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A MULTIPERIOD LINEAR PROGRAMMING MODEL OF DIVERSIFICATION INTO FRUIT ON LONG ISLAND POTATO FARMS

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ABSTRACT

A linear programming model is developed to analyze the transition, year by year, from annual crops to peaches and grapes on Long Island potato farms. Special consideration is given to labor, marketing, cash flow, and pesticide contamination constraints. Results show that fruit production is an economically viable alternative for potato farmers. Lower pesticide and nitrate loading rates and risk levels make such a transition ecologically beneficial as well. Cash flow is not a seriously limiting constraint, but hired labor availability and marketing outlets are major constraints to expansion of fruit production on Long Island.

FOREWORD

This paper is a synopsis of a linear programming model to determine the feasibility of a transition into peaches and table grapes on Long Island potato farms. It is based on research for my masters thesis, "Alternatives for Long Island Agriculture: The Economic Potential of Peaches and Table Grapes".

I would like to acknowledge the guidance of my committee member, Dr. B.F. Stanton, in building the linear programming model. I am indebted to Paul Schwartz for building a matrix generator to input the data in MPSX format. Fellow graduate student Brian Baker deserves special thanks for giving me access to an MPSX package capable of handling such a large linear programming model.

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INTRODUCTION

Tied to biological and climatic cycles, agriculture has always had to be fine tuned to the environment. However, the ecosystem of agriculture extends beyond agronomic considerations to economic, ecological, and socio-political issues as well. When agriculture is practiced in heavily populated areas, these other considerations can take on primary importance. This is the case on Long Island, New York. Traditional potato farmers are finding that suburban development pressures, rising land values, and drinking water contamination by pesticides are forcing them to alter their farming systems (crops, cultural practices, and attitudes) in order to continue to earn their livelihood from farming.

For generations, potatoes have been the mainstay of Long Island agriculture. Potato production is a land extensive enterprise which is easily mechanized and which offers a moderately high net return per acre. In recent years, decreasing effectiveness of chemicals in controlling the Colorado Potato Beetle and the contamination of groundwater by agricultural pesticides have raised doubts about the future of potato production on Long Island. If Long Island farmers hope to survive, they will have to return to a more ecologically sound agriculture involving crop rotation, crop diversification, and integrated pest management.

Already a more diversified farming system is evolving on the Island. Many farmers are switching from potatoes into vegetable and fruit crops. Past economic studies have demonstrated the possibility of attaining increased net average income by expanding the production of vegetables in the traditional potato cropping system (Fohner, 1983; Lazarus and White, 1983). This study investigated the economic feasibility of crop rotation and diversification into fruit crops on Long Island's potato farms. Specifically, the fruit crops, peaches and table grapes, were analyzed. These crops were chosen for their complementarity in use of machinery and cold storage, their suitability to the Long Island agro-economic environment, and for the availability of potential markets.

Previously, no study has analyzed the transition into perennial fruit crops on Long Island. Such a transition will necessarily require a multiperiod analysis over a long time horizon in order to evaluate the effect of perennial fruit production on a farm family's income, labor, capital, and marketing requirements. To look at fruit production, a model must take into account the initial costs of orchard or vineyard establishment, the non-income producing years while trees and vines are maturing, and the years of full production when returns on investment are finally realized.

Given Long Island's fragile environment, special focus must be placed on estimating the level and environmental hazard of the pesticide and nitrate application levels associated with the new crops. It is expected that major changes will be required in the traditional potato farming system in order to make the transition into some combination of annual and perennial crops.

A multiperiod linear programming model was constructed to analyze the transition, year by year, of a potato farm to a more diversified fruit and vegetable operation. The model covered a 15 year time horizon in order to reflect the expected costs and returns of such a transition over time.

The model was used to analyze the following objectives:

1. To determine the relative profitability of peaches and table grapes in the traditional annual cropping system of potatoes, wheat, and cauliflower.

2. To determine the major constraints to a transition into perennial crops for Long Island potato farms, specifically skilled and unskilled labor, investment capital, cash flow, and debt servicing.

3. To determine the importance of different marketing channels, direct retail (through farmers' markets and farm stands) and direct wholesale (to chain stores), on the profitability of peaches and table grapes.

4. To determine the ecological viability of peaches and table grapes in regard to groundwater contamination by determining nitrate and pesticide application levels, and by developing an environmental risk index to compare the products used on these new crops with those used on potatoes.

CHARACTERISTICS OF SUFFOLK COUNTY AGRICULTURE

MAJOR TRENDS

With its fertile well drained soils and moderate climate, Long Island offers a favorable environment to agriculture. Although the number (797) and size (63 acre average) of farms is small, Suffolk County was the leading agricultural county in New York State with average sales of $116,719 per farm in 1982.

Although Long Island is known for its importance as a potato producer, nursery and green house products, vegetables, and poultry account for large portions of the market value of sales. In fact, the importance of these crops is increasing while that of potatoes is decreasing.

From 1974 to 1982, there was a steady, slow decrease in the acres of harvested cropland and in the number of farms producing potatoes. At the same time, however, an increasing number of farms were growing grains, hay, vegetables, and orchard crops. In this same period, there was a doubling of the number of farms and acres producing fruit. Peaches are now the major orchard fruit on the Island and vineyards occupy almost 1,000 acres (U.S. Department of Commerce, 1982; Mudd, 1984).

Despite the increase in fruit and vegetable production on Long Island, potatoes are still the largest land user in Suffolk County. In 1982, 177 farms harvested over 18,998 acres of potatoes. This represented over half of the 36,731 acres of harvested cropland for that year. Potato acreage had fallen by 5,141 acres or 21 percent from the 1978 census report and the number of potato farms had fallen by 13 percent (U.S. Department of Commerce, Bureau of the Census). By 1983, potato acreage had fallen by another 2,698 acres to 16,300 acres.

The reasons for this decline are due in part to development pressures on Long Island which have caused total farmland on Long Island to drop by 50 percent in the last 30 years (Suffolk County Cooperative Extension Service [SUCO], 1983). The decline in potato acreage specifically (as opposed to farmland in general) is more directly attributable to the problems in controlling the Colorado Potato Beetle, *Leptinotarsa declemineata*. Not only has it become more difficult to find insecticides to control the beetle, but the high costs and lower yields caused by beetle infestations have cut into Long Island's comparative advantage as a potato producing area.

Potato yields were high in 1976 and 1977 after the introduction of aldicarb insecticide in 1976, but fell in later years as the beetle developed resistance and new, less effective chemical pesticides were substituted. In this same period (1976-1982), cost of production estimates for Long Island potato farmers showed an increase of over 230 percent in the average nominal cost of pesticide use (Snyder, June 1977 and July 1982). Several of the pesticides used in this period (aldicarb and oxamyl) have contaminated the Island's groundwater and have been banned from future use. Effective, alternative pesticides are becoming increasingly difficult to find.

Even integrated pest management programs where chemical, cultural, genetic, and biological controls are used in coordination have not provided satisfactory answers to the problems of controlling the beetle. Some work has been done on the following controls:

1. *Beauvaria bassiara* - a fungal disease effective against larvae,

2. *Edovum putleri* - an egg parasite,

3. *Bacillus thurigiensis var thurigiensis* - a bacteria effective against larvae,

4. a chitin synthesis inhibitor - effective on hatching eggs.

However, these methods are still in the experimental stage and offer no immediate, economically feasible solution for the Long Island potato farmer (Lansky, 1984).

The Colorado Potato Beetle is restricted almost exclusively to host plants in the *Solanaceae* family (potatoes, tomatoes, and eggplant). Thus, rotation into crops outside the *Solanaceae* family can be viable since these plants will not be subject to beetle attack. The long term effect of rotation in reducing beetle populations in the remaining potato fields has not been determined but most studies show some benefits in reducing the number of sprayings (Wright, et al. 1983).

The increased costs and difficulty in controlling the Colorado Potato Beetle are encouraging some farmers to look for alternatives. In an area where such a large suburban population exists (Suffolk County's population was 1.28 million according to the 1980 U.S. Census), one can expect that registration and screening of pesticides will become more stringent in the future. This will encourage, if not force, farmers to make a change.

DEVELOPMENT PRESSURES AND LAND RENTS

Urbanization and development pressures have had a strong effect on changing land use patterns on Long Island. Farm acreage has decreased by 50 percent in the last three decades and 60 percent of the farmland is owned by nonfarmers (Lesher and Eiler, 1978).

These investment pressures have bid up the full market value of raw farmland. It ranges from $1,500 to $15,000 per acre as compared to the agricultural value which ranges from $600 to $1,470 per acre (New York State Board of Equalization and Assessment, 1984). Although property tax assessments are quite low, taxes paid by farmers, especially estate taxes, have encouraged farm families to make decisions about selling their land to speculators and investors who then convert it to residential use.

In an effort to preserve farmland and to stem the tide of increasing suburban development, the state, county, and township governments have experimented with several programs: zoning, agricultural districts, and purchase of development rights. Since 1974, Suffolk County and some of its townships have spent $27 million to purchase development rights to 6,000 acres of farmland. However, in total, less than 15 percent of the 41,000 acres of cropland on Suffolk County are protected by agricultural districts or purchase of development rights programs (Gardner, 1984).

Since 60 percent of the farmland is not owned by those who farm it, one must look at the goals of the nonfarming landowners to determine future land use. Despite the development pressures on Long Island, Suffolk County landowners do not appear to charge significantly higher cropland rents than landowners statewide. A 1981 survey of New York State cropland rents showed rents for vegetable cropland on Long Island ranging from $10 to $175 per acre. Although $175 was the top rent reported in the survey for any parcel in the State, the average vegetable cropland rent of $75 per acre in Suffolk County was comparable to average rents charged in other prime agricultural districts in the State (Snyder, January 1982).

This raises the question of whether rents cover the costs of land ownership on Long Island. With an average value of $1,500 per acre and a nine percent return on investment, an owner would receive a return of $135 per acre per year. Assuming an average tax rate of $23 per $1,000 of assessed valuation[1], the average tax on an acre of cropland would be $35. Thus, the average cropland rent would be $170 per acre per year if the owner covered the costs of ownership and received a nine percent return on his investment.[2]

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[1] Tax rates on real property in Suffolk County vary greatly by township and by parcel. The total overall full value rate ranged from $9 to $33 per $1,000 of assessed value in 1981 for the towns of Riverhead, East Hampton, Southampton, and Southold (State of New York, Office of State Comptroller, 1982).

