Economic Impact of Introducing Rotations on Long Island Potato Farms

Sheryl S. Lazarus and Gerald B. White

Potatoes have been grown continuously on many Long Island (New York) fields. Environmental concerns have raised questions about the continued usage of this practice. A farm-level linear programming model was used to investigate the economic impacts of crop rotations which result in reduced potato acreage. Crop rotations (an Integrated Pest Management tactic) reduced total pesticide use, but also reduced returns above variable costs as successively stringent rotation requirements were forced into the solution. The crop rotations which caused the least effect on income were identified.

Potatoes are the major field crop produced on Long Island, New York and have been grown continuously on many fields. However, pest populations have increased in recent years. Insects have become resistant to some insecticides.

Until 1980, Long Island growers relied heavily on aldicarb (Temik), a systemic insecticide, to control the Colorado potato beetle, but the use of this chemical led to ground water contamination. In 1980 the use of aldicarb was banned on Long Island. The threat of ground water contamination associated with the use of aldicarb has created an increased awareness of some of the problems of intense pesticide use. Alternative pesticides used in large quantities also have the potential to cause ground water contamination.

Continuous potato production has, in the past, been an economical practice for the productive Long Island soils; it may not be economical in the future given the pest management options now available to growers. Integrated Pest Management (IPM) is a potential solution to some of the potato production problems on Long Island. IPM is the use of multiple tactics including chemical, cultural, genetic, and biological pest control methods (Apple, et al.). One IPM tactic that reduces pesticide use and incorporates other pest management tactics is crop rotation. Other IPM tactics are being developed by entomologists, plant pathologists, and plant breeders, and may be recommended in the near future. These tactics include the use of economic and/or action thresholds to schedule pesticide applications, perhaps used in conjunction with scouting to monitor pest populations; the use of potato varieties resistant to golden nematodes and partially resistant to potato late blight; manipulating vine killing practices to manage Colorado potato beetle populations; and biological controls for the Colorado potato beetle. To date, however, crop rotations remain the major nonchemical control measure available and recommended to Long Island growers.

Rotating potatoes with other crops can help reduce the population of potato pests, but this practice will not be a widely used IPM technique until its effects on farm income are more fully understood. The purpose of this paper is to evaluate the economic feasibility of one IPM tactic—the use of various crop rotations. The returns over variable costs were estimated for several cropping alternatives given successively restrictive constraints on total potato acreage. Changes in returns over variable costs demonstrate the short-run economic impact, enabling the ranking of various rotational options. The level of pesticide use was also used as a measure of performance for rotation alternatives. Current knowledge of the movement of pesticides in the soil to ground water, and the ultimate effects on human health, does not permit a complete specification of environmental quality asso-

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The authors are Research Support Specialist and Associate Professor, Department of Agricultural Economics, Cornell University, Ithaca, New York 14853-0398.

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ciated with various farm plans. In our model, reduced pesticide usage measured by pounds of active ingredients of insecticides, fungicides, and herbicides was considered an improvement in environmental quality. Sensitivity analyses were conducted for yield changes and potential changes in pesticide costs.

Background: Suffolk County Potato Production

Suffolk County, the easternmost county on Long Island, has the highest total value of farm receipts of any county in New York State. Climate and soil resources are suitable for many agricultural enterprises. The county's major agricultural enterprises include potatoes, vegetables, floriculture, nurseries, fruit, and ducks. Agriculture coexists with a large population of 1.3 million people, making Suffolk the second most populated county in the State outside the city limits of New York. One of the major commodities produced is potatoes. In 1982, there were 18,500 acres of potatoes grown on Long Island (N.Y. Crop Reporting Service), nearly all in Suffolk County. The western edge of the potato producing area is about 60 miles east of the New York City limits. Potato fields are often adjacent to beaches, summer homes, and housing developments. Furthermore, sandy soils prevail in some areas, making the leaching of fertilizer and pesticides a major problem.

