A Linear Programming Analysis of Economies of Size and Profitability in Vegetable Production

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Introduction

The declining importance of tobacco production in Connecticut and Massachusetts, the likely reduction in the acreage needed to support a shrinking dairy industry, and the growing concern with agricultural land preservation have brought about considerable interest in expanding vegetable production in Southern New England. Furthermore, the proximity to major metropolitan areas gives the cited region a major advantage in the production of vegetables for the fresh market (Swack-hamer).

In the past, economies of size, almost year-round growing seasons, easy access to migrant labor, aggressive marketing techniques, and improved transportation systems, have favored the production of fresh fruits and vegetables in the far west, southwest and Florida. Wyson, Leigh, and Ganguly present evidence suggesting that such comparative advantages in the western part of the United States may be on the decline. In California, for example, vegetable production might be adversely affected by potential water shortages, relatively high transportation and refrigeration costs, and by a growing pressure for higher farm wages.

The degree to which vegetable production might be an economically viable undertaking in the relatively small farms that characterize New England requires further investigation.

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Thus, the purpose of this paper is to present an economic evaluation of vegetable production. The specific objectives are to examine economies of size, and to determine the potential profitability of vegetable production in the Connecticut River Valley. Economic engineering and linear programming (LP) techniques are used in this study based on criteria presented by Madden. Specially relevant to this choice is the absence of vegetable production data at the farm level.

The organization of the paper is as follows. Section two contains a description of the data and assumptions, followed by a brief discussion of the LP model in section three. The major results are discussed in section four and the last section presents the summary and major conclusions of the study.

Data and Assumptions

In this study, farm size is jointly determined by machinery size and by the amount of time available to complete field operations in each of 14 time periods. Following Carter and Dean, output is measured by the level of gross returns (GR) and thus average total cost (ATC) is equal to total costs (TC) divided by gross returns (i.e., ATC = TC/GR). Gross returns are determined using Hartford Regional Market (wholesale) average prices for the period 1982-1984 and expected yields for the study area (Connecticut Department of Agriculture). Based on published price spread information (U.S. Department of Agriculture) the wholesale prices are reduced by 30 percent in order to allow for marketing costs and thus generate estimates of prices received by farmers (farm prices).

Five machinery sets, based on individual

Table 1. Selected Characteristics of Five Vegetable Farms Varying in Size.

FARM ONE (15 HP Tractor and Equipment)	
Number of Full-Time Machinery Operators	One
Tractor and Equipment Investment	$ 12,743.00
Annual Machinery Fixed Costs	$ 2,318.97
Annual Machinery Operator Labor Fixed Costs	S 15,000.00
Total Annual Farm Fixed Costs	$ 17,318.97
FARM TWO (30 HP Tractor and Equipment)	
Number of Full-Time Machinery Operators	One
Tractor and Equipment Investment	$ 29,370.00
Annual Machinery Fixed Costs	$ 5,490.74
Annual Machinery Operator Labor Fixed Costs	$ 15,000.00
Total Annual Farm Fixed Costs	$ 20,490.74
FARM THREE (30, and 42 HP Tractors and Equipment)	
Number of Full-Time Machinery Operators	Two
Tractor and Equipment Investment	S 69,906.00
Annual Machinery Fixed Costs	$ 13,072.17
Annual Machinery Operator Labor Fixed Costs	$ 30,000.00
Total Annual Farm Fixed Costs	$ 43,072.17
FARM FOUR (30, 42, and 67 HP Tractors and Equipment)	
Number of Full-Time Machinery Operators	Three
Tractor and Equipment Investment	$132,900.00
Annual Machinery Fixed Costs	$ 24,894.87
Annual Machinery Operator Labor Fixed Costs	$ 45,000.00
Total Annual Farm Fixed Costs	$ 69,894.87
FARM FIVE (30, 42, 67, and 110 HP Tractors and Equipment)	
Number of Full-Time Machinery Operators	Four
Tractor and Equipment Investment	$318,713.00
Annual Machinery Operator Labor Fixed Costs	$ 60,000.00
Total Annual Farm Fixed Costs	$100,622.47