[2] A nine percent return on investment was chosen as reflective of the return from other nonrisky investments such as savings or money market accounts.

Landowners cannot expect to receive high rents from potato acreages since potatoes are only a moderately intensive crop. With more intensive fruit production it is possible that a higher rent could be charged but it is unlikely that orchards or vineyards would be established on rented land. Thus, if nonfarmer landowners continue to rent their land as farmland it will be because there is not enough development demand to absorb all undeveloped land presently on the Island or because the owner has other reasons for retaining investments in land, such as an inflation hedge, tax shelter, expectations of future appreciation in value, or a desire to hold onto the land for the next generation.

MARKETING OPPORTUNITIES

Long Island producers face several marketing constraints to diversification. With potatoes as their major crop, traditional marketing links to packing houses, brokers, and haulers have been established over the decades. As farmers shift into more diverse and perishable crops, new marketing channels must be developed.

In 1983, Long Island supplied a substantial percentage of several crops (cauliflower, brussel sprouts, potatoes, and pumpkins) to the New York City terminal market (Table 1). Altogether, Long Island only accounted for 1.5 percent of the fruit and vegetable unloads in the New York City terminal market in 1983. The rest of the State of New York and New Jersey contributed another 7.5 percent of the total but Florida, with 17.9 percent, and California, with 33.9 percent, were the primary suppliers (USDA, AMS, 1983).[3] The fact that New York State and New Jersey supply a fair proportion of the total in many fruits and vegetables which could also be produced on Long Island, suggests that Long Island could expand and diversify its vegetable and fruit production.

The terminal market is actually a market of last resort for many Long Island farmers. In recent years, integrated wholesale-retail operations have been handling a greater percentage of total production and bypassing the terminal market altogether. However, in order to penetrate this market, Long Island growers must improve their marketing, packaging, and quality control to the point where local produce can compete in appearance and consistency to the produce shipped in from afar.

Although the shorter seasonal availability and inconsistent quality of local produce suggest that local producers will never be able to take over much of California's or Florida's share of the wholesale market, there does appear to be market potential for some locally produced fruits and vegetables including peaches and grapes.

MARKET WINDOW FOR SEEDLESS TABLE GRAPES

Table grapes, especially seedless varieties, have become very popular among American consumers. The fresh market for these grapes in Suffolk and

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[3] Since Long Island's deliveries are made in the late summer and fall months, they represent a higher percentage of seasonal unloads than suggested by the yearly percentage figure.

Table 1
Sources of Fruit and Vegetable Unloads at New York City Terminal Market, 1983

Item	Long Island	New York-New Jersey (excluding Long Island)	Primary Supplier	
	percent			
Vegetables				
Asparagus	--	1.2	70.5	CA
Beans	2.3	13.7	62.5	FL
Brussel Sprouts	30.8	--	53.8	CA
Cabbage	9.0	40.7	35.6	FL
Cauliflower	25.9	4.9	57.8	CA
Escarole	4.7	23.7	65.9	FL
Lettuce (Iceberg)	0.1	1.7	90.4	CA
Lettuce (Other)	2.6	26.1	36.9	CA
Peppers (bell)	0.9	11.2	55.8	FL
Onions (dry)	--	37.5	37.5	NY
Potatoes	8.2	5.4	37.4	ID
Spinach	3.4	44.8	34.5	NJ
Squash	1.1	27.0	35.1	FL
Tomatoes	--	2.9	59.5	FL
Pumpkins	11.1	22.2	66.7	Dom. Rep.
Fruit				
Apples	--	25.0	63.3	WS
Blueberries	--	76.9	76.9	NJ
Grapes (table)	--	0.2	86.2	CA
Peaches	--	29.5	34.8	CA
Strawberries	--	--	76.0	CA

SOURCE: USDA, AMS, "Fresh Fruit and Vegetable Arrivals in Eastern Cities", Washington, D.C., 1983.

Nassau Counties and New York City is vast. Currently, 86 percent of all table grapes entering New York City through the terminal market come from California with Chile providing most of the remainder.

California supplies the New York City market with seedless white grapes from early June through early October. Chile supplies white seedless grapes from January to June and red seedless grapes from early March through May. From early October through January, too few seedless grapes are being supplied to the New York City terminal market for price reporting. If Long Island could supply seedless grapes in this time period there would be little competition (Federal-State Market News Service, "Wholesale Prices", 1979-1983).

The harvest season for the seedless grape varieties recommended for Long Island runs from mid-August to early October. Although this falls within the time when California controls the New York City market, controlled atmosphere storage could enable Long Island to supply grapes from early October through December. Experiments have shown that the storage quality of many of these varieties ranges from good to excellent (1.5 to 4 months). Thus, if Long Island growers invested in controlled atmosphere storage, they could take advantage of this window in the New York City terminal market.

Although prices for Thompson seedless are at their lowest in October ($13 to $15 per 20 pound lug), they return to the market at twice that price ($34 to $36 per 20 pound lug) with the Chilean supply in January. While prices may remain low in October, it seems reasonable to expect that prices seek a higher level as demand increases with the holiday season (Thanksgiving through Christmas) (Federal-State Market News Service, "Wholesale Prices", 1979-1983). However, unless consumer acceptance increased to the point where New York grapes were preferred to Thompson seedless, the California seedless price would define the upper limit on the New York seedless price.

One caveat must be mentioned. New York seedless grapes differ in both appearance and taste from the standard Thompson seedless grape to which the consumer is accustomed. Though smaller in berry and cluster size, many consumers find the strong grapey flavor superior to the relatively bland Thompson seedless. Promotion, however, will be needed in order to gain consumer acceptance. Through aggressive marketing and development of convenient consumer packaging, one upstate grower has found strong acceptance nationwide for seeded concord grapes for table use (Nass, 1984). Growers on Long Island have found local supermarkets to be interested in wholesale purchase of the new seedless grape varieties.

Many Long Island farmers also market their seedless grapes through farmers markets and roadside stands. It is felt, however, that large volumes could not be accommodated through these direct retail channels. If substantial increases in seedless table grape production do appear on Long Island, more direct wholesale marketing channels will need to be developed.

MARKET POTENTIAL FOR PEACHES

Long Island will suffer from competition from nearby New Jersey whose similar season and close proximity to the New York City area market cancel any advantages that Long Island peach growers might offer in terms of timing of supply or freshness of harvest. However, as Table 1 indicates, the New York/New Jersey area (excluding Long Island) only provides 29.5 percent of the total production coming into the New York City terminal market. The largest supplier is California for whom the criticisms of lack of freshness still apply.

Consumers recognize the difference between tree-ripened peaches and those that are picked too soon and shipped long distances. In fact, some local growers market tree-ripened peaches as a different product. They charge a higher price than the grocery store despite the added inconvenience the consumer endures to purchase at the farm. At present, peach growers on the Island sell their production at their farm stands or farmers markets without any need for chain store contracts. However, if peach production increased, marketing through chain stores would become necessary.

Given the strong recognition by consumers of the quality difference in tree-ripened fruit, it seems reasonable to expect local chain store interest in purchasing local fruit. Long Island could supply the peach market from early July through mid-September. The on-farm storage potential of peaches is limited to about three weeks after picking but even this short storage enables growers to have more flexibility in controlling their supply. It might suffice to explore the marketing channels on Long Island alone since the populations of Suffolk and Nassau Counties provide a large market in and of themselves. In fact, unless growers are willing to invest in hydrocooling and brushing, their product might meet resistance in established New York City wholesale market channels.

Prices paid in the chain store market would be lower than those received by farmers at their stands. The five year season average price for New Jersey peaches at the New York City Terminal market was $10.34 per 3/4 bushel or $0.27 per pound (Federal-State Market News Service, "Wholesale Prices", 1979-1983). It is expected that this price would represent the lower limit on the price Long Island growers could expect to receive through direct wholesaling to a chain store.

BUDGET DATA

FARM RESOURCES

To determine the feasibility of diversification into peaches and table grapes on Long Island potato farms, crop budgets, based on economic engineering data and technical recommendations from extension and research personnel, were developed and verified through interviews with commercial growers on Long Island.

Price and yield data were taken from local and state statistical sources (Federal-State Market News Service, New York Crop Reporting Service) and adjusted to reflect farmer perceptions as determined through informal interviews. Budgets were developed for potatoes, wheat, and cauliflower in monoculture and in the following rotations: potatoes followed by a wheat/cauliflower double crop, potatoes followed by wheat and a rye cover crop, and a double crop of wheat and cauliflower (without potatoes). In addition to these six annual crop combinations, budgets were developed for peaches and table grapes reflecting the costs and returns for each year from establishment to maturity.[4]

The base line for the model, a typical Long Island potato farm, was constructed from the farm survey conducted by Fohner in 1983. The farm had 150 acres of which half were owned and half rented at a rate of $75 per acre. The farm was assumed to have a moveable pipe irrigation system capable of irrigating the entire acreage.

Labor resources were based on the average number of operators reported in Fohner's survey of Long Island potato farms. The farm was assumed to have two operators who were willing to work a 50 hour week. All other labor needs would be met by hiring full-time skilled labor or unskilled seasonal harvest labor. In the initial run, hired labor availability was limited to two full-time skilled workers and four seasonal unskilled workers.

Growers have complained of a shortage of local hired labor on Long Island, especially in the eastern part of Suffolk County. This is explained by the gentrification of the eastern end of the Island and its distance from the larger urban and suburban centers to the west. Increased reliance on migrant labor may be necessary if many growers attempt to grow fruit crops.

The wage rate for skilled full-time labor was estimated at $5.15 per hour plus $0.55 for Social Security and Workmen's Compensation, and $1.04 in benefits. The total variable cost to the grower was $6.74 per hour. Because harvesting labor requirements are so large for peaches, grapes, and cauliflower, many growers hire local part-time labor or extra migrants for this activity. The wages for these laborers come closer to the minimum wage, depending on the experience of the worker. During the months of June, July, August, September, and October, the model differentiated unskilled labor and charged a labor cost to the grower of $4.36 per hour ($3.88 wage plus $0.42 Workmen's Compensation and Social Security plus $0.06 benefits). Both part-time and regular labor wage rates were based on labor costs for fruit farms in New York State (Snyder, December 1983).

