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Incorporating Stochasticity into Enterprise Budgeting: A Monte Carlo Simulation Approach

Abstract

This study incorporates stochastic elements into a deterministic enterprise budget framework to evaluate economic risk in cherry tomato production. Drawing on data from two Iowa farms, Johnson and Roller/Schintler, the analysis models four key economic indicators: marketable harvest, gross revenue, total cost, and net income. These indicators are represented using triangular probability distributions, parameterized through expert-informed estimates. In the absence of historical time-series data, this approach applies a ±10% range around observed values to facilitate probabilistic risk assessment via the Monte Carlo method. Simulations comprising 50,000 iterations per variable were executed in Excel, illustrating the utility of stochastic modeling in enhancing financial planning and decision-making under uncertainty, particularly for beginning farmers and ranchers.

Keywords: Enterprise budget, Monte-Carlo simulation, stochasticity, risk, uncertainty

Introduction

Small-scale and beginning farmers often encounter substantial challenges in financial planning when organizing their agricultural operations. Strategic decisions, such as crop selection and cost-effective cultivation methods, must be aligned with the farm's overarching goals, objectives, and mission (Smith et al., 2000). For beginner producers, particularly those with limited access to financial resources and technical information and tools, achieving optimal financial outcomes are often challenging. Nevertheless, the development and application of enterprise budgets can significantly enhance the quality of decision making by providing structured, data driven insights into farm operations.

Agricultural extension programs often develop enterprise budgets to aid producers in financial decision-making. Enterprise budgets function as analytical tools that enable producers to visualize and assess the economic viability of specific agricultural enterprises. These budgets can be created using widely available spreadsheet software such as Microsoft Excel or Google Sheets, thereby removing the need for costly technologies or professional consultation. Consequently, they provide a practical and scalable solution for producers seeking to enhance financial planning without incurring additional expenses.

When historical time-series data are unavailable, analysts often rely on expert judgement to estimate variability in key parameters such as prices, yields and input costs. In such cases, triangular probability distributions are widely recommended because they require only three intuitive inputs: minimum, most likely, and maximum values (Thomopoulos, 2013; Vose, 2008). This simplicity makes triangular distributions particularly suitable for agricultural contexts where empirical data may be scarce or fragmented, yet domain experts can provide informed estimates. Compared to more complex distributions like beta or normal, triangular distributions offer a practical balance between realism and ease of implementation, especially in Monte Carlo simulations for enterprise budgeting and investment analysis.

A notable real-world example is the *Enterprise Budget of Cherry Tomatoes* report published by Practical Farmers of Iowa, which incorporates actual data collected during the 2018 growing season (Practical Farmers of Iowa, 2019). This budget offers a realistic and practical framework for producers and serves as a strong foundation for further analysis. The present study builds upon this report to develop a stochastic modeling approach. Cherry tomato production was chosen for its strong market relevance and straightforward production system, making it an accessible option for local growers. Moreover, the structure of the budget is well-suited for stochastic analysis. Unlike deterministic models, stochastic enterprise budgets account for risk and uncertainty, enabling producers to perform probabilistic assessments of potential outcomes. In this study, a triangular distribution model is applied within a Monte Carlo simulation framework to construct a stochastic enterprise budget.

Triangular distributions have been successfully applied in stochastic farm planning studies to approximate uncertainty in specialty crop profitability. For example, complementary research by Kunwar et al. (2025) investigated the profitability of blueberry production under drip irrigation in Georgia by extending a deterministic enterprise budget into a stochastic framework. Utilizing Monte Carlo simulations and triangular probability distributions to model variability in prices and yields, the study revealed that net present value (NPV) estimates derived from deterministic models were one to three times higher than those generated through stochastic analysis.

Quantifying uncertainty is essential for accurately estimating costs and evaluating the economic consequences of agricultural investments. Stochastic Budget Simulation (SBS) provides a methodological framework for representing uncertainty through intervals, quantiles, or percentiles for key parameters in enterprise budgets. Simulation techniques are then used to generate distributions of possible outcomes (Elkjaer, 2000). For instance, Ludena et al. (2003) developed a greenhouse budgeting model that incorporated risk, allowing growers to compare production costs for floral cultivars under both deterministic and stochastic conditions. Their findings revealed significant differences in profit levels between the two models, underscoring the influence of uncertainty on production decisions.

Similarly, Awondo et al. (2017) employed a stochastic enterprise budget framework for muscadine grape production in Georgia. Their model employed Monte Carlo simulations to evaluate investment outcomes and demonstrated that traditional deterministic estimates overestimated profitability by at least threefold. These results highlight the importance of incorporating uncertainty into agricultural investment analyses to avoid overly optimistic projections.

