Evaluating Alternative Agricultural Enterprises in a Flue Cured Tobacco-Producing Region of Virginia

A Case Study

Wayne D. Purcell, Alumni Distinguished Professor
Daniel B. Taylor, Professor
and Rushan Halili, former Research Assistant

Virginia's
Rural Economic Analysis Program

Department of Agricultural and Applied Economics
College of Agriculture and Life Sciences
Virginia Tech
August 2003

Evaluating Alternative Agricultural Enterprises in a Flue Cured Tobacco-Producing Region of Virginia
A Case Study

Wayne D. Purcell and Daniel B. Taylor are
Alumni Distinguished Professor
and Professor, respectively,
and Rushan Halili former Research Assistant,
Department of Agricultural and
Applied Economics, Virginia Tech

August 2003

Agricultural Competitiveness

Executive Summary

Geographic Information System (GIS) and Linear Programming (LP) are combined to analyze cropping and livestock alternatives for tobacco farmers in Pittsylvania County. A sector of the county covering 7,926.0 acres is analyzed. GIS is used to show the location and acreage of each soil type and to identify the enterprises best suited to the soil characteristics. LP is used to generate the profit maximizing combination of enterprises given constraints of soil and land characteristics and irrigation water availability for the crops and livestock characteristic of farms in Pittsylvania County. The base year for the analysis was 1997. Broccoli and tomatoes, two representative vegetable crops, were limited to three acres each to approximate the 1997 situation. While the crops and livestock selected for the Baseline scenario are typical for the county, they may not by the specific acreage mix used by Pittsylvania County farmers in 1997. The intent was to generate a *Baseline net revenue* using the profit maximizing combinations of tobacco and other selected farm enterprises before the start of the significant quota cuts after 1997.

The results of ten scenarios analyzed show that any restrictions on tobacco production reduced revenue compared to the Baseline. When tobacco was reduced by 50 percent and tomato and broccoli were not restricted by water availability and were allowed to enter with as many as 100 acres each, the profit maximizing solution was only $65,559 (2.1 percent) less than the $3,107,687 Baseline. Growing increased acreages of tomatoes and broccoli could lead to net revenues above those received before tobacco quota reductions. But the current local and regional markets could not absorb large increases in supply of broccoli and tomatoes or other alternatives such as sweet corn without reductions in selling prices. Growers would then have to compete in the global commodity market. For the quantity of any high value fruit or vegetable to be increased sufficiently to completely offset revenue lost by tobacco quota cuts, new on-farm investments would be needed and market networks in surrounding population centers would have to be developed.

Beef cattle are often recommended as an alternative in Southside. The GIS/LP model was run for several iterations, increasing the revenue above all variable costs from beef cows to as much as $100 per cow unit. Reducing tobacco acreage by 50 percent and restricting the beef cow production to land suitable only for pasture or hay allows 260 cow units in the study area. Net revenue is still $658,515 (21.2 percent) below the Baseline. When beef cows are not restricted to soils and slopes suitable only for pasture or hay acreage, 972 cow units could be raised and would require 2,430 acres (at 2.5 acres per cow unit). But the returns above variable costs at $100 per cow unit are only $40.00 per acre.

An alternative using contract hog finishing was always in the profit maximizing set of enterprises. Swine finishing floors could be an effective revenue supplement on tobacco farms, but such intensive livestock programs raise environmental questions and are not always encouraged in tobacco producing counties.

Using GIS and LP in combination to evaluate the possible crop and livestock combinations to maximize profits is a powerful tool. The implications of varying levels of tobacco quota can be examined. Restrictions can be placed on acreage or water availability to simulate what farmers face on their farms. The thresholds generated make it easy to see how much price must increase or how much costs must decrease for an enterprise to enter the profit maximizing set of enterprises or to see when any particular enterprise will leave the profit maximizing set of enterprises as costs or selling prices change. Such information on threshold costs or prices can give direction to strategic planning and diversification efforts. The results show, for example, that tobacco stays in the profit maximizing set of enterprises on some soil types even with the price as low as $0.91 per pound. Some experts do not think flue cured tobacco prices would go that low if the program and production quota were eliminated.

The power of sophisticated analysis is apparent. With a 50 percent cut in tobacco quota and with the high value broccoli and tomatoes limited to no more than 15 acres each, the profit maximizing set of enterprises generates a revenue of $2,583,160, only 16.9 percent below the Baseline revenue of $3,107,687. This type of help in making adjustments can keep tobacco-producing families in farming.

Table of Contents

Introduction

Each year, farmers must decide what crops to produce. In the Southside Virginia flue cured tobacco producing counties, the decisions were relatively easy prior to the late 1990s. For farms with tobacco quotas, tobacco has been the focus of attention because of its profitability. Financed by assessments to tobacco farmers, a federal stabilization program that protected production quotas and provided price supports blocked the over production and low prices that have plagued many field crops.

The tobacco situation and outlook has changed dramatically in recent years, forcing tobacco farmers to look at alternatives to provide for their futures. Effective quotas for flue cured tobacco were at 936.1 million pounds in 1990, increased to a high of 1,019.4 million pounds in 1997, and have since plummeted to an announced 540 million pounds for the 2003 crop. Social attitudes toward tobacco use have changed and per capita consumption of cigarettes has declined from 2,543 in 1993 to 1,906 in 2002. The decreased consumption was at least partly due to price increases for premium brands, with wholesale prices increasing from $0.57 per 1,000 cigarettes in 1995, to $0.65 in 1997, to $1.15 in 2000, and to $1.38 in 2002 as court actions of the national settlement imposed costs on manufacturers. Exports of unmanufactured flue cured tobacco declined from 256.7 million pounds in 1997 to 190.2 million pounds in 2001/02 marketing year. As of January 2002/03 of the marketing year, exports were down 25.1 percent from the same period a year earlier. Cigarette exports were at 243.9 billion in 1996 and declined to an estimated 127.2 billion in 2002. Average flue cured tobacco prices to farmers have remained between $1.75 and $1.95 per pound, but with the declines in quotas have come sharp declines in farm level revenues (USDA (c)). Farm families who have historically relied on tobacco for much of the family income are facing major adjustment problems.

The forced adjustments at the farm level will have a significant economic impact in Virginia. Virginia is the sixth largest domestic tobacco producing state following North Carolina, Kentucky, Tennessee, South Carolina, and Georgia. Tobacco is, by a significant margin, the number one cash crop in Virginia. Cash receipts for tobacco in 2001 were $124.4 million, far in excess of the $80.5 million for the number two cash crop, soybeans (VASS, 2001).

No single alternative agricultural enterprise will generate as much revenue across significant acreages as tobacco. The biggest challenge for farmers will be to find profitable alternative uses for the land, labor, and capital previously used in producing tobacco. Tobacco producers will have different options, depending on the characteristics of their farms. Reaves and Purcell (1996) identified four broad alternatives that allow farm families to remain on their farms. They could (1) remain in tobacco farming; (2) diversify and continue to farm; (3) obtain added financing to expand or diversify or both with an objective of continuing to be in farming; or (4) find off-farm employment either on a full-time or part-time basis. The purpose of this report is to provide a method to evaluate options that will help ensure that the farm family will remain in farming.

An effective analytical way to evaluate the profitability of alternative on-farm enterprises is needed to guide farmers' adjustment and diversification decisions. The research reported in this Rural Economic Analysis Program (REAP) report will help farmers and extension educators to better understand the process of evaluating alternatives and to make better informed decisions about farm-level diversification and related investments. This research extends beyond traditional partial budgeting or even whole-farm planning. It integrates opportunities based on the economic marketplace within which farmers operate and the soil characteristics and production possibilities of the farm. The focus is on adjustments on tobacco farms, but the analytical process is appropriate for any farm-level adjustment and strategic planning process.

The Analytical Approach

A case study of 7,926.0 acres located in Pittsylvania County, Virginia is used for analysis and demonstration of the analytical framework. The area is the western portion of Sheet 65 from the *Soil Survey of Pittsylvania County and the City of Danville, Virginia* (Figure 1).

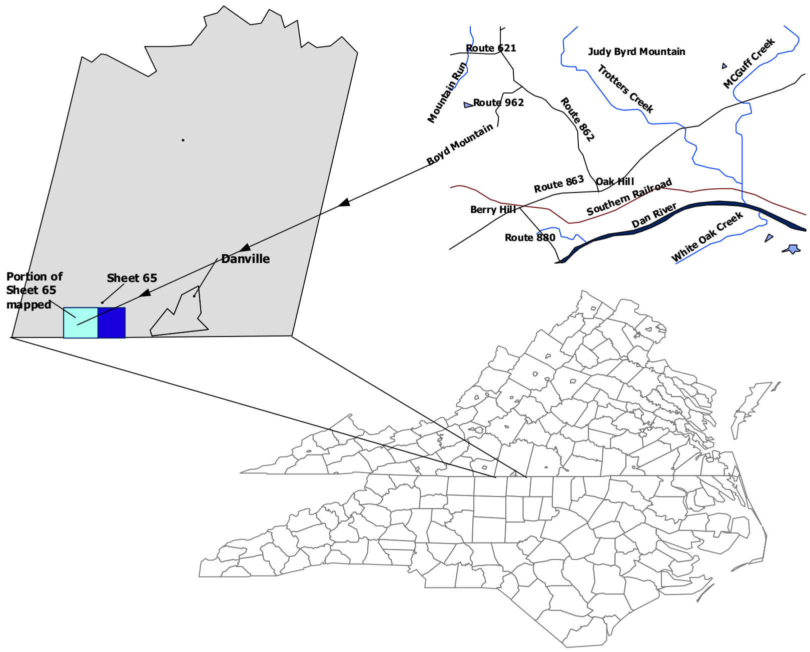

Figure 1. Location of case study area

This area was chosen for several reasons. It is part of Pittsylvania County, the number one flue cured tobacco producing county in the state and a county that is facing significant adjustments in response to the sharp cuts in tobacco quota. Production of nearly 13 million pounds (12,741,000) of flue cured tobacco in the county in 2001 attests to the importance of tobacco in this area (VASS, 2001).