and combinations of individual machinery complements, are used to determine five different farm sizes for two time scenarios.[1] In order to identify the most efficient acreage for a given machinery set, land is first treated as a variable input at a cost of $150 per acre. Once the most efficient acreage is identified, land is treated as a fixed input. This is a common approach in studies of this type. (For details see Jensen; Madden; and Miller, Rodewald, and McElroy.) An additional component of fixed costs is a $15,000 charge for each full-time skilled worker, assuming that one such worker is needed for every tractor in the machinery set. A summary of the characteristics of the five farm sizes used in the analysis is presented in Table 1.

The LP analysis is based on two time availability scenarios. For both scenarios, the length of each time period is a function of daylight hours, number of days per period, and precipitation. Light hours per day for a specific time period are approximated from a sun path diagram for 40 degrees north latitude. Total number of days for each time period is determined based on the scheduling of possible field activities that occur in vegetable production during particular times of the growing season. May and June, which typically require the greatest number of field operations within small spans of time, are each divided into three time periods. July, August and September are each divided into two time periods. The first and last of the 14 time periods are relatively long, since in these periods there are few time-specific activities to be performed. It is further assumed that two daylight hours are used for breaks, lunch, and routine machinery maintenance. Time availability for each period is calculated by the following equation:

$$TAPP = DIP \times (DLH/D - H) \times P(NDD)$$

where:

[1] In this study, a tractor and its corresponding equipment and implements are referred to as a machinery complement. A machinery set may consist of one machinery complement or some combination of two, three or four machinery complements.

Table 2. Probabilities of Dry Day Sequences and Time Availability.

Time Period	Total Days	Approx. Day[1] Light hrs./day	Total[2] Light hrs./ Period	P(D)	P{D)(D)[3]	P(D)(D)(D)[4]	Time[5] Seen. A	Time Seen. B
1 April 1-30	30	12:30 hrs.	375 hrs.	.60	.33	.21	107 hrs.	68 hrs.
2 May 1-10	10	13:30 "	135"	.70	.49	.34	56 "	39"
3 May 11-20	10	13:50"	138"	.70	.49	.34	58"	40 "
4 May 21-31	11	14:10 "	156"	.64	.40	.26	54 "	35 "
5 June 1-10	10	14:35 "	146 "	.50	.25	.13	31 "	16"
6 June 11T20	10	15:00 "	150 "	.90	·81	.73	105 "	95 "
7 June 21-30	10	14.35 "	146"	.60	.36	.22	45 "	28 "
8 July 1-15	15	14:10"	213 "	.60	.36	.22	66 '	40 "
9 July 16-31	16	13:50 "	221 "	.81	.66	.54	125 '	102 "
10 Aug. 1-15	15	13:30 "	203 "	.73	.54	.39	93 '	67 "
11 Aug. 16-31	16	13:00 "	208"	.56	.32	.18	56 '	32 "
12 Sept. 1-15	15	12:30 "	188 "	.67	.44	.30	69 '	47 "
13 Sept. 16-30	15	12:00 "	180 "	.53	.28	.15	42 '	23 "
14 Oct. 1-Nov. 10	41	10:43 "	439 "	.68	.47	.32	168 '	114 "

[1] Approximate light hours per day are estimated form sun path diagram for 40 degrees N. Latitude.
[2] Rounded to nearest hour.
[3] P(D)(D): probability of 2 consecutive dry days. Scenario One is based on P(D)(D) assumption.
[4] P(D)(D)(D): probability of 3 consecutive dry days. Scenario Two is based on P(D)(D)(D) assumption.
[5] Formula for Scenario 1 and 2: Days in period X (Day Light hours/day-2 hours) x P(D)(D) or P(D)(D)(D).

TAPP = time availability per period,
DIP = number of days in a given period,
DLH/D = average day-light hours per day,
H = two hours for lunch and break time, and
P(NDD) = probability of N consecutive dry days.

