Development of a Stochastic Model to Evaluate Plant Growers' Enterprise Budgets

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Short Abstract

A greenhouse budgeting model that incorporates risk was developed to allow growers to compare production costs for flowers. Deterministic and stochastic model simulations were performed with sample data. Results showed differences between both models in profits levels for various cultivars that could influence growers' production decisions.

Key words: Budgeting, cost accounting, greenhouse, stochastic, risk

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Introduction

Many industries, especially agriculture faces risk. Each decision by the agribusiness manager will be influenced by risk and uncertainty, since is not possible to determine the exact outcomes of a particular business decision. Good decision-making must deal with uncertainty and risk produced by external factors. Often the difference between success and failure is the ability of the manager to incorporate risk and uncertainty into the decision making process.

Greenhouse production is different to other agricultural activities. Unlike corn or soybean production, greenhouse production can control for weather factors, therefore reducing the risk of crop failure due to these factors. Ludwig (1989) identifies risk of availability, risk of production and risk of marketing as the most important sources of risk in greenhouse plant production.

Managers implicitly know their risk, even without identifying it. What matters to managers is how to reduce risk. Ludwig found improved planning data, improved production data, and preventive crop protection tools improve risk management. Decision support systems are essential for providing adequate data and information for decision-making. One way of improving planning and production data is through cost accounting methods. Cost accounting allows producers to allocate costs for each crop, giving them the basic information tools for decision making in their businesses.

Analysis of greenhouse production costs in the U.S. has been reported for several crops. Cost analyses have been reported for crops and/or production methods of potted chrysanthemums (Whipker, 1990; Brumfield, 1989b; Kirschling, 1976), zonal geraniums

(Brumfield, 1991; Brumfield, 1992b), poinsettias (Wolnick, 1990), mini-flora roses (Brumfield et al., 1986), anthuriums (Barmettler and Sheen, 1963), Easter lilies (Brumfield, 1981), cyclamen (Groenewegen, 1973), cut flowers (Brumfield, 1989), container-grown landscape plants (Foshee et al., 1997), hanging baskets (Brumfield, 1994), and bedding plants (Brumfield, 1989c).

According to Ludwig, it is important that a decision support system for growers takes the risky aspects of production into account, since producers recognize risk-return tradeoffs. Novak et al. (1992) argues that these tradeoffs have not been well addressed by electronic spreadsheet budgeting and similar user-friendly techniques in the past. With the use of computer-based simulation models sensitivity analysis can be easily done. According to Love and Spears (1992), the simulation modeling approach offers a flexible technique for incorporating and analyzing the uncertainty associated with the decision making process.

Greenhouse growers need a cost accounting system that incorporates production and price risk factors to assess various sources of risk and alternative approaches to managing those risks. A model that allows growers to compare production costs with different technologies, incorporating risk into the analysis was developed in this paper. The model also could be used as a tool to assess alternative risk management approaches.

The first part of the paper discusses risk and budgeting in greenhouse production, the methodology and model. It then compares and contrasts the results of a simulation with the deterministic model and the stochastic model, showing the advantages of each.

Risk and Greenhouse Budgeting

Greenhouse production is an activity that has a high level of risk, where the amount of capital investment is large, the products are perishable, production cannot change quickly to meet changes in demand, and price variation is high (Beierlein and Woolverton, 1991). Decision among different production alternatives depends on the grower, the situation, and the alternatives available. Growers' decisions often depend on the financial health of the business and their personal attitude toward risk. Changes in decisions often lead to different results, where attitudes toward risk are important in the adoption of new technology when information and experience are limited (Gempesaw, 1996).

A tool used by farmers to help decision making is farm budgeting. A budget is a detailed plan outlining the acquisition and allocation of financial and other resources over a given period of time (Garrison and Noreen, 1994). Farm managers use budgets as planning tools, as well as for testing different options in the management of the farm, such as changes in technology, production systems, etc. Budgets could be made for the whole farm (total farm budgeting), or for specific enterprises (partial budgeting). Partial budgeting techniques are used to determine how costs will change with different production methods, input levels, etc., which do not affect the whole farm (James and Eberle, 2000).

An important part of budgeting is to determine the costs associated with the production process. Cost accounting records measures, and reports information about costs providing information needed by using existing records used for tax purposes, and

simple cost allocation techniques. It gives farmers the basic information tools for decision making, planning strategies, and implementing tactics in their businesses.

According to Brumfield (1988), market analysis and cost reduction are two ways to increase profit. Cost accounting allows producers to seek increased profits by cost reduction. By knowing the costs in the production process, farmers can focus on cost reduction in specific areas. Based on results from cost accounting, decision-making can increase profitable crops, and decrease unprofitable crops (Brumflied, 1992).

Growers have choices related to production methods, equipment, cultivars, and technology used. Costs can vary depending on technologies, production methods, input and output prices (Brumfield, 1989b). Major factors influencing costs are geographic location, the level of investment, production technology, efficiency in space and labor, and the quality of management, dependant on the ability of an individual owner/operator to effectively manage operations (Brumfield, 1994; Wolnick, 1994; Brumfield, 1989).

Poirier (2001) argues that floriculture growers face a relative high degree of risk due to potential crop (climate, pest, and diseases) and market failure due to the nature of production, financing, pricing, and regulations. The following types of risk have been identified (James and Eberle, 2000; Libbin, 1994; Beierlein and Woolverton, 1991; Sonka and Patrick 1984; Toergerson, 1983): Production or technical risk, casualty risk, technological risk, human sources of risk, legal and social risk, and market risk.

Growers have different risk tolerance and bearing capacities. A more diversified grower would be willing to bear higher price and production risk if the profits of

production activities were negatively correlated. It is important for growers to have a decision support system that takes the risky aspects of production into account.