The soil diversity of the area also was a reason for its selection. The area contains more soil types included in soil capability classes 1 to 4 [the broadest grouping of suitability of soils for most kinds of field crops (USDA (b), p. 97)] and more prime farmland soil types than other areas of the same size in Pittsylvania County. Prime farmland is defined by USDA as that land best suited to food, feed, forage, fiber, and oilseed crops (USDA (b), p. 94). Soil classes that are excluded from the study are those soil classes usually covered with forests, located in low productivity and unimproved pasture, covered with water, or designated residential or commercial. The excluded area consists of 2,454.3 acres or 31.0 percent of the study area.

Prices in the study are taken as given and are assumed to be the same for all producers. A single producer is usually too small to influence the market price of a farm commodity. If a relatively large number of producers were to adopt the same new enterprise, the analytical process would need to be adapted to show that the supply increase could reduce selling prices. A supply impact is especially important for such alternative enterprises as direct marketing of tomatoes or sweet corn or pick-your-own strawberries. These enterprises might be profitable and generate significant new revenue if one or two farmers in the area adopt them, but widespread adoption by a number of farmers can saturate the local market and push prices sharply lower, causing profitability to disappear.

Assuming that input prices are the same for all local farmers, the crop budget for different farms can still vary due to management and yield factors such as deficit or surplus rainfall, soil pH, inherent soil fertility, and soil organic matter content. Yields and costs used in the budgets are adjusted according to differences in soil characteristics. Examples of budgets adapted for this study from the Virginia Cooperative Extension database are shown in Appendix B.

Enterprises considered in this analysis are a sample of enterprises that are typically produced in the study area: tobacco, corn, barley, double-cropped wheat and soybeans, cotton, wheat, soybeans, broccoli, tomatoes, beef cows calving in the spring, and contract swine production (Table 1). The selected enterprises were not intended to be an exhaustive listing of all enterprises that are or could be carried out in the study area. They were selected as a representative list that includes most types of production agriculture. Enterprises such as greenhouse production that use existing greenhouse facilities on some tobacco farms and nursery operations could be added as enterprises in the future if they show profit potential. *Being profitable, as used in this study, means a return to management and fixed investments above the variable costs of growing and selling the crop.*

Table 1. Acronyms for enterprises

Enterprise	Acronym
High yield tobacco	*Tob1*
Average yield tobacco	*Tob2*
Low yield tobacco	*Tob3*
High yield corn	*Cor1*
Average yield corn	*Cor2*
Low yield corn	*Cor3*
Average yield barley	*Bar2*
Low yield barley	*Bar3*
High yield, double cropped wheat and soybeans	*Wds1*
Average yield, double cropped wheat and soybeans	*Wds2*
Low yield, double cropped wheat and soybeans	*Wds3*
High yield wheat	*Whe1*
Average yield wheat	*Whe2*
Low yield wheat	*Whe3*
High yield soybeans	*Soy1*
Average yield soybeans	*Soy2*
Low yield soybeans	*Soy3*
Average yield cotton	*Cot2*
Low yield cotton	*Cot3*
Average yield broccoli	*Broc2*
Average yield tomatoes	*Tom2*
Beef cows	*Bec*
Contract swine	*Cos*

Geographical Information Systems (GIS) Analysis

Georgraphical Information Systems (GIS) analysis can be used as a valuable first step in a diversification plan. The goal is to determine whether the soil and climatic characteristics of a specific site make the site suitable for particular crops. Soil and climatic factors that can affect yields and production possibilities and similar attributes that management cannot improve at a reasonable cost are considered as given. Examples of these difficult to change factors are soil depth, soil series, soil texture, slope, flood potential, frost dates, and average summer temperatures. Some soil and climatic characteristics can be altered by management to increase crop yields. For example, lime can be applied to change the soil pH, and irrigation can be used to supplement rainfall levels that may not support specific cropping activities. But these changes that influence yields and production possibilities have costs associated with them.

ArcView 3.2[1] was used to create the map layers associated with soil characteristics for each soil type, water availability, and enterprise requirements for soil attributes. The initial selection of a set of suitable enterprises can then be approached based strictly on yield factors. Production factors that affect yields are based on T.W. Simpson, *et al*. and Hanson. Crop yields are grouped in three categories: high, average, and low. Once the fields are identified as suitable for certain enterprises according to the yield classification, any needed adjustments to costs of management intervention in the enterprise budgets are made.

The fields that are suitable for each enterprise are found by matching the required factors of production with the given characteristics of the study area fields. For example, *Tob1* fields are those selected from fields that have deep soil, sandy soil texture, 2 to 7 percent slope, and little or no potential flooding periods. Average summer ambient air temperature is 70 to 80 degrees. The GIS program is used to identify the available fields with the characteristics that match needs for *Tob1* production. The same procedure is used to find the fields or sites for all other enterprises considered in the analysis.

GIS output provides a map of the areas associated with each enterprise and a table of soil types. Maps of *Tob1* and *Tob2* potential production areas are shown in Figures 2 and 3, respectively. Unquestionably, the fields with higher yield potentials are limited, while more potential acreage exists for average yields. Since per unit costs of producing tobacco will vary inversely with yield in pounds per acre, relatively higher selling prices or higher program support prices will be needed or relatively lower net returns will be received if tobacco production is to extend to average yield or low yield fields, which tend to have higher per unit costs of production.

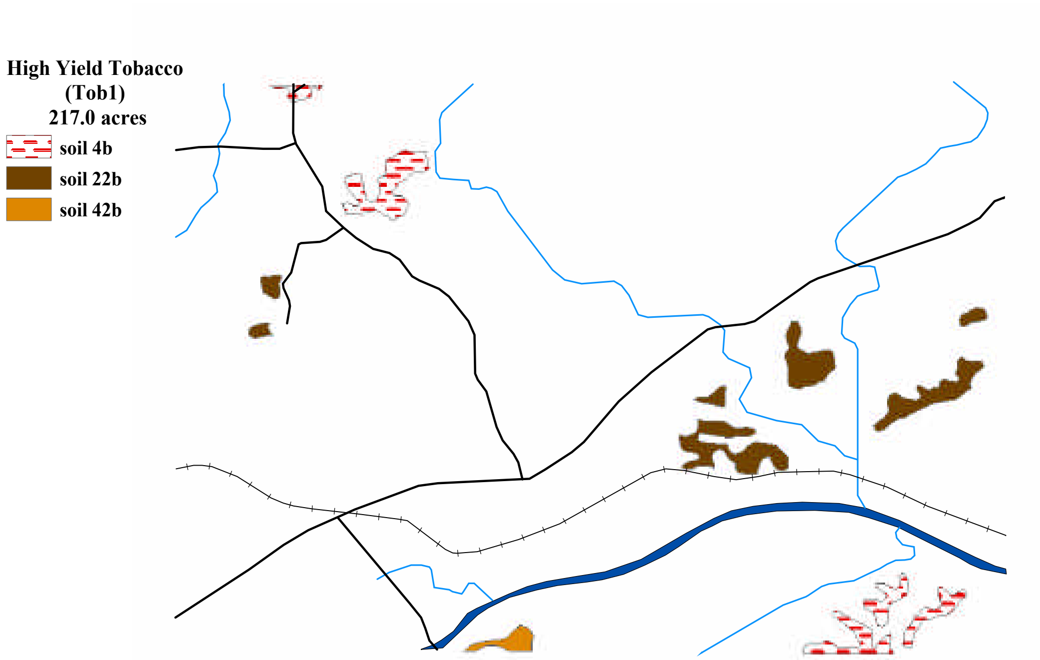

Figure 2. Map of fields having high yield tobacco potential[2]

---

[1] *ArcView 3.2*, produced by Environmental Systems Research Institute, Inc. (ESRI), is a Geographic Information System (GIS) software program.

[2] Soil types are identified in Appendix A, Table A1.