Within the sphere of financial pedagogy, Herath (2023) advocated employing Monte Carlo simulation as a technologically augmented instructional approach for teaching cash budgeting. This probabilistic approach facilitates improved decision making through data modeling and statistical inference, offering superior risk assessment and management capabilities compared to traditional budgeting methods.

Materials and Methods

This study advances the application of deterministic enterprise budgeting by integrating real-world data from Iowa farms into a stochastic simulation framework to assess the economic viability of high tunnel cherry tomato production. The deterministic component draws on enterprise budgets from two farms, Johnson and Roller/Schintler, originally published in a 2019 research report by Practical Farmers of Iowa. These budgets focus on cherry tomato production and provide standardized financial metrics such as marketable yield, gross revenue, total production costs, and net income for the 2018 growing season. Johnson’s plot measured 844 ft^2, while Roller/Schintler operated on 2,280 ft^2 (three 3-ft-wide beds with 1-ft pathways and 190-ft-long rows). These details contextualize the reported financial outcomes within each farm’s production scale and management practices. Varieties planted included Mountain Magic, Bellini, Juliet, Black Cherry, and Chocolate Sprinkles at Johnson, and Sungold at Roller/Schintler, with transplant dates in May and June and harvest windows extending from early July to mid-October.

To incorporate uncertainty into the economic analysis, a stochastic component was developed using Monte Carlo simulation. Four key economic indicators including marketable harvest, gross revenue, total cost, and net income were modeled using expert-informed parameters as outlined in the referenced research report. Minimum values were set at 90% of observed values, maximum values at 110%, and the mode at the actual observed value, thereby capturing a ±10% range for risk estimation. Mathematically, each variable follows a triangular distribution parameterized as Triangular ($a = 0.90V$, $c = V$, $b = 1.10V$), where V denotes the observed value. This structure enables probabilistic risk estimation while preserving the expert-informed central tendency of each economic indicator.

Simulations were conducted using Excel-based Monte-Carlo simulation with 50,000 iterations per variable. This integrated approach facilitates risk analysis and enhances decision-making under uncertainty by quantifying the effects of variability in marketable yield, gross revenue, total cost and net income on plot-level economic outcomes.

Table 1. Key Economic overview by farm.

Source: Practical Farmers of Iowa. (2018). E*nterprise budget for Cherry Tomatoes*.

FARM	**ROLLER/ SCHINTLER**	**JOHNSON**
Marketable harvest (lb)	1,983	1,774.00
Gross Revenue	$7,932.00	$4,650.00
Total Costs (Annual)	$3,127.85	$1,478.50
Net Income	$4,804.15	$3,171.50

Results

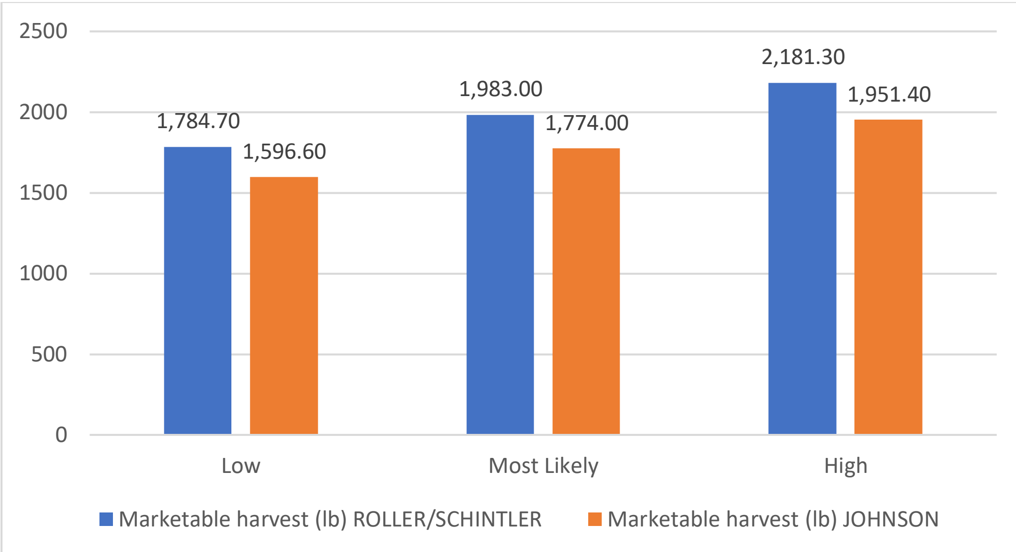

Figure 1. Triangular distribution parameters (Low, Most Likely, High) for Marketable Harvest (lb) across both farms.

