A LINEAR PROGRAMMING ANALYSIS OF PROFITABILITY AND RESOURCE ALLOCATION AMONG COTTON AND PEANUTS CONSIDERING TRANSGENIC SEED TECHNOLOGIES AND HARVEST TIMELINESS

By

TIMOTHY A. MEEKS

(Under the direction of Dr. Fred White)

ABSTRACT

Production of cotton and peanut enterprises in rotation are typical of South Georgia. With limited resources like land and labor, efficient allocation of those resources is required. Throughout the growing season, the crops require producers to make decisions of how to allocate the resources allocated for various activities required to produce the crop. Particularly, efficient allocation of resources at harvest, are necessary, as harvest timeliness is believed to be a continual problem in the rotation of these two crops. Little research exist in Georgia in the area of harvest timeliness, however agriculturalist continue to believe revenues, being lost due to harvest timeliness, are significant based on present production strategies.

Through economical analysis and linear programming optimization, the harvest timeliness issue is addressed in this research. After constructing a "typical" South Georgia farm and a linear programming optimization model, the characteristics of the typical farm are incorporated into the linear programming model and is optimized. The function to be optimized is net returns rather than profit because the research does not take into account fixed costs.

After the initial model is optimized, it is compared to the present production strategies to determine if producers are allocating their resources properly, based on assumptions made in this research. Scenarios based on the original model are conducted to determine the sensitivity of the constraints imposed. Conclusions dictate producers may need to adjust their production strategies throughout the growing season—particularly at harvest.

INDEX WORDS: Cotton, Peanuts, Optimization, Linear Programming, Harvest timeliness

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TIMOTHY A. MEEKS

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By

TIMOTHY AL MEEKS

Approved:

Major Professor: Dr. Fred White

Committee: Dr. Lewell Gunter
Dr. Jeff Mullen
Dr. Don Shurley

Electronic Version Approved:

Gordhan L. Patel
Dean of the Graduate School
The University of Georgia
August 2002

DEDICATION

In my life, I have not really known a granddad. Unfortunately, mine passed away when I was still a babe. God, however, in his infinite wisdom saw fit to allow me to have someone step into that role to teach me things that only a granddad could teach. For me, this individual was Charles Raymond Summers. Most folks called him CR – I called him Pop.

He and his wife, Mrs. Bobbie Summers, lived not far from my house in TyTy, Georgia. When I was about 12 years, Pop allowed me to start working on his farm in watermelons and cantaloupes. I couldn't do much else because I was too small. From time to time he would let me drive the tractor or truck in the field since we weren't moving too fast. Over the years, he became my best friend. Once I had a car, I would go to his farm everyday after school to help him feed up, check the cows, or just sit and visit. I love to hear him tell stories of his past like hunting trips and such. He and Mrs. Bobbie took my brother and I on as their own grandkids and loved us the way grandparents do.

Pop, thanks for being a granddad to me. Thanks for teaching me about farming, for fixing what I tore up, and for not getting angry with me when I really messed up. You hold a very special place in my heart and I will never forget you. I love you very much and hope that my life brings me as much joy as yours, and that I might bring some happiness to someone's life like you have brought to mine.

Mrs. Bobbie, thank you for caring way and general concern. Most of my time at the farm was always spent helping Pop, but I have always admired your attitude about things and respected you. Thank you for caring about Steven and I, and for letting us be part of your lives. I love you very much. Neither of you ever forget, I am never far away.

Because of the kindness and the impact that these two have made in my life, I dedicate this work to Mr. CR Summers and Mrs. Bobbie Summers. This is the only way I could come close to thanking them for their kindness, love, and support. I will never be able to repay them for all they have done for me. I love you both and will be there whenever you need me.

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Obtaining this degree and finishing this thesis would not have been possible without the help of many people in my life. First and foremost, to God the Father I give thanks for his wisdom, grace, and mercy. He has helped me through many stressful times, and I continue to need him daily.

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To my church, my pastor, my friends, and those who have lifted me up in prayer, I say thank you for your support, your thoughts, and your prayers. It has been a long hard road, but thankfully this chapter of my life is over and now I begin a new journey. Please continue to keep me in your thoughts and prayers, and may God bless all of you.

To my committee, I say thanks for your wisdom, guidance, and support. Each of you has played a major role in helping correct the problems with my model and other areas of my thesis. Most of all, thank you for your signatures, as they make it possible for me to graduate. Good luck to each of you in your careers.

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CHAPTER 1

INTRODUCTION

Section I: Historical Production

King Cotton is no stranger to the Southeast Coastal Plain. Cotton has long been a staple in many states, including Georgia. Production over the last few decades has not been stable. Disaster threatened cotton in the 1980's when the boll weevil became the most damaging pest to ever have affected cotton. During the early 1990's, cotton production averaged approximately 350,000 acres. Eradication of the boll weevil regenerated cotton production in Georgia, and by 1995, Georgia ranked second in the U.S. with 1,500,000 acres planted. Since expansion in 1995, acreage has remained stable.

As in the past, management strategies have determined the profitability associated with producing a crop. For most producers, profitability is dependent upon their ability to properly allocate resources across various commodities. In South Georgia, most cotton producers incorporate peanuts into their rotation, and many of them are also vested in livestock operations. With such a wide range of production responsibilities and limited resources, efficient management strategies are required to sustain ever-changing market conditions.

Cotton prices in GA have declined since obtaining a level of 77 cents per pound in 1995. In 1999, an imbalance of supply and demand around the globe caused cotton prices to fall. Current cotton prices loom in the 40 cents per pound range. With the loan deficiency payment (LDP), producers are receiving prices in the upper of 50 cents per pound. With depressed cotton prices, producers are faced with increasing production costs and few means of increasing enterprise profitability.

Peanut production has experienced similar peaks and valleys of production like cotton. Production rose from 508,000 acres in 1965 peaking in 1990 at 900,000 acres (NASS). Reduced demand and quota reductions caused acreage to decrease throughout the 1990's, and by 2001 acreage had rebounded to only 515,000 acres (NASS). In 1996, a new farm bill was introduced lowering loan rates to $610 per ton on quota peanuts. Prices for additional peanuts have been from $132 per ton to $375 loan rate (contract price). These prices allowed most farmers to continue producing at a profit (Smith, 2002).

Section II: Forecasting Production

Today, producers are no longer under the protection of the 1996 Farm Bill. With the expiration of the farm bill on the horizon, Congressional leaders have now passed a new six-year farm bill. While government officials are pleased with the new bill, quota owners and landowners oppose the bill. Unlike the 1996 Farm Bill, the 2002 Farm Bill replaces the quota system with a marketing loan system of production (Smith, 2002).