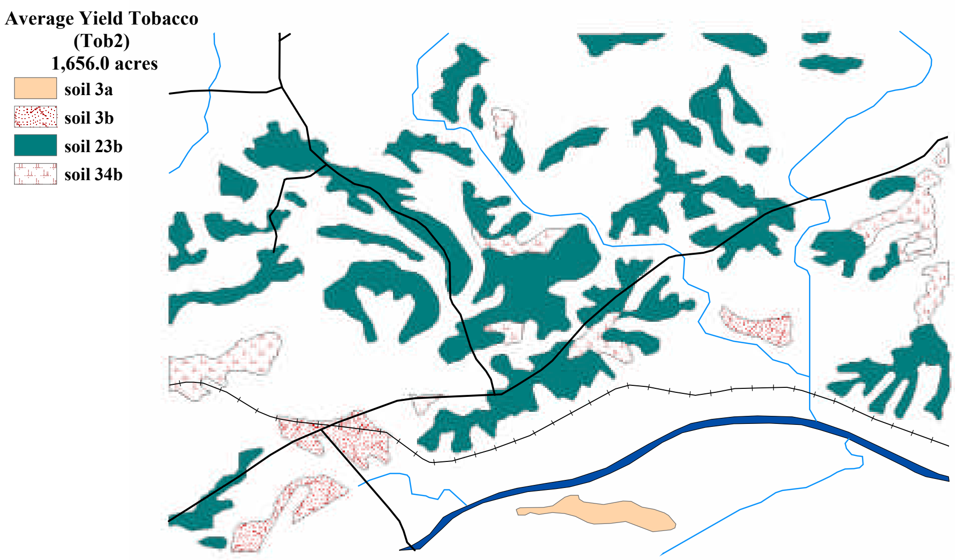

Figure 3. Map of fields having average yield tobacco potential

Further illustrations of the GIS database application help clarify what is accomplished by the study. If, for example, wheat is a profitable crop only at relatively high prices and high yields, the initial GIS-based filtering of potential enterprises for profitability might largely rule out the possibility of significant acreages in *Whe1* because of soil requirements. Only a very small area has the characteristics needed for *Whe1* (Figure 4). The likelihood of farmers making a mistake and investing in wheat-producing equipment to diversify into wheat production should be significantly reduced by the early filtering of enterprises with the GIS analysis since that analysis shows little available acreage for high yield wheat.

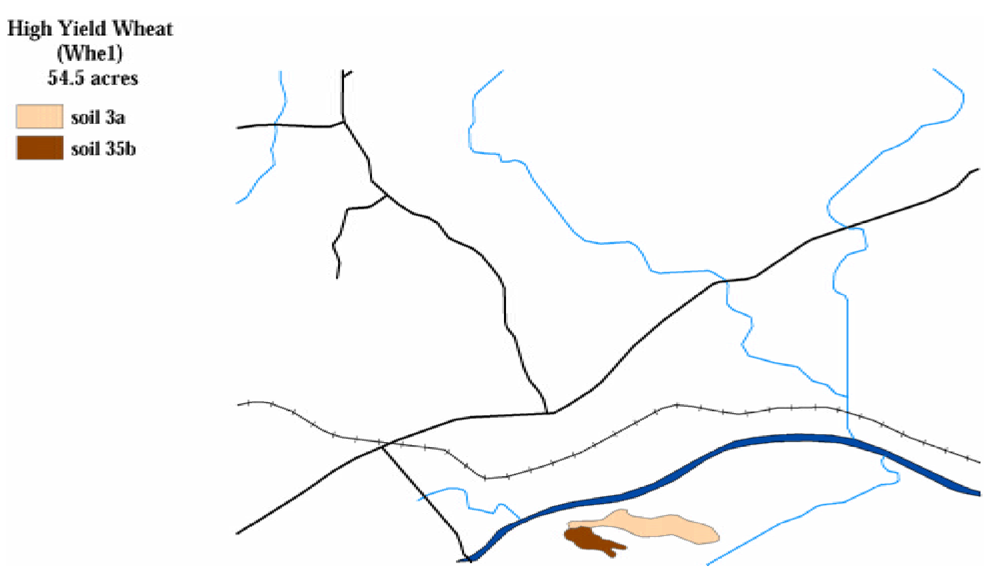

Figure 4. Map of fields having high yield wheat potential

By contrast, Figure 5 shows significant acreage would be appropriate for *Tom2* or *Broc2* if these crops are profitable at average yields per acre. If a large supply response results in the local and regional markets being saturated, however, a secondary market in the broader national market that would not impose huge price discounts would be needed to justify very large acreages of *Broc2* or *Tom2*.

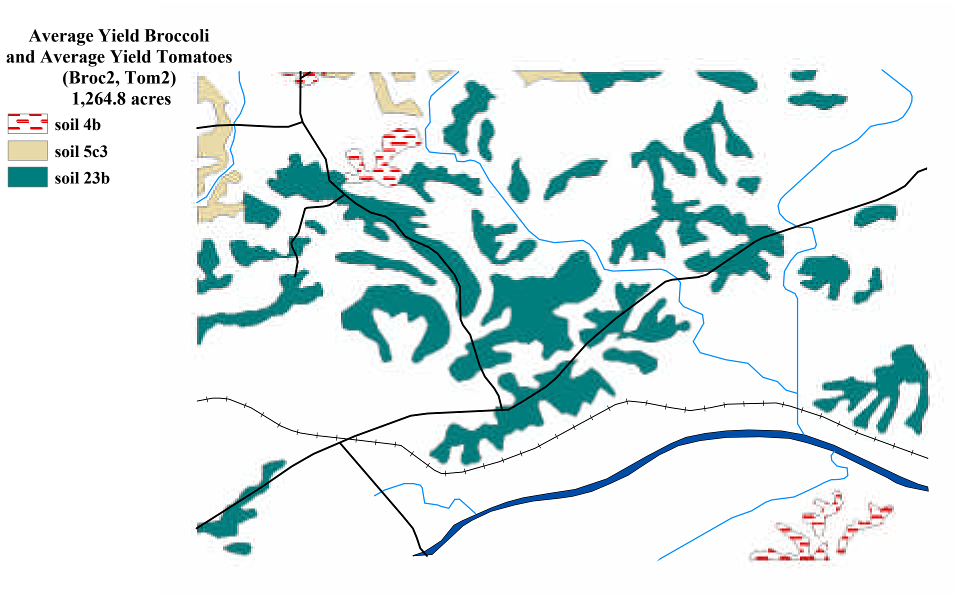

Figure 5. Map of fields having average yield broccoli and tomatoes potential

The first filter, therefore, is the GIS system to identify fields with soil characteristics that determine yields and, indirectly, costs of production. GIS will help to show that it is unlikely that low or even average yield production possibilities will be competitive, especially for widely grown grain, fiber, and oilseed crops. These guidelines, based on the biologically constrained production possibilities, will help producers focus on promising enterprises and avoid wasting investment dollars on enterprises or diversification schemes that have little chance of being profitable.

Market Window Analysis

For enterprises such as vegetables where planting and marketing times can be adjusted through management, market windows should be identified. A market window, or marketing opportunity, is identified when the average historical price for an identified time segment within the year is above the per unit variable costs of production.

Market window analysis will often be limited by the availability of data. Local markets that might offer higher prices are often not considered in a market window analysis because of a lack of price data. Another significant limitation, which comes from using historical prices to conduct market window analysis, is that historical prices show a general tendency for price patterns but similar seasonal patterns may not be observed in any given year.

Recognizing the difficulties associated with available data to calculate market window possibilities, producers need to examine minimum, maximum, and average selling prices. These prices would then be compared to the cost of production to determine if a market window exists that allows the sale of the produce at a price above variable (out-of-pocket) production costs. Prices above average variable costs are used rather than average total costs because the investments in land and other fixed capital and equipment vary significantly across operations.

Market window analysis is demonstrated in this study using prices for tomatoes and broccoli collected from terminal markets. Terminal markets are large national and global markets rather than a local market or network of regional markets that might command higher prices. Market prices for the two vegetables are found at the University of Florida website, *http://marketing.ifas.ufl.edu/* (last accessed 21 July 2003).