A day is considered to be dry if it has less than 0.10 inches of precipitation. Time availability for Scenario A is based on the probability of two consecutive dry days (N — 2), while time availability for Scenario B is based on the probability of three consecutive dry days (N = 3). The dry day probabilities are calculated using twenty years of precipitation data from the Bradley Field Weather Station, which is located in the study area. Table 2 summarizes the length of each time period, probabilities of dry day sequences, and time availability for both scenarios. The data indicates that Scenario A has a total of 1,075 hours compared to 746 hours in Scenario B, or what amounts to about 31 percent less hours in the latter case compared to the former.

A total of 23 vegetable crops have been included in the model. Enterprise budgets for each crop specifying variable costs, machinery and labor requirements, and gross returns per acre have been constructed to reflect recommendations made by the PJant Science Department at the University of Connecticut. These recommendations are for soil and weather conditions that prevail in the study area. Enterprises were defined to allow for double cropping when feasible. The per acre costs of purchased inputs and non-machinery labor variable costs are assumed to be constant for all farm sizes. Table 3 presents estimated farm prices and per acre yields, gross returns, cost of purchased inputs, and return over purchased inputs for the 23 vegetable enterprises included in the model. (For details on the enterprise budgets see Bravo-Ureta, Fueglein, and Ashley.)

As indicated earlier, operator labor is treated as a fixed input and is assumed to provide the labor needed to perform all machinery operations. Unskilled labor, needed for transplanting and harvesting, is assumed to be available in unlimited amounts at a cost of $4.50 per hour. The harvest rates for the various vegetable crops are based on published information (Christensen, Martin, and Lucier; Dhillon; and Phelps and How) supplemented by a telephone survey of selected producers. Finally, machinery variable and fixed costs were calculated following standard procedures established by the American Society of Agricultural Engineers. (For details on machinery costs see Fueglein).

The Linear Programming Model

The linear programming model used to determine economies of size and optimal cropping

Table 3. Estimated Farm Prices and per Acre Yields, Gross Returns Cost of Purchased Inputs (COPI) and Return Over Purchased Inputs (ROPI) for 23 Vegetable Enterprises[1]

	Unit	Yield	Farm Price[2]	Gross Returns	COPI	ROPI
Early Broccoli	crate	200	$ 4.97	$ 994	$ 449	$ 545
Late Broccoli	"	200	4.97	994	598	396
Early Cabbage	"	320	3.92	1,254	602	652
Late Cabbage	"	320	4.20	1,344	533	811
Early Cauliflower	"	450	3.36	1,512	784	728
Late Cauliflower	"	450	4.34	1,953	582	1,371
Early Cucumber	bushel	350	6.30	2,205	569	1,636
Late Cucumber	"	350	5.74	2,009	569	1,440
Eggplant	"	300	4.62	1,386	605	781
Early Leaf Lettuce	crate	600	2.73	1,638	1484	154
Late Leaf Lettuce	"	600	3.64	2,184	493	1,691
Peas	bushel	125	11.83	1,479	280	1,199
Peppers	bushel	300	5.25	1,575	497	1,078
Snap Beans	bushel	150	8.40	1,260	265	995
Early Spinach	"	350	5.46	1,911	346	1,565
Late Spinach	"	350	5.46	1,911	349	1,562
Summer Squash	1/2 bushel	700	3.82	2,674	607	2,067
Early Sweet Corn	dozen	1,000	1.05	1,050	237	813
Late Sweet Corn	"	1,000	0.91	910	293	617
Early Tomatoes	bushel	50	40.32	2,016	673	1,343
Late Tomatoes	"	140	16.03	2,244	851	1,393
Turnips	"	200	6.30	1,260	261	999
Winter Squash	"	270	4.27	1,153	317	836

[1] For details see Bravo-Ureta, Fueglein and Ashley.
[2] Farm prices are assumed to be equal to 70 percent of the Hartford Regional Market average prices for the period 1982-1984.

patterns is divided into two stages. In Stage One the objective function is the maximization of farm profits, which in this model represent a return to management and entrepreneurship. Stage One is solved once for each of the five farm sizes considered. The solution of each maximization problem yields the lowest point on the short run average cost (SRAC) curve for a given farm size.

