

Research Highlights

Economic Viability of Robotic Fruit Harvesters to Reduce Large Seasonal Labor Demands: Evidence from Gala and Honeycrisp Apples

Diane Charlton; Stephen Devadoss; R. Karina Gallardo; Jeff Luckstead; Stavros Vougioukas

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Overview

Fruit harvesting is one of the most labor-intensive operations in specialty crop production and relies heavily on a shrinking supply of seasonal farmworkers. Rising wages, uncertainty in the availability of H-2A guest workers, and increasing global competition have intensified interest in labor-saving technologies. This study evaluates whether robotic apple harvesters can be an economically viable alternative to manual harvest in the U.S. apple industry.

Methods

The authors develop a profit-comparison model grounded in agricultural production economics to evaluate manual versus robotic harvesting systems. Using detailed Washington State enterprise budgets and engineering performance parameters from the literature, the analysis compares costs, revenues, and profits under each harvest method. The baseline scenario assumes that current robotic prototypes harvest 60 percent of fruit, with the remaining fruit hand-picked. Break-even analyses are conducted to estimate the maximum investment cost a grower could afford for a robotic harvester while maintaining profits equivalent to manual harvest.

Key Findings

For Gala apples, the results indicate that robotic harvesting can generate labor-cost savings that offset revenue losses associated with fruit damage and incomplete harvest. Under baseline assumptions, a grower could invest approximately \$79,000 in a robotic harvester for a 40.5-acre operation and earn the same profit as under manual harvest. Rising wage rates substantially increase the economic feasibility of robotic adoption; a 25 percent increase in wages more than doubles the break-even robot investment cost.

Sensitivity analyses show that robotic profitability improves with faster picking speeds, higher harvest efficiency, and lower robot-induced damage rates. In contrast, robotic harvesting of Honeycrisp apples is less economically viable under current technology due to higher susceptibility to bruising, unless damage rates are significantly reduced.

Implications

The findings demonstrate that robotic fruit harvesters are approaching economic viability for some apple varieties, particularly as labor costs continue to rise. The study provides actionable benchmarks for engineers, growers, and policymakers by quantifying tradeoffs

among robot speed, accuracy, fruit damage, and labor costs. More broadly, the results contribute to ongoing debates on agricultural labor shortages and highlight the role of technological innovation in sustaining the competitiveness of high-value specialty crop industries.