Figure 6 demonstrates average price patterns for tomatoes at the Atlanta terminal market for weeks 33 through 43 (August through late October for the five years from 1994 to 1998). During that period, a significant profit opportunity was available in weeks 33 and 34 and 42 and 43 if variable costs per carton were below $7.00. It is important to remember that a response by a large group of producers to the apparent profit opportunity can generate a supply response big enough to drive prices down. Such supply-driven price responses are not usually considered in market window analyses.[3]

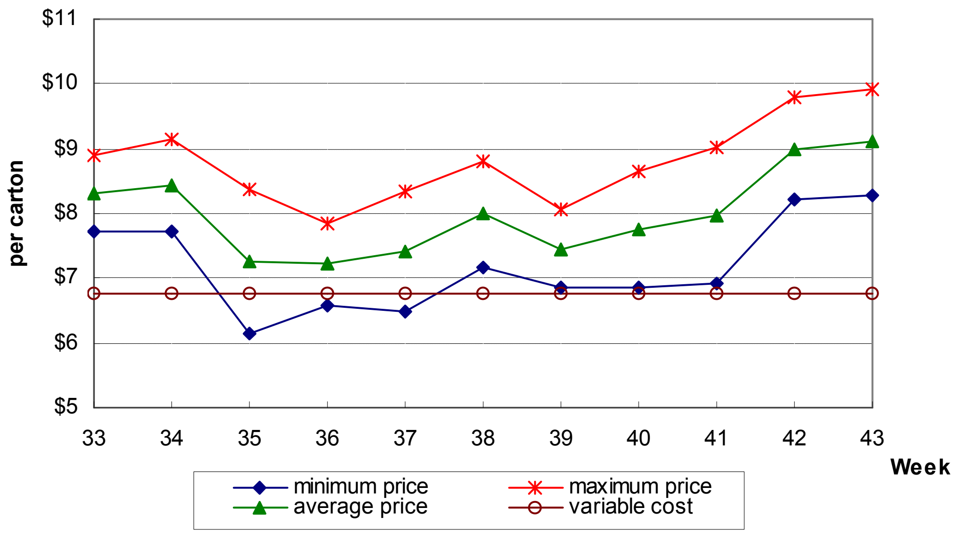

Figure 6. Market window for tomatoes, Atlanta Market, with price range and variable costs per carton

For any seasonal crop that allows changes in the timing of planting and marketing, a similar examination needs to be completed using recent data to determine the presence of market windows. If the data show no time period during which the historical prices were significantly above variable costs of production, the enterprise will be largely eliminated unless costs can be reduced or higher prices can be secured elsewhere.

Linear Programming, a Profit Maximizing Model

After determining the potential enterprises and adjusting costs and selling prices in the budgets, the next step is to effectively and systematically evaluate potential enterprises to find the profit maximizing subset of enterprises. This necessary strategic planning step is accomplished with a Linear Programming (LP) model.

Not all resources needed for farm enterprises are available in unlimited amounts. Constraints on resources such as land, acreage for crop rotations, selling and buying activities, irrigation, and livestock numbers can be provided for in the LP model. For example, the LP model limits a particular enterprise to the appropriate number of suitable acres based on the GIS analysis. Furthermore, LP simultaneously considers the trade-offs among resource use in alternative enterprises.

[3] In more sophisticated efforts, research based estimates of demand elasticity can be used to approximate how much price will decrease for a given percentage increase in supply if demand is constant. Technically, elasticity is a price-quantity relationship that can be expressed as Elasticity = % change in quantity/ % change in price. For many farm-level and widely grown commodities, research estimates show a demand elasticity near – 0.5, which means a 1 percent increase in supply will prompt a 2 percent decrease in price. The potential for large supply increases to drive prices down is always present.

Developing a sustainable farming system requires crop rotations. Rotations are, therefore, established for land that is suitable for the specific set of rotated crops. Limitations on the number of *Bec* or the number of *Cos* are established only to consider the profitability of these enterprises and do not represent any technical constraint. Technical constraints could be added if, for example, local ordinances limited the number of confined animal units per acre. In addition, if livestock or poultry enterprises enter the profit maximizing array of enterprises, sensitivity analysis can indicate whether production will still be profitable if local zoning or environmental constraints add to the costs of the enterprise.

While the costs of operating capital and machinery operation are included in the budgeted costs per unit of production (Appendix B), no constraints are assumed on labor, capital, and machinery. Farmers can borrow money to buy machinery or they can hire more labor. A more sophisticated LP model could include a bi-weekly machinery schedule, labor constraints in certain time periods, timing of irrigation versus water availability for irrigation, or a combination of any of these resources. However, such additional sophistication is not needed for this basic analysis.

The whole study area is treated as one farm. First, ten scenarios, including a baseline scenario as a basis for comparison, are evaluated followed by a sensitivity analysis of some components of the LP model. All scenarios and the differences that distinguish them from the Baseline, Scenario 1, are summarized in Table 2. The Baseline scenario shows the profit maximizing solution considering the selected set of crops typically planted in Pittsylvania County *with no reduction in tobacco quota*. Because this Baseline scenario maximizes profits, the net returns may be higher than actual net returns in the area in the 1997 base year where the crop/livestock mix had not been optimized. Therefore, any comparisons to the Baseline scenario result in alternative crop and livestock enterprises having to compete with the high-value tobacco enterprises and with the other enterprises in profit maximizing combination with tobacco before any tobacco quota reductions. It will be impossible, therefore, for any LP results to show a revenue level above the revenues in the baseline solution without a large increases in another high value enterprise such as tomatoes, broccoli, or contract swine.

The completed analysis incorporates variable costs in the LP model (Table 3). Fixed costs depend on individual farm conditions and management with large differences in fixed costs existing across producers. While fixed costs for individual operations are important factors to be considered, the variable costs associated with an enterprise will determine whether that enterprise enters the profit-maximizing solution in a diversification strategy and makes some contribution above variable costs to management and the fixed investment. Once the profit maximizing set of enterprises for each scenario has been generated by the LP algorithm, sensitivity analysis can be used to provide the answers to questions such as "How low can the price go before this enterprise leaves the profit maximizing solution?" or "Would tobacco still be in the profit maximizing set of enterprises at the lower prices that would result if the tobacco program were voted out?"

Results

The Baseline scenario, Scenario 1, is the profit maximizing cropping and livestock mix generated by the LP model for the enterprises considered in the study area in 1997. It includes *Tob1*, *Tob2*, *Tob3*, *Cor1, Wds1*, *Whe1, Whe2, Soy2, Cot2, Soy3, Cot3, Broc2*, *Tom2*, and *Cos*. (Maps showing soil acreage locations for each enterprise in the baseline scenario and for hay/pasture are in Appendix A.) No *Cor2*, *Cor3*, *Bar2*, *Bar3*, *Wds2*, *Wds3*, *Whe3*, *Soy1*, or *Bec* entered the profit maximizing solution for the Baseline scenario. In this scenario, *Broc2* and *Tom2* were limited to only 3.0 acres each to reflect the small production of each in the study area in 1997. The revenue above variable costs from the Baseline scenario, $3,107,687, becomes the standard against which other scenarios will be evaluated—a level of revenue that is not likely to be exceeded when scenarios with reduced tobacco quota are being considered.

Table 2. Distinguishing features and intentions of LP scenarios

Scenario	Broccoli acreage limit (≤)	Tomatoes acreage limit (≤)	Tobacco reductions	Irrigation constraint (inches/acre[a])	Intention
1	3	3	none	0.95	Describe 1997 situation (Baseline).
2	3	3	1/3 acreage reduction	0.95	Reflect a 1/3 decrease in tobacco quota.
3	3	3	1/2 acreage reduction	0.95	Reflect a 1/2 decrease in tobacco quota.
4	3	3	2/3 acreage reduction	0.95	Reflect a 2/3 decrease in tobacco quota.
5	6	6	1/2 acreage reduction	0.95	Determine the optimal enterprise mix in presence of more vegetables.
6	6	6	1/2 acreage reduction	1.04	Determine the optimal enterprise mix in presence of more irrigation.
7	6	6	only *Tob1*	0.95	Determine the optimal enterprise mix in presence of only high yield tobacco.
8	15	15	2/3 acreage reduction	0.95	Determine the optimal enterprise mix in presence of 2/3 cuts in tobacco quota and more vegetables.
9	15	15	2/3 acreage reduction	1.04	Determine the optimal enterprise mix in presence of 2/3 cuts in tobacco quota and more vegetables and irrigation.
10	15	15	100% reduction	0.95	Determine the optimal enterprise mix in absence of tobacco.

[a] A total of 5,198.1 acre inches of water for irrigation was available in 1997 for the 5,471.9 acres of study area used for production. Thus, 0.95 acre inches of water are available for each acre in the study area.

The Baseline solution illustrates the behind-the-scenes dynamics at work in the LP model. Some findings, like *Soy1* not included in the Baseline but *Soy2* and *Soy3* being included, may seem counter-intuitive. However, this result occurs because more profitable enterprises use the better soils that *Soy1* with its higher yields would need. *Cor1* is in the solution, but *Cor2* and *Cor3* are not because more profitable alternatives use the lower yielding soils that *Cor2* and *Cor3* would otherwise have used. By simply observing prices and costs, one cannot anticipate such a complex, interactive solution. The LP algorithm can evaluate such alternatives and, very importantly, LP allows analysis of what changes in prices or costs or both would be needed for the optimal mix of enterprises to change.