COMPARISON OF CROP BUDGETS

A preliminary analysis of the costs and returns per acre for all crops showed that peaches and table grapes offered the greatest return over variable costs of any crop. The return per acre from peaches was twice that from table grapes and the establishment costs were 44 percent lower over the first three years ($2,985 for peaches versus $5,335 for grapes). Therefore, peaches can be expected to be the more attractive of the two fruit crops (Table 2).

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[4] For more information on the crop budgets, fixed costs, machinery and building complement for the farm, see A.E. Research 85-12.

Table 2
Comparisons of Costs and Returns Per Acre, All Crops, Long Island

	Gross Returns	Selected Variable Costs	Skilled Labor Costs	Unskilled Labor Costs	Total Variable Costs	Net Returns
Continuous potatoes	$1,448	$ 919	$113	$ 51	$1,083	$ 365
Rotated potatoes	1,448	868	110	51	1,029	419
Continuous wheat	164	111	11	0	122	42
Rotated wheat	164	82	7	0	89	75
Cauliflower	2,548	1,101	239	432	1,772	776
Peaches-Year 1	0	704	184	14	902	-902
Year 2	0	148	126	21	295	-295
Year 3	1,762	1,191	337	260	1,788	-26
Year 4*	3,525	681	412	428	1,521	2,004
Year 5	5,287	969	565	633	2,167	3,120
Years 6, 8, 10, 12	5,287	890	546	633	2,069	3,218
Years 7, 9, 11, 13	5,287	995	562	633	2,190	3,097
Table Grapes - Year 1	0	2,743	305	21	3,069	-3,069
Year 2	0	202	303	28	533	-533
Year 3	1,913	862	743	128	1,733	179
Years 4, 6*-9, 11-14	3,825	940	994	214	2,148	1,677
Years 5, 10	3,825	1,070	999	214	2,283	1,542

*Breakeven point on cash basis.

Among the annual crops, cauliflower was by far the most profitable with potatoes and wheat following. In the case of both potatoes and wheat, growing the crop in rotation yielded a higher return (for the year when potatoes were grown) than growing the crop in monoculture. Although wheat had the lowest returns per acre, it also had the lowest variable costs and the lowest labor requirements of any of the crops. Thus, it would not be surprising to see farmers use wheat as a substantial land user while devoting a smaller acreage to the more intensive but highly valued fruit and vegetable crops.

The costs and returns of the peach and grape budgets were evaluated with net present value analysis in order to determine the annual equivalent of discounted net returns for comparisons of profitability with annual crops.[5] Peaches, with an equivalent annual net return of $1,753 and grapes with an equivalent annual net return of $927 were clearly superior

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[5] The average life of a peach orchard was assumed to be 12 years and the vineyard was discounted over 25 years. Implicit in this analysis was the assumption that the orchard and vineyard would be replaced at the end of the average life and the cycle would start again. Investment costs in new machinery and cold storage for peach and grape production were also included as costs in the NPV analysis. A seven percent (real rate) discount rate was used.

to any of the annual cropping combinations. Only cauliflower came close to grapes in profitability ($851 average annual return for the wheat/cauliflower double crop) and continuous potatoes offered a return less than half this level ($365).

To achieve these higher returns from fruit, a farmer would have to commit more resources and intensity to production per acre. Operating costs increased from $1,000 per acre for potatoes to more than $2,000 per acre for peaches, grapes, and cauliflower. Marketing costs for peaches, grapes, and cauliflower increased threefold over those for potatoes and represented approximately 30 percent of total variable costs. For potatoes, marketing costs only amounted to $200 per acre, representing 17 percent of total variable costs.

Labor use also increased significantly. Only 29 hours per acre were needed to produce potatoes but cauliflower (135 hours), grapes (197 hours), and peaches (229 hours) required many times that amount. For grapes, labor was even more of a problem because 75 percent of the labor requirement could only be met by hiring skilled workers or using operator labor. For peaches and cauliflower, a much lower proportion of skilled labor was needed, only 36 and 27 percent, respectively.

Considerable attention was given to evaluating the potential environmental risk of the pesticides used on the crops presented as alternatives to potato production. Data on pesticide soil persistence (speed of degradation) and mobility (leaching through the soil) were used to determine the likelihood of pesticide contamination of surface water and groundwater. These data were combined with data on acute toxicity in order to rank each pesticide according to its potential environmental risk. Pesticides were ranked on a scale of one to ten where one was nontoxic and ten was highly toxic with a high likelihood to contaminate surface or groundwater. These risk rankings were used to compare the risk to groundwater and surface water from each fungicide, insecticide, and herbicide program for each crop. Loading rates for each pesticide program and for nitrate fertilizers were also determined for each crop.[6]

These data on costs and returns, labor requirements, and pesticide risk were used in a linear programming model to evaluate the feasibility of a transition into fruit crops on Long Island potato farms given various resource constraints.

METHODOLOGY

MODELING FARM TRANSITION OVER TIME

The issue of farm firm growth has been one of great interest to economists. Many studies have focused on capital accumulation over time in an attempt to unravel the mechanisms by which farmers make capital investment decisions. Economists have attempted to model the interplay of capital, labor, and other resource constraints in determining the options

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[6] See A.E. Research 85-11 for a more detailed description of the pesticide risk index.

available to the profit maximizing farmer. Mathematical programming models have been used in attempts to model a farmer's optimizing decision process. In the current application, a linear programming model was used to determine when, and under what constraints, Long Island potato farmers could be expected to diversify from potatoes into peaches and grapes.

Many studies have modeled farm firm growth using linear programming.[7] Most have focused on the capital constraints to farm firm growth. In fact, Boehlje and White (1969) criticized most polyperiod models for taking the organization of production as exogenous and irrevocable, and focusing on investment rather than production.

Boehlje and White felt that the exogenous determination of production activities was inappropriate in cases where resource fixities in production, labor or credit exist at certain points in the planning horizon and might cause the optimal production organization to change. In this study, resources fixities in labor, pesticides, and capital were the motivation for building the linear programming model. The major portion of the matrix dealt with labor, marketing, pesticide, and cash flow activities and constraints, so investment and consumption were expressed in less detail. Since an adequate representation of taxes would require such a large portion of the matrix, the model was developed on a before tax basis.

A search of the literature yielded only one past study which used multiperiod LP to analyze the transition into perennial crops. The study by Dean and Benedictis (1964) sought to determine the development pattern of newly irrigated peasant farms in southern Italy and to measure the productivity of government loans for orchard development. They modeled the transition from annual crops to oranges, peaches, and grapes over a 60 year time horizon. The model was relatively small, encompassing a matrix of 45 constraints and 59 activities.

The model used in this study covered a shorter time horizon of 15 years but involved much more detail. The annual cropping combinations and rotational schemes were determined by the model, not exogenously as in the Dean and Benedictis model. The key decision processes were given much more attention with respect to production alternatives, and interactions with constraints on labor availability, cash flow, and marketing.

CHOOSING THE OBJECTIVE FUNCTION

One of the most commonly used objective functions in multiperiod linear programming models is the maximization of the net present value of the stream of net returns over the time horizon of the model. Another commonly used objective function is the maximization of net worth at the end of the planning horizon plus the present value of consumption in each period. Martin and Plaxico (1967) analyzed five objective functions in their model of farm growth and capital accumulation. These included maximization of land operated, net worth, the cash value of net returns, and the value of net returns discounted to net present values. They claimed that the same

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[7] Linear programming (LP) is a mathematical technique which determines the best way to reach a specific objective given limited resources.

growth conditions occurred under each of the objective functions because the structure of the firm and the environment in which it operated overwhelmed specific operator objectives. Different structural relationships resulted in different growth rates, however.

While the need for discounting is obvious in multiperiod models, there are empirical problems with determining the appropriate discount rate. When farms are limited to internally generated equity funds and debt obtained with the leverage provided by this equity, capital rationing occurs. In this case, the discount rate should be the marginal product of investment capital but this "interest rate" cannot be determined until the optimal capital budget is determined (Reid, Musser, and Martin, 1980).

The objective function used in this model was not discounted to net present values. A major drawback of the model is the assumption that a dollar earned in year 15 is worth as much as a dollar earned in year one. However, the purpose of this model was to determine the cash flow constraints which necessarily must appear as current dollar values. The superiority of both the net present values and annuity values for peaches and grapes over all other annual crops in the model was determined exogenously.

A simple form of discounting did occur in that the interest on operating capital and intermediate term debt was charged and time was explicitly considered as a factor in the investment and income streams. For example, the LP model clearly saw the advantage of the earlier returns achieved by early planting of peaches and grapes. Only binding constraints on capital and labor availability in the early years could cause the model to choose to wait to plant peaches and grapes until later in the time horizon.

DESCRIPTION OF THE MODEL

General Overview

To analyze the feasibility of the transition from potatoes into peaches and grapes, a multiperiod LP model covering a 15 year time horizon was built. Crop options in the first year consisted of potatoes, wheat, and cauliflower, with a constraint requiring at least half the acreage to be planted in potatoes. This established the typical potato farm base from which comparisons with more diversified and intensive fruit and potato production could be made.

It was assumed that the transition into fruit crops would be made cautiously, starting out with a few acres and then planting more if the crop appeared to be doing well. The model attempted to show this kind of transition by allowing grapes to be planted in year two, peaches in year three, more grapes in year five, and more peaches in year six. This would enable a gradual transition to take place with a year (year four) between plantings to take stock of how things were going before committing more resources to fruit production. The fourth year was used to build the cold storage facility which would be needed when peaches and grapes came into production.

Since the breakeven point for grapes occurred the sixth year after planting and for peaches in the fourth year after planting, the second plantings of these crops would only reach the breakeven point by year 10 of the model. Thus, a final period composed of five years was added to the model to enable these second plantings to enter the solution if profitable.

Six annual cropping options were included in the model to allow for diversification in the farm's crop mix. The model was allowed to chose the optimal combination of annual and fruit crops, given the substantial set of constraints in each period.

The model was composed of 11 periods: 10 one year periods and one final period representing five years.[8] In each period, there were approximately 47 columns representing the producing, selling, and cash flow activities, and 72 rows representing land, labor, pesticide, marketing, and cash flow constraints. Over the 11 periods, this yielded a matrix of 517 columns and 728 rows.

In multiperiod programs, even a simple model becomes quite large because each period must contain all activities and constraints plus a few "consistency constraints" tying it to the preceding and following periods. Table 3 presents a simplified example of the structure of the model.