The introduction of the 2002 bill spells the demise of the quota system, which is the main source of controversy among landowners. Many quota owners have retired from farming and now rent out their quota allotment and land. By leasing out their quota acreage, landowners are able to maintain a steady income without producing. Under the marketing loan system, landowners no longer have this right.

While eliminating the peanut quota, the new bill does provide for quota compensation while establishing a loan schedule for peanuts. In the absence of quota and historical yields, a peanut base has been developed dependent upon yields from 1998-2000. While there are some guidelines to the base calculation, producers are given the opportunity to assign the base to whatever farm or land they wish, but once it has been assigned, it cannot be moved. The base is then used to calculate the Direct Payments and the Counter Cyclical Payments to be received by the producer. Producers receive a loan deficiency payment (LDP), the direct payment, the counter cyclical payment, and the buyout (Smith, 2002).

The new Farm Bill has little effect on cotton production. While already under a marketing loan system, cotton price is approximately 40 cents per pound with the target price approaching 72 cents per pound. The bill has the loan rate increasing only .08 cents to 52 cents per pound. The Agriculture Market Transition Act (AMTA) provided payments be made to producers in the 1996 Farm Bill. Under the 2002 Farm Bill, these AMTA payments will increase to 6.67 cents per pound and the Counter Cyclical Payment being 13.73 cents per pound maximum (Shurley, 2002).

Section III: Improving Technologies

Crop production is a task full of important decisions that must be taken seriously. With new innovations continually entering the market place, producers are flooded with new technologies and products claiming to increase yields while keeping costs per acre at a minimum. For instance, BtRR cotton has been genetically altered to cause the cotton plant to produce the Bt toxin. Introduced in 1996 as Bollgard cotton, this stacked gene variety has been genetically altered by incorporating bacillius thurengensis, a bacterium known to control tobacco budworm and cotton bollworm infestations with an oral mode of action, into the cotton plant's genetic makeup. The RR stands for "roundup ready". Roundup ready cotton is a variety genetically modified to allow producers to spray Roundup over the top of the plant for weed control until squaring occurs, usually the fourth of fifth leaf stage. Other varieties, of genetically modified cotton, are available to the producer as well. This, and other genetically modified varieties of cotton are available on the market, but they do not come without a higher price reflecting a "technology fee".

When deciding to plant a genetically modified crop, the producer assumes certain responsibilities in addition to the technology fee. Producers pay different technology fee depending on the variety of cotton they chose to produce. As part of the resistance pest management agreement, producers must choose between three refuge options. One option is the 20% sprayed refuge which requires that 20 acres of conventional be planted for every 80 acres of BtRR. Under this option, the refuge may be treated with any insecticide, except B.t.k. products (containing the Bt toxin). A second option would be the 5% unsprayed option requiring 5 acres of conventional be planted for every 95 acres of BtRR. Under this option, the refuge may not be sprayed with any Lepidoptera-active insecticides to control tobacco budworm or cotton bollworm. The final option is the 5% embedded option. This option requires 5 acres of conventional for every 95 acres of BtRR, but may be sprayed. The only restriction on spraying is that the refuge be treated when the BtRR is treated, and with the same chemicals (FarmSource, 2002). This is the option chosen for this research.

Tillage strategies are another area of technological improvements that have been made in the agriculture industry. Producers now have the options of tillage ranging from the conventional method of turning the land before planting to no-till. Strip-till, (till a strip only where seed will be planted) is also a popular form of conservation tillage. From soil conservation to fewer trips through the field, strip-till has been hailed as a more cost effective tillage method. However, producers have not been quick to adopt the new method and conventional tillage is still the more common practice in South Georgia (Ward, 2000).

Section IV: Problem Statement

Profitability must exist in production agriculture, otherwise producers would have all gone out of business. While producers may realize a profit, they may not be obtaining their maximum profit potential. Through good management strategies, they can increase their profits. Good strategies require making profitable decisions like the variety of seed to grow, the tillage practice to incorporate, formulating a cost effective input regime, deciding when to plant and when to harvest, and estimating the number of laborers to employ.

Traditionally, producers begin cultivating the land to prepare for planting in the early spring. They then set out to plant their peanut crop, delaying cotton planting until a desirable amount of heat units are reached to germinate the seed and initiate plant growth. This type of planting strategy matures the peanut crop a couple of weeks prior to complete cotton maturity. This allows producers to harvest peanuts before cotton and prevents the deterioration of peanuts. Today, this strategy is no longer efficient for producing these commodities.

Due to the introduction of the Tomato Spotted Wilt Virus (TSWV), the University of Georgia Extension Service reports that delaying planting of peanuts until May 1-20 gives the greatest chance of reducing the intensity of the virus among the crop (Brown et al, 2001). Cotton planting in Georgia usually begins around April 20, with most of the planting occurring during the month of May (USDA, 1997). Therefore, planting of the two crops occurs generally within the same time period when attempting to avoid TSWV in peanuts.

Physiologically, the plants mature at approximately the same rate with harvest occurring at the same time. Producers have generally delayed cotton harvest until peanut harvest has been completed, or is nearly complete. This overlap of planting and harvest creates a resource allocation conflict for producers. The amount of available labor, equipment, and workable hours could be the most binding constraints producers face in accomplishing all of their tasks.

Therefore, an efficient model is needed to determine the optimal planting and harvest combinations for producers to optimize net returns. Of primary concern is the harvest timeliness issue associated with delaying cotton harvest and reducing returns due to quality reductions. Using the many technologies available to improve timeliness, such as transgenic varieties, is preferable as adoption for these cost effective technologies increases.

Section V: Objectives

The objectives of this research are three fold. The first objective of this research is to construct a farm typical of South Georgia, including equipment, land, and labor resources. The second objective is to develop a linear programming model capable of optimizing the allocation of resources in such a way that profit is optimized. The third objective is to have the LP optimize the planting of cotton and peanuts.

Section VI: Manuscript Organization

The following chapters will explore the resource allocation problem and profitability associated with harvest timeliness. First, literature of research in the area of harvest timeliness, as well as other relative topics, will be explored. Next, some economic theory and methodology associated with this research will be introduced. Following the methodology, the process of data collection and analysis will be explained. Finally the results and conclusions of the research will be presented.

CHAPTER 2

LITERATURE REVIEW

In the southeast, cotton is produced in a rotation with peanuts. This research is primarily concerned with the opportunity costs that arise between cotton and peanuts. In the southeastern United States, historical production of peanuts and cotton simultaneously dictated that peanuts be planted prior to the start of cotton season. This allows the majority of peanut harvest to be complete prior to cotton harvest. This type of management allows producers to efficiently allocate resources in such a way that both crops can be harvested to maximize profits. Presently though, this management strategy is no longer optimal for producers. Over time, the introduction of new plant pests, technologies, and other factors have caused agricultural production to change in order to maintain profitability.