Stage one of the LP model can be expressed as:

$$\text{Maximize } Z = \Sigma C_{j}X_{j} - \Sigma C_k X_k - FC$$

$$\text{Subject to } \Sigma A_{ij} X_j \neq B_j$$

where:

Z = profits,

C_i = returns over purchased inputs for growing activity j,

X_i = the level of activity j,

C_k = variable cost of machinery activity k,

X_k = the level of machinery activity k,

FC = total annual fixed costs,

A_{ij} = the amount of resource i consumed by each unit of activity j, and

B_j = the amount of resource i available

Additional points on the SRAC curve for each farm size are generated in Stage Two where the objective function is the minimization of total costs of production. For a given farm size, the minimization problem is solved several times by fixing gross returns (i.e., output) at decreasing percentages of the maximum gross return level obtained in Stage One. This procedure is repeated several times in order to generate SRAC curves for each of the five farm sizes under both time availability scenarios. The long run average cost (LRAC) curve for each time scenario is then drawn as the envelope to the minimum points of the various SRAC curves generated in Stage One.

Stage Two of the model can be expressed as:

$$\text{Minimize } M = \Sigma F_j X_j + \Sigma C_k X_k + FC$$

$$\text{Subject to } \Sigma A_{ij} X_j \neq Bi$$

$$GR = PT\ MGR$$

$$L = LMAX$$

where:

M = total costs,

F_j = costs of purchased inputs

Table 4. Gross Returns, Total Costs, Average Total Costs, Profits and Land Used under Time Scenario A.

Farm[1] Size	Gross Returns	Total Costs	Ave. Total Costs	Pro-fits	Land Used
FARM I	$	$	$	$	$
100%	37,819	32,782	0.87	5,037	9.65
80%	30,225	27,971	0.92	2,284	9.54
60%	22,961	25,670	1.13	(2,979)	7.16
40%	15,128	23,369	1.54	(8,241)	4.77
FARM II					
100%	79,999	53,434	0.67	26,565	20.40
80%	63,999	43,233	0.68	20,766	20.18
60%	47,999	38,313	0.80	9,686	15.13
40%	31,999	33,393	1.04	(1,394)	10.09
FARM III					
100%	208,203	129,531	0.62	78,672	53.34
80%	166,563	102,443	0.62	64,120	52.27
60%	124,922	89,335	0.72	35,587	39.39
40%	83,281	76,576	0.92	6,705	26.26
FARM IV					
100%	390,328	231,054	0.59	159,274	99.75
80%	312,262	182,940	0.59	129,322	98.47
60%	234,197	156,590	0.67	77,607	73.85
40%	156,137	132,613	0.85	23,518	49.24
FARM V					
100%	599,215	352,215	0.58	246,893	153.91
80%	479,372	275,857	0.58	203,515	153.91
60%	359,529	234,132	0.65	125,397	113.38
40%	239,686	197,128	0.82	42,558	75.59

[1] 100%, 80%, 60%, and 40% refer to the percentage of maximum gross returns obtained in Stage One of the model for a particular farm.

GR = total gross returns,
P T = percentage of maximum gross returns obtained in Stage One set equal to 80, 60, or 40,
MGR = maximum gross returns determined in Stage One for a particular farm,
L = land, and
LMAX = optimal amount of land determined in Stage One for a particular farm.

The meaning of the remaining abbreviations in Stage Two are the same as in Stage One.