Potato production on Long Island declined from an estimated 31,000 acres in 1970. Urban encroachment was one reason for the decreased acreage, but potato pests also had an important impact. Since potato production is very intense on the island, pest populations have grown. Probably more pesticides, on the average, are used in Long Island potato production than in any other region of the United States (for one estimate, see Putnam).

There are two major areas that produce potatoes on Long Island. Both are in the eastern portion of Suffolk County. One area is commonly called the South Fork, the other the North Fork. Soils on the North Fork are very light and irrigation is required to raise potatoes. Many growers on the North Fork have traditionally raised continuous potatoes. Rye, which is planted as a cover crop to prevent wind erosion during the winter, is plowed down in the spring. Although the land on the North Fork is well suited for the production of various vegetable crops, many potato growers prefer not to raise vegetables due to the necessity for hiring seasonal labor.

Compared to the North Fork, the soil on the South Fork is heavier. Irrigation is not widely used to grow potatoes, due to the greater water-holding capacity of the soil. Even though many South Fork growers do not irrigate, potato yields are estimated to be approximately 5–10 percent higher than on the North Fork. South Fork growers have lower costs because they do not need irrigation equipment. At the same time they receive higher gross returns due to higher yields. Growers on the South Fork have traditionally raised two years of potatoes followed by a year of rye. Like the growers on the North Fork, they plant a rye cover crop, but allow it to mature every third year. Few South Fork potato growers raise vegetables. In addition to labor problems, irrigation equipment may need to be purchased to grow vegetables economically.

Despite these differences, the results of our analyses were similar for the two Forks with respect to the level of returns above variable costs, the profitability of alternative crops, sensitivity of the solution to parametric changes in yields and pesticide costs, and changes in the level of pesticide use as intensity of potato production decreased. The major difference was that the South Fork cropping plan (and hence, returns above variable costs) was not affected until potato production was restricted to less than two-thirds of the farm acreage; i.e. the current practice. Due to the similarity of results from the two Forks, results will be presented only for the North Fork. Detailed results for both the North Fork and the South Fork were reported in Lazarus and White.

The Model

This paper reports on a linear programming model for a representative 150 acre farm on the North Fork. The objective function was to maximize returns above variable costs. Variable costs in crop budgets included seed, fertilizer, chemicals, custom harvesting charges for grain, and machinery and irrigation variable costs. Variable costs included as activities in the linear programming model were hiring labor, borrowing operating capital, and selling and buying rye. A set of sample budgets for the potato-cauliflower rotation is shown in Table 1.

Table 1. Budgets for Potato-Cauliflower Rotation, North Fork, Suffolk County, New York

Item	Unit	Price	Quantity	Total	Contribution to Objective Function[a]
Potatoes					
Receipts:					
90% size A, U.S. No. 1	cwt.	$ 5.30	286	$1,515.80	
10% culls & size B	cwt.	2.50	31	77.50	
Total Receipts				$1,593.30	
Expenses:					
Seed	lb.	.073	2,130	155.49	
Fertilizer					
Nitrogen	lb.	.32	175	56.00	
Phosphorus	lb.	.28	300	84.00	
Potassium	lb.	.14	175	24.50	
Chemicals					
Fungicide				38.59	
Insecticide				332.50	
Herbicide				23.98	
Machinery Variable Cost				94.49	
Selected Variable Costs				$ 809.55	
Returns above Selected Variable Costs					$ 783.75
Rye Cover Crop					
Machinery Variable Cost				−$ 2.73	−$ 2.73
Cauliflower					
Receipts:	cwt.	$19.30	150	$2,895.00	
Expenses:					
Plants	1,000	26.40	10	$ 264.00	
Fertilizer					
Nitrogen	lb.	.32	160	51.20	
Phosphorus	lb.	.28	320	89.60	
Potassium	lb.	.14	160	22.40	
Lime (hydrated)	ton	122	.5	61.00	
Chemicals					
Insecticide				102.96	
Herbicide				10.60	
Fungicide				19.25	
Containers		1.45	429	622.05	
Machinery Variable Cost				73.71	
Selected Variable Costs				$1,316.77	
Returns above Selected Variable Costs					$1,578.23

[a] The objective function value for the entire rotation is ($783.75 − $2.73 + $1,578.23) ÷ the land requirement, or $2,359.25 ÷ 2 = $1,179.63 per acre per year for the rotation.