Sensitivity analysis is a way to assess uncertainty when building budgets. Sensitivity analysis is conducted using different prices and loss rate, subtracting changes in costs no longer incurred, and adding new costs (Brumfield, 1989b). The incorporation of uncertainty into budgets estimates is useful because it allows exploring among different alternatives (Maher and Deakin, 1994). The simulation modeling approach offers a flexible technique for incorporating and analyzing the uncertainty associated with the decision making process. Bio-economic models to support decision-making under risk have been developed to help farmers make better decisions in their business. One of these tools is stochastic budgeting.

Stochastic budgeting incorporates risk analysis into budgeting. A stochastic budget may be a whole farm budget or a partial budget that can be built as a cash-flow budget, profit budget, or an investment appraisal. It can also represent a single or multi period. Stochastic properties are introduced in the budget by specifying probabilistic distributions for certain variables. Variables selected are usually those that are considered most important when determining the riskiness of selected measures of performance. Stochastic dominance may be used to rank different alternatives produced by the stochastic budget. Stochastic dominance is a methodology that uses cumulative probabilities associated with alternatives to rank them (James and Eberle, 2000).

Brumfield (1992) produced a greenhouse cost accounting program, but that did not introduced risk. There are several models that have been developed to incorporate

risk in farm production, King et al., (1988), Ludwig, (1989), Alderfer and Harsh (1992), Novak et al. (1992), McKissick (1992), Love and Spears, (1992), and Gempesaw et al. (1996). Only Ludwig incorporates risk in production planning for pot plant firms.

The objective of this paper was to develop a greenhouse stochastic budgeting model that incorporates cost accounting and risk to provide a tool to help grower's decision-making process. The stochastic model evaluates grower financial and income statements. Production data assumptions about environmental and financial data from different sources were collected to produce this model. The model allows growers to insert their own production data in order to evaluate how various assumptions change their income and expense projections, an ultimately, the statistical distribution of profit.

We hypothesized that incorporating risk into a greenhouse budgeting model generates results that suggest resource and production allocation decisions for a risk-averse grower that would be different from those that would result from a model that did not incorporate risk. The distribution of growers' profit will depend on different risk levels determined by their production and financial decisions, market prices, and environmental conditions. The final outcome as a function of inputs (i.e. seed or plant material), and technology is used in the production process.

Data and Methodology

Two types of data sets were used in the analysis: financial and cultural. Cultural data included plant environment and production data. Production data are physical development of the crop at the greenhouse. These data were collected from Gerbera daisy (*Gerbera jamesonii* Bolus ex. Hook f.) greenhouses trials at Purdue University in 2000

and 2001, a flowering plant. Flowering uniformity is one determinant of Gerbera production cost. Germination and flowering variability introduces risk in gerbera production. These are important factors why Gerbera was used in this investigation.

Gerbera plant material used in these trials was obtained from different plug producers, using different cultivars in order to measure varying conditions and possibilities that growers experience. Parameters measuring flowering characteristics of the plant material were recorded in these trials. Other parameters such as germination rates, seedling to plug ratio, were obtained from the plug growers.

Plant environment data included monthly heating degree days[1] using a base of 65ºF collected from the National Climatic Data Center website. Data were divided into 5 regions: Central, Great Lakes, Northeast, South and West. Within each region, additional data were collected from Weather Observation Stations during the last 20 years, from 1980 to 2000. Weather stations were chosen based on the location of major Gerbera producers across the U.S. These data were used to assign heating costs based on annual fuel costs, charging more to the winter months with more accumulated heating degree days, and vice versa.

Financial data included income and expenses. Income was calculated assuming selling prices of the finished product, and a percentage of marketable finished products. Prices for potted Gerbera plants at the wholesale level were collected through personal interviews with Indiana and Michigan growers. Percentage of marketable product was obtained from the greenhouse trials. Expenses were divided into fixed and variable costs.

[1] Heating degree days refers to the heat accumulation for a given base temperature corresponding to a specific species and that are cumulative within the growing season.

Variable costs data was collected from trials at the greenhouses, and previous reports on the subject. Costs of materials data were collected from supplier catalogs.

Overhead or fixed costs data used in the analysis were obtained from Brumfield, 1982. Overhead Cost data were adjusted for inflation using the Consumer Price Index (CPI) to 2001 price levels. The analysis assumes the same cost structure as 1982. One limitation of using these overhead cost data is that technology used in the industry has changed since the analysis was performed, changing the cost structure of the business. According to Hammer (2001), there is a trade off between higher investment in cost reducing technology and increased efficiency that lower labor and production costs. Brumfield (2001) argues that the overhead costs from her 1982 publication would not be accurate now, but these costs as a percentage of sales have not changed much.

Data were used to build the stochastic model, and generate different production alternatives. Model output was used for risk analysis assuming risk-averse producers. @Risk software was used to generate random simulations using the data collected. Finally, generalized stochastic dominance (GSD) was used to rank and evaluate different profit alternatives generated by the model under the assumption that growers.

Stochastic Crop Budgeting Model

The crop budgeting model was constructed in computer spreadsheet form to assist decision makers in choices between management alternatives. The spreadsheet can be used to compare production alternatives, changing prices, market channels, quantity produced, vertical arrangements (e.g. contracts), and other characteristics a greenhouse

grower may want to compare. The output variables used to compare alternatives were direct costs, overhead costs, total costs, net income, and net profit (or loss).

The spreadsheet model is divided in four parts: Input, Stochastic, Income Statement, and a Summary sheet. The Input sheet allows the user to modify data to a fit particular firm's situation. It allows the user to change prices, costs, production, etc. The grower's data is combined with flowering, overhead costs, and temperature data to specify the cost analysis. The stochastic sheet manipulates the flowering, overhead costs, and temperature data according to the variation observed in greenhouse trials and weather station data to make resulting cost and revenue stochastic (Figure 1). The data of the input and stochastic sheets are combined in the Income Statement sheet, where all the calculations are generated. The results of the Income Statement sheet are consolidated and summarized in the Summary Sheet.