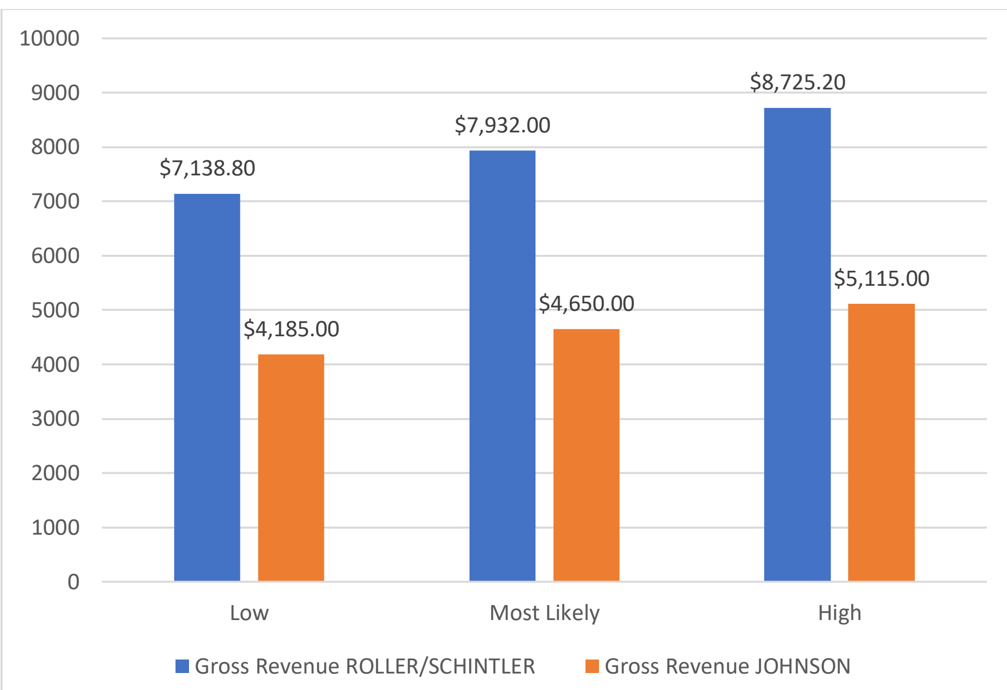

Figure 2. Triangular distribution parameters (Low, Most Likely, High) for Gross Revenue ($) across both farms.

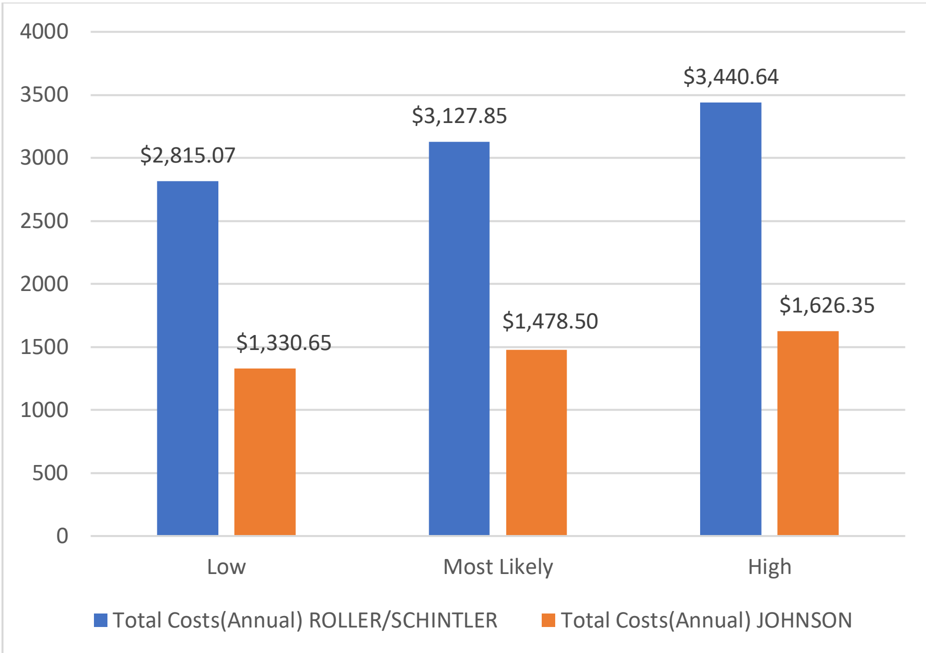

Figure 3. Triangular distribution parameters (Low, Most Likely, High) for Total Costs ($) across both farms.