Section I: The Peanut Situation

The 1990's brought the introduction of the Tomato Spotted Wilt Virus (TSWV), which is prevalent in peanuts. In fact, "in 1995 TSWV became the most damaging disease problem in peanuts in Georgia and Florida" (Luke, Fletcher, and Martin, 1999). Research indicates peanut yields are significantly affected by spotted wilt severity. "For each 10% increase in final TSWV severity, yields were reduced by 280.2 kg/ha" (Luke, Fletcher, and Martin, 1999). This obviously demonstrates the need for TSWV control, but currently chemical control or immune varieties are not available.

Fortunately, researchers have discovered different strategies to control the spread of the virus. The transmission of tomato spotted wilt is believed to be through certain species of thrips. Therefore, controlling the transmitter helps control the virus. While there are a few chemicals that help control thrip populations, they are ultimately ineffective. The University of Georgia Extension in 1996 introduced the TSW Risk Index for evaluating the potential for infestation. "The UGA TSW Risk Index for peanuts was developed as a tool for evaluation of risk associated with individual peanut production situations" (Brown et al, 2001).

The researchers discovered that "optimum planting dates vary from year to year, but in general, early-planted and late-planted peanuts tend to have higher levels of TSWV than peanuts planted in the middle of the planting season" (Brown et al, 2001). The index is based on risk points associated with different production decisions. For example, the variety of peanuts a producer selects is associated with a certain number of risk points. Currently, no variety is immune to the virus, but the cultivar GA Green has the lowest anticipated risk points, implying the most tolerant variety (Brown et al, 2001).

Other research dealing with tomato spotted wilt risk index showed "twin rows pattern averages higher yields, better grades, and lower TSWV incidence" (Baldwin et al, 1997). While twin row peanuts tend to be the best yielding method of production, many producers in South Georgia have not adopted the new method. Another management practice is strip-till. "Studies have consistently shown that peanuts grown in strip-till have less thrips damage and slightly less TSWV (Luke et al., 2000).

Recent research shows the TSW Risk Index to be the best tool for reducing the severity of TSWV and boosting yields. Under the most recent version of the index, the best period to plant the peanut crop in South Georgia is between May 1st and May 20th. This puts peanut planting during the same period as cotton planting—hence the beginning of the resource allocation conflict.

Section II: The Cotton Situation

Cotton is a tropical plant requiring a large amount of heat units in order to produce fruit. Therefore, cotton should not be planted too early because late frost could have a detrimental effect on the crop. Also, in the past, late-planted cotton was devastated by boll weevil infestations. However, due to the success of the Boll Weevil Eradication Program, planting dates can be extended. Historically, most cotton planting in South Georgia occurs between the end of April and the middle of June. However, the current, optimal planting period for cotton in Georgia is considered to be mid May. If possible, planting should occur no later than this period because the longer the growing season, the higher the anticipated yield. For cotton, a longer growing season or "early planting date shows larger boll size, longer fiber, stronger fiber, and lower micronaire" (Jenkins, McCarty, and Parrot, 1990).

Planting too early or late can both have negative effects on cotton yield, while planting too early can cause late frost to reduce stand counts. Planting too late creates the risk of early frost in the fall that could cause the plant to shut down and abort unopened fruit. Larson, Mapp, and Varhalen (1996) reported "delayed planting generally results in a consistent daily decrease in lint yield due to a reduced growing season-if after the optimal date" in a South Carolina study. This conflicts with research by Micinski, Colyer, and Nguyen (1990) reporting that "yields increase as planting was delayed and a highly significant correlation exist between plating date and yield (r-square = .40)." In general, it is believed that yields decrease the later the cotton is planted.

Georgia research has not been successful in establishing the relationship between planting date and yield. One study by Shurley and Deal (1993) concluded that "in no equation was planting date alone or in combination with other variables sufficient to explain yield variability or predict yield." Lacking a definite relationship between planting date and yield, the possibility of one between harvest date and yield should be explored.

Harvest date in cotton is difficult to judge. If harvest is initiated too early or too late, yields could be reduced. Cotton plants do not mature all at once because each square or boll matures at different time periods. According to Shurley and Bednarz (2000) "peak maturity of a cotton boll occurs the day it opens. Once open, a boll will decline in quality, and yield loss becomes more probable. A cotton plant will open bolls for a period of 6 weeks. The objective of crop termination is to apply harvest aids at such a time that as many bolls as possible can be harvested while not suffering offsetting losses in yield and quality." Good management decisions must be made to determine the optimal time to defoliate and begin harvest.

Producers are faced with difficult decisions when it comes to harvest. Shurley and Bednarz (2000) found that "each one week delay in harvest after 100% open bolls resulted in an average loss of $15.76 per acre in net return. Maximum net return occurred one to two weeks before 100% open bolls and decline each week thereafter." In 1990 Parvin reported that in Mississippi "September 25 is the standard harvest initiation date.

If harvest is started one week early, profits increase by 30%, but one week late will decrease profits by 63%."

Little research exists for Georgia cotton producers to estimate appropriate defoliation to maximize profits at harvest. Thus far, the best estimate of when to defoliate cotton is "at 80% open bolls. If beginning harvest two weeks following defoliation, this would place harvest at time when 30% of the state's peanut crop remains to be harvested" (Shurley, 2000).

This overlap of harvest periods is an example of where the resource allocation problem becomes evident. With 30% of the peanuts left to harvest, cotton harvest initiation is usually delayed to ensure quality peanuts are harvested. This delay pushes cotton quality to the point that profits begin declining. "Each week delay in defoliation and harvest after 100% open bolls resulted in $16.46 per acre per week decline," according to Shurley and Bednarz (2000).

Planting date/harvest date/yield data is not widely available for Georgia. States like Texas, the Carolinas, and Arkansas have some research available, but discrepancies arise across their data. This could be due to differences in soils, temperatures, weather patterns, and other naturally occurring phenomena. Different areas of the U.S. require different cropping strategies and practices in order to produce a profitable crop. For this reason, much of the research found cannot be applied to this research. However, the relationships found in most southern states may be useful in this study.