Results

Table 4 shows gross returns, total costs, average total costs, profits and land used for the five farm sizes considered under Scenario A. Farm One, the smallest operation, shows a minimum SRAC of 87 cents (i.e., 87 cents per dollar of gross returns) when output (i.e., gross returns) is $37,819. By moving from Farm One to Farm Two, the low point on the SRAC curve drops to 67 cents when output reaches $79,999. For the other three farms SRAC continues to decline, reaching a minimum of 58 cents at the $599,215 gross return level for Farm Five. Stated differently, expanding from Farm One to Farm Two results in a 23 percent reduction in the minimum SRAC. Minimum SRAC for Farms Three, Four, and Five are 29, 32, and 33 percent lower, respectively, than Farm One.

As discussed earlier, additional points on the SRAC curves are generated by sequentially lowering gross returns from 100 percent to 40 percent of the optimal output levels obtained in the maximization problem and then solving the LP model as a minimization problem. The highest points on the SRAC curves generated in this manner range from $1.54 for Farm One to $0.82 for Farm Five at 40 percent of the optimum output. It should be noted that the break-even point occurs when SRAC is equal to $1.00.

Table 5 shows gross returns, total costs, average total costs, profits, and land used for the five farm sizes considered under time Scenario B. The reader should remember that Scenario B has approximately 31 percent less time

Table 5. Gross Returns, Total Costs, Average Total Costs, Profits and Land Used under Time Scenario B.

Farm[1] Size	Gross Returns	Total Costs	Ave. Total Costs	Pro-fits	Land Used
	$	$	$	$	acres
FARM I					
100%	23,821	27,034	1.13	(3,213)	6.07
80%	19,057	24,028	1.26	(4,971)	6.00
60%	14,293	22,579	1.58	(8,286)	4.50
40%	9,529	21,129	2.22	(11,600)	3.00
FARM II					
100%	50,162	41,433	0.83	8,729	12.86
80%	40,130	34,891	0.87	5,239	12.86
60%	30,097	31,675	1.05	(1,578)	9.49
40%	20,065	28,590	1.42	(8,525)	6.32
FARM III					
100%	128,762	100,284	0.78	28,478	33.74
80%	103,008	82,359	0.80	20,649	33.74
60%	77,257	71,797	0.93	5,460	24.36
40%	51,505	63,906	1.24	(12,401)	16.24
FARM IV					
100%	241,368	176,459	0.73	64,909	63.10
80%	193,095	143,129	0.74	49,966	63.10
60%	144,821	123,821	0.85	21,113	45.67
40%	96,547	108,895	1.13	(12,348)	30.44
FARM V					
100%	370,629	266,733	0.72	103,896	97.32
80%	296,503	214,900	0.72	81,603	97.32
60%	222,377	183,503	0.83	38,874	70.12
40%	148,251	160,623	1.08	(12,372)	46.75

[1] 100%, 80%, 60%, and 40% refer to the percentage of maximum gross returns obtained in Stage One of the model fora particular farm.

available for machinery operations than Scenario A. The results in Table 5 show a minimum SRAC of $1.13 for Farm One when output reaches a maximum level of $23,821. Moving to Farm Two and then to Farm Three yields a minimum SRAC equal to 83 and 78 cents when gross returns are $50,162 and $128,762, respectively. SRAC drops to 73 cents for Farm Four and reaches a low point at 72 cents for Farm Five when output is $370,629.

The results of Scenario B indicate a 27 percent reduction in the minimum SRAC by moving from Farm One to Farm Two. The lowest SRACs associated with Farms Three, Four, and Five are 31, 35, and 36 percent lower than the corresponding figure for Farm One. The highest points on the SRAC curves shown in Table 5 range from $2.22 for Farm One to $1.08 for Farm Five.

Figure 1 shows the LRAC curves obtained by drawing an envelope to the SRAC curves for each farm size under both time scenarios. Also shown are the SRAC curves for scenario B. Both LRAC curves are clearly ‘L' shaped and indicate that average costs in vegetable production decrease rather rapidly up to about $100,000 and $60,000 of gross returns in Scenarios A and B respectively, leveling off thereafter. It should be noted that the methodology employed in this paper excludes the possibility of increasing average costs and thus of a 'U' shaped LRAC curve.

