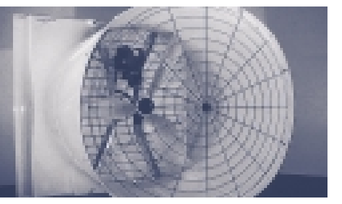


Tuberous begonia grown on a trough bench system.

Comparing Investment and Return Risks for Subirrigation Systems

Weighing returns, initial investment costs, material costs, indirect variable costs and overhead costs shows that zero runoff subirrigation (ZRS) systems can maximize production profitability.

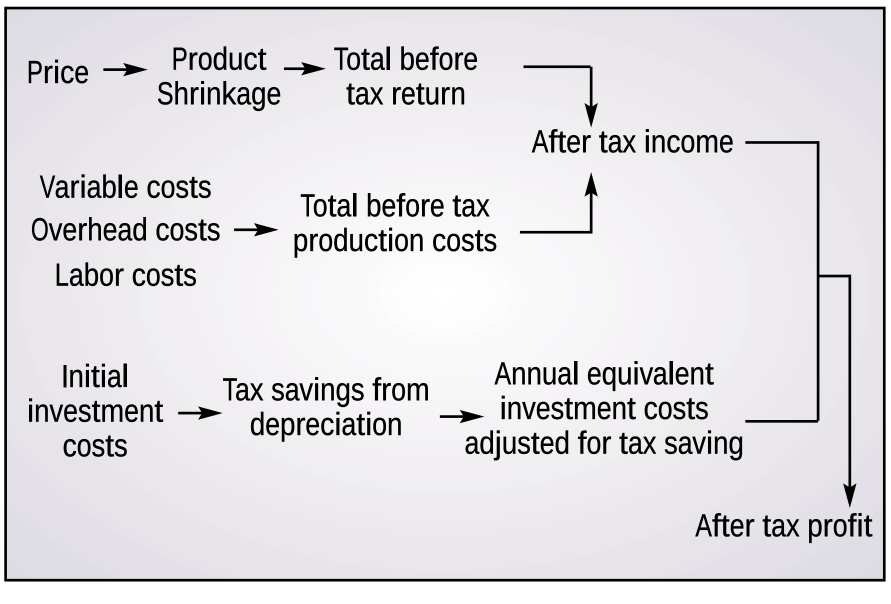
By Wen-fei L. Uva

Minimizing fertilizer and water requirements has become increasingly important to greenhouse growers who are facing higher water and fertilizer costs, decreasing availability of quality water and increasing environmental concerns to protect surface and ground water. Zero runoff subirrigation (ZRS) technology can effectively manage fertilizer input while improving greenhouse production efficiency. In a subirrigation system, potted plants are grown on a leak-proof bench or floor surface. Irrigation solution from an enclosed holding tank is pumped onto the surface and transported up through the growing medium by capillary action. Water that is not absorbed by the media after a few minutes drains back into the tank for recirculation.

Subirrigation is widely used in the European greenhouse industry. In the United States, however, many greenhouse growers have indicated that high initial investment costs and a lack of technical production information impede the adoption of this technology. Studies have shown that plants produced under subirrigation systems exhibited equal or better growth and quality compared to plants grown with traditional overhead irrigation systems.

Although a new technology like subirrigation often provides some benefits, the extra investments required in durable inputs are not always offset by the benefits. Managers need to evaluate the changes in the input-output relationships and prices associated with the new technology to determine profitability. From a financial perspective, the key factors to consider when making capital investment decisions are a project's profitability and potential risk (i.e., profit uncertainty). The study this article is based upon used a Monte Carlo simulation to compare the investments and profitability risks of four subirrigation systems for greenhouse operations in the northeastern and north central United States.

Figure 1. Capital Investment Analysis Model.



SUBIRRIGATION SYSTEMS

Many different subirrigation systems are available to greenhouse operators. Each subirrigation system has different input and management requirements, and each has different characteristics best suited to different production objectives. Four subirrigation systems commonly used by greenhouses in the United States are:

Ebb-and-flow benches (EFB). In this system, plants are placed on leveled, water-tight benches. The benches can accommodate different pot and flat sizes, and each bench can be irrigated separately, giving growers the flexibility to produce versatile crop mixes.

Movable trays (MT). This system is a mechanized EFB system. Trays are the growing benches and also serve as the container to transport crops between the greenhouse and work area. Plants can be moved with little or no labor in this system, and work crews and production machines remain in the work area where all production tasks can be completed. Flexible spacing is also available in this system.