CHAPTER 3

ECONOMIC THEORY AND METHODOLOGY

The early 1990's brought technological changes that have diversified the inputs farmers use to produce a crop. They must make decisions of which enterprises (or commodities) they are going to produce, how many acres of each to produce, and the most efficient mix of inputs. For farm managers, decision-making is a never-ending process. Throughout the growing season, they must continuously make critical choices like whether or not to spray for insects, which insecticide to use, when to defoliate cotton, and when to initiate harvest. Of these decisions, they must decide what brand of pesticide to use and the appropriate rate to use. Then, they must efficiently allocate their limited resources in order to maximize profits. The scope of their decision possibilities is so large that mathematical tools like Linear Programming (LP) are beneficial to guide producers toward profitable positions. A general understanding of resource allocation will be useful in understanding LP's application for this research.

Section I: The Product-Product Model

The product-product model is an optimization model that explains the general relationships in a multi-product enterprise. This model applies to this research because, in general, a South Georgia cotton farmer will enter into multiple enterprises during one growing season. Most producers in the Southeast Coastal Plains who produce cotton also produce peanuts. Firms producing multiple products must allocate resources in such a way that total farm profit is maximized, not individual enterprise profit. One method for producers to find the most efficient combination of resources is to look at its production possibilities curve, or product transformation curve (PTC) in a two-dimensional graph. The PTC is useful in this model because numerous products are being produced. "A product transformation curve is the locus of output combinations that can be obtained from a given amount of the variable factor. The notion of the product transformations curve is analogous to that of an isoquant—the only difference being the former holds the factor constant while the latter holds output constant" (Beattie, 1985). In figure 3.1, assume one resource or input (y_1) is being used to produce two products ($x_{1,}$ x_2). With a limited amount of the resource, there exists a combination of x_1 and x_2 such that no other optimal position can be reached. Once this point is reached, the firm has found the profit maximizing combination. To shift from this optimal point to another would require taking resources from say x_2 and applying them to produce more $x_{1.}$ This relationship between competing products is often referred to as the rate of product transformation (RPT)

Algebraically, RPT is given by

$RPT = - \partial x_2 / \partial x_1$ where RPT is the negative slope of the PTC.

The derivation of the RPT implies the RPT equals the ratio of the marginal physical productivity of y in production of x_2 to the marginal physical productivity of y in the production of x (Beattie, 1985). Thus, the RPT defines the relationship between the two outputs, and defines the proportion of how much of one product must be decreased to produce more of the other output.

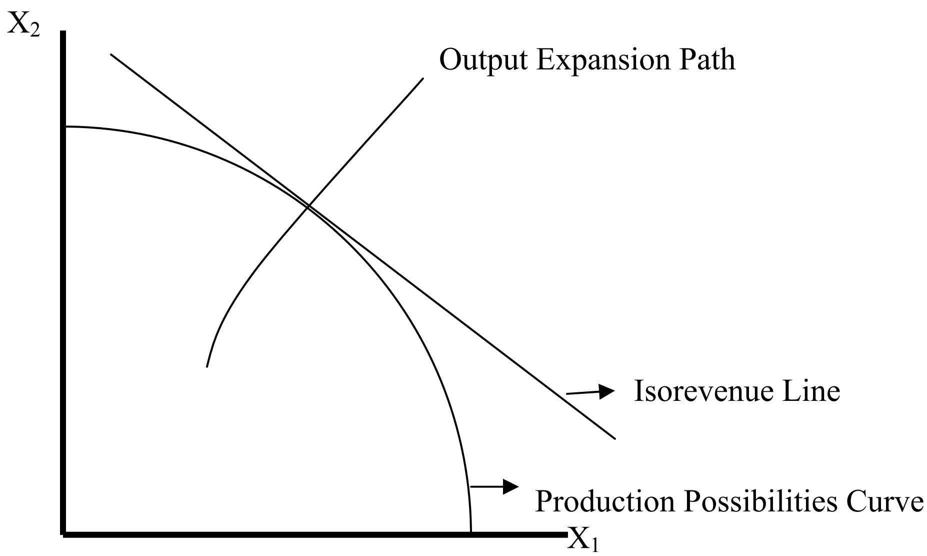

Figure 3.1. PTC and Profit Maximization

Profit maximization is synonymous with a certain point on the product transformation curve (PTC). In figure 3.1, this point is where the output expansion path intersects the PTC. The output expansion path is defined to be a locus of points (x_1, x_2) that maximizes revenue subject to a fixed amount of the variable factor. More importantly, the first order conditions require that the isorevenue curve be tangent to the product transformation curve, or where MR_1/MR_2 equals MPP_{12}/MPP_{11} (Beattie, 1985). Note MR_n represents the marginal revenue and MPP_{ij} represents marginal physical product.

While this is simplistic enough for output-output scenarios, graphical representation for most farms is not practical. There would simply be too many variables to incorporate into a two dimensional graph. It is for this reason that Linear Programming is utilized in this research.

Section II: Linear Programming Theory

Dating back to before World War II, Linear Programming (LP) has been used under numerous conditions as a tool for overcoming planning problems. LP is an important tool to know because it "gives an appreciation for the complex manner in which prices; yields; and such scarce resources as land, capital, and labor interact during critical seasons to determine the best farm plan" (Beneke and Winterborer, 1973). "Linear Programming, a type of mathematical modeling, is a prescriptive model where the values of independent variables are under the decision maker's control" (Ragsdale, 1998). LP falls under Mathematical Programming, which allows decision makers to determine the most efficient use of limited resources in order to optimize production.

As stated earlier, the production possibilities curve could be plotted on a two dimensional graph. Graphical representations of resource allocation in the agricultural industry are not practical for evaluating economical production. Production agriculture requires producers to utilize numerous inputs in the production of the different crop enterprises. This is precisely why LP is the best tool for optimization. LP is most useful for optimizing large-scale operations where n products are going to be produced using m inputs. Thousands of possible input applications exist leaving producers with millions of production plans to evaluate. Hence, "the great advantage of programming is that it allows one to test a wide range of alternative adjustments and to analyze their consequences thoroughly with a small input of managerial time" (Beneke and Winterboer, 1973).

However, LP is not without its limitations. These limitations include: the inability to predict prices, the lack of operator risk preference accounting, difficulty accounting for diminishing marginal returns, and poor handling of decreasing cost. These limitations should not be enough to keep operators from using the method. It simply requires them to be knowledgeable about their firm, and have all of the necessary data available. In other words, firms need to determine all of the coefficients required for optimization in the model. For example, because the model doesn't know current commodity prices or forecasted prices, the operator must have that information available.