The productive activities in many of the periods were similar, so a matrix generator was used to mechanically generate the MPSX input for 35 rows and 11 columns in each period (Schwartz, 1984). The rest of the matrix was entered by hand but most of these rows and columns had only a couple of nonzero values.

Labor and Marketing Constraints

Much focus was placed on labor constraints. Labor needs for all crops were divided into skilled and unskilled categories. Labor was divided into nine periods within each year: 1) January - March, 2) April, 3) May, 4) June, 5) July, 6) August, 7) September, 8) October, and 9) November - December. Unskilled labor was made available from June through October for hand hoeing, irrigation, thinning, and harvesting activities.

The total labor hours available in each month were skilled operator labor: 434 hours; hired skilled labor: 434 hours; and hired unskilled labor: 868 hours.[9] This was equivalent to four full-time skilled workers and four seasonal unskilled workers. The labor constraints in each period were as follows:

1) Skilled Labor Needs by Crop and Month - Hired Skilled Labor by Month $\leq$ Operator Labor by Month

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[8] In this final period, all costs, returns, and resource requirements were multiplied by five.

[9] With 52 weeks in a year, each month was estimated to have 4.3 weeks or 217 hours per worker (50 hour work week).

Table 3 Simplified Example of Structure of Two Periods in a Multiperiod Model

	Constraints \ Activities	Period 1: Annual Crops	Period 1: Fruit Crops	Period 1: Hire Labor	Period 1: Sell Crops	Period 1: Operating Loan	Period 1: Fixed Costs	Period 1: Consumption	Period 1: Intermediate Loan	Period 1: Debt Retirement	Period 1: Carry Over Cash	Period 1: Previous Debt	Period 2: Annual Crops	Period 2: Fruit Crops	Period 2: Hire Labor	Period 2: Sell Crops	Period 2: Operating Loan	Period 2: Fixed Costs	Period 2: Consumption	Period 2: Intermediate Loan	Period 2: Debt Retirement	Period 2: Carry Over Cash	Period 2: Previous Debt	Right Hand Side
	Objective Function	−c	−c	−w	+p	−r	−1	−1	−r	−1	0	−r	−c	−c	−w	+p	−r	−1	−1	−r	−1	0	−r	z
Period 1	Land	1	1																					=150 Acres
	Labor Needs	hr	hr	−1																				≤Operator Labor
	Hired Labor			1																				≤Hired Labor
	Pesticide Load. Rates	AI	AI																					≤Max. Loading Rate
	Pest. Risk Indices	RI	RI																					≤Max. Risk Index
	Marketing	y	y		−1																			=0
	Oper. Cap.	c	c	w		−1																		≤0
	Returns				−p	+(1+r)	+1	+1	+r	+1	+1	+r												≤0
	Debt								1	−1		1											−1	≤0
	Consistency		1											−1										=0
Period 2	Land												1	1										=150 Acres
	Labor Needs												hr	hr	−1									≤Operator Labor
	Hired Labor														1									≤Hired Labor
	Pesticide Load. Rates												AI	AI										≤Max. Loading Rate
	Pest. Risk Indices												RI	RI										≤Max. Risk Index
	Marketing												y	y		−1								=0
	Oper. Cap.												c	c	w		−1							≤0
	Returns										−1					−p	+(1+r)	+1	+1	+r	+1	+1	+r	≤0
	Debt																			1	−1		1	≤0
	Consistency													1										=0

y=yields, c=costs, p=prices, w=wages, r=interest rate, AI=loading rates, RI=risk indices.

2) Unskilled Labor Needs by Crop and Month - Hired Unskilled Labor ≤ 0

3) Hired Skilled Labor $\leq$ 434 hours per month, and

4) Hired Unskilled Labor $\leq$ 868 hours per month.

Producing and selling activities for all crops were kept separate in order to see the effect of changes in yield and price on the optimal crop mix. The yield after culling for each crop was divided among the appropriate marketing channels to determine gross returns. For potatoes, wheat, and cauliflower, assumptions about the proportion of production entering each market channel were made exogenously and were reflected in a composite farm price.[10]

For peaches and grapes, the two marketing channels (direct retail and direct wholesale) were explicitly represented in the model with a retail/wholesale ratio constraint determining the proportion of production entering each marketing channel. The marketing constraints were as follows:

1) Yield (after culling) = Quantity Marketed Retail + Quantity Marketed Wholesale

2) Quantity Marketed Retail = Quantity Marketed Wholesale.

Since transportation and container costs change with each marketing channel, the price used was the effective producer price, i.e., the average market price minus transportation and container costs.[11] In subsequent runs, the proportion of the crop allowed to enter each marketing channel was varied to determine the profitability of these fruit crops under different marketing conditions.

Pesticide and Nitrate Constraints

Accounting rows kept track of the loading rates (ΣAI_j) and weighted average risk indices ($\overline{RI}$) for the fungicide, insecticide, and herbicide programs for each crop.[12] Separate accounting rows were included to monitor the loading rates and weighted average risk indices for those insecticides and herbicides likely to contaminate surface water and those

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[10] See A.E. Research 85-12 for descriptions of the marketing channels and proportion of each annual crop entering each marketing channel.

[11] The effective producer prices for direct retail and direct wholesale channels were \$0.46 per pound and \$0.26 per pound for peaches and \$0.95 per pound and \$0.37 per pound for grapes, respectively.

[12] $\overline{RI} = \sum_{j=1}^{n} \frac{RI_j \; AI_j}{AI_j}$ where RI_j is the risk index for a particular pesticide, AI_j is the pounds active ingredient for each pesticide and j represents each pesticide in a crop's fungicide, insecticide or herbicide program.

likely to contaminate groundwater. In the case of nitrates, only the loading rate was monitored since the fate of nitrogen in the environment (volatilization, plant take up, leaching or runoff) is unclear.[13]

These accounting rows measured the loading rates and weighted average risk indices for the various spray programs used on the entire farm. This was achieved by taking the loading rate and weighted average risk index for each fungicide, insecticide, and herbicide program for each crop, and multiplying these by the number of acres planted to each crop, and aggregating this across the entire farm. The pesticide and nitrate constraints were as follows:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} AI_{ij}X_j \leq \text{Maximum Loading Rate on The Farm}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} \overline{RI}_{ij}X_j \leq \text{Maximum Risk Index on The Farm}$$

Where: i = the fungicide, insecticide, and herbicide programs (separated according to surface and groundwater contamination potential) and the nitrogen application rate,

j = each crop or rotation,

X = acres of each cropping activity,

AI = the loading rate (pounds active ingredient of each pesticide or pounds actual of nitrogen),

$\overline{RI}$ = the weighted average risk index for each pesticide spray program.

The Objective Function and Cash Flow Constraints

The model determined the feasibility of the transition into peaches and grapes by maximizing net returns over the 15 year time horizon subject to constraints on capital and labor availability, pesticide contamination, and family expenses for living. The objective function was composed of the nondiscounted net returns for each productive activity in each period. Future inflation rates were not predicted in the model; all costs and returns were in current dollars (1982-1984 period). The model was considered on a before tax basis since income taxes are variable depending on each farmer's individual situation.

The objective function consisted of the selected variable costs of production for each crop (-), wages (-), interest payments (-), debt repayment (-), fixed costs (-), family living expenses (-), and gross returns for each crop (+) (adjusted for marketing costs). The objective function and cash flow constraints of the basic model were as follows:

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[13] A.E. Research 85-11 gives an additional discussion of loading rates and risk indices.

MAXIMIZE:

$$\text{Net Returns} = \sum_{t=1}^{11} (\text{Total Sales}_t - \text{Production Costs}_t - \text{Wages}_t - \text{Interest on Operating Loan}_t - \text{Interest on Intermediate Term Debt}_t - \text{Debt Retired}_t - \text{Fixed Costs}_t - \text{Family Living Expenses}_t - \text{Excess Cash For Investment}_t)$$

SUBJECT TO:

$\text{Asset Equity}_{t=1} = \$587{,}764$

$\text{Previous Debt}_{t=1} \geq \$50{,}000$

$\text{Consumption}_t \geq \$24{,}000_{t=1-10},\ \$120{,}000_{t=11}$

$\text{Fixed Costs}_t \geq \$10{,}668_{t=1}\ \ \$11{,}112_{t=2-10},\ \$55{,}558_{t=11}$

$\text{Machinery Replacement}_t \geq \$16{,}364_{t=1,4-6},\ \$28{,}427_{t=2},\ \$26{,}119_{t=3},\ \$17{,}673_{t=7-10},\ \$88{,}364_{t=11}$

Debt Security Ratio:

$0.8\ \text{Asset Equity} \geq \text{New Debt}_t + \text{Continued Debt}_{t-1}$

Debt Retirement:

$0.14\ \text{New Debt}_t + 0.14\ \text{Continued Debt}_{t-1} \leq \text{Debt Retired}_t$

Debt Level:

$\text{Continued Debt}_t = \text{Continued Debt}_{t-1} + \text{New Debt}_t - \text{Debt Retired}_t$

Asset Equity:

$\text{Asset Equity}_t = \text{Asset Equity}_{t-1} + \text{Debt Retired}_{t-1} - 0.5\ \text{Machinery Replacement}_{t-1} + \text{Excess Cash For Investment}_{t-1}$

Intermediate Loan:

$\text{Machinery Replacement}_t + \text{Investment in Peach and Grape Establishment}_t \leq \text{New Debt}_t + \text{Excess Cash For Investment}_{t-1}$

Operating Capital:

$\text{Production Costs for all Crops}_t + \text{Insecticide Costs for all Crops}_t \leq \text{Operating Loan}_t + \text{Excess Cash for Operating Costs}_{t-1}$

Insecticide Costs:

Insecticide Costs for All Crops_t	$\leq$ Total Insecticide Costs_t

Containers and Transportation:

Container and Transport Costs for All Crops_t	$\leq$ Total Container and Transportation Costs_t

Returns:

1.09 (Operating loan_t) + 0.09 (Container and Transport Costs_t) + 0.12 (Intermediate Loan_t) + 0.12 (Continued Debt_{t-1}) + Debt Retired_t + Fixed Costs_t + Family Living Expenses_t + Excess Cash_t (for Operating Costs_{t+1}, Machinery Replacement_{t+1}, Fixed Costs_{t+1} and Family Living Expenses_{t+1})	$\leq$ Gross Returns_t + Excess Cash from Returns_{t-1}

Machinery replacement rates and fixed costs were set exogenously. Machinery replacement costs were especially high in years two and three. In these years, the machinery complement for fruit production had to be purchased (an additional \$12,063 in year two and \$9,755 in year three) in addition to the regular yearly replacement cost of the existing machinery complement (\$16,364)[14]. Since the orchard/vineyard machinery complement was new, it was assumed that replacement would not start to occur for five years. Thus, the full \$17,673 annual contribution to the machinery replacement fund was not charged until year seven. Machinery replacement had to be financed through intermediate term loans (or excess cash from the previous period). Fixed costs had to be covered from returns in each period or excess cash from the previous period.