Two important constraints in selecting rotations were identified in conversations with growers and with research and extension personnel familiar with the Long Island potato industry. The first constraint was the necessity for hiring seasonal labor for vegetable crops. Potatoes are harvested mechanically, but migrant labor is typically used to harvest vegetable crops. Many of the growers who have traditionally specialized in potato production lack the managerial expertise to handle seasonal labor crews. Most farms in the past relied largely upon family labor or full-time hired employees. Growers expressed a strong preference to continue to avoid the use of seasonal labor. For this reason, and because existing machinery and irrigation equipment are compatible, field crops would fit well into the farm plans.

A second constraint on the selection of rotations was the necessity to maintain soil acidity for potato production. A low pH is required to minimize problems with potato scab. Rye, cauliflower, and cabbage are crops that tolerate a low pH soil. These crops are relatively common on Long Island. Many other crops, however, require higher pH to produce economical yields. It is possible to raise the soil pH slightly to allow the production of these crops, yet not so much that potato scab would be a major problem the following year. This results in slightly reduced yields for most of the field crops considered.

With these considerations in mind, field crops were permitted as alternatives in the initial maximization. Rotations analyzed and their contribution to the objective function are listed in the activities in Table 2. Field crops rotated with potatoes included rye, corn, a double crop of wheat and soybeans, oats, sunflowers, and dry beans. Facilities exist for Long Island growers to market grain. A large amount of feed grain is transported into the area and formulated into commercially mixed feed for ducklings.

The vegetable crop rotations, requiring seasonal labor, were permitted in the second maximization. Crops selected were those which tolerate a relatively low pH and are currently grown by some potato growers on Long Island. Vegetable crops grown in rotation with potatoes were cauliflower and cabbage, as shown in the activities (Table 2).

Budgets were constructed fo. each of the crops considered in the models and were then combined into budgets for the respective rotations (see Table 1). Information for these budgets was gathered from a variety of sources. Three Long Island potato growers were interviewed to discover their current cultural practices. Suffolk County Extension personnel helped to specify typical fertility programs and cultural practices. Average yields and prices over the past five years for various Long Island crops were obtained from the *New York Crop Reporting Service*. If the information was not available for Long Island, average New York State data were used with modification for Long Island soil and climatic conditions. Cost data for field crops were obtained from Knoblauch (1981). Revenue and cost data for sunflowers were obtained from Lazarus. Pesticide usage for crops other than potatoes were estimated from *Cornell Recommends for Field Crops* and *Cornell Recommendations for Commercial Vegetable Production*. Potato pesticide usage was obtained from 1981 surveys of Long Island

Table 2. Linear Programming Model, Constraints and Activities, North Fork, Suffolk County, New York

Constraints	*Value of Constraint*
Land	≤150 acres
Family labor (semimonthly periods, March–October)	≤217 hours per two week period
Operating capital	≥0 dollars
Rye	≤0 bushels
Maximum potato acreage	≤150 acres[a]
Maximum cauliflower acreage	≤25 acres
Maximum cabbage acreage	≤25 acres
Fungicides	≥0 pounds active ingredient
Insecticides	≥0 pounds active ingredient
Herbicides	≥0 pounds active ingredient
Activities	*Objective Function*
Continuous Potatoes	$ 755.06
(1) Potatoes (2) Rye	372.98
(1) Potatoes (2) Corn	426.88
(1) Potatoes (2) Winter wheat/soybeans	457.47
(1) Potatoes (2) Winter wheat/soybeans (3) Corn	333.38
(1) Potatoes (2) Oats	402.19
(1) Potatoes (2) Sunflowers	419.18
(1) Potatoes (2) Dry beans	447.21
(1) Potatoes (2) Cauliflower	1,179.63
(1) Potatoes (2) Cabbage	840.10
Hire labor	−5.50
Borrow operating capital	−.08[b]
Sell rye	2.80
Buy rye	−5.00

