



WASHINGTON STATE UNIVERSITY

College of Agricultural, Human,
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Research on People and Machines: The Future of Farm Labor



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In this presentation

- Automation solutions
 - Cost benefit analyses of robot prototypes
- H-2A in Washington
 - Job features that workers currently employed in WA apple farms, value
- Potential H-2A workers
 - Results from surveys in rural Mexico



Automation solutions



Cost-benefit analyses of robotic harvester
prototypes



Create an Excel tool to measure the cost-benefit of an innovation in the field

- Model is based on economic theory
- Flexible: Inputs and features could be changed
 - Useful outputs to decision makers



Model

Profits from manual harvest π_M :

$$\begin{aligned} \pi_M &= p \times Y \gamma_M \beta_M + p_C \times Y \beta_M \times (1 - \gamma_M) \\ &- (w \times HL_M + pck_M + w \times OL + ovc + \delta \times fc) \end{aligned}$$

p is the fresh-market apple price in \$/bin,

Y is the yield in bins/acre,

γ_M is the packout rate (% of apples sold in the fresh market),

β_M is the picking efficiency (%),

p_C is the price of apples sold to processors,

w is the wage rate,

HL_M is the picking rate for labor (hours per acre per worker),

$pck_m = (rc + pb \times fb) \times Y$ is the packing cost,

rc is the receiving charge by packers,

pb is the variable cost or packaging fee per box,

fb is the number of boxes per bin.

OL represents other labor hours such as checkers and hauling in hour per acre,

ovc are other variable costs for horticultural management, maintenance and repair costs for buildings and machinery, fuel and lubricant costs of equipment,

$\delta \times fc$ is the annualized fixed costs discounted at the rate of δ .

Net revenues from robotic harvest (N_R), excluding the robot cost:

$$\begin{aligned} N_R &= p \times Y \beta_R \gamma_R + p_C \times Y \beta_R (1 - \gamma_R) \\ &- (w_R \times HL_R + pck_R + m_R \\ &+ w \times OL + ovc + \delta \times fc), \end{aligned}$$

β_R is the percent of apples the robotic harvester removes from the tree

γ_R is the packout rate for the robotic harvester

w_R is the robot operator wage rate,

HL_R is the robot operator hours per acre,

$pck_R = (rc + pb \times fb) \times Y \beta_R$ is the packing cost for robotic harvest,

m_R is the annual per acre cost of robot maintenance, fuel, and lubrication



Notes about the model

- **Robot price is unknown**
 - Development and licensing costs not available.
- **The model compares profits**
 - Manual harvest vs. prototype.
- **Profit difference** = minimum producer's willingness to pay
- **Constant model improvement**
 - Based on industry/extension feedback
 - Prototype improvements – addition of features



Cost-Benefit Analysis for Manual Versus Robotic Harvesting for Gala Apples (2024 Crop Enterprise Budget Parameters)

*Font in orange are inputs, can be changed

**Font in black are formulas cannot be changed.

Yields and revenues	Unit	Manual	Manual Sorter removes 15% of apples for defects (No Robot)	Robot (no sorter)	Robot with In-field Sorter that removes 5% of apples for defects	Robot with In-field Sorter that removes 15% of apples for defects
FOB price for fresh apples	\$/40-lb box	26	26	26	26	26
FOB price for fresh apples	\$/bin	481	481	481	481	481
Yield	bins/acre	80	80	80	80	80
Percentage harvested	%	1	1	0.8	0.8	0.8
Share suitable for fresh market	%	0.8	0.8	0.75	0.75	0.75
Fresh fruit harvested yield after culling	bin/acre	64	64	45	45	45
Harvested yield for cleanup crew after robot	bin/acre	-	-	16	16	16
Fresh apple revenue	\$/acre	30,784	30,784	29,341	29,341	29,341
Bruised apple revenue	\$/acre	1,036	1,036	1,230	1,230	1,230
Total revenue	\$/acre	31,820	31,820	30,571	30,571	30,571
Revenue difference	\$/acre	-	-	-1,249	-1,249	-1,249

Cost-Benefit Analysis for Manual Versus Robotic Harvesting for Gala Apples (2024 Crop Enterprise Budget Parameters)

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Harvest labor costs-Set up	Unit	Manual	Manual Sorter removes 15% of apples for defects (No Robot)	Robot (no sorter)	Robot with In- field Sorter that removes 5% of apples for defects	Robot with In- field Sorter that removes 15% of apples for defects
Variable						
Wage including overhead	\$/hr	23.75	23.75	23.75	23.75	23.75
Wage premium for operating robot	%	-	-	1.40	1.40	1.40
Wage robot operator	\$/hr	-	-	33.25	33.25	33.25
Weight of 1 bin of apples	lb	925	925	925	925	925
Weight of 1 apple	lb	-	-	0.60	0.60	0.60
Number of apples per bin	number	-	-	1,542	1,542	1,542
Time to pick 1 apple	seconds/arm	-	-	4	4	4
Number of arms per robot	number	-	-	8	8	8
Picking rate	hours/bin	1.56	1.56	0.21	0.21	0.21
Machine idle time	%	-	-	0.30	0.30	0.30