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[14] The existing machinery complement, if purchased at 1982-1984 prices, would cost \$272,728. After deducting 10 percent for salvage value, the annual replacement costs over a 15 year period were \$16,364.

Family living expenses were also set exogenously. No attempt was made to estimate the marginal propensity to consume and make consumption a function of income. Clearly, the level of family consumption, especially in the early years when peaches and grapes were being established, could have a great impact on the level of investment in orchards and vineyards. However, it was assumed that some minimum level of income to cover family living expenses would be required even in the early years of the model. The median family income for Suffolk County, New York in 1980, $24,000, was used as the minimum to be set aside each year for family living expenses (U.S. Department of Commerce, 1980). Like fixed costs, family living expenses had to be covered through current income or excess cash from the previous year.

Intermediate loans (seven year life) were used to finance the establishment of peaches and grapes for the first year of production, the construction costs of the cold storage facility, and machinery replacement. The interest rate charged on intermediate term debt was 12 percent. Total debt was limited to 80 percent of asset equity in keeping with the lending practices of the Farm Credit Service, P.C.A. in Riverhead, New York. Repayment had to occur over a seven year period with at least one-seventh of the debt retired each year (Wolfe, 1984). In the final period, all remaining debt was subtracted from the objective function.

Asset equity and previous debt levels were determined exogenously at the beginning of the model but changed as new loans were taken out and old ones retired over the course of the model. Initial asset equity was composed of the following assets:[15]

House for Labor	$ 25,000
Shop, 30' by 40'	14,400
Equipment Storage	26,600
Potato Storage	20,400
Home of Operator	65,000
1/2 Replacement Value of Machinery Complement	136,364
75 Acres Owned @ $4,000 per Acre	300,000
	$587,764

15 The 1982 Agricultural Census of Suffolk County farms with sales of $10,000 or more estimated the average market value per farm of machinery and equipment at $72,637 and of land and buildings at $407,847. The $107,280 difference between the Census total and the one presented here is accounted for in the value of the home of the operator (not included in the Census figure) and the higher value given the machinery complement.

The machinery complement was only valued at half its current replacement value because it was composed of equipment of various ages. When machinery had to be replaced, asset equity was only decreased by one half the replacement cost. When machinery replacement occurred, asset equity was increased by the full replacement value to reflect the value of the upgraded complement at current 1982-1984 prices.

Two cash flow rows appeared in the model, one for operating costs and the other for returns. Operating costs consisted of the selected variable production costs for each crop, plus the insecticide costs which were accounted for in a separate row to allow for separate sensitivity analysis. Operating costs were financed out of a line of credit at nine percent interest (12 percent per year, repayment in nine months) or excess cash from the previous period. The credit line was assumed to be large enough to cover all production expenses. Lines of credit of $60,000 to $100,000 are common on Long Island and some of the larger growers have credit lines well beyond these levels (Wolfe, 1984).

The second cash flow row was composed of gross returns (price x marketed yield) minus all operating and fixed costs. From the net returns, interest on operating loans and intermediate term debt, fixed costs, debt retirement, and family living expenses all had to be met annually. Any left over cash was placed into capital inventories which served as an additional source of cash to cover operating costs, machinery replacement or consumption and fixed costs in the following period. In the final period (representing five years), excess cash could be used for covering expenses in the same period that it was generated.

The model was run using the linear programming package MPSX3330. Several variations were made in the model and are described along with the results in the next section.

RESULTS

The linear programming model was run many times to test the robustness of the results to changes in resource levels and expectations about the future. The results of the basic model are described in terms of the transition in crop mix, investment patterns, labor use, and pesticide risk. The effect on these results of variations in initial debt levels, increases in unskilled labor availability, changes in marketing outlets and yield, and alternative scenarios of Colorado Potato Beetle control, are also presented.

RESULTS OF THE BASIC MODEL

Transition in Crop Mix

The first period of the model was designed to represent the crop mix of a typical Long Island potato farm and only potatoes, wheat, and cauliflower were given as cropping options. The crop mix in this period was remarkably similar to that of the average potato farm reported in Fohner's survey of Long Island potato farms. Potatoes grown in continuous production occupied the majority of the farm, 125 acres. The rest of the land was planted to potatoes in rotation with a double crop of wheat and cauliflower (Table 4).

Table 4
Transition in Cropping Patterns

Year	Continuous Potatoes	Rotated Potatoes* Pt/Wt	Pt/Wt/Cl	Table Grapes	Peaches
			(acres)		
1	125.3	12.5	12.1	---	---
2	118.2	13.1	12.5	6.2	---
3	109.9	11.9	13.1	6.2	8.9
4	115.7	7.4	11.9	6.2	8.9
5	122.3	5.3	7.4	6.2	8.9
6	126.4	3.2	5.3	6.2	8.9
7-15	128.5	3.2	3.2	6.2	8.9

*The potato rotations were as follows: Pt/Wt: potatoes followed by wheat (year 1); Pt/Wt/Cl: wheat and cauliflower double crop (year 2); Pt/Wt/Ry: wheat and rye cover (year 2).

Despite the clear superiority of the profitability of peaches and grapes over the annual crops, only six acres of grapes were planted in year 2 and nine acres of peaches in year 3. Ranging analysis showed that the costs per acre would have to be reduced or returns increased by $171 for peaches and $787 for grapes before more would be planted in years 2 and 3. Although options were given to establish more grapes and peaches in years 5 and 6, no additional plantings were undertaken. Net returns from grapes planted in year 5 would have to increase by $1,323 before they would be planted. For peaches to be planted in year 6, net returns would have to increase by $4,189. Thus, only risk aversion or lack of capital or labor resources would cause a farmer to delay planting peaches or grapes until later years in the model.

After diversification into fruit, the majority of the acreage remained in potatoes grown in monoculture. This result was explained by the lack of unskilled labor in months when thinning and harvesting took place (unskilled labor was constrained to the equivalent of four workers per month). Fruit was substituted for the potato/wheat/cauliflower rotation and continuous potato acreage increased slightly.

It had been expected that as the farm switched into peaches and grapes, labor and capital constraints would encourage production of wheat since it requires such a low level of inputs. A look at the sensitivity analysis showed that if the costs of production for the potato/wheat rotation were reduced by $12, or if the costs of producing potatoes in monoculture rose by the same amount in any of years 6 through 15, then the potato/wheat rotation in year 7 would be substituted for monoculture potatoes. In years 9 and 11-15, the potato/wheat rotation was in the basis at zero indicating that this was a degenerate solution.

The importance of peaches and grapes was much greater than that suggested by acreage alone. Only 10 percent of the farm was planted to fruit, but once the vineyards and orchards matured (years 5 and 7 respectively), they accounted for 24 percent of gross returns. Although the proportion of gross returns represented by potatoes fell from 86 percent in the first year to 73 percent in years 7-15, this reduction was a reflection of the 13 percent increase in gross returns (from $232,390 in year 1 to $262,443 in years 7-15) after fruit came into production, not of a reduction in potato acreage.

Investment Patterns

Investment capital and debt repayment were not as limiting to the model as might have been expected. Excess cash was available from the very first year (shown here as "Internal Investment") and was used to finance investment in fruit and machinery replacement, and to reduce the level of new intermediate term loans. Only in the first four years was the requirement that one-seventh of principal be retired binding. At no time did the debt security ratio constraint, which required that intermediate term debt be less than 80 percent of asset equity, become binding (Table 5).

Table 5
Debt Servicing and Investment

Year	Old Debt	New Debt	Total Debt	Debt Retired	Internal Investment	Interest
1	$50,000	$16,364	$66,364	$ 9,291	$21,742	$ 7,964
2	57,073	23,554	80,672	11,288	15,944	9,675
3	69,339	16,414	85,753	12,005	10,027	10,290
4	73,748	25,040	98,788	13,830	9,511	11,855
5	84,958	6,853	91,811	15,234	16,364	11,017
6	76,577	---	76,577	30,864	17,673	9,189
7	45,712	---	45,712	43,372	17,673	5,485
8	2,340	---	2,340	2,340	17,673	281
9	---	---	---	---	17,673	---
10	---	---	---	---	---	---
11-15 (total)	---	---	---	---	88,364	---

Asset equity increased by 43 percent, from $537,764 in year one ($587,764 farm equity - $50,000 initial debt) to an ending level of $769,104. The ending level reflected the updated value of the machinery complement ($117,624 in 1982-1984 prices), and the investment in the establishment of peaches ($6,242) and grapes ($16,953), the cold storage facility ($18,703), the initial purchase of the machinery complement for fruit production ($21,818), and the repayment of $50,000 in initial debt.

Family living expenses did not prove to be a serious constraint on the model. Excess cash was available in all periods so increased levels of consumption could have been accomodated. Sensitivity analysis showed the range in consumption levels to be at a minimum in year five when consumption could only vary between $22,000 and $26,000 before a change in solution occurred. The solution became quite insensitive to consumption levels by the end of the model when family living expenses could vary from zero to $86,069 without changing the solution.

Once all intermediate term debt was retired and investment in machinery replacement covered by excess cash from net returns, the remainder of the excess cash was used to finance operating capital. The first excess cash for operating expenses appeared in year eight and was used to reduce operating loans in year nine. In the five year period from year 11-15, no operating loans were required because, in this period, excess cash from net returns was allowed to be used to cover fixed and operating costs in the same period (Table 6).[16]

Table 6
Operating Costs

Year	Total Production Expenses	Operating Loan	Excess Cash	Total Interest*
1	$144,973	$144,973	$ ---	$13,752
2	139,150	139,150	---	13,251
3	132,196	132,196	---	12,659
4	137,167	137,167	---	13,159
5	147,597	147,597	---	14,124
6	144,281	144,281	---	13,825
7	146,737	146,734	---	14,067
8	146,004	146,004	47,035	14,001
9	146,939	99,904	99,905	9,852
10	146,004	46,099	176,225	5,010
11-15 (total)	733,658	---	1,044,003	4,304
Returns to Management & Equity Capital			$ 486,570	

*Includes interest on container and transport costs not included in total production expenses figure.