[a] Base plan constraint. This constraint was changed to 125, 100, 75, and 50 acres for subsequent runs.
[b] Borrowing at the rate of 12 percent per year for nine months.

potato growers participating in a Cornell-sponsored IPM program. Additional information about production practices for vegetable crops was obtained from Dhillon, Phelps and How, and Snyder. Input prices were obtained from three Long Island suppliers.

The major difference between budgets for continuous potatoes and potatoes grown in rotation was a reduced spray schedule (10 applications for potatoes in the second year of a rotation, 12 for continuous potatoes). This resulted in a $24 savings per acre in insecticide materials for potatoes grown in rotation and a slight reduction in machinery variable costs and labor requirements. Theoretically, higher yields for potatoes grown in rotation might be expected. This could result from improved soil tilth, increased nutrients and organic matter from crop residues, reduced compaction, and reduced carryover of certain pests. Cooperating potato and pest management specialists at the Long Island Horticultural Laboratory believed, however, that with adequate nutrition and pest management practices for continuous potatoes, no significant yield advantage would be apparent for potatoes grown in rotation, at least for several years. Therefore, potato yields in the budgets were the same for both continuous potatoes and potatoes grown in rotation.

Labor requirements and machinery costs were estimated using an economic engineering approach. The labor and machinery time required for each field operation was calculated based on factors such as machine width, operating speed, and machine efficiency (Benson; Knoblauch, et al.). This approach produced an estimate of time required per operation and fuel consumption. Repairs were based on a percentage of the new cost of machinery and the estimated hours of annual use. Labor was supplied in the model by 217 hours of family labor semimonthly (the equivalent of two persons each working a 50 hour week) or hired at $5.50 per hour.

The representative 150 acre farm was assumed to have sufficient machinery to plant the entire farm in potatoes since this crop was currently grown. The farm was also assumed to have sufficient machinery to raise the various vegetable crops considered in the programming model variations. Some potato growers currently raise vegetables and have the necessary machinery. Furthermore, the vegetable crops considered for rotations require the same tillage equipment as potatoes. The machinery and equipment complement includes two big-gun irrigation sets which can be used for field crops as well as vegetables. This type of irrigation equipment has been purchased by some growers in recent years.

Custom corn planting, custom combining, and custom grain drying were assumed for rotations requiring these operations. Custom machinery operations are currently available to Suffolk County growers in limited quantities. The use of custom machinery is a method of avoiding the problem of having too few acres of a particular crop to economically justify the purchase of a specialized machine. A grower trying a new rotation with just a few acres of a field crop is not likely to purchase an expensive machine to produce or harvest that crop.

The farm operator was permitted to borrow operating capital at a 12 percent annual rate for nine months. The various crops were assumed to be sold at harvest. The representative farm could either raise the rye that was used as seed for the cover crop or buy the seed. The purchase price for rye seed was $5.00 per bushel, and excess rye could be sold for $2.80 per bushel.

In the model variations which included vegetable crop rotations, the acreage of any one crop was limited to 25 acres. This was done because of the price risk of having a large acreage in any one vegetable crop and due to the reluctance of growers to deal with hired harvest labor.

Model variations were also run to examine what effect various acreage limitations on potato production would have on returns over variable costs. The constraints first allowed all acreage (150 acres) to be planted to potatoes. Maximum potato acreage was then reduced by increments of 25 acres in successive runs. This procedure examined potential reductions in farm returns over variable costs from using crop rotation as an IPM tactic.

Some researchers from the plant protection and vegetable crops disciplines have noted that there are limited options now available to growers in chemical control strategies. If rotations are not implemented, two impacts are possible. First, chemical costs for potatoes grown in monoculture are likely to increase to maintain the same level of control; or, alternatively, yields may decrease if chemical costs remain constant. We investigated these effects by sensitivity analyses on variable costs for potatoes and potato yields, respectively.