Ragsdale (1998) gives five steps for formulating an LP model. First of all, the manager must understand the problem, and be able to clearly define the problem so that the formulation depicts the production method. Second, the manager must identify the decision variables. For example, how many acres of cotton to produce? Next, he/she should state the objective function as a linear combination of the decision variables. A system of equations explains the mathematical relationship between the decision variables. Next the decision maker must state the constraints as linear combinations of the decision variables. These constraints identify the restrictions the producer faces preventing a solution utilizing more resources than are available. Finally, the upper and lower bounds of the decision variables must be identified. These are defined by adding in any equality or inequality constraints.

LP is accomplished by using a series of equations to solve the optimization problem. Usually this formulation begins with the objective function and then applies a series of constraints. The equality or inequality constraints define the feasible region of production for the firm. This feasible region, however, is not the optimal point. Rather it is the set of all possible solutions. Chiang (1984) gives the following system of equations as a representation of a longhand problem. Note the equations will have *n* variables and *m* constraints.

$$
\begin{array}{lll}
\text{Maximize} & \Pi = c_1x_1 + c_2x_2 + \dots + c_nx_n & \\
\text{Subject to} & a_{11}\,x_1 + a_{12}\,x_2 + \dots + a_{1n}\,x_n \leq r_1 & \\
 & a_{21}\,x_1 + a_{22}\,x_2 + \dots + a_{2n}\,x_n \leq r_2 & \\
 & a_{m1}\,x_1 + a_{m2}\,x_2 + \dots + a_{mn}\,x_n \leq r_m & \\
 & \text{and} \quad x_j \geq 0 & (j=1,2,\dots n)
\end{array}
$$

where Π is symbolic for maximand (the object to be maximized). The x variables are the choice variables and the c variables are their coefficients. The r variables on the RHS represent the restrictions imposed on the program.

The task of determining the optimal plan in LP is accomplished using the simplex method. To use the simplex method, all of the constraints must be entered as equalities. This is not typical of most production factors. Therefore, the inequality constraints must be transformed into equalities. This is accomplished by creating slack variables. This transformation of inequalities to equalities yields a system of linear equations. If more variables exist than constraints, then the variables used to solve the system of equations are basic variables. If a solution is obtained using these basic variables, then that solution is a basic feasible solution, which falls in the feasible region. Evaluating the different resource combinations will yield all of the solutions in the feasible region, and the boundary of that region. The solutions on the boundary line, or the production possibilities curve, are referred to as the extreme points. With so many points, how is the finite optimal solution to be determined?

Again, Chiang (1984) demonstrates the transformation using slack variables. Given the objective function

$$
\begin{array}{lrcl}
\text{Maximize} & \Pi = 40x_1 + 30x_2 & & \\
\text{Subject to} & x_1 \qquad\quad & \leq & 16 \\
 & x_2 & \leq & 8 \\
 & x_1 + x_2 & \leq & 24 \\
\text{and} & x_1, x_2 & \geq & 0
\end{array}
$$

Adding slack variables gives,

$$
\begin{array}{lrcl}
\text{Maximize} & \Pi = 40x_1 + 30x_2 + 0s_1 + 0s_2 + 0s_3 & & \\
\text{Subject to} & x_1 + s_1 & = & 16 \\
 & x_2 + s_2 & = & 8
\end{array}
$$

$$x_1 + 2x_2 + s_3 = 24$$

$$\text{and} \quad x_1, x_2, s_1, s_2, s_3 \geq 0$$

where Π represents profit, x_n represents the decision variables, and s_n represents the slack variables. The slack variables help to maintain the nonnegative requirement. Since their coefficients in the objective function are 0, they may be omitted altogether. Adding the slack variables helps to determine the basic feasible solutions and the extreme points.

"The simplex method operates by first identifying any basic feasible solution (or extreme point), then moving to an adjacent extreme point, if such a move improves the value of the objective function. When no adjacent extreme point has a better objective function value, the correct extreme point is optimal and the simplex method terminates" (Ragsdale, 1998). In order to move from one extreme point to another, basic variables are interchanged with non-basic variables.

Section III: LP Models Made Easy by Technology

LP is the most useful tool for optimizing large-scale operations where *n* products are going to be produced using *m* inputs. In cases where only two products are to be produced with one input, two-dimensional graphs are useful, but they are inappropriate for multiple input and output models. LP's use of the extreme points on the feasible region is the link to optimal resource allocation along the product transformation curve.

Computer programs simplify the task of optimization for problems with multi-product production. Operating systems like *Excel©* are capable of carrying out all of the formulations and steps to find finite optimal solutions. The operator has only to enter the data into the spreadsheet using columns and rows and the constraints into particular cells. Keeping with the longhand explanation, *Excel*© utilizes the simplex method for analysis.

Excel© uses a tool called *Solver* to optimize models. Once the data and constraints are entered, *Solver* is initiated to solve, and the model iterates until the finite optimal solution is reached. The final result is the most profitable program for the producer. The results of running the model are given along with sensitivity analysis. This sensitivity analysis report informs the operator of how changing different variables will change the level of net returns. For instance, in the sensitivity report, there is an Lagrange Multiplier column (LM) that represents a shadow price. This shadow price is synonymous with marginal revenue in economics. These prices will be discussed in Chapter 6.

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CHAPTER 4

DATA COLLECTION

Section I: Creating a Typical South Georgia Farm

To begin, it is necessary to define a typical South Georgia farm. Currently, this type of model farm does not exist. The are typical acreage, allotments for enterprises, the amount of equipment available, the typical inputs used in production, labor, and various other particulars needed to estimate costs. Without a model farm already in existence, one had to be created. Decidedly, the best way to construct this "typical" farm is to talk to "typical" farmers. Dr. Don Shurley suggested attendance to a meeting held by Gary Bullen of North Carolina State University, who was working on gathering the same information for a similar project. Dr. Shurley coordinated the meeting on behalf of Dr. Bullen. He was in charge of setting up the meeting and contacting participants to participate.

The meeting was held August 31, 2001 at the Rural Development Center located in Tifton, Georgia. Those agents attending the meeting included: Tom Jennings of Wilcox County, Rick Reed of Coffee County, Gibbs Wilson of Irwin County, and various producers from those respective counties. That same day, a different meeting was held with county agent Tom Cary of Worth County and producers from that county who were unable to meet that morning in Poulan, Georgia. During the four and a half hour meeting in Tifton, Dr. Bullen questioned the agents and producers about the different characteristics making up a typical South Georgia farm. Questions ranging from the amount of land in production to the amount of off farm income were posed. To view some specific questions see Appendix A-1. Through controlled discussion, unanimous answers to all questions were rendered so that no difference of opinion existed. These same questions were asked to the producers and agents at the meeting in Poulan. To make sure there were no discrepancies between meetings, Dr. Bullen would pose questions relating to the answers from the Tifton meeting to see if they were plausible.