Operating costs after fruit was planted increased by only $1,000 to $2,000 per year. Total production expenses did not include container and transport costs which increased by almost $2,000 per year as well (from $7,817 in year one to $9,564 in years 7 through 15). These costs were reflected in an effective producer price net of container and transport costs. Although these charges did not appear directly as costs in the model, interest at the rate of nine percent per year was charged since the operator would need capital to purchase containers and transport in order to market the harvest.

Naturally, as debt burdens fell, interest payments on operating and intermediate term loans also fell. However, throughout the first seven years of the model, total yearly interest payments (totals from Tables 5 and 6) ranged from $19,000 to $25,000, a substantial sum.

After all debts were retired and operating loans were no longer needed to finance production expenses, excess cash continued to accrue. In year 10, $176,225 in excess cash remained and was not needed to finance operating expenses in years 11 through 15. In years 11 through 15, excess cash

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[16] In all previous periods, excess cash from one period only could be used to cover investment or operating costs in the following period.

exceeded production expenses by $310,345 leaving a total excess of $486,570 (Table 6). This figure represents net returns of the model over the entire 15 year time horizon. It can be viewed as returns to management and equity capital. It represents gross returns net of variable and fixed costs, debt repayment, and family living expenses of $24,000 per year.

Although lack of investment or operating capital did not limit the cropping choices in the LP model, the internal cost of capital to the farm was substantial. The dual values given by the LP solution show the marginal value product of investment and operating capital in each time period. The duals for capital leakages (i.e., family living expenses, fixed costs, and intermediate debt) in one period, were equal to the dual values for new intermediate debt and machinery replacement in the following period. The dual value for an extra dollar of returns was equal to one less than the duals of the above capital leakages. This meant that if there were one more dollar of returns in time period t, it could be used to retire more debt, cover fixed costs or family living expenses in time period t, or cover machinery replacement or new intermediate debt in time period t+1. The marginal value product of the extra dollar would be a function of the interest that would no longer need to be paid. The dual values for the capital leakages were one greater than the dual value for returns because a one dollar reduction in these leakages would save one dollar in costs plus the interest that dollar could "earn" (i.e. save) throughout the rest of the model (Table 7).

Table 7
Dual Values For Cash Flow Constraints

Year	Consumption, Fixed Costs or Debt	New Debt & Machinery Replacement	Returns	Operating Capital
1	2.63	2.94	-1.63	-1.86
2	2.35	2.63	-1.35	-1.56
3	2.09	2.35	-1.09	-1.28
4	1.87	2.09	-0.87	-1.04
5	1.67	1.87	-0.67	-0.82
6	1.49	1.67	-0.49	-0.62
7	1.33	1.49	-0.33	-0.45
8	1.19	1.33	-0.19	-0.30
9	1.09	1.19	-0.09	-0.19
10	1.00	1.09	0.00	-0.09
11-15	1.00	1.00	0.00	0.00

The dual value for operating capital only reflected the savings in interest payments if one dollar less of operating capital were needed since operating costs were charged out of the objective function separately under the cropping activities. The dual value for operating capital was larger than that of returns since not only would the interest on operating capital be saved, but one more dollar of returns would be freed for use in investments, thus saving the interest charge on that extra dollar of debt.

For example, in year eight there was no more intermediate term debt. Since an extra dollar of returns could only be used to reduce operating loans in the succeeding years, the dual for returns was equal to the interest (9 percent) saved on one less dollar of operating loans in year nine and year 10 compounded yearly.

Year 9: $0.09 x $1.00 = $0.09
Year 10: $0.09 x $1.09 = $0.10
Total = $0.19

After year 10 there were no more operating loans so no more interest could be saved (i.e. avoided) and the marginal value product of an extra dollar of returns dropped to zero.

For operating capital in year eight, the marginal value product was larger than for returns because it included the saved interest payment in year eight as well.

Year 8: $0.09 x $1.00 = $0.09
Year 9: $0.09 x $1.09 = $0.10
Year 10: $0.09 x $1.19 = $0.11
Total = $0.30

In years 10 through 15, the dual values for debt, fixed costs, and family living expenses were equal to one, reflecting only the direct savings from lowered expenses. Likewise, the dual for operating capital and returns fell to zero since the farm had no debt at this point, so there could be no savings from avoiding interest payments. With all debt retired it is easy to see how the earlier investment in fruit had begun to pay off and the internal marginal cost of capital had fallen to less than the interest rate for borrowed funds.

Labor Usage and Constraints

With the introduction of peaches and grapes, labor usage increased significantly. In the first year, when fruit was not produced, the farm employed 53 percent (approximately one worker) of the available operator labor, hired no skilled labor, and hired only 65 percent (approximately 2.6 workers) of the available unskilled labor. By the time peaches and grapes reached maturity, years 7 through 15, operator labor had increased by 33 percent to 70 percent (approximately 1.4 workers) of the total available. Skilled labor was being hired, though in small quantities, and unskilled labor hiring was up by 23 percent to 79 percent (approximately 3.2 workers) of the total available (Table 8).

Table 8
Labor Usage

Year	Operator	Skilled	Unskilled
	hours		
1	2,761	---	2,800
2	2,945	---	2,753
3	3,008	40	2,781
4	3,280	71	2,826
5	3,520	194	3,041
6	3,577	254	3,205
7	3,675	314	3,443
8-15 (average)	3,667	309	3,443
Change: year 1 to year 15	33%		23%

Aggregate comparisons do not present the whole picture. A look at the labor usage breakdown by month shows that labor was constraining the level of crops chosen in every year of the model. In the first three years, more cauliflower would have been grown if more unskilled labor had been made available in October for harvesting. By year four, the shortage in unskilled labor appeared in September instead of October due to the harvesting of grapes. By year six, unskilled labor shortages also appeared in June due to the substantial labor required to thin peaches. Dual values (marginal value products) for all unskilled labor shortages remained well above the $4.36 per hour labor cost in every year (Table 9).

Table 9
Dual Values* For Months of Maximum Labor Use

	Operator				Unskilled Labor		
Year	April	June	July	September	June	September	October
1	---	---	---	---	---	---	81.6
2	---	---	---	---	---	---	74.6
3	15.38	---	---	---	---	---	67.5
4	13.7	13.7	---	---	---	64.4	---
5	12.3	12.3	---	12.3	---	57.6	---
6	10.9	10.9	---	10.9	---	51.4	---
7	9.8	9.8	9.8	9.8	---	39.0	---
8	8.7	8.7	8.7	8.7	---	39.0	---
9	8.0	8.0	8.0	8.0	41.8	39.8	---
10	7.3	7.3	7.3	7.3	---	32.4	---
11-15	6.7	6.7	1.8	6.7	61.3	39.7	---

*Marginal value product in dollars for one additional hour of labor.

Operator labor was used at its maximum in April, June, July, and September to prune, thin, and harvest peaches and to cane girdle and harvest grapes. Skilled labor was hired in these months to meet the excess demand for operator labor. Dual values for operator labor showed that in all but years 11 through 15, reducing the requirement of operator labor by one hour would increase the net return by more than the skilled labor wage rate ($6.74).

Bounding analysis showed that the model was quite sensitive to changes in labor resource levels, especially in June, July, and September. In years 7, 9, and 11-15, a one hour increase in these labor resource levels would cause a change in the basis of the LP solution. For this reason a parametric option of labor resource levels was run.

Pesticides and Nitrates

While production of peaches and grapes made a large difference in net returns and labor usage, the difference in pesticide and nitrate levels was rather slight. As expected, the high fungicide application rates of peaches, grapes, and potatoes caused the loading rates of fungicides on the farm to rise by 15.8 percent between year one and year 15. Despite this dramatic rise, there was essentially no change in the sum of the environmental risk indices for the fungicide programs. This suggested that the farm was not worse off with respect to fungicides (Table 10).

Table 10
Comparison of Farm Loading Rates and Risk Indices
For All Pesticide Groups

Year	1	2	3	4	5	6	7-15
Fungicides							
$\Sigma AI_{ij}X_j$	2,769	2,737	2,645	2,798	3,151	3,179	3,207
$\Sigma RI_{ij}X_j$	187	186	185	187	187	187	188
Insecticides (Groundwater)							
$\Sigma AI_{ij}X_j$	14	27	28	63	94	91	89
$\Sigma RI_{ij}X_j$	109	137	143	131	126	108	89
(Surface Water)							
$\Sigma AI_{ij}X_j$	1,923	1,832	1,711	1,737	1,820	1,845	1,864
$\Sigma RI_{ij}X_j$	916	879	878	878	892	891	891
Herbicides (Groundwater)							
$\Sigma AI_{ij}X_j$	778	748	712	715	733	741	749
$\Sigma RI_{ij}X_j$	1,046	1,011	998	961	978	985	993
(Surface Water)							
$\Sigma AI_{ij}X_j$	0	0	0	2	2	2	2
$\Sigma RI_{ij}X_j$	0	0	0	19	19	19	19
Nitrates							
$\Sigma AI_{ij}X_j$	26,796	25,858	24,708	24,840	24,637	24,545	24,452 (yr.7)
							25,029 (yr.8+)

For insecticides, there was a dramatic increase in the loading rates of those insecticides likely to contaminate groundwater due to the use of carbaryl in grapes and diazinon in cauliflower. However, the sum of the risk indices was lower, suggesting that the problem might not be as serious as the loading rates suggest. There was essentially no change in the loading rates or the sum of the risk indices for insecticides likely to contaminate surface water.

Herbicides presented the opposite case of insecticides. The loading rates of those herbicides likely to contaminate groundwater fell slightly while the loading rates of those likely to contaminate surface water rose. The sum of the risk indices followed a similar pattern.

In general, pesticide loading rates fell in years two and three when potato acreage fell and before peaches and grapes demanded heavy spray programs. Likewise, insecticide costs fell by $3,000 to their lowest level in year three ($24,627) only to rise to within $700 of their original level in years 7 through 15 ($26,964). This $700 savings after the transition to peaches and grapes represented a 2.5 percent decrease in total insecticide costs.