Table 3. Optimal Rotations with Limitations on Maximum Potato Acreage, Field Crop Rotations, North Fork, Suffolk County, New York

	Maximum Potato Acreage Constraint				
	150	125	100	75	50
Returns above variable costs ($)	101,088	88,389	75,244	61,742	44,865
Rotations (acres)					
Continuous potatoes	150	100	50	0	0
Potatoes—rye	0	12	12	12	4
Potatoes—corn	0	0	0	0	0
Potatoes—winter wheat—wheat/soybeans	0	38	88	138	0
Potatoes—winter wheat/soybeans—corn	0	0	0	0	146
Potatoes—oats	0	0	0	0	0
Potatoes—sunflowers	0	0	0	0	0
Potatoes—dry beans	0	0	0	0	0
Unused land resource	0	0	0	0	0
Total acres in potatoes	150	125	100	75	50
Hired labor activity (hours)	152	60	0	0	0
Unused labor resource (hours)	1,161	1,394	1,647	1,959	2,121
Pesticide active ingredients (pounds)	6,854	5,672	4,498	3,322	2,439
Fungicide	1,907	1,589	1,271	953	639
Insecticide	4,047	3,314	2,580	1,847	1,426
Herbicide	900	769	647	522	374

Results

If only field crops were considered as cropping alternatives, continuous potato production was the most profitable cropping practice on the North Fork. Returns above variable costs were $101,088 and all available cropland was planted to potatoes (Table 3). Only 152 hours of hired labor was required.

As the maximum potato acreage was reduced by 25 acre increments, returns over variable costs were reduced by successively larger amounts; pounds of active pesticide ingredients were also reduced. Potato producers did not have an economic incentive to use additional field crop rotations according to the model results. If the government restricted pesticide use, the results show which rotations were the most economically feasible. With potato acreage limited to 75 acres (potatoes grown one year out of two), returns above variable costs were $61,742, 61 percent of the optimal plan with all acreage planted to potatoes. Total pesticide use was 48 percent of the optimal plan with all acreage in potatoes.

As potato acreage was restricted, the first field crop to enter the solution was rye in quantities just sufficient to provide seed to plant the cover crop. The next rotation to appear was a year of potatoes followed by a double crop of winter wheat and soybeans. Finally, if only 50 acres of potatoes were permitted, a three year rotation of potatoes, winter wheat/soybeans double crop, and corn came into the solution. Total pesticide use was 36 percent of the optimal plan with all acreage in potatoes.

If rotations with cauliflower and cabbage (cole crops) were considered, returns above variable costs with potato acreage not restricted were increased to $107,515 (Table 4). The optimal plan for all scenarios included 25 acres of cauliflower. The representative farm is consistent with some North Fork farms where just a few acres of vegetables are grown. As the acreage constraint for potatoes was decreased, the farm plans included cauliflower up to the maximum of 25 acres. Then field crop rotations began to appear in the same order of profitability as in the earlier analysis when only field crops were permitted as alternatives. Pesticide use was reduced by each successive potato acreage constraint. Hired labor decreased as field crops came into the optimal solution. Hired labor for the 25 acre cauliflower crop totaled more than 2,000 hours of seasonal labor hired from August through October.

Optimal solutions were not very sensitive to yield changes or changes in pesticide costs (Table 5). If growers' adjustments were made in the form of increased pesticide use while maintaining potato yields, a doubling of pesticide costs did not change the cropping pattern. Even though a 100 percent increase in pesticide costs did not cause changes in crop-

Table 4. Optimal Rotations with Limitations on Maximum Potato Acreage, Field Crop and Cole Crop Rotations, North Fork, Suffolk County, New York