To better understand what the model can do we decided to select specific scenarios to test how the model can introduce risk into the crop budget. We decided to choose a large wholesale pot producer from plugs in Lafayette, Indiana. The crop was assumed to be transplanted the 4th week of January, and the total number of pots produced was 10,000 pots. All pots were assumed to be sold through the wholesale mass market channel at a price of $2.25. These specifications are common to all scenarios.

Two models were tested, a deterministic and a stochastic model. The deterministic model is without the introduction of risk. For example, the budget that a grower uses is a deterministic model. The stochastic model is a deterministic model with

variability. The variability is introduced into the model when variables are made stochastic by assigning them statistical distributions.

One important factor in Gerbera production from seed is the flowering window of this crop. The variability of flowering between cultivars and is affects not only direct costs, but also overhead costs. Two factors are included when measuring flowering: how early the cultivars flower and how fast (or compact) they flower. All fifteen cultivars from the second trial were selected to test the variability on flowering pattern.

Two variables were considered as stochastic: price, and flowering. For price an "Ideal GRK", a modified triangular distribution was assumed. Richardson (2001) argues that one of the advantages of the GRK over the triangular distribution is that it generates random values outside the elicited minimum and maximum. For the simulation model, values were elicited from Indiana and Michigan growers. The price values used were $1.95 (minimum), $2.25 (expected price) and $2.75 (maximum). To measure determined how fast and how compact the different cultivars flowered, weeks after transplanting that 25, 50, 75 and 100% of the plants reached second open flower was used as the random variable.

A cumulative or empirical distribution was assumed for the flowering data to estimate the parameters for a continuous distribution. According to Richardson (2001), an empirical distribution is generally used when the random variable has few observations, and is infinitely divisible. In the case of the data available for this model, the data from Trial 2 was used. This trial had 4 observations for each one of the cultivars, and those 4 observations were used to generate the empirical distribution. The error terms were

calculated as $e_i = X_i - \overline{X}$ where e_i is the error term from the mean, X_i is the observed value for each block, and $\overline{X}$ is the mean from the 4 samples. The deviations from the mean were calculated, and then transformed as percentage of the mean.

A problem of the model as in Love and Spears, (1992), and McKissick (1992) is that it imposes a normal distribution and does not consider variation in input price or the risk-reaction management of the farmer.

The @Risk software was used to generate the random number for the simulation. The data generated by @Risk was analyzed with Simetar©, an Excel add-in developed at Texas A&M. Simetar© was used for the analysis of stochastic dominance to compare the alternative scenarios. The type of stochastic dominance method used by this program was stochastic dominance with respect to a function (STODOM). STODOM compares the simulated observations for different type of decision makers (risk averse and risk neutral decision makers), and ranks the different alternatives. STODOM can also indicate the premiums, which are the quantity to be given for a decision maker to switch between alternatives.

For stochastic dominance, a risk aversion coefficient (RAC) of 0.0000 was used to simulate the utility function of a risk neutral decision maker, and a RAC of 0.0001 was used to simulate the utility function of a risk-averse decision maker. The RAC in Simetar© has to be specified as an absolute value. To convert a relative value to an absolute value, we needed to have an estimate of the firms overall wealth. Relative values generally ranging between 0 and 5, so the range for the RAC was between 0 and 5/equity.

The publication by Brumfield (1982) was used to calculate the amount of equity investment for a greenhouse. The number obtained was a RAC of 0.0001.

Previous studies to measure agricultural decision maker's risk preferences performed by Halter and Manson (1978) obtained values of the Arrow-Pratt coefficient in the range of -0.0002 to 0.0012. Wilson and Eidman (1983) estimated risk attitudes for Minnesota swine producers. Seventy eight percent of swine producers were in the Arrow-Pratt interval of –0.0002 and 0.0003. The data used in our model is therefore within the range of previous studies.

Additionally, the model was used to conduct sensitivity analysis with cultivar 2. The sensitivity analysis was divided in two parts. The first part analyzed the variation of bloom time on expected profit. The analysis examined the influence of a one week forward and backward shift in flowering for all quartiles. The sensitivity analysis shifted the mean, but did not change the standard deviation.

The second part examined the effect of flowering time, as well as the change in the flowering window on expected returns of cultivar 2. Four scenarios were tested. The "compact" scenarios had intervals between quartiles of 0.7 weeks, with the "early compact" case flowering one week earlier than cultivar 2, and the "late compact" case flowering one week later. The "loose" scenarios had intervals between quartiles of 1.7 weeks, with the "early loose" case flowering one week earlier than cultivar 2, and the "late loose" scenario flowering one week later (Table 1).

A limitation of this model is that it cannot be used for scheduling or annual space production planning for a greenhouse. The crop budgeting model can analyze and

calculate the production schedule for one crop from the moment it is sowed or transplanted. Most production scheduling models use a backward planning based on market delivery dates. This model is structured different, based on forward planning.

This model does not optimize crop mix to minimize risk. The model takes the input data and treats each crop as separate. Crop mix can be examined by running the model for each crop separately. This could prove time consuming and not cost efficient. One model limitation is that it assumes that all pots were saleable when two flowers open. Consideration of pricing for different products, such as one or two open flowers could be included into the model. The model is designed for greenhouse production. Budgeting of other production systems would be difficult. The data itself limit the model. In our particular case, the model is limited to the data from the greenhouse trials.

Deterministic Results

The crop budgeting model in its deterministic form allows growers flexibility to manage data of their businesses, giving them a tool that they can use to make decisions. The model allows growers to compare different crops or cultivars, prices, market channels, and technologies that they use in their businesses. To illustrate how the model works and what it can do we discuss the cultivars simulated by the model.