A comparison of the results from the two scenarios reveal, as would be expected, larger gross returns and acreages for Scenario A farms. Under Scenario A, gross returns on the lowest points of the SRAC curves range from a low of $37,819 to a high of $599,215, whereas output levels for Scenario B range from $23,821 to $370,629. The most efficient acreages identified for farms under Scenario A range from 9.65 acres (Farm One) to 153.91 acres (Farm Five). Corresponding acreages for Scenario B are 6.07 and 97.32.

The profit figures displayed in Table 3 and Table 4 clearly show a positive relationship between profits and farm size. In Scenario A Farm One shows a loss at both the 40 and 60 percent gross return levels, and Farm Two shows a loss at the 40 percent level only. All other solutions for Scenario A exhibit positive

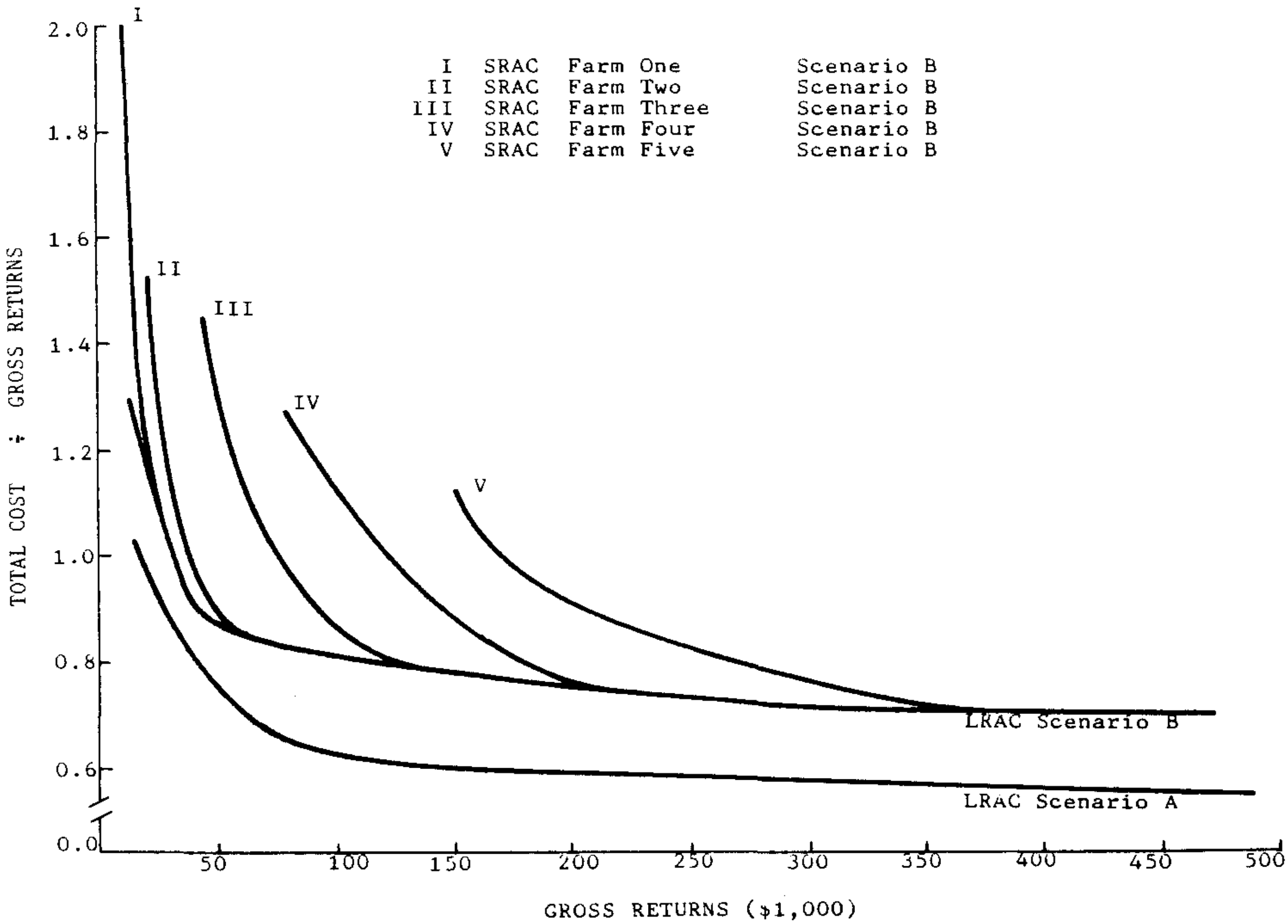

Figure 1. Long Run Average Cost Curve for Scenario A and Short and Long Run Average Cost Curves for Scenario B

profits. By contrast, in Scenario B Farm One shows a loss at all output levels, Farm Two shows a loss at the 40 and 60 percent levels, and the remaining three farms experience a loss at the 40 percent output level.

Table 6 presents gross returns, land used, and cropping patterns at the 100 percent gross return level for all farms considered. The Scenario A results indicate that Farm One and Farm Two grow three crops—early spinach, followed by late cucumbers, and late cauliflower. By contrast, Farms Three, Four, and Five grow four crops—early spinach, and peas, followed by late cucumbers, and late cauliflower. The cropping patterns for Scenario B are the same as those for Scenario *A* except for Farm One which does not grow cauliflower and Farm Two which also grows peas.