Flood floors (FF). Plants are placed on leveled, watertight concrete floors. ➧

Table 2. Profitability and Risk of Alternative Production Models[a]

IRRIGATION SYSTEM	Mean[b]	Std. Dev.	Minimum	Maximum	Coefficient of Variation[c] (%)
	PROFIT PER SFW GREENHOUSE FLOOR ($/SFW)				
Small potted plant — 4" Geraniums					
Ebb-and-flow benches	$0.22***	$0.080	$0.006	$0.424	36.48%
Movable trays	0.25*	0.079	0.047	0.455	31.08
Flood floors	0.24**	0.083	0.021	0.445	34.82
Trough benches	0.19****	0.071	0.006	0.378	37.18
Large potted plant — 6" Poinsettias					
Ebb-and-flow benches	-$0.003**	$0.018	-$0.053	$0.045	680.2%
Movable trays	0.006*	0.018	-0.049	0.046	303.3
Flood floors	0.007*	0.019	-0.046	0.054	249.9
Trough benches	-0.001***	0.016	-0.051	0.036	1721.6
Bedding crop — 1204 Impatiens flats					
Ebb-and-flow benches	$0.084**	$0.014	$0.041	$0.124	17.12%
Movable trays	0.083**	0.014	0.043	0.120	16.34
Flood floors	0.092*	0.014	0.047	0.128	15.69
Trough benches	N/A	N/A	N/A	N/A	N/A

[a] Profits were estimated in 1998 values.
[b] Means within each crop category followed by *, **, *** and **** are significantly different when the Fisher's LSD multiple comparison analysis (a = 0.05) was performed.
[c] The coefficient of variation is calculated by standard deviation/mean.

There are no ground-level aisles, so all the floor space is potentially available for plant production. Labor can be more intensive because of the bending involved when working on the floor.

Trough benches (TB). In this system, plants are placed in shallow, sloped troughs on the top of a rolling bench stand. Water is fed in at the high end and flows to the lower end of the trough into the holding tank and is recirculated. TB systems are less flexible for spacing pots: Once the troughs are made, the trough size can't be changed, and it usually cannot accommodate plug and flat trays.

INVESTMENT RISK ANALYSIS

To compare the investment risks of the four subirrigation systems, each system was designed to operate in a 100 x 200 ft. gutter-connected glass greenhouse in the northeastern and north central United States. Greenhouses had a concrete foundation for producing pot and bedding crops The profitability of producing three crops in each of the four subirrigation systems was compared, except that the trough bench system was not used for bedding crop flat production. The three crops studied were: 1) geraniums grown in 4-inch standard pots for the Memorial Day market; 2) poinsettias grown in 6-inch azalea pots for the Christmas market; and 3) impatiens marketed in AC 4-12 (or 1204 with 48 cells) flats for the spring market. A total of 11 production models were simulated.

Five categories of costs and returns were associated with each subirrigation investment model: 1) returns — product prices and shrinkage rates; 2) initial investment costs — costs of greenhouse structure, costs of irrigation systems and space utilization efficiencies; 3) material costs — costs of plant materials, containers, media, fertilizer, pesticide and shipping material; 4) indirect variable costs — costs of labor, heating, electricity and water; and 5) overhead costs — insurance, taxes, interest and maintenance and repairs. Although the three crops are each designed for a specific market during the year, the greenhouse is assumed to have year-round production when allocating overhead costs. Risk and uncertainty are inherent features of most business ventures and need to be understood for rational decision making. When comparing profitability of subirrigation systems, we need to recognize that no matter how we estimate the cost and return variables, the values will not be absolute, and all the uncertain values have the potential to vary simultaneously and in different directions.