Table 4 shows total net revenue (total revenue above variable costs), net revenue per acre, acreage for crops, total crop acres used, number of cow units, and contract swine in various enterprises for each scenario. Selling prices and average variable production costs (Table 3) are held constant for this analysis. Across all scenarios, the limits imposed by soil and other resource availability are apparent. *Wds1* is possible on only 39.5 acres because of soil quality as indicated by the GIS analysis. *Cos* requires relatively little acreage and could possibly be put on some of the 2,454.3 acres not available for crop production or pasture. In all scenarios, *Broc2*, *Tom2*, and *Cos* entered the solution at the maximum allowable levels. Allowing any or all three enterprises to come in at significantly higher levels would

Table 3. Prices, yields, and variable operating costs for enterprises considered for optimum mix

Enterprise	Units	Price/lb ($)	Yield/acre	Variable Costs ($) Per acre	Per unit
Tob1	pounds	1.78	2,700	2,453.91	0.91
Tob2	pounds	1.78	2,400	2,360.60	0.99
Tob3	pounds	1.78	1,800	2,314.92	1.29
Cor1	bushels	2.50	100	236.33	2.36
Cor2	bushels	2.50	90	223.60	2.48
Cor3	bushels	2.50	70	212.38	3.03
Bar2	bushels	2.07	80	135.67	1.70
Bar3	bushels	2.07	70	125.11	1.79
Wds1 wheat	bushels	2.78	50	235.19[b]	—[c]
soybeans	bushels	5.41	30		—[c]
Wds2 wheat	bushels	2.78	45	236.91[b]	—[c]
soybeans	bushels	5.41	25		—[c]
Wds3 wheat	bushels	2.78	40	225.30[b]	—[c]
soybeans	bushels	5.41	20		—[c]
Whe1	bushels	2.78	75	181.35	2.42
Whe2	bushels	2.78	65	177.35	2.73
Whe3	bushels	2.78	50	161.98	3.24
Soy1	bushels	5.41	35	125.34	3.58
Soy2	bushels	5.41	30	130.70	4.36
Soy3	bushels	5.41	35	116.4	4.66
Cot2	pound	0.60	650	347.00	0.54
Cot3	pound	0.60	600	347.15	0.59
Broc2	20 pound carton	10.18	370	1,920.58	5.19
Tom2	25 pound carton	7.99	1,600	10,000.96	6.25
Bec steers	100-wt	61.00	45		248.47[d]
heifers	100-wt	48.00	30		
Cos	3 groups/year	4,557.00[a]	490/group		5,190.00[e]

[a] per group sold receipts based on net feed conversion and weight gain
[b] includes both wheat and soybean costs per acre
[c] did not separate per unit costs for double-cropped wheat and soybeans
[d] per cow unit, includes cost of cull cows and bulls
[e] per group sold

raise the revenues toward or possibly even above the level from the baseline $3,107,687. *Bec* never enters the optimal solution in any of the scenarios, due to the relatively low prices for steer and heifer calves in 1997.[4]

The top three scenarios based on total net revenues are Scenario 1 (Baseline), Scenario 2, and Scenario 6. Revenues of Scenarios 2 and 6 are $2,653,571 and $2,583,160, down 15.6 and 16.9 percent, respectively, from the $3,107,687 revenue in the Baseline. Clearly, these LP results could not have been anticipated with a less interactive analysis, such as comparing enterprise budgets. Further, these results demonstrate the power and value of the LP analysis in a strategic planning process since tobacco quota was reduced 33 and 50 percent for Scenarios 2 and 6, respectively. The decreases in revenue were much smaller than the decreases in tobacco quota, results that could not have been anticipated without detailed analysis.

Scenario 2, a 1/3 or 33 percent cut in tobacco quota (Table 2), shows tobacco acreage decreased by only 20.9 percent. Both *Tob1* and *Tob3* decreased acreage, but *Tob2* acreage increased as the LP model reorganized enterprises using GIS constraints on soils to maximize profits. Reducing *Tob1* would

[4] *Bec* is discussed in more detail in the section on sensitivity analysis

Table 4. Optimal farm plans: acres in various enterprises, total net revenue, and net revenue per acre.

	Scenario I Baseline	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10
Total net revenue	3,107,687.00	2,653,571.00	2,426,517.00	1,758,523.00	2,428,544.00	2,583,160.00	652,414.00	1,813,390.00	1,813,390.00	183,779.00
Per acre net revenue[a]	627.53	528.12	479.48	361.75	480.47	502.84	151.4	373.04	373.04	45.65
	----------acres----------									
Tob1	217.03	144.69	108.52	72.34	108.52	108.52	217.03	72.34	72.34	–
Tob2	643.07	715.41	751.58	552.00	745.33	828.00	–[b]	552.00	552.00	–
Tob3	1,441.16	960.77	720.58	480.39	720.58	720.58	–	480.39	480.39	–
Cor1	486.20	486.20	486.20	486.20	486.20	486.20	486.20	486.20	486.20	486.20
Cor2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cor3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bar2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bar3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wds1	39.50	39.50	39.50	39.50	39.50	39.50	39.50	39.50	39.50	39.50
Wds2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wds3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whe1	15.04	15.04	15.04	15.04	15.04	15.04	15.04	15.04	15.04	15.04
Whe2	463.60	608.28	680.62	517.22	668.37	751.04	43.39	493.22	493.22	242.41
Whe3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soy1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soy2	743.16	706.99	688.90	788.7	692.03	650.70	950.27	788.70	788.70	950.27
Soy3	77.15	317.34	437.44	557.53	437.44	437.44	797.73	557.53	557.53	797.73
Cot2	743.16	706.99	688.90	788.70	692.03	650.70	950.27	788.70	788.70	950.27
Cot3	77.15	317.34	437.44	557.53	437.44	437.44	797.73	557.53	557.53	797.73
Broc2	3.00	3.00	3.00	3.00	6.00	6.00	6.00	15.00	15.00	15.00
Tom2	3.00	3.00	3.00	3.00	6.00	6.00	6.00	15.00	15.00	15.00
Bec (cow units)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cos (head)	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00

[a] includes crops only, not *Bec* or *Cos*.
[b]– not applicable

probably not have occurred to most farmers. LP/GIS analysis resulted in smaller profit reductions than expected and with *Tob1* acreage reduced.

Restrictions on tobacco make acreage available for other crops. The acreages of the remaining enterprises change in favor of *Whe2*, *Soy3*, and *Cot3*, decreasing the acres of *Soy2* and *Cot2*. The *Whe2* enterprise increases significantly, occupying land with average yield potential, and moving the increases in cotton and soybeans to low-yield acres. Though impressive, Scenario 2 results do not look as good, in some respects, as the findings for Scenario 6 where tobacco quota was cut by 50 percent.

In Scenario 6, with a 50 percent tobacco quota reduction, the revenues from tobacco were partially replaced by increased soybean, wheat, cotton, broccoli, and tomato production. Once again, acreage reductions compared to the Baseline occurred in *Tob1* and *Tob3* and an increase in *Tob2*. Allowing a 10 percent increase in irrigation water prompted a doubling of *Broc2* and *Tom2* production from the three acres in the Baseline to six acres, the maximum allowed, in Scenario 6. As the irrigation restriction is relaxed, better revenues from tobacco and from the high value crops, like broccoli and tomatoes, start to push revenues up. Irrigated tobacco, even on average yield soils, is more profitable than alternatives such as cotton and soybeans. With tobacco quota cut by 50 percent, the revenues in Scenario 6 were only down 16.9 percent ($524,427) from the $3,107,687 Baseline revenue. Such an outcome, better than most would have anticipated, is a direct indication of the value of the simultaneous comparison of alternatives by the LP model in strategic planning efforts. An appraisal of the findings show that vegetables like *Broc2* and *Tom2* have the potential to offset the revenue losses from tobacco if the costs and prices in the budgets for the two vegetables can be sustained.

In scenarios 3 and 4, tobacco acreage is decreased even more because of the reduction in quota. The optimal plan selects the same enterprises as in the Baseline, but acreages change significantly. More soybeans and cotton are included on low yield soils. *Whe2*, *Soy3*, *Cot3*, *Soy2*, and *Cot2* all have greater acreage in Scenario 4 where tobacco acreage is reduced by two-thirds. Revenues are down 22.0 percent ($681,170) and 43.4 percent ($1,349,164) for scenarios 3 and 4, respectively, compared to the Baseline. The impacts of large reductions in quota for tobacco are huge and cannot be offset by other traditional field crops even with LP to find the profit maximizing combinations. The big decrease in revenues in Scenario 4 compared to Scenario 3 can be traced directly to the bigger reduction in tobacco quota. Once again, however, the importance of this systematic analysis is apparent. With the help of LP profit maximization, revenues are down only 43.4 percent in Scenario 4 with the huge 67.0 percent cut in quota.

In Scenario 5 with the tobacco quota reduced by 50 percent (roughly the 1997 – 2001 reduction), more *Broc2* and *Tom2* are produced without relaxing the irrigation constraint. This substitution does not completely solve the revenue problem. Revenue is still 21.9 percent ($679,143) below that of the Baseline. With the acreage in tobacco constrained by quota levels to 50 percent below 1997 levels, vegetables are produced on acreage where tobacco would have been produced, but the lack of irrigation water is still a major constraint even though the acreage limit for *Broc2* and *Tom2* is raised to 6 acres each.

Scenario 7 is designed to limit tobacco production to the maximum high yield acreage—217.03 acres, the equivalent of a 90.0 percent tobacco quota cut. The acreage reduction from tobacco goes mostly to average and low yield soybeans and cotton. Revenue is 79 percent below (a $2,455,273 decrease) Baseline levels. These results clearly confirm that lower yielding tobacco is still much more profitable than many of the alternative enterprises. *Broc2* and *Tom2* are at 6 acres each, the maximum allowable. The acreage from *Tob2* and *Tob3* (2,084 acres in the Baseline) is forced into soybeans and cotton, but these crops cannot replace the revenue from tobacco. Higher revenue enterprises like tomatoes and broccoli (and likely other vegetables and fruits that generate more revenue per acre) continue to emerge as effective alternatives.