Results produced by the deterministic model for all cultivars are shown in table 2. The deterministic model calculated that producing 10,000 gerbera pots of cultivar 1 was the most profitable option. The estimated profit was $3,639 or 16% of revenue. Of all 15 cultivars, three produced a net profit.

Compared to the next most profitable option most cultivars had higher revenue and lower cost. Exceptions to this pattern were cultivars 2 and 4, where both cultivars had the same revenue ($22,472), but cultivar 2 total cost of $22,454 was less than cultivar 4 total cost of $22,487. The same situation was observed with cultivars 8 and 6. Some cultivars had more revenue and higher costs that offset the higher revenue than the next most profitable cultivar (cultivars 13 and 3, and 12 and 9).

The deterministic model is capable of summarizing the production characteristics of the crops used by the grower. This allows growers to better understand the production characteristics of each one of the crops or cultivars, based on flowering patterns and shrinkage. The following discussion exemplifies this model feature. Cultivars were ordered by flowering patterns and shrinkage, with flowering affecting the allocation of overhead and direct costs. Shrinkage affects revenue with the total quantity produced, since the price is the same for all cultivars.

Cultivar 1, the most profitable, had the lowest total cost due to its early and compact flowering pattern. Twenty five percent of all pots flowered 8 weeks after transplanting, that is, at least 1 week earlier than the next earliest flowering cultivars, and flowered a 100% in 11.4 weeks compared to 12-14 weeks for all other cultivars grown. Cultivar 1 had zero loss due to shrinkage, with the other 14 cultivars having losses between 1-25%. In addition to lost revenue, shrinkage increases average production costs because resources are allocated although pots are not sold.

With the model, growers are able to understand the iteration between production characteristics of the crops used, and the costs, revenue and profit that these crops incur.

The grower is then able to measure the economic effects that production characteristics of crops have on profit, informing him about what changes he can make on production technologies that can improve profit. The next discussion exemplifies this.

Comparing the ranking of cultivars, it shows a progressive increase in loss, so the cultivars with less loss had higher profit, and cultivars with higher loss had larger economic deficits. Exceptions to this pattern were cultivars 13 and 3. Cultivar 13 had shrinkage of 8% compared to 7% of cultivar 3, but cultivar 3 had a loss of $1,614 compared to $2,116 of cultivar 13.

Profit of cultivars 3 and 13 was differentiated by their flowering patterns. Cultivar 13 can be characterized as an early and loose cultivar, with 25% of all pots flowered in 9.13 weeks, but with 92% (the maximum % achieved) of pots flowering in 14.86 weeks. Cultivar 3 can be characterized as a late and compact cultivar. Twenty five percent of pots flowered in 10.29 weeks, one week later than cultivar 13. Same flowering characteristics are found when the 50th and 75th percentiles are compared between the two cultivars. Ninety three percent of all pots of cultivar 3 flowered in 14.43 weeks, one-half week earlier than cultivar 13. Despite the “catch-up” and lower loss due to shrinkage of cultivar 3, the early flowering of cultivar 13 economically meant less loss. The same situation was observed with cultivars 12 and 9 (Table 3).

The model, as shown in the example, summarizes the sources of variability that affect cost and revenue. The model enables the grower to measure the effects that a change in productivity or technology at the greenhouse might have on profit. This would aid growers in planning decisions related to technologies and production schedules. The

model can be used to identify “profit drivers,” items that have a greater effect on profitability enabling the grower to measure the economic impact of an item on the budget. Growers can then focus on managing profit drivers to improve profitability of their businesses.

Stochastic Results

The crop budgeting model in its stochastic presentation offers growers the same characteristics of the deterministic model, plus the inclusion of risk analysis. Illustration and simulation results of the stochastic model were analyzed by stochastic dominance (STODOM) analysis. Results of the STODOM analysis for the hypothetical risk neutral and risk-averse grower are shown in table 4. Cultivar 1 with a mean profit of $3,639 was the most profitable cultivar for both risk neutral and risk-averse growers.

The stochastic model estimates the probability of each profit outcome of occurring, providing the grower with the profit range, minimum and maximum, and mean profit. The ranking procedure with the stochastic model, allows for the inclusion of risk aversion in the analysis. The grower can assign a range of risk aversion coefficients, and determine the preferences for different types of growers. The output of the stochastic model allows the STODOM analysis.

The stochastic model allows the grower, through the STODOM analysis, to have a visual illustration of the range of possible profit outcomes that a certain cultivar or crop may have. In the example used in this chapter, visual inspection of the cumulative density functions (CDFs) of profit from the 15 cultivars (Figure 2) shows that cultivar 1 dominates all other cultivars with first degree stochastic dominance (FSD). The second

most profitable cultivar, cultivar 5 dominates all cultivars, but cultivar 1 with FSD. Furthermore, the distribution dominates in the stochastic dominance with respect to a function sense for any level of risk aversion. These results are similar to the STODOM analysis.

Ranking for both types of growers, the risk neutral and risk-averse, are identical except for two rankings (Table 4). For a risk neutral grower, cultivar 13 is preferred to cultivar 3, but for a risk-averse grower cultivar 3 is preferred to cultivar 13. Using second stochastic dominance (SSD), for a risk neutral grower cultivar 3 dominates cultivar 13, but for a risk-averse grower cultivar 13 dominates cultivar 3 with SSD (Figure 3).

The grower to compare between different technologies, crops, prices, etc., can use PDF generated by the stochastic analysis. The grower can compare the probability of each alternative to have a gain or a loss, and make decisions about the use of these technologies. The next discussion exemplifies the comparison of different alternatives, depending on the variability of expected profit.

