Valley	CA Napa Valley	CA San Joaquin Valley
Field worker	$12.37	$13.94	$11.70	$14.89	$22.98	$15.18
Equipment operator	$21.72	$19.68	$14.89	$19.15	$29.79	$17.94

[2] 2015 data provided by the panel members, and adjusted for inflation to 2017. Compensation costs include wages, benefits, and employment taxes.

The assumptions used in this analysis are outlined in Table 2 which contains assumptions specific to finish spur pruning on the left side. For all other vineyard tasks, it is assumed that the speed of new technology will be equal to human speed. While human speed will most likely have faster peak speeds, it is assumed that robotics will have a more consistent speed over the long run, making the speeds on average equal over time. The assumptions on the right side of Table 2 apply to all vineyard tasks. When purchasing new technology, one important assumption is that operating costs include the cost of a technology manager working 50% of the time the equipment is running. This person is paid at the higher equipment operator wage rate (Table 1).

Table 2. Assumptions for estimating maximum labor replacement price for new technology

Assumptions specific to finish spur pruning			Other Assumptions (wine & table grapes)	
	Wine Grapes	Table Grapes	Years of expected life	7
Acreage per robotic machine	100	100	Total annual hours of operation	varies by task
Vines per acre	1,000	519	Technology manager annual hours (%)	0.50%
Total vine count	100,000	51,900	Tech. manager employment class.	equipment oper.
Days for operating	60	60	Insurance (% of price)	0.50%
Acres per day	1.667	1.667	Property taxes (% of price)	0.25%
Vines per day	1,667	865	Repair cost per hour	$2.78
Running hours per day	18	18	Fuel gallons per hour	1.25
Vines per hour	92.6	48.1	U.S. regular gasoline price/gal.[1]	$2.15
Seconds per vine	38.9	74.9	Interest rate (I.T. loan)	5.5%
Hours per acre	10.80	10.80	Years financed	7
Total annual hours of operation	1,080	1,080	Down payment %	10%
			Discount rate	5.0%

Note: For all vineyard tasks other than finish pruning, no improvement in efficiency is assumed. New technology operates at the same rate of speed as human labor.

[1] U.S. Energy Information Administration, 11/28/2016

Table 3 provides a summary of the range of labor hours (across the five states) required per acre using the current method of performing each vineyard task with human labor, and the range of NPV of the associated labor cost over 7 years for a 100 acre vineyard.[3] These data and the assumptions from Table 1 were then used to calculate the maximum labor replacement price for each vineyard task, by state. The NPV of labor costs is a function of the labor hours required per acre and the cost of labor (Table 1).

The variation in production systems across the five states is evident in the wide range of labor hours required per acre for some vineyard tasks, and there are some tasks that are not used in every state (indicated by a blank cell for the price). As a result, there is corresponding variation in the maximum labor replacement prices. An asterisk indicates that based on the data and assumptions, developing new technology is not currently feasible from an economic standpoint. To illustrate, *shoot thinning* ranges from 10 (California) to 45.0 hours (Oregon) per acre, is used by 4 of the 5 representative vineyards, and developing new technology for this task is currently not feasible for New York and Oregon as indicated by the asterisks. Part of the reason that *shoot thinning* in Washington and California is feasible is because the fieldworker-equipment operator wage differential is less than it is in New York and Oregon.

In general, for areas that have an adequate supply of vineyard labor, growers may not be incentivized to pay more than these maximum prices. In areas where there is a shortage of labor or the labor supply is tight, growers may have an incentive to pay more than this maximum technology price. These prices are not an indication or an endorsement of what the authors believe would be a fair price for new technology. Rather, the prices are intended to serve as a guide for technology developers to determine if they can develop the

[3] For this analysis, a 100 acre vineyard is the base for one piece of the new robotic technology equipment.

technology for a price that is at or below this general price level. While these data and prices are intended to be representative of a specific production area within each respective state, the data and prices of actual vineyards could be higher or lower than the data and prices in Table 3. For smaller vineyards that may not be able to afford the price of new technology, a leasing or equipment sharing arrangement could be considered for this segment of the market.

While there is some variation across states, in general, the panels indicated the tasks that are the most in need of new technology are pruning, shoot thinning, cluster thinning, and suckering. One option that could be