Another meeting of this same type was conducted in Bainbridge, Georgia, Decatur County. This meeting was conducted by Joe Outlaw and James Richardson of Texas A&M and Dr. Shurley. Again, county agents were asked to contact producers from the area, and invite them to participate in a meeting to discuss a typical South Georgia farm. After comparing and summarizing the characteristics from all meetings, the typical South Georgia farm was constructed. Appendix 2 defines the characteristics of a typical South Georgia farm.

Section II: Budgeting the Farm's Resources

After defining the farm layout, budgets were needed for each enterprise to make any economical conclusions from this type of research. Dr. Don Shurley published budgets for the University of Georgia consisting of irrigated and dry land cotton in 2001. When updating the budgets for 2002, input prices were gathered through phone calls and the use of fax machines for long lists. These input prices were obtained from co-ops around the Tift County, in South Georgia are shown in the budgets in appendix A-4 and A-5.

Dr. Shurley's (2000) Budgets estimated the hours per acre, labor hours, and other technical coefficients for 2001. The same spreadsheets used in 2001 were used for the

2002 update. While updated budgets for 2002 were nearly complete, they were never published. For this reason, budgets published by Dr. Bill Givan (2002) of the University of Georgia College of Ag and Environmental Sciences were used to validate the coefficients of the unpublished budgets.

The only peanut budgets available were published in 2002 by Dr. Bill Givan. In order to determine the needed coefficients, a peanut budget was generated using the cotton template from Dr. Shurley's budgets. This allowed coefficients like hour per acre for each activity to be calculated. In order to maintain accuracy, Dr. Givan's budgets were used as a guide for production. Using Dr. Shurley's budgets as the primary source allowed for the use of the technical coefficients for the constraints in the LP model. Though unpublished, the reliability of Dr. Shurley's calculations was verified by Dr. Givan's budgets and the use of ASAE Standards as a calculation tool. See Appendix A-4 for the cotton budgets and A-5 for the peanut budgets.

The budgets were then used to create partial budgets where costs associated with yield (like ginning costs) were adjusted. Partial budgets were created for each plant/harvest combination under BtRR cotton production, conventional cotton production, and peanut production. These individualized partial budgets will be used in creating the model. Partial budgets are found cotton are found in Appendix A-6 and peanuts are found in A-7.

Section III: Calculating the Coefficients

In order to look at the timeliness aspect of cotton planting and harvesting, all of the jobs or activities are defined using information discussed above. Time periods for the production season are established to correspond to feasible dates for each field activity.

The time periods are defined by T_n, where *n* is the period number, and are defined in table 4.1. These jobs are scheduled beginning March 16-31 and ending January 16-30. Table 4.2 is a summary of all of the jobs necessary to produce a BtRR cotton crop. The table includes the labor hours per acre and the machine hours per acre required to accomplish each task.

Like cotton, it is necessary to understand the time line of events necessary to produce peanuts. Table 4.3 is a summary of all of the activities required to produce a peanut crop. The jobs for peanuts are basically the same as cotton, using up the same amount of labor hours in most instances. Once the time-line of events is determined the resource allocation problem begins to unfold.

Section IV: Cotton Calculations

Calculations of the cotton coefficients are based on a study conducted by Shurley and Deal. According to their research published in 1993, "on average there are 41 days between planting and squaring, 23 days between squaring and boll set, 63 days between boll set and open bolls, and 41 days between open bolls and harvest." This implies there are approximately 168 days between planting and harvest. In order to determine what period harvest could occur in, 168 days are added to the planting date on a calendar and the period of harvest is determined. For example, if planting occurs between May 1 and May 15, harvest would occur approximately 168 days later between October 1 and October 15.

Table 4.1. Time periods defined

MONTH	PERIOD
March 16-31	T_1
April 1-15	T_2
April 16-30	T_3
May 1-15	T_4
May 16-31	T_5
June 1-15	T_6
June 16-30	T_7
July 1-15	T_8
July 16-31	T_9
August 1-15	T_{10}
August 16-31	T_{11}
September 1-15	T_{12}
September 16-30	T_{13}
October 1-15	T_{14}
October 16-31	T_{15}
November 1-15	T_{16}
November 16-30	T_{17}
December 1-15	T_{18}
December 16-31	T_{19}

Table 4.2. BtRR Cotton Jobs, Labor Hours/Acre, and Machine Hours/Acre

Activity	Labor Hrs/Ac	Machine Hrs/Ac
Disk	0.1621	0.0917
Disk with Herb.	0.1802	0.1019
Rip and Bed	0.1908	0.1078
Plant	0.2269	0.1282
Early Post Herb. OTT	0.0576	0.0325
Apply N	0.2079	0.1175
Layby Post Direct Herb.	0.2079	0.1175
Growth Regulator/Boron	0.1151	0.0651
Insecticide/ Boron App.	0.0576	0.0325
Growth Regulator App.	0.1151	0.0651
Defoliate	0.0576	0.0325
Harvest	0.5791	0.3274
Mow Stalks	0.2172	0.1228

*A break down of these into time periods is shown for scenario 2 in Appendix A-7.

Table 4.3. Peanut Jobs, Labor Hours/Acre, and Machine Hours/Acre

Activity	Labor Hrs/Ac	Machine Hrs/Ac
Burn Down	0.0576	0.0325
Disk	0.2059	0.1164
Rip & Bed	0.1908	0.1078
Plant with Insect/Herb	0.2268	0.1282
Dig	0.2268	0.1282
Herbicide App.	0.5613	0.3173
Fungicide App. (6X)	0.5613	0.3173
Combine	0.4212	0.1190

***** A break down of these into time periods is shown for scenario 2 in Appendix A-7.

Raw data from research by Shurley and Bednarz (2000) is analyzed to determine a relationship between the number of days after planting (DAP) and percent open boll. Essentially, the goal is to estimate yield in terms of time and quality. This elected method of estimating yield evaluates yield as a function of DAP. Knowing the relationship between DAP and percent open bolls is important because according to Shurley and Bednarz (2000), "defoliation should occur at 70%-80% open bolls, with harvest occurring two weeks later." This is accomplished by running a regression on the data to find a relationship. Figure 4.1 shows a graphical representation of the polynomial regression, including the regression equation.

Looking at figure 4.1, $y = -0.0326x^2 + 10.521x - 748.05$ is the regression equation used to calculate the percent open bolls given a certain number of days after planting (defined as x in the equation). Looking at the figure, the trend upward implies that as the number of DAP increase, the percent open bolls also increases. Substituting 168 for x in the regression equation estimates the cotton to be at approximately 100% open bolls (see column A, row T_3T_{14} in appendix A-11). The intercept, x, and x^2 in the regression are all significant at a level of 0.01 (see table 4.4).