Cultivar 3 expected average profit of -$2,116 was lower than cultivar 13 expected average profit of -$1,889, but the variation from the expected average profit of cultivar 3 of $1,715 was lower than cultivar 13's variation of $2,238 (Table 4). Visual inspection of the profit distribution of cultivar 13 shows that it had a larger range than cultivar 3, which meant more variability, explained by the larger deviation from the average profit. This comparison demonstrates the sort of tradeoff between expected profit and the variance of profit that risk-averse growers are willing to make relative to their risk neutral

counterparts. The same analysis can be done for cultivars 7, 9, and 11, where differences between both types of risk-averse growers were also found.

The model could also be used by the grower to perform sensitivity analysis. As an illustration of this capability, a sensitivity analysis of flowering time and compactness was performed with cultivar 2, one of the cultivars that breakeven, with a profit of $29. Results of the sensitivity analysis are presented on table 5. Flowering one week earlier or later had the effect of increasing or decreasing profit by $1,032, respectively. Flowering one week earlier increased profit to $1,061, and flowering one week later decreased profit to -$1,003. Figure 4 shows the shift in the distribution of the expected average profit, either to the right when flowering one week earlier, or to the left when flowering one week later. The distribution of the one week early flowering scenario shifted to the right, making it dominant with FSD over the other two alternatives.

On the second sensitivity analysis, the expected average profit of early compact flowering increased to $1,521. All the other scenarios, except for the original cultivar 2, had a loss (Table 5). The early compact flowering scenarios had a higher expected profit than the late flowering scenarios. Between each pair of early and late scenarios, the compact scenario had higher expected profit than the loose scenarios. Early compact flowering dominated with FSD the other alternatives (Figure 5).

Deterministic and Stochastic Results Comparison

Cultivar 1 in both simulation models has been the best alternative. The ranking has been similar for both models except for cultivars 3, 7, 9, 11 and 13. Even though these cultivars only reported loss, the decision with the deterministic model is different

from the decision with the stochastic model for a risk-averse grower. We have to notice that the ranking for the deterministic model and the risk neutral grower are identical.

The source of the difference between the two models is that the stochastic model includes the variability of variables into the model. In the deterministic model, that variability is not taken into account, and the grower doesn't know about it. It can be included by sensitivity analysis, but that takes time and money for the grower. With the stochastic model, the grower is given a complete picture of what the possible profit would be with a set of parameters.

With the stochastic model, the variability is taken into account, without the need for a sensitivity analysis. The stochastic model gives the possible range of outcomes that could be achieved if with one or more alternative. With cultivars 3, 7, 9, 11, and 13, the stochastic model gives a more accurate decision based on the ranking by second degree stochastic dominance, which takes into account the variability of flowering and price.

These are distributions of Gerbera profit only. Most growers might diversify production with other crops and/or cultivars. It is possible that correlations between other crops and/or cultivars besides 1 with profit from other (non-gerbera) enterprises could lead a risk-averse grower to form a portfolio of enterprises that includes other cultivars.

Results in this example are presented per crop, but they can also be summarized on a per-unit, per-square feet, and per-square feet per-week basis, which are most commonly used by greenhouse growers, enabling them to compare between crops and technologies. Using per square feet per week units to compare crops with different space use and timing are going to be different than the results of using per crop budgets in an

ordinary budget. With this model differences no longer exist, since the time and space use are considered and included in the results of the model, so the grower can automatically compare technologies.

Concluding Remarks

This paper developed and illustrated a greenhouse crop budgeting model that introduces risk into growers' decision analysis. The model can be used as either a stochastic or a deterministic model, and the application presented demonstrates how results differ for the two approaches. The model used data collected from Gerbera trials of 15 cultivars performed at the greenhouses of the Department of Horticulture at Purdue.

This paper tested the hypothesis that incorporating risk into a grower greenhouse budgeting model results in resource allocation and production decisions for a risk-averse grower different from those that would result from a model that did not incorporates risk. This is particularly true for a risk-averse grower. The differences in ranking between the deterministic and stochastic models illustrate that decisions made from a deterministic model could be different from those made with data from a stochastic model.

Regardless of the data used, the value of this model is the aid to growers to take decisions on situations that include risk. The versatility and flexibility of the crop budgeting model allows greenhouse growers to apply it to a variety of plant evaluation and production planning decisions. The model can also evaluate production possibilities based on the quality of the growing material, enabling growers to assess the influence seed and plug quality on returns.