A risk analysis of cost uncertainty examines the various costs associated with a project, their uncertainties, and any risks or opportunities that may affect these costs. In a Monte Carlo simulation, relatively certain input variables are specified by single values, while more uncertain variables are specified by probability distributions (i.e., Uniform, Triangular and Normal distributions). Table 1 presents the range of parameters used for all cost and return variables. The simulation ➧

Table 1. Uncertain Variable Distributions and Their Parameters [a]

VARIABLE	Min.	Most likely	Max.	Std. Dev	Probability Distribution
RETURNS					
Product price					
- 4 geranium ($/pot)	$1.20	N/A	$2.50	N/A	Symmetric Triangular
- 6" poinsettia ($/pot)	2.70	N/A	5.50	N/A	Symmetric Triangular
- 1204 impatiens flat ($/flat)	6.00	N/A	7.50	N/A	Symmetric Triangular
Shrinkage rate					
- 4" geranium (%)	0%	N/A	3%	N/A	Symmetric Triangular
- 6" poinsettia (%)	1	N/A	4	N/A	Symmetric Triangular
- 1204 impatiens flat (%)	0	N/A	3	N/A	Symmetric Triangular
INITIAL INVESTMENT OF THE IRRIGATION SYSTEMS ($)					
Ebb/flow benches	N/A	$502,500	N/A	$50,250	Normal
Movable trays	N/A	514,500	N/A	51,450	Normal
Flood floors	N/A	493,100	N/A	49,310	Normal
Trough benches	N/A	447,500	N/A	44,750	Normal
DIRECT INPUT COSTS					
Plant material					
- geranium cutting ($/cutting)	$0.42	N/A	$0.45	N/A	Symmetric Triangular
- poinsettia cutting ($/cutting)	0.58	N/A	0.70	N/A	Symmetric Triangular
- impatiens seeds ($/1000 seeds)	8.00	N/A	25.00	N/A	Symmetric Triangular
Container					
- 4" standard pot ($/1,000)	$30.00	N/A	$52.50	N/A	Symmetric Triangular
- 6" azalea pot ($/250)	12.50	N/A	20.00	N/A	Symmetric Triangular
- 288 plug tray ($/100)	55.00	N/A	82.00	N/A	Symmetric Triangular
- 1204 flat tray & insert ($/100)	77.60	N/A	118.50	N/A	Symmetric Triangular
Media					
- Metro-mix 360 ($/3 ft^3)	$4.11	N/A	$8.80	N/A	Symmetric Triangular
- Metro-mix 200 ($/3 ft^3)	4.11	N/A	8.80	N/A	Symmetric Triangular
Fertilizer					
- Peter Excel 15-5-15 ($25/lb)	$12.00	N/A	$21.60	N/A	Symmetric Triangular
Growth Regulator					
- Cycocel 11.8% ($/qt)	$19.00	N/A	$24.00	N/A	Symmetric Triangular
- Bonzi ($/qt)	91.60	N/A	112.00	N/A	Symmetric Triangular
INDIRECT VARIABLE COSTS					
Price of gas ($/therm)	N/A	$0.43	N/A	$0.04	Normal
Price of electricity ($/$ft^2$/year)	N/A	0.25	N/A	0.03	Normal
Price of water ($/1,000 gal)	N/A	1.65	N/A	0.17	Normal
LABOR COSTS					
Supervisory grower salary ($/year)	$28,500	$32,800	$43,000	N/A	Triangular
Hourly employee wage ($/hour)	6.00	9.00	12.00	N/A	Triangular
Worker's compensation (%)	15%	N/A	25%	N/A	Symmetric Triangular
OVERHEAD FIXED COSTS				($/$ft^2$/year)	
Insurance	$0.20	N/A	$0.30	N/A	Uniform
Maintenance & repairs of irrigation sys.					
- Ebb/flow benches	N/A	$0.10	N/A	$0.010	Normal
- Movable trays	N/A	0.15	N/A	0.015	Normal
- Flood floors	N/A	0.05	N/A	0.005	Normal
- Trough benches	N/A	0.05	N/A	0.005	Normal
Greenhouse maintenance & repairs	$0.10	N/A	$0.20	N/A	Symmetric Triangular
Property tax	N/A	0.10	N/A	0.20	Symmetric Triangular
Miscellaneous	N/A	0.10	N/A	0.15	Symmetric Triangular
GREENHOUSE DESIGN & PRODUCTION REQUIREMENTS					
Space efficiency					
- Ebb/flow rolling benches (%)	81.0%	N/A	93.1%	N/A	Symmetric Triangular
- Dutch movable trays (%)	80.60	N/A	89.1	N/A	Symmetric Triangular
- Flood floors (%)	85.50	N/A	94.0	N/A	Symmetric Triangular
- Trough benches (%)	72.00	N/A	82.7	N/A	Symmetric Triangular
Irrigation requirements					
- Ebb/flow rolling benches (gal/ft^2)	0.50	N/A	0.8	N/A	Symmetric Triangular
- Dutch movable trays(gal/ft^2)	0.50	N/A	0.8	N/A	Symmetric Triangular
- Flood floors (gal/ft^2)	0.80	N/A	1.0	N/A	Symmetric Triangular
- Trough benches (gal/ft^2)	0.30	N/A	0.8	N/A	Symmetric Triangular
Solution uptake rate (%)	150%	N/A	200%	N/A	Symmetric Triangular
ECONOMIC PARAMETERS					
Cost of equity capital (%)	10%	13%	20%		Triangular
Cost of borrowed capital (%)	6%	8.5%	10%		Triangular
Proportion of equity capital used to finance the investment (%)	0%	N/A	100%		Symmetric Triangular
Total marginal tax rate (%)	20%	N/A	40%		Symmetric Triangular
Annual inflation rate (%)	2.3%	3.5%	5%		Triangular