Figure 4. Triangular distribution parameters (Low, Most Likely, High) for Net Income ($) across both farms.

Monte Carlo Simulations

Percentiles serve as statistical indicators that delineate the proportion of data falling below a specified threshold. For instance, the 10th percentile signifies that 10% of the simulated values lie at or below this point, often representing a lower-bound or worst-case scenario. The 50th percentile, commonly referred to as the median, reflects the central tendency of the distribution, with half of the observations falling below or equal to this value. Conversely, the 90th percentile typically corresponds to a best-case scenario, indicating that 90% of the outcomes are less than or equal to the associated value.

These percentile-based measures are instrumental in characterizing uncertainty and underpinning risk-informed decision-making processes. For example, in the case of Johnson, a cumulative probability of 0.75 at a marketable harvest level of 1,850 lbs implies that 75% of the simulated outcomes do not exceed this threshold. In probabilistic terms, this translates to a 75% likelihood that the marketable harvest will be at or below 1,850 lbs. Such insights are vital for assessing production risk and guiding strategic decisions under conditions of uncertainty.

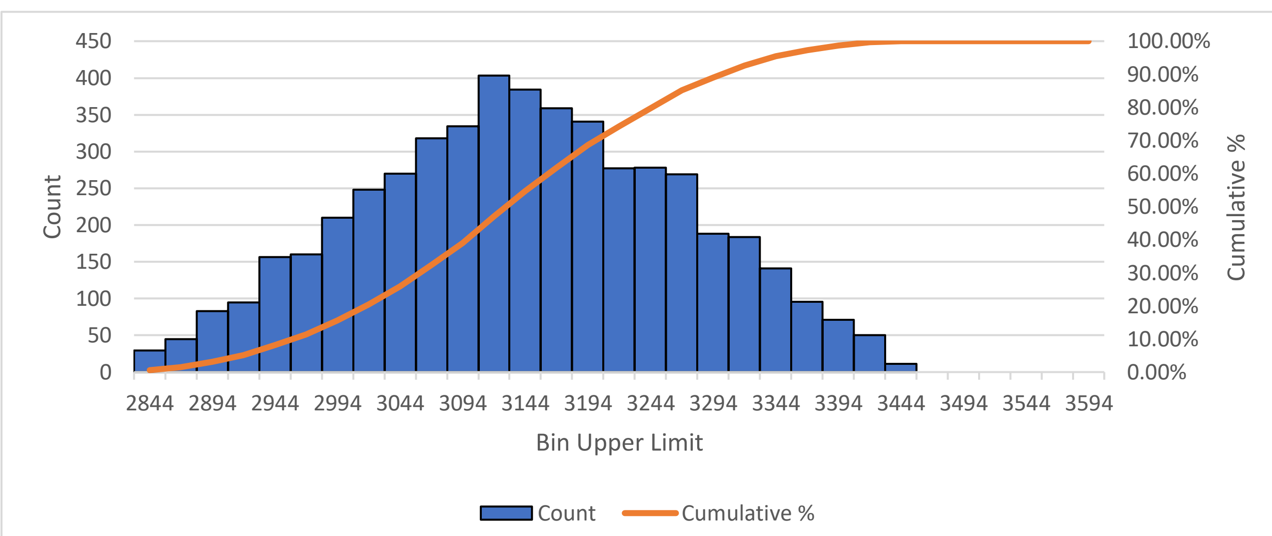

Figure 5. Distribution of Marketable Harvest of Roller/Schintler

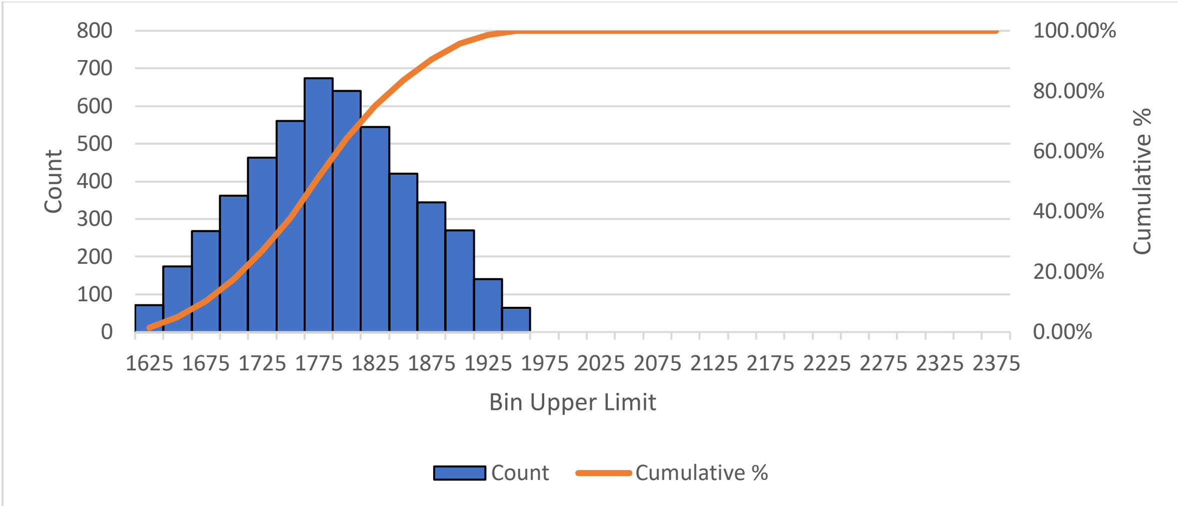

Figure 6. Distribution of Marketable Harvest for Johnson

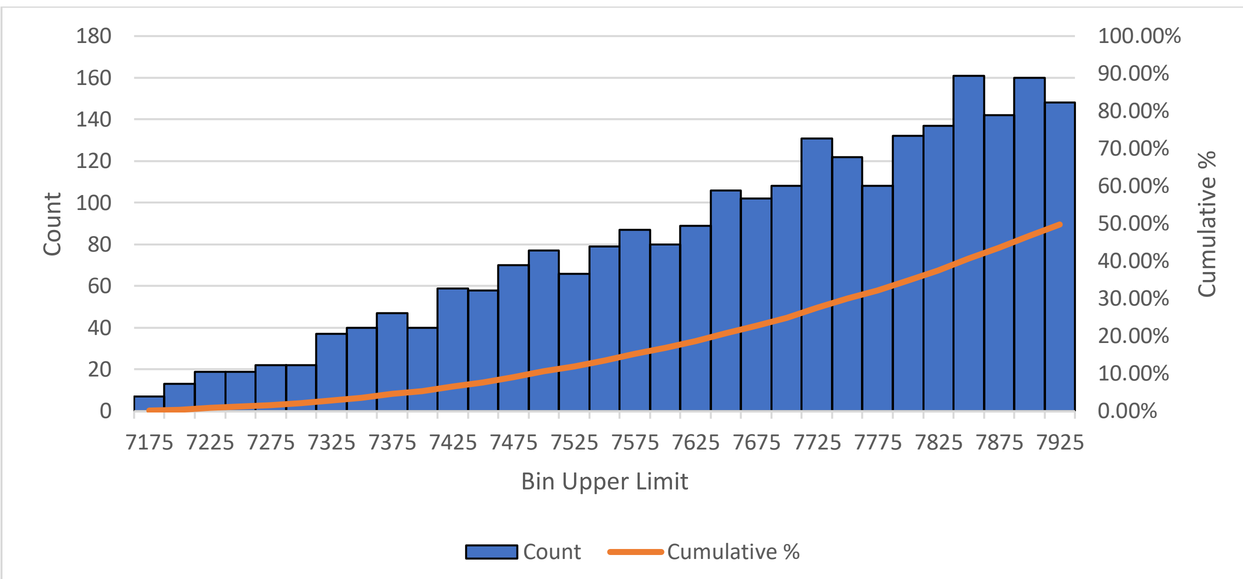

Figure 7. Distribution of Gross Revenue ($) of Roller/Schintler

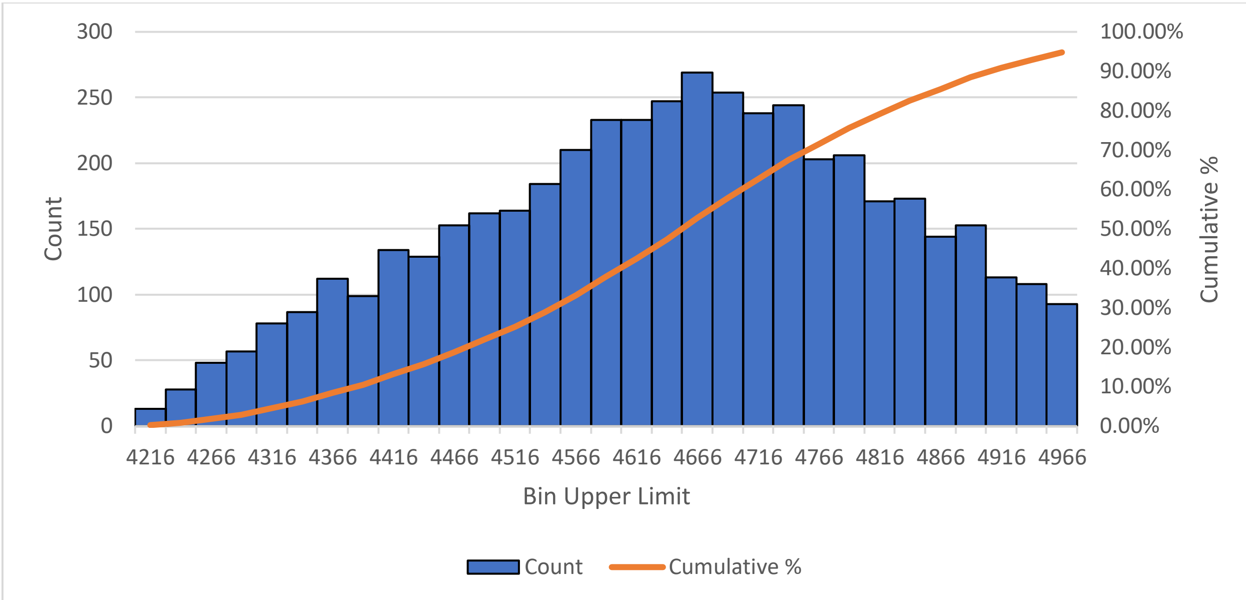

Figure 8. Distribution of Gross Revenue of Johnson

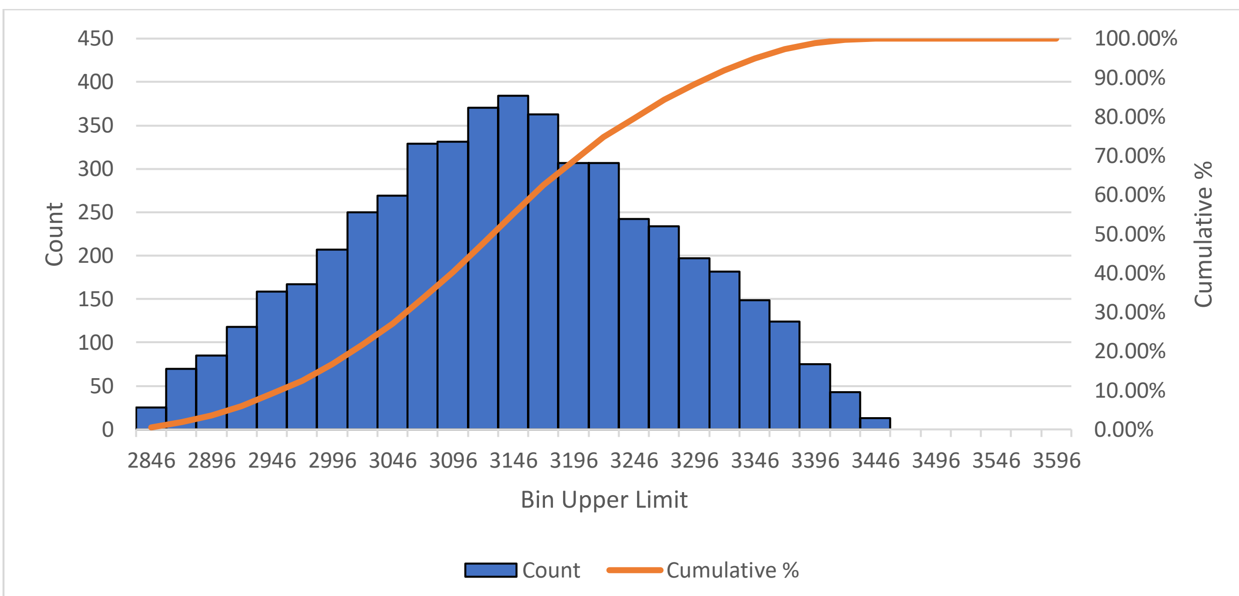

Figure 9. Distribution of Total Costs ($) of Roller/Schintler

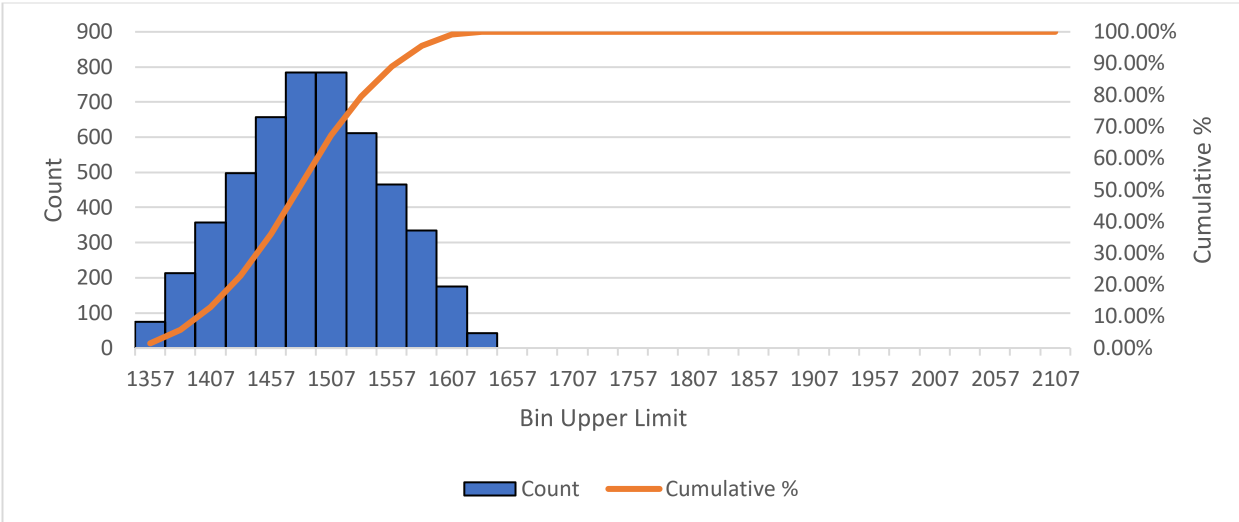

Figure 10. Distribution of Total Costs of Johnson

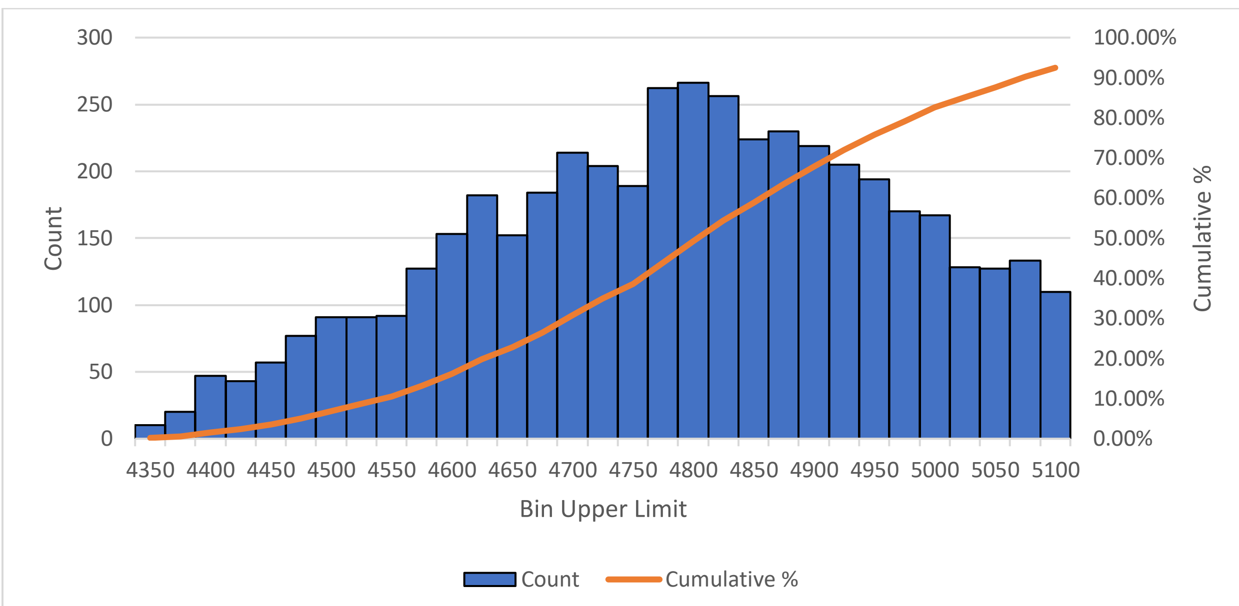

Figure 11. Distribution of Net Income of Roller/Schintler

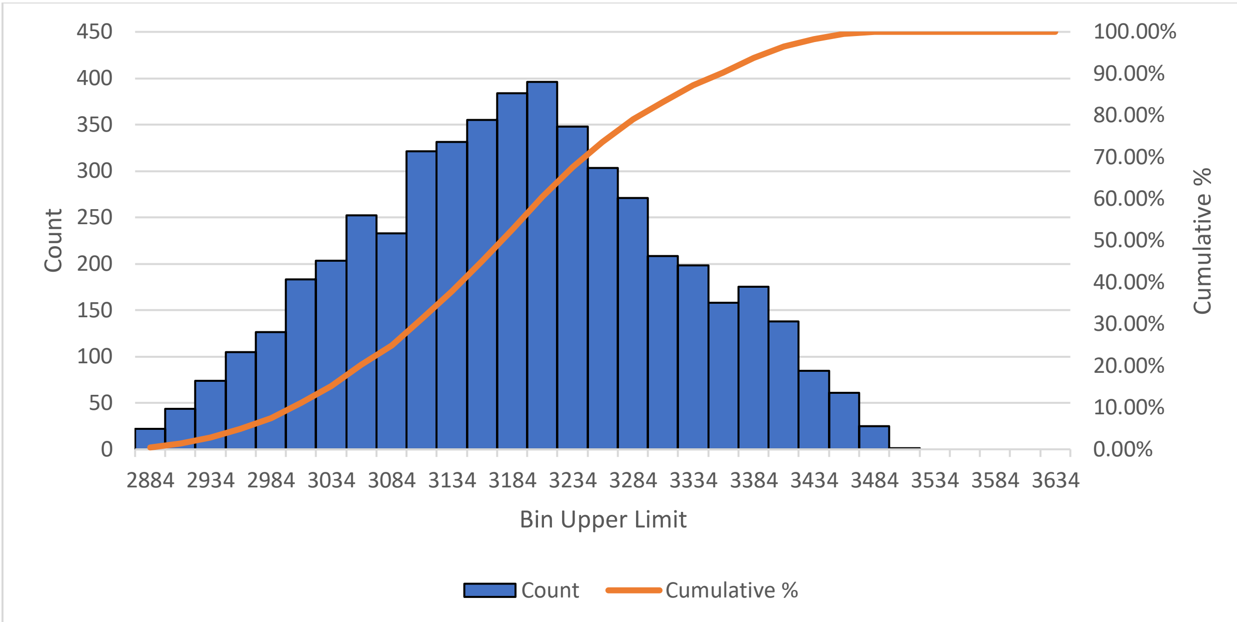