Unskilled labor costs were increased frorr $4.50 to $9.00 per hour in order to determine the sensitivity of optimal cropping patterns and farm profitability. This sensitivity analysis was performed only for Scenario B in conjunction with the 100 percent gross return option. The resulting optimal cropping pattern, shown in the lower portion of Table 5, reveal that in all cases, except Farm One, a different mix of crops is grown. In addition, gross returns and land used exhibit small declines in all cases except for the smallest farm where there is no change.

Table 7 displays profits, average investment[2] and rate of return on average investment (ROR) for Scenarios A and B. The ROR figures range from 17.3 to 57.4 percent in Scenario A, and from — 16.0 to 32.0 percent in

[2] Average investment includes land, valued at $2500 per acre, plus average machinery investment.

Table 6. Gross Returns, Land Used, and Optimal Cropping Patterns at 100 Percent Gross Return Levels.

Farm Size	Gross Returns	Total	Crop Mix[1]							
		Acres			Acn	;s	Acres		Acre	is
Time Scenario A		9.65	SPN1	9.65	CUC2	9.38	CAL2	0.27		
I	37.819									
II	79,999	20.40	SPN1	20.41	CUC2	19.84	CAL2	0.57		
III	208,203	53.34	SPN1	51.52	CUC2	51.27	PEA1	1.81	CAL2	2.06
IV	390,328	99.75	SPN1	98.49	CUC2	96.60	PEA1	1.26	CAL2	3.15
V	599,215	153.91	SPN1	145.46	CUC2	145.46	PEA1	8.44	CAL2	8.44
Time Sc enario										
I	23,821	6.07	SPN1	6.07	CUC2	6.07				
II	50.162	12.86	SPN1	12.30	PEA1	0.55	CUC2	12.30	CAL2	0.55
III	128,762	33.74	SPN1	26.59	PEA1	7.14	CUC2	26.59	CAL2	7.14
IV	241,368	63.10	SPN1	50.83	PEA1	12.26	CUC2	50.83	CAL2	12.26
V	370,629	97.32	SPN1	75.07	PEA1	22.23	CUC2	75.07	CAL2	22.23
Time Sc •enario		*Unskilled Labor at $9 per Hour*								
I	23.821	6.07	SPN1	6.07	CUC2	6.07				
II	49,487	12.80	SPN1	12.31	CAB1	.49	TRN1	.49	CUC2	12.31
III	119.370	32.61	SPN1	26.60	CAB1	6.01	TRN1	6.01	CUC2	26.60
IV	228,917	62.08	SPN1	50.84	CAB1	5.18	TRN1	11.24	PEA1	6.06
V	335,216	97.30	SPN1	75.07	PEA1	22.23	(Crop 5) TRNI	22.23	CUC2 PEA!	50.84 75.07

[1] SPNl - early spinach; CUC2 - late cucumbers; CAL2 - late cauliflower; PEAI - peas; CABI - early cabbage; TRNI - turnips.