Once a relationship between days after planting and percent open bolls is determined, a relationship between percent open bolls (%OB) and yield is needed. This is determined by again running a regression on the raw data from Shurley and Bednarz. By regression analysis, a relationship is able to be determined and the graphical representation, including the regression equation appears below in Figure 4.2. The regression equation $y = -0.0559x^2 + 11.101x + 742.29$ is used to estimate the yield given a percent open boll (which is substituted for x in the equation) for an allotted days after

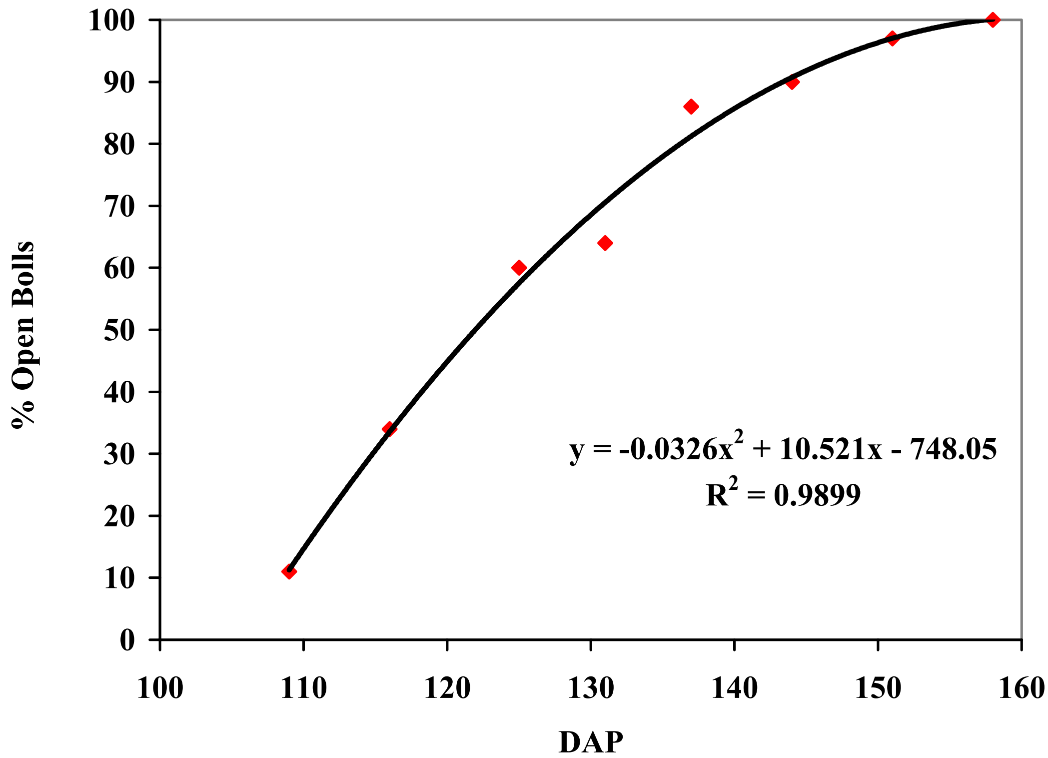

Figure 4.1. DAP and %OB Regression

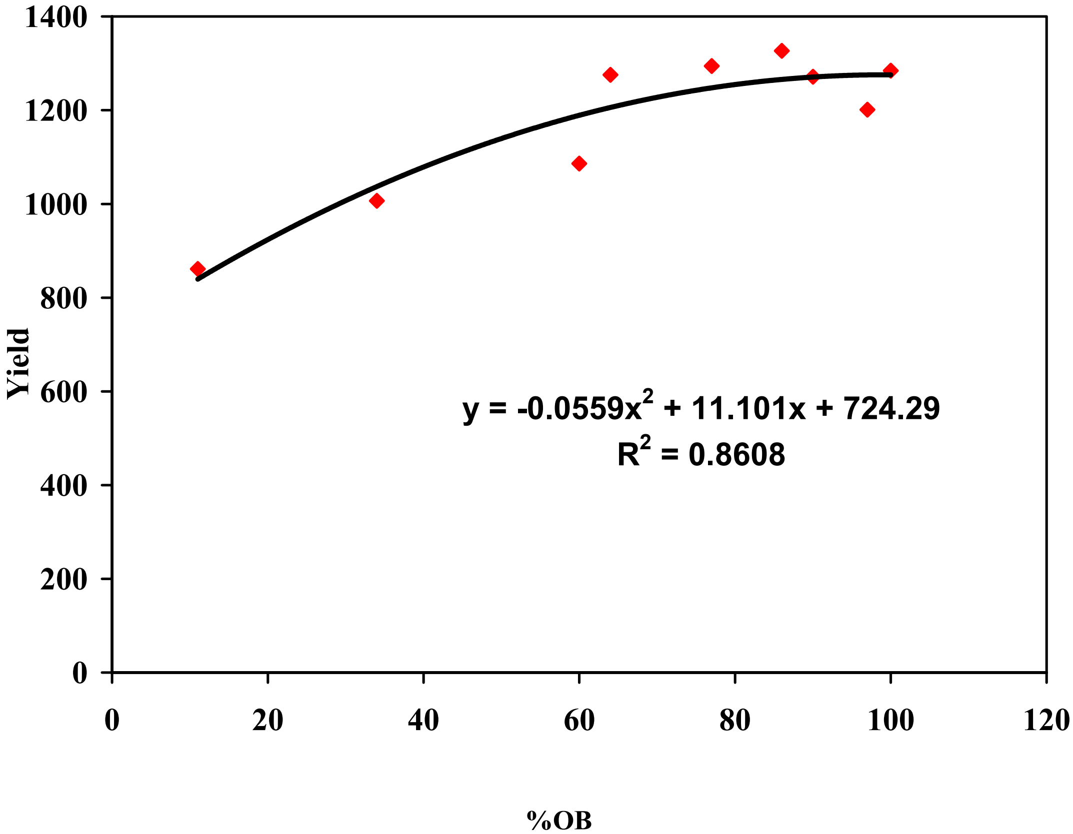

Figure 4.2. % OB /Yield Regression

planting—provided by the previous regression. Using the regression equation, any given %OB can be entered into the regression equation by substituting the %OB for x.