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Harvest labor costs Variable	Unit	Manual	Manual Sorter removes 15% of apples for defects (No Robot)	Robot (no sorter)	Robot with In-field Sorter that removes 5% of apples for defects	Robot with In-field Sorter that removes 15% of apples for defects
Picking rate hours to pick one acre	hr/acre	124.63	124.63	16.70	16.70	16.70
Picking rate for cleanup crew after robot	hr/acre	-	-	31.16	31.16	31.16
Picking rate robot alone - acres to be covered by 1 robot in 1 hour	acre/r	-	-	0.06	0.06	0.06
Number of operators	number	-	-	1	1	1
Picking cost	\$/acre	2,960	2,960	1,295	1,295	1,295
% saved/additional on checker labor cost of sorting in the field	%	-	1.50	-	0.05	0.05
Checkers labor cost	\$/bin	11.00	16.50	11.00	10.45	10.45
Hauling labor cost	\$/bin	11.00	11.00	11.00	11.00	11.00
Checker and hauling cost	\$/acre	1,760	2,200	1,760	1,716	1,716
Total harvest labor costs	\$/acre	4,720	5,160	3,055	3,011	3,011
Labor cost savings	\$/acre	-	-440	1,665	1,709	1,709

Cost-Benefit Analysis for Manual Versus Robotic Harvesting for Gala Apples (2024 Crop Enterprise Budget Parameters)

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Packing costs Variable	Unit	Manual	Manual Sorter removes 15% of apples for defects (No Robot)	Robot (no sorter)	Robot with In- field Sorter that removes 5% of apples for defects	Robot with In- field Sorter that removes 15% of apples for defects
Share of bruised apples culled in the field	%	-	0.15	-	0.05	0.15
Bins to packing house (includes fresh not culled in the field)	bin/acre	80	68	80	76	68
Number of packed boxes of fresh fruit per acre	number	1,480	1,480	1,411	1,411	1,411
Weight of one box of apples	lbs	40	40	40	40	40
Receiving charge	\$/bin	110	110	110	110	110
Packing fee	\$/box	8	8	8	8	8
Packing cost	\$/acre	20,640	19,320	20,085	19,645	18,765
Packing cost savings	\$/acre	-	1,320	555	995	1,875

Cost-Benefit Analysis for Manual Versus Robotic Harvesting for Gala Apples (2024 Crop Enterprise Budget Parameters)

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Robot costs / number of acres per robot	Unit	Manual	Manual Sorter removes 15% of apples for defects (No Robot)	Robot (no sorter)	Robot with In-field Sorter that removes 5% of apples for defects	Robot with In-field Sorter that removes 15% of apples for defects
N. of hours of robot operation per year	hrs	-	-	900.00	900.00	900.00
N. of acres covered by 1 robot	acres	-	-	53.89	53.89	53.89
N. of robots needed to cover 1 acre	robots	-	-	0.02	0.02	0.02
Maintenance and repair	\$/arm	-	-	400.00	400.00	400.00
Maintenance and repair	\$/acre	-	-	59.38	59.38	59.38
Diesel use	gallon/hour	-	-	3.70	3.70	3.70
Diesel price	\$/gallon	-	-	3.97	3.97	3.97
Fuel cost	\$/acre	-	-	245.33	245.33	245.33
Lubrication cost (0.1xFuel cost)	\$/acre	-	-	24.53	24.53	24.53
Maintenance, Repair, Fuel, and Lubrication Costs	\$/acre	-	-	329.24	329.24	329.24

Cost-Benefit Analysis for Manual Versus Robotic Harvesting for Gala Apples (2024 Crop Enterprise Budget Parameters)

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Variable	Unit	Manual	Manual Sorter removes 15% of apples for defects (No Robot)	Robot (no sorter)	Robot with In- field Sorter that removes 5% of apples for defects	Robot with In- field Sorter that removes 15% of apples for defects
Total variable cost	\$/acre	32,086	31,206	30,196	29,712	28,832
Total variable cost savings	\$/acre	-	880	1,890	2,374	3,254
Fixed cost (excluding robotic harvester)	\$/acre	11,934	11,934	11,934	11,934	11,934
Net revenue per acre	\$/acre	-15,490	-14,520	-14,654	-14,121	-13,150
Net revenue difference – pay per acre custom harvest	\$/acre	-	970	835	1,369	2,339
Plot size - number of acres to harvest	acres	100	100	100	100	100
Length of shift	hours	8	8	16	16	16
Number of days to harvest	days	3	3	3	3	3
Number of robots needed to harvest the entire plot	robots	-	-	2	2	2
Number of humans to harvest the entire plot	humans	519	519	65	65	65

Cost-Benefit Analyses

Take-aways

Variable	Compared to manual labor			
	Manual sorter removes 15% of apples for defects No Robot (\$/acre)	Robot No sorter (\$/acre)	Robot with In-field Sorter that removes 5% of apples for defects (\$/acre)	Robot with In-field Sorter that removes 15% of apples for defects (\$/acre)
Revenue difference	-	-1,249	-1,249	-1,249
Harvest labor cost <u>savings</u>	-440	1,665	1,709	1,709
Packing cost <u>savings</u>	1,320	555	995	1,875
Net Revenue Difference - Custom harvest	970	835	1,369	2,339



Conclusions

- Robot prototypes imply *both* revenue losses and cost savings
 - Across all robotic scenarios: ~ \$1,250 loss in revenue
 - Harvest labor savings: ~ \$1,700
- In field sorting
 - If manual increases harvest cost: \$440
 - Reduces packing costs. Removing 15% of non-fresh market apples implies savings \$1,875 with robot vs. \$970 manual.
- Comparing all four alternatives – net revenues
 - **BEST:** Robot + sorter (15% defects): \$2,339
 - Robot + sorter (5% defects): \$1,369
 - Manual in-field sorting (15% defects): \$970
 - Robot no sorter: \$835

*All revenues & costs in \$/acre