Figure 12. Distribution of Net Income of Johnson

Enterprise budget analysis of two farms, Johnson and Roller/Schintler reveals distinct production and economic patterns in high-tunnel cherry tomato systems. Johnson's distributions of yield, cost, and net income exhibit steeper slopes and minimal skewness, indicating outcomes concentrated near central estimates and greater certainty (Figures, 5-12). This reflects their intensive trellising strategy, multi-leader system, and varietal diversity, which optimized space and extended harvest windows. Johnson achieved more than double the yield per square foot (2.10 lb/ft²) compared to Roller/Schintler (0.87 lb/ft²), resulting in higher net income per unit area ($3.76/ft²) despite slightly greater costs. Roller/Schintler's gross revenue distribution was positively skewed (Figure 7), signaling variability linked to reliance on Sungold, a small, labor-intensive variety prone to splitting and premium pricing strategies. Labor dominated costs at both farms, but Johnson demonstrated superior efficiency per pint and per pound. These findings underscore how trellising intensity, varietal selection, and labor allocation shape profitability and risk in high-tunnel cherry tomato production.

Conclusion/Discussions

The results of this study provide a framework for risk analysis, rather than a prescriptive policy or financial recommendation. Therefore, application of this example should be approached with caution, ensuring that the probability of outcomes falling below defined thresholds is carefully evaluated for each farm to support decision-making under uncertainty. The use of triangular distributions, which adjust skewness based on the position of the mode (the most likely value), provides a more realistic representation of variability by concentrating probability near the mode and creating steeper slopes around this point. Percentile-based analysis further enhances the interpretation of risk by quantifying uncertainty and enabling decisions to be made with varying levels of confidence. Specifically, percentiles help define risk thresholds (e.g., the 10th percentile as a worst-case scenario and the 90th percentile as a best-case scenario), guide budgeting and revenue expectations, and facilitate comparisons between alternative strategies. For instance, a strategy with a lower 90th percentile loss is considered less risky at the high end. Moreover, percentiles serve as an effective communication tool for conveying risk to stakeholders, such as stating that there is a 90% probability that costs will remain below a certain value. Practical applications of this framework may include using the 75th or 90th percentile for budgeting, the 25th or 50th percentile for conservative revenue forecasting, the 10th percentile for establishing safety margins, and the 90th percentile for setting performance targets. These insights contribute to a more informed and data driven decision-making process in farm budgeting and financial planning.

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