Scenarios 8 and 9 generate identical results. With a two-thirds reduction in the tobacco acreage from 1997 levels, the irrigation constraint is relaxed allowing *Broc2* and *Tom2* to be produced at a maximum of

15 acres each (Table 2). Even these small increases in acreage temper the impact of the 67.0 percent decrease in tobacco acreage. Revenues are down 41.6 percent ($1,813,390) from Scenario 1, a strong indication that further reductions in quota would have a devastating impact on tobacco farmers. However, the possibilities for *Broc2* and *Tom2* will be limited by price decreases if the aggregate supply response is large enough to cause the selling prices to drop. The enterprise *Tom2*, for example, would leave the optimal solution if price drops below $5.13 per carton.[5]

Scenario 10 is designed to further investigate the impact of tobacco on farm revenues. Tobacco acreage is set to zero. When tobacco is excluded from the optimal solution, *Whe2* acres decrease drastically. Alternative crops like *Broc2* and *Tom2* serve as effective supplementary enterprises. Both enterprises continue to enter at the maximum acreage allowed. *Cos* is a profitable enterprise. It is a close alternative to tobacco and occupies essentially none of the acres that can be used for crops, but *Cos* expansion may be limited due to environmental concerns and local zoning requirements.[6] Maximum possible production of *Cor1*, expanded *Cot2*, *Cot3*, *Soy2*, and *Soy3* production, and maximum levels of *Tom2* and *Broc2* generate only $42.65 in revenue per acre above variable costs. This $42.65 in net revenue or profits per acre is in sharp contrast to the $627.53 per acre in the Baseline solution before tobacco quotas are reduced. The $183,779 in net revenue for Scenario 10 is $2,923,909 below the Baseline net revenue—a 94.1 percent decrease.

Shadow Prices

Prices generated by changing a restriction by one unit are called *shadow prices*. Shadow prices provide useful information about the opportunity cost, or next best use, of resources. In the case of land, the shadow price shows the lost revenue of not being able to use one more acre of land in the most profitable enterprise available. If the shadow price of land in its most profitable use is higher than the market price of land, buying land could be profitable. The shadow price of one acre of land for *Tob1* is $2,348.92 in scenarios 4, 5, 6, 8, and 9. The shadow price of one acre of land for corn is only $13.67 in all scenarios, clear evidence of the low profitability of the corn enterprise, even with high yields. One additional acre planted to *Broc2* results in the highest shadow price of $4,572.26 in Scenario 4 and in scenarios 6 through 10. If fixed costs of irrigation and production and harvesting equipment are taken into account, the results would look somewhat different, however. Vegetables tend to have higher fixed costs than other crops and require higher periodic payments on debt because of investments in irrigation and production and harvesting equipment. This $4,572.26 per additional acre that *Broc2* would contribute to revenues is also before any price reduction that might result from increased production in the area.

The estimated average per acre market value of land including buildings in Pittsylvania County in 1997 was $1,273.00 (USDA (a)). If average shadow prices for land are calculated using the acreage in each enterprise in the optimal solutions, the highest weighted average shadow price or contribution from an added acre is $1,147.72 in Scenario 6, slightly below the $1,273.00 average per acre market value. This difference suggests that farmers using the profit maximizing set of enterprises in the scenarios that involve tobacco quota reductions could not afford to buy additional land. For the individual enterprises of broccoli and tobacco, the shadow price of land is well above $1,273.00. The limits on irrigation water for *Broc2* or lower prices from an increased broccoli supply or both would eventually constrain *Broc2* production.

---

[5] This finding comes from the sensitivity analysis, which is covered in a later section.

[6] The potential from contract swine parallels the findings in the 1991 REAP publication *The Financial Feasibility of Finishing Feeder Pigs under Production Contracts in Virginia*. Harper, Kenyon, and Thornsbury found significant supplemental revenues for tobacco farmers who manage one or more hog finishing floors.

Sensitivity Analysis

The flexibility of the LP model is powerful. Different scenarios can be analyzed to determine the impact of changing selling prices and production costs. *Sensitivity analysis* produces the thresholds of prices and costs beyond which enterprises move into or out of the optimal plan. Net revenues or revenues above variable costs in the profit maximizing combination will change as the optimal mix of enterprises changes. Reducing costs of production or increasing selling prices or both will increase the net revenue in the new optimal solution and, of course, increasing costs or declining prices or both will reduce the net revenue in the optimal solution.

Tob1 is in the optimal solution of the Baseline with 217.03 acres and a selling price of $1.78 per pound. All the acreage that can be planted to *Tob1* based on the GIS analysis of soil capacities is planted to tobacco. If the price of *Tob1* were lower than $1.60 (Table 5), *Tob1* would leave the optimal enterprise mix and be replaced with something else. The Baseline scenario can be modified by setting the price of *Tob1* equal to $1.55, thereby forcing *Tob1* to leave the optimal solution. The acreage of other variables in the new optimal solution show increases in acres planted to *Tob2* and *Whe1* and decreases in acres planted to *Soy2* and *Cot2*. Further, if the variable costs of *Tob1* were greater than $2,932.56 per acre, *Tob1* would be excluded from the optimal mix even at the documented $1.78 selling price in the 1997 baseline year (Table 5). Without the LP model, conducting this type of analysis would be nearly impossible.

The LP model looks at each selling price and production cost to determine if the enterprise will stay in the optimal mix of enterprises. Something must replace *Tob1* if either the selling price or the production cost is changed. *Tob1* occupies the better soils, 83 acres of which are the same soil type (4b) needed for alternative enterprises with the next highest revenue potential such as *Broc2* and *Tom2*. If tobacco prices go below $1.60 per pound, alternatives like *Broc2* and *Tom2* on some of these 83 acres will then contribute more revenue than *Tob1*. *Broc2* and *Tom2* are not nearly as competitive on the same soil types required for *Tob2* where the threshold tobacco price would have to decline to $1.30 before *Tom2* and *Broc2* would replace it on some of the 1,078.54 acres of soil type 23b where all three crops could be grown. If tobacco prices move above $1.92 or average per acre production costs fall below $2,043.19, more *Tob2* would be produced in Scenario 1 and in scenarios 2, 3, and 5, where tobacco acreage is reduced by 1/3 to 1/2 of its original acreage (Table 5). All other scenarios limit tobacco production even more. The price threshold for *Tob1* is down to $0.91 per pound in Scenario 10, and *Tob2* and *Tob3* thresholds are $1.00 and $1.30, respectively.[7] If tobacco is not totally eliminated, it will remain in the optimal enterprise mix even at prices down to $0.91 per pound. When tobacco is eliminated and vegetable production is restricted to 15 acres, traditional crops like corn, cotton, and soybeans make only nominal contributions to revenue.

Whe1 enters the optimal solution of Scenario 1 with 15.04 acres. However, if the price of *Whe1* were greater than $3.30 per bushel, *Whe1* would be selected with all 54.54 possible acres being used, and some other enterprise would leave the solution or remain in the solution with fewer acres. Scenario 1 is rerun with the *Whe1* at a price of $3.35. Results indicate that *Whe1* enters the optimal solution with the expected maximum allowable 54.54 acres and *Wds1* leaves the optimal solution. The same results would occur if the variable costs per acre of *Whe1* are less than $142.09. If the price of *Whe1* were less than $2.42 or the variable costs were greater than $208.49 per acre, *Whe1* would not be in the optimal enterprise mix for any of the ten scenarios.

Bar2 is completely excluded from the optimal set of enterprises. To be included, the price of *Bar2* would have to be above $2.61 per bushel or variable costs for *Bar2* would need to be below $92.40 per

[7] These findings are helpful in analyzing what would happen if production quotas were eliminated and the supply of tobacco increased without control. Prices would need to be below $1.00 per pound before *Tob1* and *Tob2* would leave the profit maximizing solution. More importantly, however, revenues above variable costs would ***not*** be anywhere close to the $3,107,687 of Scenario 1.