[a] Cost and return prices were estimated in 1998 values.

process involved generating random samples from the probability distributions of the uncertain parameters and repeating the process a large number of times to yield a range of possible results. The profitability of investing in the four subirrigation systems to produce the three different crops was calculated based on the capital budgeting model shown in Figure 1. The related costs and profits of each model were estimated as dollars per square foot week (SFW) of greenhouse area in production. Square foot week (SFW) is an important concept when allocating greenhouse indirect variable costs and fixed overhead costs to different crops with different time periods of production cycles. The costs allocated to different crops are calculated by multiplying the per SFW cost base by crop spacing (square feet) and production length (weeks) of each crop. The SFW costs and profits would, therefore, vary according to production length, crop spacing, and the space efficiency of each subirrigation system. The risk of investment was compared by the relative variability of profits using the coefficient of variation (CV). There are an infinite number of possibilities for each variable's values associated with each model. In this study, 300 simulations were performed for each production model.

Flood floor system maximizes efficiency in a high greenhouse space.

RESULTS

Table 2 shows the statistical summary of the simulation results for the 11 production models. The results from the analysis show that different ZRS systems maximize profitability of production of different crop categories. For small potted plant production, represented by 4-inch geraniums, the average profit per SFW greenhouse floor showed that the movable tray (MT) system was significantly higher than the production models with flood floor, ebb-and-flow and trough bench systems. For large potted plant production, represented by 6-inch poinsettias, the average profit per SFW greenhouse floor of the flood floor (FF) systems was the highest among the four large potted plant production models. However, it was not significantly higher than the production model with the second highest profit, the movable tray (MT) systems. For bedding crop flat production, represented by 1204 impatiens flats, the production model with flood floor (FF) systems had a significantly higher average profit per SFW greenhouse floor than the other two production models (movable tray and ebb-and-flow bench systems).

The risks of the production models were compared by the variability of the simulation results and are considered to be higher when the coefficient of variation of the simulation results was higher. The most risky investment projects among alternative subirrigation systems are trough bench systems for small potted plants and large potted plants, and ebb-and-flow systems for bedding crop flat production. The least

Bench-moving rails for the movable tray system.

risky investment projects are movable tray systems for small potted plant production and flood floor systems for large potted plant and bedding crop flat production.

In addition to the representative cases presented above, we also tested the profitability of a special case of possible high personnel costs. The maximum and most likely parameter values defining the labor cost variables were increased to $24/hour and $15/hour, from $20/hour and $9/hour, respectively, for hourly labor wage, and $84,000/year and $50,000/year from $43,000/year and $32,800/year, respectively, for supervisory costs. All other parameter values stayed the same.

Table 3 shows the simulation results for this case study. The relative profitability rankings of alternative production models for each crop category were the same as in the general case simulations. However, the profitability of using flood floor systems to produce the more labor-intensive and time-consuming large potted plants became more uncertain and, therefore, riskier.

The second special case is the potential for high inflation rates. The maximum and most likely inflation rates were increased to 20 percent and 7 percent from 5 percent and 3.5 percent, respectively, while all other parameter values were unchanged. Table 4 shows the simulation results for this case study. As in the personnel cost special cases, the relative profitability rankings of alternative production models for each crop category were the same as in the general case simulations. The only change in the risk rankings was that the risks of flood floor systems exceeded movable tray systems when producing large potted plants at higher inflation rate uncertainty.

The trough bench (TB) system is the most risky and is not competitive compared to the other three subirrigation systems studied because of its low average and highly volatile profitability. The results also showed that the most suitable systems for small potted plant and bedding crop flat production were the movable tray system and the flood floor system, respectively.