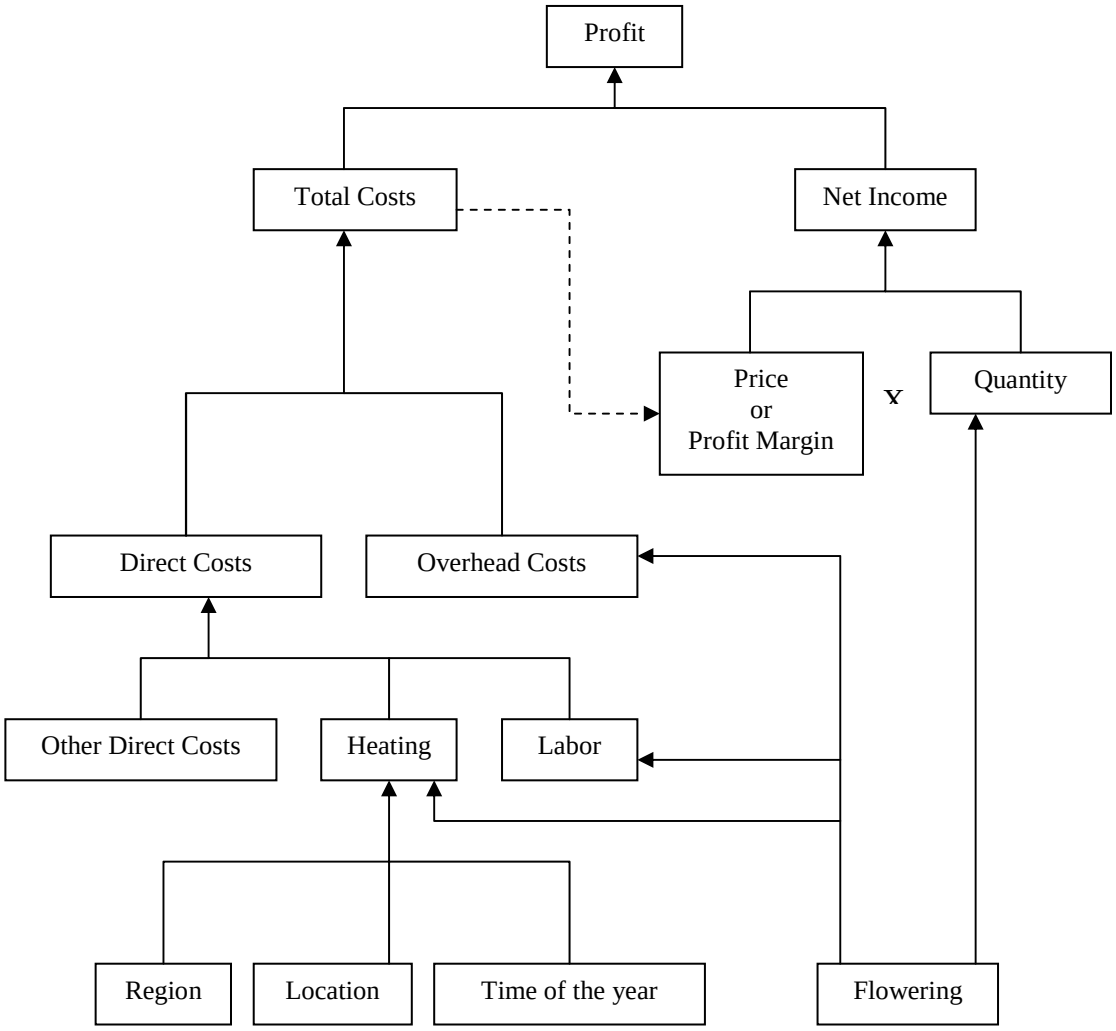

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Figure 1. General Relationship Framework of Data and Output Variables

Table 1. Weeks After Transplanting that a Given Percentage of Plants Have Flowered for Each Scenario

Scenario	25%	50%	75%	100% or max[1]
Cultivar 2	10.14	10.71	11.43	14.14
One week early	9.14	9.71	10.43	13.14
One week late	11.14	11.71	12.43	15.14
Early Compact	9.14	9.84	10.54	11.24
Late Compact	11.64	12.34	13.04	13.74
Early Loose	9.14	10.84	12.54	14.24
Late Loose	11.64	13.34	15.04	16.74

[1]Maximum percentage of pots, depending on shrinkage.

Table 2. Profit Results of Producing 10,000 Gerbera Pots Calculated by the Deterministic Model

Cultivar	Profit ($)	Profit over sales (%)	Revenue[1]	Total Costs	Overhead Costs	Variable Costs
			($)			
1	3,639	15.7	23,167	19,528	8,375	14,628
5	1,406	6.1	22,935	21,529	9,973	14,994
2	17	0.1	22,472	22,454	10,401	15,130
4	-15	-0.1	22,472	22,487	10,425	15,146
8	-516	-2.3	22,240	22,756	10,479	15,114
6	-910	-4.1	22,240	23,150	10,796	15,248
13	-1,614	-7.6	21,313	22,927	9,861	15,057
3	-2,116	-9.8	21,545	23,661	10,681	15,196
10	-3,710	-18.2	20,387	24,097	10,131	15,090
15	-4,573	-23.0	19,923	24,497	10,223	15,109
14	-7,147	-38.6	18,533	25,680	10,037	15,048
12	-8,208	-45.4	18,070	26,278	10,197	15,060
9	-8,937	-48.8	18,302	27,238	11,031	15,282
7	-9,715	-54.5	17,838	27,554	10,931	15,263
11	-10,802	-62.2	17,375	28,177	11,064	15,288

[1]Wholesale price per pot was $2.32.

Table 3. Shrinkage and Flowering Time for 10,000 Gerbera Pots Simulated by the Deterministic Model

Cultivar	Shrinkage (%)	Total Plants Sold (units)	Weeks after transplanting that X percentage of plants have flowered			
			25%	50%	75%	100% or max
1	0	10,000	8.00	8.72	9.29	11.43
5	1	9,897	10.14	10.57	11.01	12.85
2	3	9,702	10.16	10.71	11.43	14.13
4	3	9,702	10.15	10.71	11.29	14.43
8	4	9,597	9.99	10.43	13.00	13.44
6	4	9,600	10.42	11.00	11.71	15.14
13	8	9,200	9.13	9.71	10.42	14.86
3	7	9,302	10.29	11.00	12.00	14.43
10	12	8,800	9.14	10.14	11.53	14.43
15	13.3	8,667	9.42	10.01	11.86	14.43
14	20	8,000	9.29	9.85	11.86	13.86
12	21.8	7,815	9.29	10.28	12.57	13.46
9	21	7,900	10.00	10.99	13.43	14.86
7	23	7,700	9.71	10.43	13.86	14.82
11	25	7,503	9.43	10.29	14.86	14.86

Table 4. Stochastic Dominance Analysis Results of Producing 10,000 Gerbera Pots Simulated by the Stochastic Model ranked by Risk-neutral Grower