Nitrate levels also fell with the introduction of peaches and table grapes but rose again slightly with the increase in monoculture production of potatoes toward the end of the time horizon and the heavier fertilization required in mature orchards and vineyards. Nevertheless, a 6.7 percent decrease (1,767 pounds or almost 12 pounds per acre) from the first year was sustained.

A look at the sensitivity analysis showed that the potato/wheat rotation would come into solution if the constraints on loading rates and the maximum allowable sum of the risk indices were lowered. It can be expected that if more stringent pesticide constraints were imposed, rotations of potatoes with wheat would enter the solution despite their lower returns. Peaches and grapes could also stay at their levels if parathion were substituted for carbaryl in the insecticide program since it is not likely to contaminate groundwater.

VARIATIONS ON THE BASIC MODEL

Varying Initial Debt Levels

To determine the effects of the level of initial debt on the investment stream and crop transition pattern, a fixed interval parametric option was run, allowing debt to vary from zero to $118,209 (the maximum feasible level) at $25,000 intervals.

Grapes, with their higher investment requirements, fell in acreage while peach acreage remained stable up to the maximum debt level where it fell to practically zero. This preference for peaches over grapes could be explained by peaches' higher returns and lower establishment costs which made them even more attractive than grapes on a farm with higher debt levels. Total fruit acreage fell from 15.6 acres when initial debt was zero, to 12.1 acres when initial debt was $100,000. At the maximum feasible initial debt level, fruit acreage dropped to less than half an acre.

Major changes occurred at this maximum debt level. Cauliflower took the place of peaches and grapes as the high valued crop and potatoes were no longer grown in monoculture. At the earlier debt levels, 129 acres of the 150 acre farm had been devoted to production of potatoes in monoculture. At the maximum debt level, however, potatoes in rotation with wheat and rye replaced continuous potatoes (beginning in year seven) as the major mode of potato production. At this maximum debt level all 150 acres were grown in rotation with potatoes (75 acres), cauliflower (16 acres), and wheat (59 acres).

Severe cash flow problems developed at these higher debt levels, especially for debt servicing. Debt was carried over into successively later years in the model and new loans were required to finance investment in later periods than before since excess cash for investment was not generated until much later in the model. At the maximum debt level, all previous debt was not retired by the end of the 15 year time horizon. This resulted in a negative objective function value equal to the outstanding debt of $39,946 plus interest of $4,793.

Although capital did not seem to be too constraining at lower initial debt levels, at levels above $100,000 investment in fruit would seem unlikely. One difference between the case of a debt ridden farmer and the model's depiction is that a farmer strapped with debt would not continue to replace machinery at the rate projected in this model, but would continue to use it beyond what would normally be considered its "economically useful" life. The result remains, however, that a debt ridden farmer would be unlikely to invest in fruit. The production of high valued annual crops, such as cauliflower, would be the more likely response to declining returns from potatoes.

Varying Labor Availability

Labor was a major constraint determining the maximum level of fruit that could be grown. If a potato farmer were to begin producing peaches and grapes, he could be expected to change his labor mix to include more seasonal and unskilled workers for harvesting and thinning labor. A fixed interval parametric option was run allowing the skilled/unskilled labor ratio to vary from 1:1 to 1:3. The initial ratio was that of the base model: four skilled laborers (two operators, two hired) and four unskilled laborers. Unskilled labor was increased in increments of two workers (434 hours per month) up to a level of 12 unskilled workers. The final skilled/unskilled labor ratio reflected that found in Snyder's survey of New York fruit farms (December 1983).

In these runs, a constraint was placed on the transition into peaches and grapes allowing only 10 acres of each to be planted in the first years of the model. No limit was placed on the later plantings made in years five and six.

As unskilled labor availability increased, grape acreage fell, then rose and then fell again. Peaches showed a steady increase in acreage. With their high unskilled labor requirements, peaches became the preferred fruit as unskilled labor availability increased. At some ratios, such as 1:2 and 1:2.5, the increase in unskilled labor enabled both peach and grape acreage to increase because the new ratio allowed a fuller utilization of existing skilled labor needed for grapes.

As fruit acreage increased, continuous potato production fell. As more unskilled labor was made available, more acreage was devoted to potatoes rotated with wheat and cauliflower since this offered a higher average income than potatoes grown in monoculture. Increased availability of unskilled labor caused the rotation of potatoes with wheat not to appear because enough unskilled labor was then available to make the rotation with the double crop of wheat and cauliflower possible. Since grapes competed with cauliflower for harvest labor in September, this made peaches the preferred complement to cauliflower (Table 11). Net returns increased dramatically with the increase in labor, from $486,570 in the base model to almost two million when 12 unskilled workers were made available.

Table 11
Beginning and Ending Crop Mix Under Different Skilled/Unskilled Labor Ratios

Labor Ratio	Continuous Potatoes	Rotated Potatoes* Pt/Wt	Rotated Potatoes* Pt/Wt/Cl	Wt/Cl**	Grapes	Peaches
	acres					
Skilled:Unskilled						
1:1						
year 1	125	13	12	--	--	--
year 15	128	3	3	--	6	9
1:1.5						
year 1	103	23	23	--	--	--
year 15	106	10	10	--	5	19
1:2						
year 1	81	35	34	--	--	--
year 15	87	13	12	--	10	28
1:2.5						
year 1	59	46	45	--	--	--
year 15	64	21	20	--	7	38
1:3						
year 1	50	50	50	--	--	--
year 15	49	21	21	8	4	47

*The potato rotations were: Pt/Wt: potatoes followed by wheat (year 1); Pt/Wt/Cl: wheat and cauliflower double crop (year 2); Pt/Wt/Ry: wheat and rye cover crop (year 2).
**Wheat/cauliflower double crop (not in rotation with potatoes).

September and June continued to be the months of shortage in unskilled labor, although at the higher labor ratios, shortage of unskilled labor appeared at later years in the model.

Operator labor was always used at the maximum in April, June, July, and September. As more unskilled labor was made available, operator labor reached its maximum levels in May, August, and October as well, and June and July operator labor reached the maximum at earlier years in the model.

At the 1:2.5 labor ratio, hired skilled labor reached its maximum for the first time. This was for the month of April to help with pruning in the mature orchard and vineyard in the last years of the model. At no other time was the model ever constrained by lack of skilled labor. Operator labor was used to the maximum but skilled hired labor was always available to take up the slack.

Labor management was not captured in the model except in the requirement that a percentage of the labor needed for unskilled tasks (harvesting, thinning, and hauling) be done by skilled labor to serve as supervision. The pressures on management time and ability will dramatically increase with radical changes in crop mix like those shown under increasing levels of labor availability. Overseeing 14 workers requires much more time than overseeing two or three and such strains on management could limit plantings of peaches and grapes to less than what is seen here.

Sensitivity to Marketing Outlet and Yield

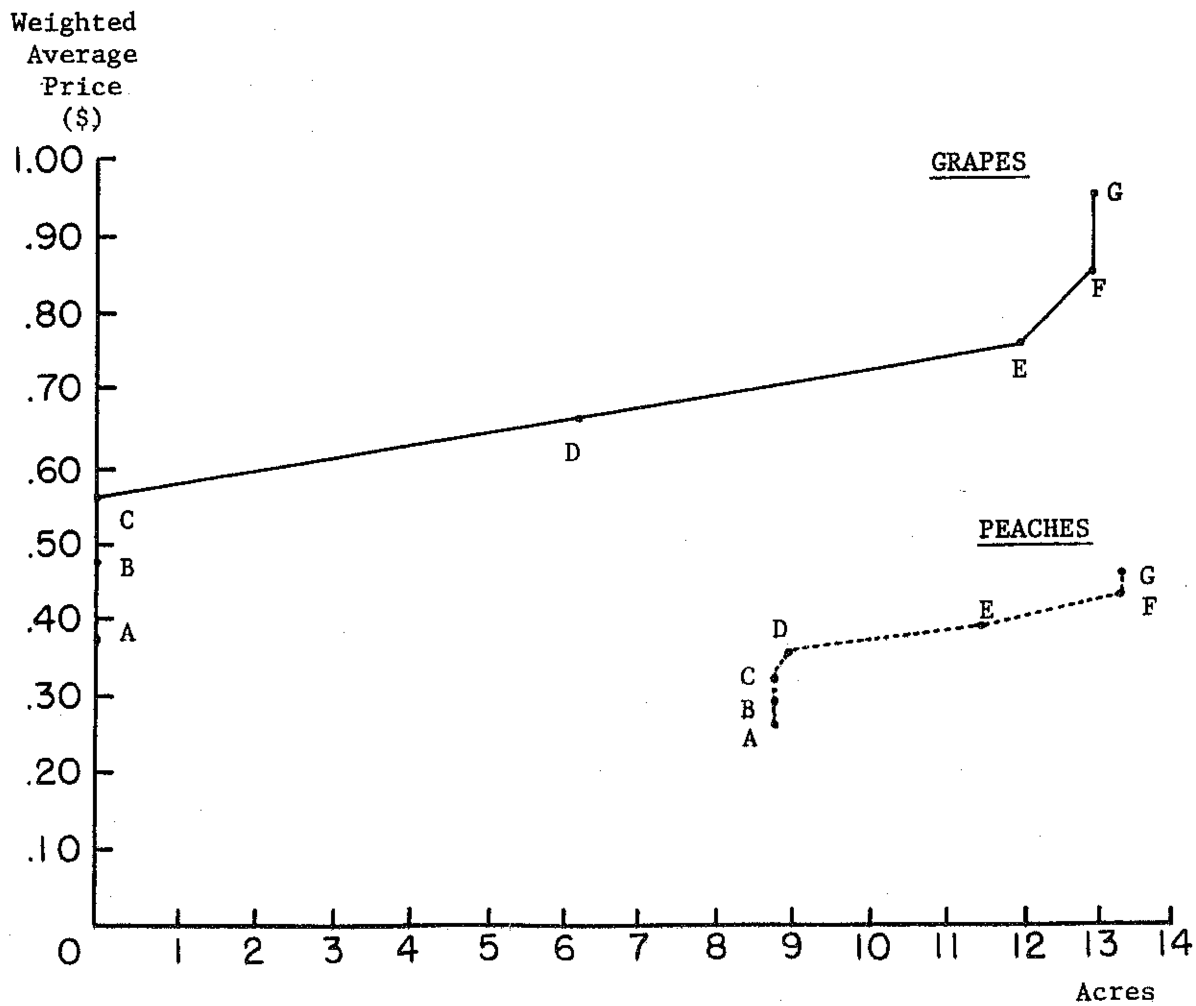
As grape and peach production on Long Island expand, it is expected that a smaller proportion of production will be marketed through direct retail channels and more through direct wholesale channels. The changing proportion of production going into each marketing channel will have an impact on the profitability and acreage devoted to fruit.