Scenario B. Increasing unskilled labor costs from $4.50 to $9.00 produces a marked reduction in projected RORs as shown in the lower portion of Table 7. In all cases, RORs are positively and strongly related with farm size, although there is little gain when moving beyond Farm Four especially in Scenario B.

Table 7. Profit, Average Total Investment (ATI), and Rate of Return on Investment (ROR) at 100% Gross Return Levels.

Farm	Profit	ATI	ROR
	$	$	%
Scenario A I	5,037	28,991	17.3
II	26,565	61,995	42-8
III	78,672	158,856	49-5
IV	159.274	297.152	53.6
V	246,893	429,684	57.4
Scenario B			
I	-3,213	20,041	-16.0
II	8.729	43.120	20.2
III	28,478	109,856	25.9
IV-	64.909	205.527	31.5
V	103,896	324,209	32.0
Scenario B -	*Unskilled Labor at $ 9 per Hour*		
I	-6,166	20,041	-30.7
II	2.379	43.120	5.5
III	10,571	107,356	9.8
IV	31.593	203.027	15.6
V	51,784	324,209	16.0

Summary and Conclusions

The purpose of this paper was to present an economic evaluation of vegetable production in the Connecticut River Valley. The specific objectives were to analyze economies of size and profitability, using a linear programming model, for five farms varying in size. Five individual machinery sets in conjunction with two field time availability scenarios were the factors determining farm size.

The results show that economies of size in vegetable production are largely exhausted by a one full-time operator farm with a 30 H.P. tractor and complement. Moving beyond two full-time operators yields negligible cost savings. The results also indicate that when operating at the lowest point on the short-run average cost curve all farms analyzed are profitable except for the smallest. A sensitivity analysis demonstrates that farm profitability is sharply affected by assumptions concerning labor costs and field time availability.

Calculated rates of return on average investment range from a low of negative 30.7 percent for the smallest farm to a high of 57.4 percent for the largest farm. The figures suggest that moving from four to five full-time operators leads to a minimal increase in the rate of return on average investment. The acreage associated with the minimum points on the SRAC curves vary from 6.07 to 153.90 for the smallest and largest farms, respectively.

In conclusion, this study suggests that economies of size in vegetable production are exhausted rapidly and that vegetable production can be profitable in the Connecticut River Valley even in relatively small operations. As usual with this type of study, the results should be interpreted with caution for several reasons. First, price and yield variability (i.e., risk) are excluded from the model, which suggests that different and/or more diversified cropping patterns than those generated by the model might be preferable. The exclusion of risk also suggests that the rates of return actually experienced in vegetable production are lower than those reported in this paper. A second concern stems from assuming that unskilled labor is available in unlimited quantities at a constant price. In areas where the labor market is relatively tight and the growing season short, such as New England, a sudden expansion in agricultural production could drastically increase labor costs, particularly in a labor intensive enterprise such as vegetable production. A third limitation of the study concerns the assumption that marketing costs are equal to 30 percent of the wholesale price for all crops and farm sizes. This assumption may not be viable, since conversations with growers, extension agents, and others suggest that costs such as grading, packing and transportation might vary widely across crops and, more importantly for this study, across farm sizes. It is clear that this area requires further investigation. Finally, and closely related to the issue of marketing costs, is the lack of explicit consideration given to alternative marketing channels. Since New England producers can choose from a variety of marketing options, it would be useful to expand the model to simultaneously optimize cropping patterns and marketing channels.

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