Table 5. Selling price and AVC thresholds for leaving and entering the optimal solution or changing the level of production for each enterprise

Enterprise	Selling price	AVC of production per acre	Scenarios 1, 2, 3, and 5: Leave optimal solution at P <	Scenarios 1, 2, 3, and 5: Leave optimal solution at AVC >	Scenarios 1, 2, 3, and 5: Enter optimal solution at P >	Scenarios 1, 2, 3, and 5: Enter optimal solution at AVC <	Scenarios 4, 6, 7, 8, 9, and 10: Leave optimal solution at P <	Scenarios 4, 6, 7, 8, 9, and 10: Leave optimal solution at AVC >	Scenarios 4, 6, 7, 8, 9, and 10: Enter optimal solution at P >	Scenarios 4, 6, 7, 8, 9, and 10: Enter optimal solution at AVC <
Tob1	1.78/lb.	2,453.91	1.60	2,932.56	–	–	0.91[c]	4,802.83[c]	–	–
Tob2	1.78/lb.	2,367.60	1.00	4,237.87	1.92	2,043.19	1.00[d]	4,237.87[d]	–	–
Tob3	1.78/lb.	2,314.92	1.30	3,188.15	–	–	1.30[d]	3,188.15[d]	–	–
Cor1	2.50/bu.	236.33	2.36	250.00	–	–	2.36	250.00	–	–
Cor2	2.50/bu.	223.60	–	–	–	180.33	–	–	–	180.33
Cor3	2.50/bu.	212.38	–	–	–	163.09	–	–	–	163.09
Bar2	2.07/bu.	135.67	–	–	2.61	92.40	–	–	2.61	92.40
Bar3	2.07/bu.	125.11	–	–	2.77	75.82	–	–	2.77	75.82
Wds1	3.77/bu.[a]	235.19	3.74	237.61	–	–	3.74	237.61	–	–
Wds2	3.72/bu.[a]	236.91	–	–	3.92	223.10	–	–	3.92	223.10
Wds3	3.66/bu.[a]	225.30	–	–	4.02	203.75	–	–	4.02	203.75
Whe1	2.78/bu.	181.35	2.42	208.49	3.30	142.09	2.42	208.49	3.30	142.09
Whe2	2.78/bu.	177.53	2.29	180.70	3.30	143.40	2.29	180.70	3.30	143.40
Whe3	2.78/bu.	161.98	–	–	3.56	123.15	–	–	3.56	123.15
Soy1	5.41/bu.	125.34	–	–	5.48	122.94	–	–	5.48	122.94
Soy2	5.41/bu.	130.70	4.49	158.32	–	–	4.49	158.32	–	–
Soy3	5.41/bu.	116.40	4.14	148.10	–	–	4.14	148.10	–	–
Cot2	0.60/lb.	347.00	0.56	374.62	–	–	0.56	374.62	–	–
Cot3	0.60/lb.	347.15	0.55	378.85	–	–	0.55	378.85	–	–
Broc2	10.18[b]	1,966.04	8.35	2,641.90	–	–	–	–	–	–
Tom2	7.99[b]	10,005.96	7.57	10,681.80	–	–	5.13	14,578.20	–	–
	Net above variable costs									
Bec (cow units)	1.66	–	–	–	9.91	–	–	–	9.91	–
Cos (head)	5.65	–	0	–	–	–	0	–	–	–

[a] Weighted average prices
[b] Price per carton (20 lb. for broccoli and 25 lb. for tomatoes)
[c] Not in Scenario 10
[d] Not in scenarios 7 and 10

acre at the $2.07 price used in the analysis. Scenario 1 is modified by setting the price of *Bar2* equal to $2.62. *Bar2* enters the optimal solution with 743.2 acres. *Cor2* enters the optimal solution with the same acreage as *Bar2*.

Changes in prices or costs of enterprises that are not in the optimal mix but are being considered in the analysis are very important. Discussions about the wisdom of starting to grow or increasing production of an enterprise such as barley are widespread. Knowing the increases in selling prices or the decreases in costs that are needed for such enterprises to become competitive in a particular area can eliminate mistakes in investments in these enterprises. The $2.61 price that would bring barley into the optimal solution is $0.54 per bushel above the $2.07 barley prices in the area in 1997, the base year.

Bec is another enterprise that never enters the optimal solution. Calf prices are low in the 1997 budget (steers at $61.00 per hundredweight and heifers at $48.00 per hundredweight) at least partly because of record high corn prices in 1996 (Appendix B). Feedlots buy steers and heifers at low prices when corn prices, their second largest cost per head for slaughter animals, go up. The $61 and $48 selling prices for steers and heifers generates $1.66 profits per cow unit (costs and revenue measured per beef cow) in the Baseline scenario. That $1.66 would need to increase to $9.91 per cow unit for *Bec* to enter the optimal solution (Table 5). Based on the budget, each cow unit requires 2.5 acres. If the $9.91 per cow unit in revenue above variable costs were available, the net returns would still only be $3.96 per acre ($9.91/2.5 acres).

If steer and heifer prices are increased to $81.00 and $68.00, respectively, labor costs are increased from $6.25 to $8.25 per hour, and pasture costs are increased from $18.00 to $25.00 per acre, to make revenues and costs more consistent with current conditions, the revenue per cow unit above variable costs would then be $40.16, and *Bec* would enter the optimal solution. However, revenue above variable costs is still only $4,016 for a 100-cow enterprise or $40.16 per cow unit. On a per acre basis, the revenue is only $16.06 ($40.16/2.5 acres per cow). Clearly, the *Bec* enterprise will not be a major contributor to the relatively small acreage tobacco farms in the study area. The average farm size in Pittsylvania County is 216 acres, which would support only part of a 100-cow operation. On the other hand, the beef cow program might utilize forage and resources from some of the 2,454.3 acres, especially the low productivity pasture, that are not included as potential crop or pasture land. In this analysis, *Bec* has to compete with low yield crops for acreage on soils that would support crops or improved pasture and *Bec* is not very competitive.

Nevertheless, beef cows are often mentioned as an alternative enterprise in Southside tobacco producing counties. Recognizing that reality, the analysis was extended to examine the current (2002) situation in terms of tobacco quota. Scenario 3, with tobacco quota cut in half to approximate the cumulative quota cuts from 1997 to 2002, was used in the LP analysis and per cow unit revenues of $100, $75, $50, $25, $15, $10, and $5 were examined. When *Bec* is constrained to only pasture acreage (Figure A10) in Scenario 3 and per cow unit revenues are $100, a total of 260 cow units with related revenue streams from steers, heifers, and cull cows would be produced—the maximum allowable given the acreage requirements (Table 6). Relaxing the acreage requirement and using net cattle revenues between $50 and $75 per cow unit would result in over 950 beef cow units. Between $10 and $15 per cow, 164 units are produced, and below $10, *Bec* does not enter the optimal solution. *Bec* at $100, with no land restrictions, results in 972 cow units raised on 2,430 acres. Net returns to the entire study region are then $616,197 below the Baseline but are $64,973 above the original Scenario 3 without *Bec* in the optimal solution. Even with revenues at $100 per cow unit, on a per acre basis, the revenue is only $40.00. Seemingly, *Bec* contributes to revenues when the program is on pasture-only acreage but does not compete effectively on acreages that support even low yield crops nor would it be at all competitive as a revenue generator with the vegetable crops or the contract swine program.

A second detailed look at Scenario 3, with tobacco quota cut in half, was conducted by relaxing the constraints on vegetable acreage. The acreage to which *Tom2* and *Broc2* can be planted is increased from 3 to 30, to 50, and then to 100 acres for each enterprise. Water restrictions are removed in this set of

Table 6. Optimal farm plans: tobacco quota reduced by 1/2, beef prices at $100, $75, $50, $25, $15, $10, and $5 per cow unit

	Scenario 1 Baseline	$100 cow Hay/pasture land	$100 cow All land	$75 cow All land	$50 cow All land	$25 cow All land	$15 cow All land	$10 cow All land	$5 cow All land
Total net revenue	$3,107,687	$2,449,172	$2,491,490	$2,467,218	$2,443,074	$2,430,937	$2,427,344	$2,426,522	$2,426,507
	--------acres--------								
Tob1	217.03	108.52	108.52	108.52	108.52	108.52	108.52	108.52	108.52
Tob2	643.07	751.59	751.59	751.59	751.59	751.59	751.59	751.59	751.59
Tob3	1,441.16	720.58	720.58	720.58	720.58	720.58	720.58	720.58	720.58
Cor1	486.20	486.20	38.52	38.29	38.29	486.20	486.20	486.20	486.20
Whe1	15.04	15.04	0.00	15.04	15.04	15.04	15.04	15.04	15.04
Whe2	463.60	441.58	0.00	0.00	0.00	0.00	680.66	680.66	680.66
Soy2	743.16	688.50	688.50	688.50	688.50	688.50	688.50	688.50	688.50
Soy3	77.15	437.44	0.00	0.00	0.00	437.44	437.44	437.44	437.44
Cot2	743.16	688.90	688.90	688.90	688.90	688.90	688.90	688.90	688.90
Cot3	77.15	437.44	0.00	0.00	0.00	437.44	437.44	437.44	437.44
Broc2	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Tom2	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Bec (cow units)	0.00	260.00	971.67	965.74	965.74	436.63	164.37	164.37	0.00
Cos (head)	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00

iterations. Given the prices used, in each case *Broc2* and *Tom2* enter the mix using the maximum 100 acres allowed (Table 7). With no water restrictions and 100 acres each of *Broc2* and *Tom2*, net returns to the optimum mix of enterprises are $2,492,066, or $65,559 more than the original Scenario 3, but still $615,621 less than the Baseline. If water availability limits the vegetable acreage, net returns would be lower reflecting the increased cost of more irrigation or the lower yields resulting from a lack of sufficient water. If acreages in *Broc2* and *Tom2* were allowed to move above 100 acres each, the net revenue drain from the 50 percent cut in tobacco quota in the Scenario 3 would eventually be completely offset. However, acreages at these levels would likely reduce selling prices for *Broc2* and *Tom2* unless corollary efforts are made to expand the available market outlets.