To test the sensitivity of the solution to changes in marketing channels, seven retail/wholesale marketing proportions were tested. When more than 5/6 of total production was marketed through retail channels, fruit acreage was high (13 acres each for peaches and grapes). As the proportion marketed through retail channels dropped from 5/6 to 1/3, dramatic decreases in acreage occurred. In this sensitive range, the weighted average price of the two marketing channels fell from $0.76 to $0.56 per pound for grapes and from $0.39 to $0.33 per pound for peaches. Peach acreage fell by 34 percent and grapes were no longer produced (Figure 1).

Peaches always appeared in greater acreages than grapes. To test the competition and complementarity between peaches and grapes, the model was run with only the peach option and only the grape option. When only peaches were grown, there was essentially no change in the acreage devoted to peaches. The acreage which would have been devoted to grapes was devoted to the rotation of potatoes with cauliflower and wheat instead. Continuous potato production fell by three acres and net returns dropped by five percent. When only grapes were grown, production of grapes increased by one acre. The acreage that would have gone to peaches went to the rotation of potatoes with wheat and cauliflower instead. The loss of peaches as an option caused net returns to fall by 36 percent.

Figure 1

Farm Acreage Supply Response of Peaches and Table Grapes to Various Retail/Wholesale Marketing Proportions



MARKETING PROPORTIONS

A: All Wholesale
B: 1/6 Retail, 5/6 Wholesale
C: 1/3 Retail, 2/3 Wholesale
D: 1/2 Retail, 1/2 Wholesale
E: 2/3 Retail, 1/3 Wholesale
F: 5/6 Retail, 1/6 Wholesale
G: All Retail

Because grapes always had such a low acreage, an additional run was made with yield estimates increased from 1.5 to 2.0 tons in year three, and from 3 to 5 tons in the mature vineyard (year four onward). Harvesting and marketing labor were also increased proportionally. Under these conditions, grape acreage increased by nine percent (0.6 acres) to 6.8 acres and peach acreage increased by the same percentage (0.8 acres) to 9.7 acres. Five ton yields are highly unrealistic for seedless table grapes, and yet, even at these yields, large acreages were not devoted to grapes. Thus, the superior profitability of peaches seems clear.

<u>Alternative Scenarios of Colorado Potato Beetle Control</u>

The future of potato production and Colorado Potato Beetle control on Long Island is uncertain. Past studies have suggested that rotations could help reduce the number of insecticide applications required in potato fields but the exact savings is unknown. It is also possible that decreasing effectiveness of chemical controls could cause production of potatoes in monoculture to become impossible and force all farmers to grow potatoes in rotation or not at all.

To determine the effect such changes might have on the production of fruit and the environmental risk from pesticide contamination, two additional variations of the model were run. In one, rotated potatoes were assumed to enable farmers to reduce insecticide applications by 40 percent (from 10 sprays to 6) rather than by 20 percent as in the base model. The insecticide costs of rotated potatoes were reduced by $42 or 26 percent, representing the savings in materials of approximately two insecticide sprays. Under these conditions, rotation became the dominant mode of potato production (90 acres, 41 of which were in rotation with wheat only), and potatoes produced in monoculture dropped to 42 acres. Compared with the base model, peach acreage increased by a third to 11.8 acres and grape acreage remained unchanged (Table 12).

In the other scenario, it was assumed that potatoes could not be grown in monoculture after the first year of the model. This was done to gain insight about what would be profitable if the existing profitable alternative were omitted. Total potato production dropped from 138 acres to 65 acres, all of which were grown in rotations and the rotation with wheat again represented the dominant mode. Acreage of both peaches and grapes increased over the base model, and prevented net returns from falling as much as they would have if no alternative had been offered. Even so, a 24 percent decrease in net returns (compared to the base model) was suffered but this still represented an equivalent annual net return of $24,709 over and above the $24,000 already subtracted each year for family living expenses (Table 12).

Thus, if monoculture production of potatoes did become impossible, fruit could provide a way to keep income from falling while using the same resource mix. If more labor became available, incomes could actually increase as seen in the parametric variations of labor resource levels.

In regard to pesticide risk, these scenarios dramatically improved the picture. The increase in potato rotations, especially those with wheat only, caused reductions in the loading rates and risk indices for all pesticides except groundwater contaminating herbicides and insecticides.

Table 12
Beginning and Ending Crop Mix Under Various Scenarios

Crop & Year	Base Model	Increased Rotation Benefits	No Continuous Potatoes
	acres		
Continuous Potatoes			
Year 1	125.3	125.3	72.0
Year 15	128.3	41.5	0.0
Potatoes/Wheat (Pt/Wt)			
Year 1	12.5	12.5	65.9
Year 15	3.2	45.3	65.0
Wheat/Cauliflower (Pt/Wt/Cl)			
Year 1	12.1	12.1	12.1
Year 15	3.2	4.4	4.4
Wheat/Rye (Pt/Wt/Ry)			
Year 1	--	--	--
Year 15	--	40.9	60.6
Grapes			
Year 1	--	--	--
Year 15	6.2	6.2	6.9
Peaches			
Year 1	--	--	--
Year 15	8.9	11.8	13.2

Loading rates for groundwater-contaminating herbicides also fell by 32 to 46 percent but the risk indices remained almost the same. This was due to the use of small quantities of highly toxic 2, 4-D in wheat fields.

Groundwater-contaminating insecticide loading rates increased dramatically due to increased production of fruit in which carbaryl was used. However, despite its mobility, carbaryl has a low toxicity and, thus, a low risk index which caused the overall risk indices to be lower than those in the base model.

With the increase in rotated potatoes, there was a dramatic fall in nitrate loading rates. In the base model, nitrates had only fallen 6.7 percent by year 15. Under these scenarios, nitrate loading rates fell by 25 and 34 percent, representing an average reduction of 44 to 61 pounds per acre (Table 13).

Table 13
Pesticide Loading Rates and Risk Indices Under Different Scenarios

	Base Model		Increased Rotation Benefits		No Continuous Potatoes	
	Year 1	Year 15	Year 1	Year 15	Year 1	Year 15
Fungicides						
$\Sigma AI_{ij}X_j$	2,769	3,207	2,769	2,459	2,769	2,119
$\Sigma RI_{ij}X_j$	187	188	187	135	187	110
Insecticides (Groundwater)						
$\Sigma AI_{ij}X_j$	14	89	14	102	14	113
$\Sigma RI_{ij}X_j$	109	89	109	111	109	120
(Surface Water)						
$\Sigma AI_{ij}X_j$	1,923	1,864	1,923	1,146	1,775	797
$\Sigma RI_{ij}X_j$	916	891	916	646	916	525
Herbicides (Groundwater)						
$\Sigma AI_{ij}X_j$	778	749	778	527	778	420
$\Sigma RI_{ij}X_j$	1,046	993	1,046	1,044	1,046	1,067
(Surface Water)						
$\Sigma AI_{ij}X_j$	0	2	0	2	0	2
$\Sigma RI_{ij}X_j$	0	19	0	19	0	21
Nitrates						
$\Sigma AI_{ij}X_j$	26,796	25,029	26,796	20,178	26,796	17,736
Pounds/acre	179	167	179	135	179	118

CONCLUSION

Ultimately, the viability of fruit as an alternative for Long Island agriculture lies in the ability of farmers to make the necessary changes. Attitudes and management skills must be adapted to the more intensive production and marketing systems required by peaches and grapes. These results have indicated that more ecologically sound practices, such as crop rotation and diversification, are economically feasible and provide a profitable alternative to Long Island potato growers.

This linear programming model has shown that a transition into peaches and grapes would be possible using the resources of a typical Long Island potato farm and would result in increased net returns. Specifically, diversification into peaches and grapes would permit farmers to rotate their potato fields with grains and vegetables without severe loss of income.

Employment of both skilled and unskilled labor would increase dramatically with the production of fruit. In the basic model, utilization of operator labor increased by 33 percent and unskilled labor increased by 23 percent as a result of the transition into fruit. Therefore, radical changes in the size and composition of the labor force on Long Island will be required if fruit is to become a major crop on the Island. Most likely, this will mean increased reliance on migrant labor.

Despite the high investment costs for fruit, debt retirement and cash flow did not seriously constrain the model although cash flow in the first five years was tighter than in later years of the model. The initial debt level of the farm will affect the level of fruit acreage, however, with higher debt levels affecting grapes more strongly than peaches because of their higher investment costs. These higher capital investment requirements will increase the need for intermediate term credit and could increase farmers' risks from fluctuating interest rates.

Marketing channels were quite important determinants of the level of peach and grape production. Without adequate direct retail markets (or improved direct wholesale prices), peaches and grapes would not be produced in large acreages and grapes might not be produced at all. If fruit is to become a viable, significant industry on Long Island, research and development of additional marketing channels will be needed.

As an answer to Long Island's groundwater contamination problem, the transition into peaches and grapes was shown to have slight beneficial effects in reducing environmental risk through lower loading rates and risk indices for most pesticides. However, only when larger fruit acreage caused rotated potatoes to be substituted for continuous potatoes did significant reductions in loading rates of nitrates and pesticides and risk indices of pesticides occur.

Parametric treatment of labor, debt, and marketing outlets suggests that there are wide ranges in resource combinations over which grapes and peaches are a profitable alternative worth incorporating into a farm business. Thus, it seems reasonable to suggest that diversification and rotation on Long Island potato farms are potentially profitable and feasible. Extension agents and researchers should recommend that such practices be given further consideration by farmers. Even potato rotations, despite their lower returns, can be promoted since the high returns from cauliflower and fruit can be used to offset much of the income loss. The benefits in terms of decreased risk to the environment from pesticides and nitrates lend even stronger support to such a recommendation. Thus, there appears to be a sound economic basis for encouraging more ecological practices on Long Island potato farms.

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