The decision-making criteria were not as clear, however, for large potted plant production. The flood floor system had the highest average profitability and was least risky under most conditions; however, under higher variable uncertainty circumstances of potential high labor costs and inflation rates, the flood floor (FF) system was relatively risky compared with the movable tray (MT) system, which had the second highest average profitability. Therefore, the decision of selecting a subirrigation system for large potted plant production will depend on whether other crop categories are scheduled to be produced in the same greenhouse area and the greenhouse operator's attitude toward risk.

Table 3. Profit Per SFW Greenhouse Floor of the Eleven Production Models for High Labor Cost Simulations[a].

Production Model	Mean[b]	Std. Dev.	Minimum	Maximum	Coefficient of Variation[c] (%)
PROFIT ($)/ SFW GREENHOUSE FLOOR					
Small Potted Plant - 4" Geraniums					
Ebb-and-flow benches	$0.190***	$0.081	$0.007	$0.418	42.75%
Movable trays	0.228*	0.086	0.023	0.444	37.87
Flood floors	0.213**	0.090	0.015	0.431	42.37
Trough benches	0.158****	0.079	-0.011	0.332	50.12
Large Potted Plant - 6" Poinsettias					
Ebb-and-flow benches	-$0.017**	$0.023	-$0.073	$0.047	130.2%
Movable trays	-0.016**	0.020	-0.070	0.046	122.3
Flood floors	-0.013*	0.023	-0.072	0.038	181.9
Trough benches	0.020**	0.021	-0.073	0.038	1060.0
Bedding Crop – 1204 Impatiens Flats					
Ebb-and-flow benches	$0.072**	$0.016	$0.030	$0.111	22.02%
Movable trays	0.070**	0.014	0.030	0.105	20.58
Flood floors	0.081*	0.016	0.042	0.130	19.92
Trough benches	N/A	N/A	N/A	N/A	N/A

[a] Profits were estimated in 1998 values.
[b] Means within each crop category followed by *, **, *** and **** were significantly different when Fisher's LSD multiple comparison analysis (a = 0.05) was performed.
[c] The coefficient of variation is calculated by standard deviation/mean.

Table 4. Profit Per SFW Greenhouse Floor of the 11 Production Models for High Inflation Rate Simulation[a].

Production model	Mean[b]	Std. Dev.	Minimum	Maximum	Coefficient of Variation[c] (%)
PROFIT ($/SFW) GREENHOUSE FLOOR					
Small potted plant - 4" Geraniums					
Ebb-and-flow benches	$0.215***	$0.085	$0.010	$0.469	38.86%
Movable trays	0.253*	0.085	0.058	0.468	33.78
Flood floors	0.236**	0.090	0.031	0.446	37.88
Trough benches	0.191****	0.071	0.029	0.373	37.20
Large potted plant - 6" Poinsettias					
Ebb-and-flow benches	$0.005**	$0.020	-$0.050	$0.051	439.6%
Movable trays	0.010*	0.018	-0.028	0.057	182.2
Flood floors	0.011*	0.020	-0.038	0.060	191.7
Trough benches	-0.001***	0.018	-0.044	0.055	1,928.7
Bedding crop – Impatiens flats					
Ebb-and-flow benches	$0.085**	$0.015	$0.049	$0.119	17.22%
Movable trays	0.085**	0.016	0.046	0.119	18.51
Flood floors	0.095*	0.015	0.053	0.130	15.93
Trough benches	N/A	N/A	N/A	N/A	N/A

[a] Profits were estimated in 1998 value.
[b] Means within each crop category followed by *, **, *** and **** were significantly different when Fisher's LSD multiple comparison analysis (/ = 0.05) was performed.
[c] The coefficient of variation is calculated by standard deviation/mean.

Finally, the majority of greenhouse operations grow more than one type of crop to meet seasonal and customer demands; interviews with the greenhouse industry showed that large operations tend to use more than one type of subirrigation system to meet their needs. To maximize total profit, the subirrigation system most suitable for the major crop category in the production plan should be selected. However, when multiple crop categories of small volumes are grown simultaneously in the greenhouse production plan, compromise might be necessary when selecting a subirrigation system for a production area depending on available resources. If multiple crop categories in large volumes are emphasized in the production plan, more than one type of subirrigation system can be installed in different production areas for growing different crop categories. GPN

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