Table 7. Optimal farm plans: tobacco quota decreased by 1/2, broccoli and tomato acreage each increased to 30, 50, and 100 acres

	Scenario 1 Baseline	Scenario 3	Scenario 3A	Scenario 3B	Scenario 3C
Total net revenue	$3,107,687	$2,426,507	$2,444,756	$2,458,273	$2,492,066
Vegetable acreage	3 acres	3 acres	30 acres	50 acres	100 acres
	acres				
Tob1	217.03	108.52	108.52	108.52	108.52
Tob2	643.07	751.59	695.35	653.68	549.52
Tob3	1,441.16	720.58	720.58	720.58	720.58
Whe2	463.60	680.66	570.41	488.74	284.57
Soy2	743.16	688.50	717.02	737.85	789.94
Soy3	77.15	437.44	437.44	437.44	437.44
Cot2	743.16	688.90	717.02	737.85	789.94
Cot3	77.15	437.44	437.44	437.44	437.44
Broc2	3.00	3.00	30.00	50.00	100.00
Tom2	3.00	3.00	30.00	50.00	100.00
Cos (head)	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00

Conclusions

Soil survey data can be important in strategic farm planning. With digitized soil map data, Geographical Information Systems (GIS) capabilities can be used to identify what can and cannot be produced effectively on the acreages available to the farm manager. The GIS procedure thus provides an initial filtering that eliminates enterprise alternatives that require soil attributes, topography, or water that are either not available or would be available only at significant additional investment costs. After GIS analysis has identified enterprises that are technically possible given soil characters, linear programming (LP) techniques can be used to guide investments and diversification plans to maximize profits to management and fixed investments in the farm.

The integrated GIS/LP approach was applied to a section of Pittsylvania County in the heart of the flue cured tobacco production region. As tobacco quotas continue to be reduced, tobacco farmers will need to find other sources of revenue if they are to continue farming. The objective of the study was to analyze alternative enterprise combinations, given the soil capabilities of the study area, that would help to offset reduced tobacco quotas and maximize profits to farming operations in Southside.

The results of the study are interesting, useful, and not surprising in the sense that they confirm what is clear up front—tobacco is the dominant contributor to revenues on Southside farms. The results show that the reduced revenues associated with quota reductions are hard to replace, but very effective solutions to the revenue dilemma are possible.

Soybeans and cotton contribute to farm revenues and use land with lower yield potentials, but the revenue streams are small. Wheat and corn are used mostly in rotations. Given the costs and selling prices used in the analysis, the beef cow enterprise did not enter the profit maximizing solution. Extended analysis of the beef cattle enterprise shows it will enter the profit maximizing solution when prices and costs are updated, but returns per acre are still only a fraction of what tobacco provides. Any enterprise like beef cattle that requires large acreage, minimal management, few inputs, little capital per acre, and limited technology will not generate large revenue streams. Hay or improved pasture and even dairy operations are other farm enterprises that, like beef cattle, require relatively large acreages per unit of production and revenue streams will tend to be small compared to tobacco.

Intensive livestock enterprises are the other extreme and are, by definition, intensive in nature, requiring large amounts of capital and significant application of technologies. The concentrated swine finishing enterprise was always in the profit maximizing combination of enterprises at the limits allowed, and increased production in such intensive livestock programs could offset the losses in revenue associated with the tobacco quota cuts. This finding is consistent with earlier REAP research that shows swine finishing floors could be profitable on tobacco farms and require relatively few hours of labor or management time (Harper, Kenyon, and Thronsbury).

Among other intensive enterprises, tomatoes and broccoli could add significantly to farm revenues and offset the losses from tobacco under the right set of conditions. Acreage restrictions in the study were set at relatively small levels initially to reflect the base year, 1997, situation. With very little vegetable activity in the area, substantial investments in access to water and irrigation equipment would be required before such vegetables can be widely grown. When acreage for broccoli and tomatoes was allowed to increase to as many as 50 to 100 acres each and assuming no limits on irrigation capacity, the profits moved back up toward the Baseline revenue being generated before the cuts in tobacco quota started after 1997. However, even 50 acres of each crop would likely require that local markets be developed so that producers would not have to compete in a national or global market. An increase in local supplies that saturates the local market, even if a network of local market outlets is developed, could still drive prices down and threaten the added profit possibilities. Extending into these types of enterprises looks promising in spite of mixed historical results when past efforts in broccoli production were launched. The missing ingredient in the historical efforts may have been market development. Looking at the feasibility of a network of modern retail outlets in and near population centers and along major highways in Southside should precede or accompany any reconsideration of widespread production of vegetables, berries, nuts, melons, or tree fruit. The contribution from tobacco is hard to replace. Therefore, attention to the feasibility of such enterprises as tomatoes may be merited since enterprises of this type have the potential to generate significant revenues per acre.

Obviously, reductions in tobacco quota and the related reduction in tobacco acreage result in sharply lower farm revenues. Some tobacco farmers have already left the business and had to give up the farm as a place to live. More will be forced to stop farming unless they are able to make new investments to modify their farm plans to accommodate new, high value enterprises such as broccoli and tomatoes or intensive livestock (and possibly poultry) operations. Moving to such solutions will require changes in attitudes toward intensive livestock programs and will require companion efforts in economic development programs focusing on expansion of tourism and local markets so that prices will not be driven sharply lower with the expanded supplies.[8]

Developing a diversified farm plan can help tobacco farmers make a transition to other alternatives. Diversification planning and new investments *must* focus on the alternatives that have a chance of being competitive and profitable. The results of the integrated GIS/LP approach help identify the alternatives that could offset revenue losses associated with decreased tobacco production. Many of the profit maximizing solutions offset a large portion of the revenue declines coming from reduced tobacco quotas. There are, therefore, major reasons to look at alternatives using rigorous tools like GIS and LP as demonstrated in this study. Such sophisticated analyses as those allowed by GIS and LP could be used in completing an examination of all reasonable possibilities facing the tobacco producing families throughout Southside.

[8] More detail on the possibilities of local market networks is available from REAP based on analysis of farming potentials in Virginia Beach and Chesapeake where development rights are being purchased to keep land in designated areas in farming. Heatwole, Conrad, Wayne Purcell, Michael Chandler, Rushan Halili, Mary Leigh Wolfe, and Eugene Yangow. *A Strategic Plan for Agriculture in Chesapeake and Virginia Beach.* Hampton Roads Planning District Commission. Mar. 30 , 2001.

References

ESRI. *Using ArcView GIS. The Geographic Information System for Everyone*. Redlands, Cal.: 1996.

Hanson, A. A. ed., *Practical Handbook of Agricultural Science*. CRC Press. Boca Raton, Fla.: 1990.

Harper, Lauren , David Kenyon, and Suzanne Thronsbury. *The Financial Feasibility of Finishing Feeder Pigs under Production Contract in Virginia*. VCE Pub. No. 448-205/ REAP R006. 1991.

Heatwole, Conrad, Wayne Purcell, Michael Chandler, Rushan Halili, Mary Leigh Wolfe, and Eugene Yangow. *A Strategic Plan for Agriculture in Chesapeake and Virginia Beach.* Hampton Roads Planning District Commission. Mar. 30 , 2001.

NCSU. Fruit and Vegetable Budgets. At *http://www.ag-econ.ncsu.edu/extension/Ag_budgets.html*. Last accessed 24 Apr. 2003

Reaves, D. W., and W. D. Purcell. "Potential Change in the Tobacco Industry and the Impacts on Those Who Produce It: What Does the Future Hold?" Unpublished paper, Virginia Tech: 1997.

Simpson, T. W., S. J. Donohue, G. W. Hawkins, M. M. Monnett, and J. C. Baker. "The Development and Implementation of The Virginia Agronomic Land Use Evaluation System (VALUES)," Virginia Tech, 1993.

U. Fla. Market Information System. Found at *http://marketing.ifas.ufl.edu/*. Last accessed 21 April 03.

USDA (a). "AC97-A-46. Virginia, State and County Data. Volume 1, Geographic Area Series. Part 46," *1997 Census Of Agriculture*. NASS: March 1999.

_____ (b). *Soil Survey of Pittsylvania County and the City of Danville, Virginia*. SCS in cooperation with Va. Tech. 1994.

_____ (c). *Tobacco Situation and Outlook Report*. ERS, various years. Found at *www.ers.usda.gov/Briefing/Tobacco*. Last accessed 6 May 2003.

VCE. "Virginia Farm Management. Crop and Livestock Enterprise Budgets." VCE Pub 446-047. 1997. Found at *http://www.ext.vt.edu/cgi-bin/WebObjects/Docs.woa/wa/getcat?cat=ir-fbmm-bu*. Last accessed 24 April 2003.

VCES. *A Handbook of Agronomy*. VCE Pub 424-100. 1984

VASS. *Virginia Agricultural Statistics Bulletin.* Richmond, Va., various years.