Table 3. Wine grapes labor cost summary and maximum labor replacement price

	Perform task with manual labor		Perform task with new robotic technology				
	Range of labor hrs required per acre	Range of total NPV of 7 year labor costs (100 ac.)	Purchase priace of new technology to equal labor NPV				
Vineyard Task			TX	NY	WA	OR	CA
Shoot positioning	7.00 - 25.00	$66,510 - $197,300	*	*		*	
Remove cover crop with herbicide	0.60	$8,300	$1,872				
Tie canes	18.00	$171,026				*	
Plant winter cover crop	0.50 - 0.60	$5,701 - $8,300	$1,872		$3,386	$1,183	
Hedging	1.00 - 2.50	$13,900 - $23,754	$3,184			*	
Shred brush	1.00 - 1.50	$13,900 - $18,324	$3,184	$3,034		$3,550	
Sucker removal with herbicide	0.60 - 7.00	$8,300 - $62,282	$1,872	*	$5,642		
Hilling-up	2.00	$25,111		$5,055			
Pre-emergent herbicide	0.60 - 1.00	$5,701 - $19,864	$1,872		$3,386		$5,852
Mowing vineyard floor	0.70 - 3.00	$8,789 - $36,648		$1,770	$8,464	$7,100	$5,852
Trellis maintenance & repair	2.00 - 3.00	$19,003 - $37,666		$7,583		*	
Bird & rodent control	3.00 - 11.00	$37,666 - $104,516		$7,583		*	
Take away (de-hilling)	3.00	$37,666		$7,583			
Insecticides application	0.30 - 2.00	$4,200 - $39,728	$983	$884	$2,822	$4,733	$11,704
Leaf pulling (mechanical)	0.50 - 3.00	$6,900 - $39,728	$1,545	$3,163	$5,642	$7,100	$11,704
Till alleyway (mechanical)	1.20 - 3.00	$16,600 - $39,728	$3,745			$7,100	$11,704
Post-emergent herbicide	2.00 - 3.60	$19,003 - $49,889	$11,318	$7,583	$11,850	*	
Machine harvest support labor (skilled)	1.00 - 4.00	$9,501 - $55,400	$12,546		$5,642		
Tie cordons	4.00	$29,862		*	$14,879	*	
Pull/rake brush	0.50 - 5.00	$4,751 - $69,300	$15,729		$2,822		
Pre-prune (mechanical)	0.50 - 3.00	$4,751 - $41,600	$9,456		$2,822		
Pre-prune (manual)	13.00	$201,767					$22,742
Sucker removal (manual)	8.00 - 25.00	$63,100 - $237,536	*			*	$26,240
Move catch wires	8.00 - 20.00	$59,700 - $263,849	*	*	$29,758	*	$29,739
Fungicides application	1.50 - 7.00	$20,800 - $119,183	$4,728	$6,445	$16,928	$16,567	$35,110
Irrigation management	3.30 - 10.00	$38,006 - $74,654			$37,198	*	$5,773
Shoot thinning	10.00 - 45.00	$88,974 - $427,565		*	$44,638	*	$17,493
Tractor Operated[1]	12.30 - 23.50	$116,700 - $325,800	$74,012	$42,375	$69,248	$46,863	$81,924
Cluster thinning	21.60 - 30.00	$195,865 - $410,462			$113,039	*	$48,982
Cane prune	18.00 - 37.00	$219,891 - $329,205		$210,161		$108,636	
Finish spur prune	13.50 - 40.00	$100,783 - $605,301	$190,774		$59,212		$432,283
Contract manual harvest	22.50 - 36.00	$203,602 - $1,001,629		*		$183,721	$481,288

* Not feasible based on current data and assumptions. A blank cell for a state means the task is not applicable in that state.

[1] Labor hours for all tasks include both field labor and tractor operator labor (when applicable). The "tractor operated" task represents the sum of all tractor operator hours for all tasks, which will be useful for technology developers considering the development of a self-guided tractor.

pursued by technology developers is to develop a robotic vehicle that has multi-tasking capabilities.

California Table Grapes

For table grapes produced in California's San Joaquin Valley, Table 4 provides a summary of the field and tractor labor hours required per acre, labor cost ($/hr.), total labor cost ($/ac.), NPV per acre, total NPV for 100 acres, and the maximum technology price for each vineyard task. Finish pruning has the highest maximum labor replacement price, followed by spread, swamp and haul (bagging, boxing, and hauling).

Table 4. California table grape labor summary and maximum labor replacement price (San Joaquin Valley)

	Field & Tractor Labor Hours Per Acre	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	$7.89	$59	$5,885	$1,434
Post-emergent Herbicide	0.74	$13.27	$99	$9,895	$2,409
Shred Brush	0.75	$13.45	$100	$10,028	$2,441
Fruit Management: Bloom Thin	0.75	$13.45	$100	$10,028	$2,441
Fruit Management: Color Enhancement	0.75	$13.45	$100	$10,028	$2,441
Fruit Management: Berry Size	0.76	$13.63	$102	$10,161	$2,473
Sucker Removal - manual	3.00	$45.48	$320	$32,029	$2,128
Trellis Maintenance and Repair	3.00	$45.48	$320	$32,029	$2,128
Post-emergent Herbicide (Spot Spray)	0.80	$14.35	$107	$10,700	$2,607
Irrigation Management	3.83	$58.07	$409	$40,893	$2,720
Mowing Vineyard Floor	1.20	$21.52	$160	$16,046	$3,906
Insecticides Application	2.25	$40.36	$301	$30,091	$7,329
Tie Canes	13.50	$204.66	$1,441	$144,130	$9,577
Fungicides Application	4.56	$81.80	$610	$60,980	$14,849
Fruit Management: Girdling	18.00	$272.65	$1,920	$192,008	$12,614
Fruit Management: Cluster Tipping	30.00	$454.81	$3,203	$320,289	$21,283
Cordon/Shoot Thinning	80.00	$1,212.82	$8,541	$854,103	$56,754
Spread, Swamp and Haul	20.50	$367.73	$2,742	$274,152	$66,763
Tractor Operated[1]	34.25	$614.37	$4,580	$458,022	$111,532
Finish Prune	25.95	$393.41	$2,771	$277,054	$160,436
Pick and Field Pack	275.00	$4,169.07	$29,360	$2,935,980	$195,094

[1] Labor hours for all tasks include both field labor and tractor operator (when applicable). The "tractor operated" task represents the sum of all tractor operator hours for all tasks, which will be useful for technology developers considering the development of a self-guided tractor.

For more information about this analysis, please contact:

Dean McCorkle, PhD.
Texas A&M AgriLife Extension Service
Department of Agricultural Economics
d-mccorkle@tamu.edu | 979-845-1861

Ed Hellman, PhD.
Texas Tech University
Viticulture and Enology
ed.hellman@ttu.edu | 806-834-1681

Reeg Allen
RE2, Inc.
Business Development
reeg.allen@resquared.com

This research project is supported by the Agricultural and Food Research Initiative (AFRI) Competitive Program of the USDA National Institute of Food and Agriculture (NIFA), grant number 2013-05171.