	Maximum Potato Acreage Constraint				
	150	125	100	75	50
Returns above variable costs ($)	107,515	107,515	95,275	82,685	64,629
Rotations (acres)					
Continuous potatoes	100	100	50	0	0
Potatoes—rye	0	0	12	12	0
Potatoes—corn	0	0	0	0	0
Potatoes—winter wheat/soybeans	0	0	38	88	0
Potatoes—winter wheat/soybeans—corn	0	0	0	0	76
Potatoes—oats	0	0	0	0	0
Potatoes—sunflowers	0	0	0	0	0
Potatoes—dry beans	0	0	0	0	0
Potatoes—cauliflower	50	50	50	50	50
Potatoes—cabbage	0	0	0	0	0
Unused land resource	0	0	0	0	24
Total acres in potatoes	125	125	100	75	50
Hired labor activity (hours)	2,492	2,492	2,321	2,169	2,045
Unused labor resource (hours)	939	939	1,096	1,254	1,418
Pesticide active ingredients (pounds)	5,828	5,828	4,650	3,472	2,482
Fungicide	1,639	1,639	1,321	1,003	687
Insecticide	3,414	3,414	2,681	1,947	1,432
Herbicide	775	775	648	522	363

ping patterns, net returns above variable costs were obviously greatly reduced.

If yields in the continuous potato rotation decreased due to a continuing development of resistance in the Colorado potato beetle to pesticides, a reduction of 30 percent was required to change the rotations in the optimal solution if field crops were the only cropping alternatives. A 28 percent yield decrease in continuous potato yields caused a change in the optimal solution if cole crops were also an alternative. At yield reductions of about 32 percent, a significant change in the acreage of continuous potato production occurred. Even though returns were greatly reduced in both of these sensitivity analyses, continuous potatoes remained a profitable crop over a wide range of increased pesticide costs and yield decreases. Relaxing the 25 acre constraint on vegetables would, however, significantly reduce the negative impact that increased chemical costs and decreased potato yields had on income.

Conclusions and Implications

As potato acreage was reduced, total pesticides used decreased by significant amounts, indicating a probable improvement in environmental quality. However, the results of the study indicated a strong economic incentive for growers on Long Island to continue growing potatoes intensively rather than changing to field crop rotations. There were relatively large sacrifices in returns above variable costs associated with more diversified farm plans. Potato and cauliflower rotations had high returns over variable costs. If Long Island potato growers can overcome the managerial problems of using seasonal labor, a potato-cauliflower rotation is a good alternative to continuous potato production. Cauliflower grows on low pH soils, like potatoes, and there is a well developed market for the crop. Our results indicated that continuous potatoes and potato-cauliflower rotations are relatively profitable alternatives even with increased pesticide costs and decreased yields for potatoes, which are likely developments with the loss of the chemical aldicarb.

The development of insect resistance to pesticides in Long Island potato fields caused many problems and was one factor leading to the decline of potato acreage on Long Island. In the past, growers had been able to cope by using new and/or heavier applications of insecticides. In the future, the development of a more complete IPM strategy holds promise for reducing pesticide use without affecting potato yields and quality.

Table 5. Sensitivity of Optimal Rotations to Increases in Chemical Costs and Decreases in Potato Yields, North Fork, Suffolk County, New York

	Chemical costs increase		Potato yields decrease			
	Field Crops	Field & Cole Crops	Field Crops		Field & Cole Crops	
Crop Alternatives	100%	100%	29.8%	32.6%	28.4%	31.5%
	acres					
Continuous potatoes	150	100	138	67	88	10
Potatoes—rye	0	0	12	12	12	12
Potatoes—corn	0	0	0	0	0	0
Potatoes—winter wheat/soybeans	0	0	0	71	0	78
Potatoes—winter wheat/soybeans—corn	0	0	0	0	0	0
Potatoes—oats	0	0	0	0	0	0
Potatoes—sunflowers	0	0	0	0	0	0
Potatoes—dry beans	0	0	0	0	0	0
Potatoes—cauliflower	NA	50	NA	NA	50	50
Potatoes—cabbage	NA	0	NA	NA	0	0
Returns above variable costs	$38,318	$55,790	$29,841	$23,564	$50,935	$45,126

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