Ranking	Risk Neutral Grower (0.000)	Risk Averse Grower (0.001)	Mean	Std. Dev	Mode	5%	25%	50%	75%	95%
1	1	1	3,639	1,652	2,803	1,106	2,403	3,503	4,778	6,535
2	5	5	1,413	1,685	768	-1,269	199	1,290	2,606	4,344
3	2	2	27	1,655	-1,175	-2,622	-1,202	-104	1,228	2,897
4	4	4	-27	1,750	382	-2,755	-1,324	-56	1,112	3,041
5	8	8	-553	1,756	-1,029	-3,337	-1,791	-596	610	2,506
6	6	6	-920	1,730	-856	-3,604	-2,182	-1,045	291	2,051
7	13	3	-1,889	2,238	-2,940	-5,459	-3,598	-1,931	-266	1,802
8	3	13	-2,116	1,715	-3,091	-4,861	-3,399	-2,164	-926	843
9	10	10	-3,713	2,094	-4,287	-7,422	-5,075	-3,658	-2,237	-283
10	15	15	-4,719	2,438	-3,219	-8,609	-6,790	-4,560	-2,902	-749
11	14	14	-7,147	1,855	-8,113	-10,272	-8,492	-7,166	-5,867	-4,014
12	12	12	-8,241	1,391	-8,135	-10,350	-9,225	-8,285	-7,360	-5,784
13	9	7	-8,933	3,158	-5,934	-13,657	-11,729	-8,994	-6,120	-4,153
14	7	11	-9,717	2,231	-10,376	-13,472	-11,267	-9,596	-8,058	-6,235
15	11	9	-10,803	1,519	-10,957	-13,313	-11,862	-10,846	-9,758	-8,200

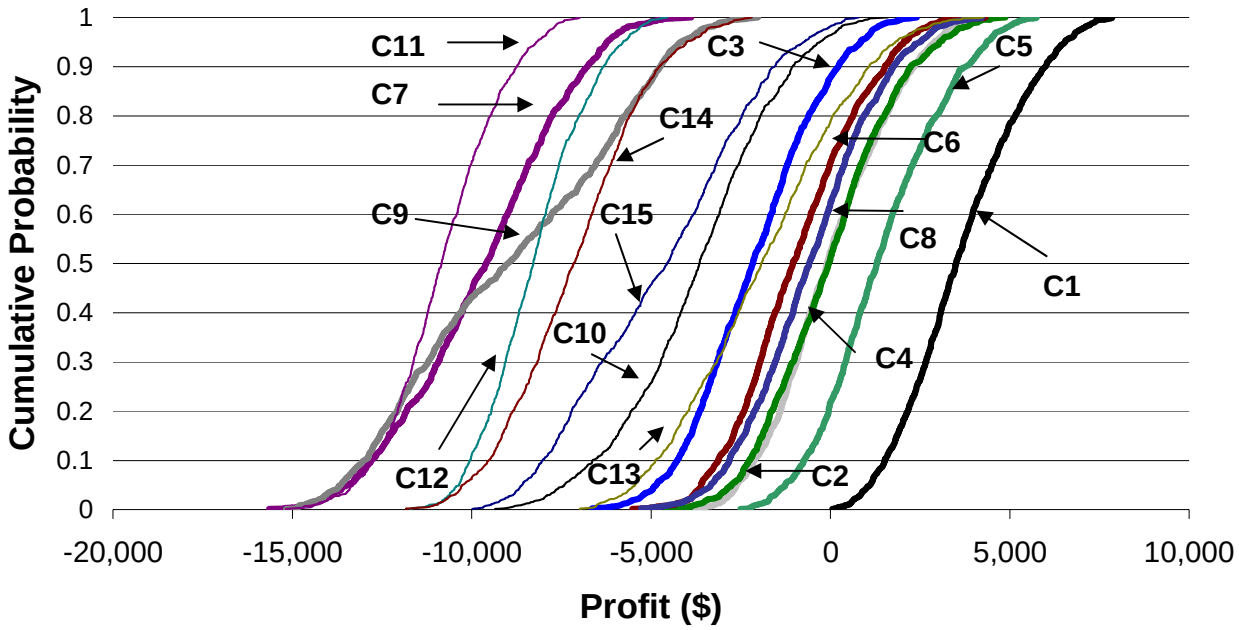

Figure 2. Cumulative Profit Density Functions for All Cultivars Simulated by the Stochastic Model

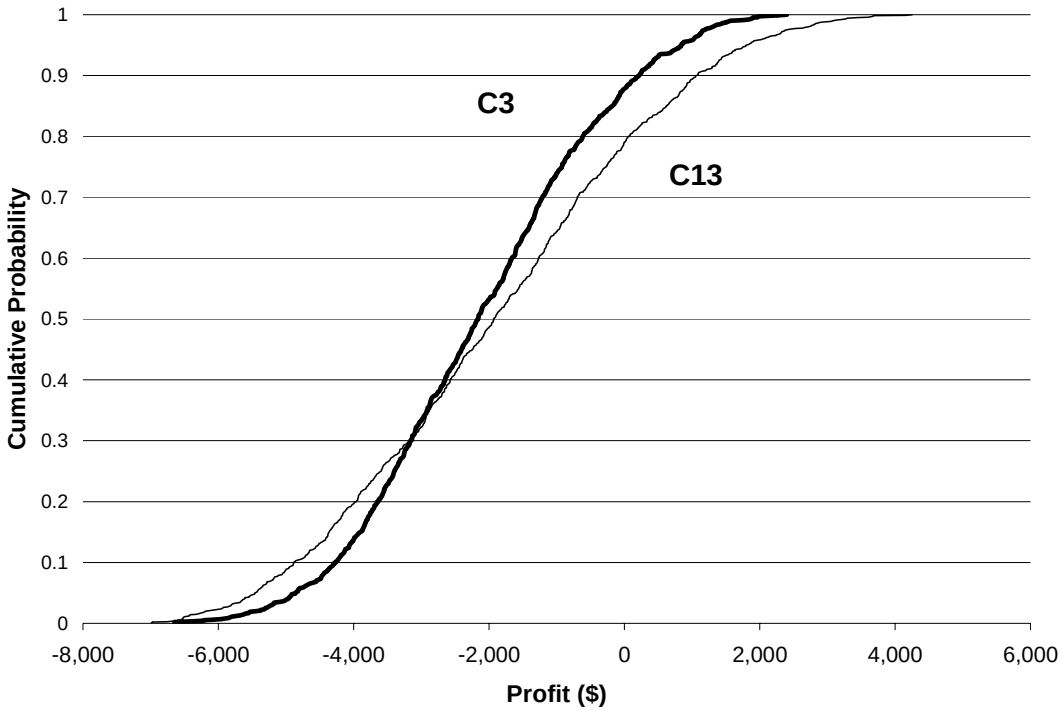

Figure 3. Cumulative Profit Density Functions for Cultivars 3 and 13 Simulated by the Stochastic Model

Table 5. Simulation Results of Two Sensitivity Analysis Performed by the Stochastic Model for Cultivar 2

Scenario	Minimum	Maximum	Mean	Std Dev
	($)			
Cultivar 2	-3,765	4,491	29	1,655
One week early	-2,701	5,444	1,061	1,649
One week late	-4,829	3,537	-1,003	1,663
Early Compact	-2,234	5,866	1,521	1,648
Late Compact	-4,893	3,484	-1,058	1,666
Early Loose	-3,848	4,335	-59	1,652
Late Loose	-6,509	1,951	-2,641	1,670

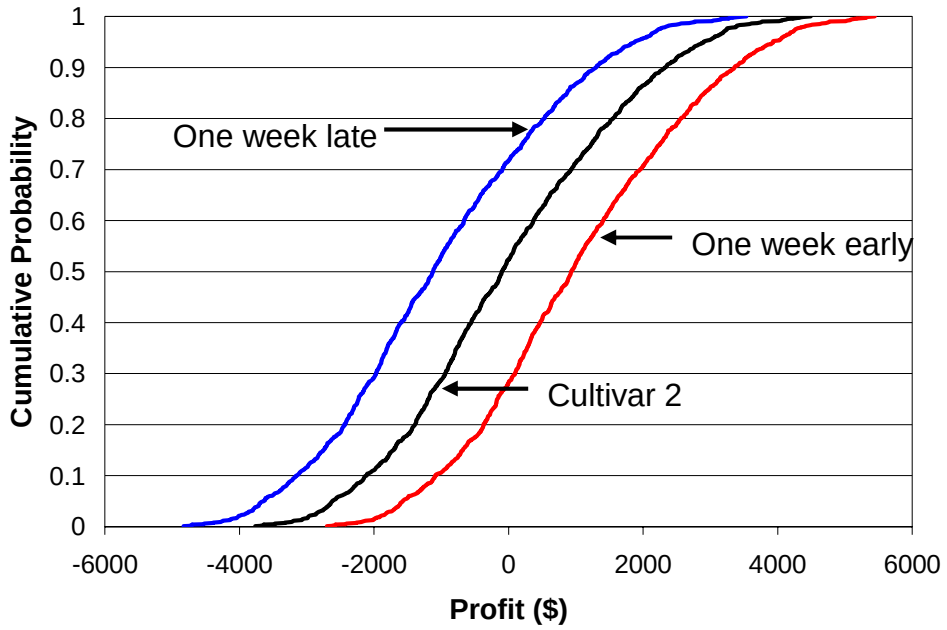

Figure 4. Cumulative Profit Density Functions of Results of First Sensitivity Analysis Simulated by the Stochastic Model

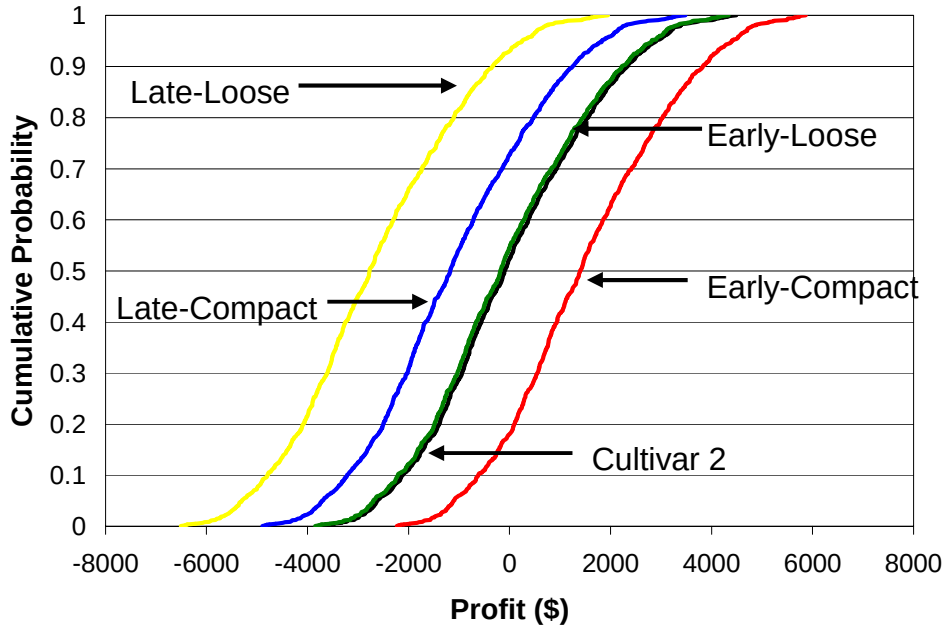

Figure 5. Cumulative Profit Density Functions Results of Second Sensitivity Analysis Simulated by the Stochastic Model

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