For example, substituting 100% OB into the regression equation, the anticipated yield is 1275.42 lbs/acre (see column D, row T_3T_{14} in appendix A-11), which falls on the black line at 100%OB. The trend line implies yield increases as %OB increases. This is logical in that lint cotton cannot be harvested until open bolls occur. However, this regression equation is useful only to the point that 100% OB is reached. The applied regression equation assumes that at some point the %OB will begin to decline. Therefore, any planting/harvest combination with more than 168 days will use a different regression to determine the relationship between the weeks after 100%OB and yield. The intercept and x variable in the regression are significant at a level of 0.01 (see table 4.4).

For instance, what is the anticipated yield per acre of the crop one week after 100% OB has been reached? The regression equation in Figure 4.3 would be used to answer the question. Again, a regression is constructed from the data obtained from research by Shurley and Bednarz. The regression equation is $y = -2.04x^2 – 5.648x + 1246$, where x is defined as weeks after 100% OB. Using this regression in Figure 4.3, one week after 100% OB the yield is approximately 1238.12 lbs per acre. Comparing this yield to the 1275.42 lbs per acre at 100% OB from the precious paragraph, a yield decrease of 37.3 lbs per acre occurs. The intercept in the regression is significant at a level of 0.01 (see table 4.4).

As weeks after 100% OB increases, yields continue to decline demonstrating an inverse relationship. In Figure 4.3, a definite trend is not clearly defined.

Table 4.4. Parameter Estimates and t-statistics[a] for Regression Equations

	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5	Equation 6
Intercept	-748.05	723.46	1245.96	-1.91	-61.65	22611.43
	(-7.19) *b	(7.58)*	(10.07)**	(-0.17)	(-3.25)*	(3.52)*
X	10.52	11.16	-5.65	0.35	23.57	-462.13
	(6.68)*	(3.01)*	(-0.05)	(0.77)	(1.36)	(-2.56)**
X^2	-0.03	-0.06	-2.04	-0.01	-6.00	2.80
	(-5.54)*	(-1.78)	(-0.09)	(-1.61)	(-1.76)	(2.25)**

[a] t-statistics are in parentheses
[b] *significant from zero at the .01 level
*significant from zero at the .05 level

However, without the availability of other data or research, the regression equation is used as the estimation tool. Calculating yield in this manner is a respectable effort to address the timeliness issue of planting and harvest. However, this estimation does not account for quality adjustments. Therefore, another set of regressions is used to determine the dollar value of the quality adjustments associated with delaying harvest.

Quality adjustments in cotton are reported in premiums and discounts. A premium is a dollar amount added to the value of the cotton for quality. A discount, on the other hand, is a dollar amount subtracted from the value of the cotton. This amount is subtracted as a result of quality lost for allowing the crop to remain un-harvested. To accomplish this step, the data from Shurley and Bednarz is used to determine the nature of the relationship.

Figure 4.4 represents the regression used to estimate the value of the discount measured against a given %OB. Based on the data, the regression equation $y = -0.0062x^2 + 0.3461x - 1.9076$ is obtained, where x is defined as the %OB. Again, the regression is only useful until 100%OB is reached because %OB cannot exceed 100%, which indicates the crop is completely matured. In this case, substituting 100% OB into the equation for x gives a discount of \$28.74 (see column E , row T_3T_{14} in appendix A-11). The downward sloping trend line is associated with increasing %OB. A cotton boll is at its highest quality the day it opens. Physiologically, fruit on the lower part of the plant may deteriorate while bolls continue to open in the top portion. Table 4.4 gives the test statistics. For this information to be useful it must be converted into a more user-friendly form.

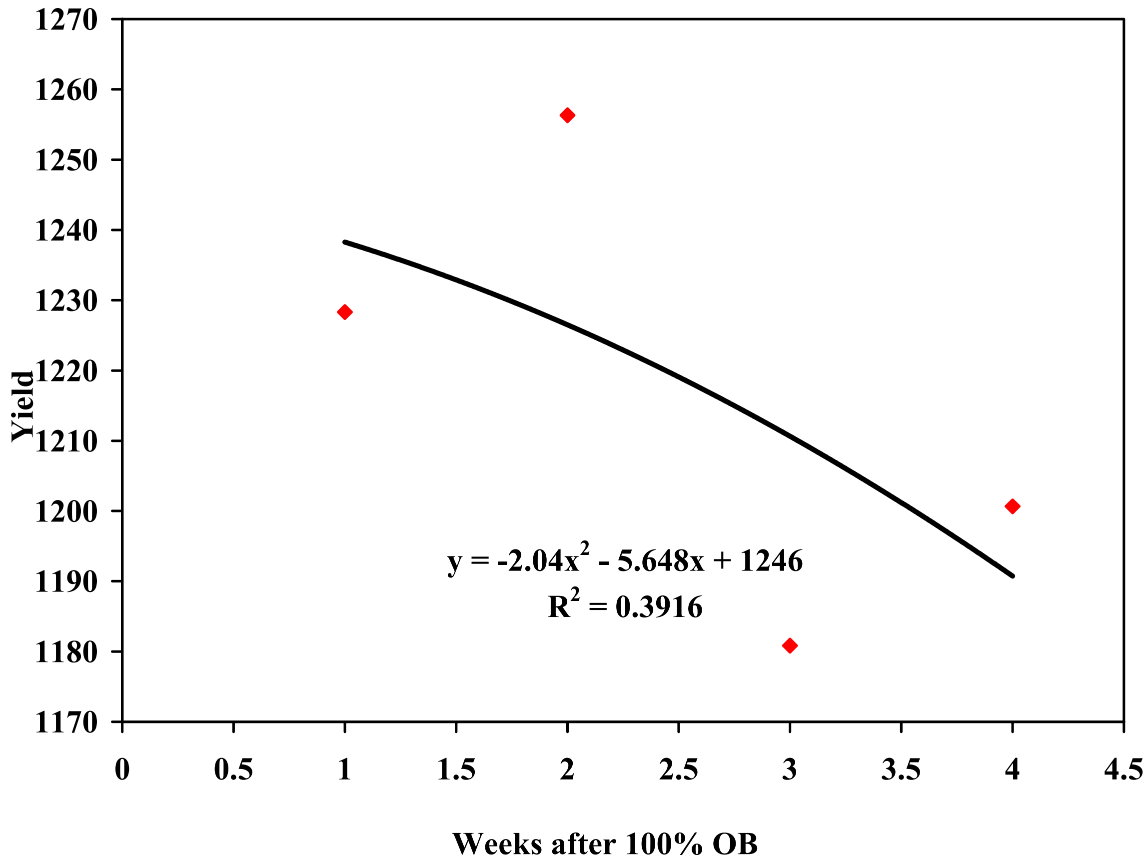

Figure 4.3. Weeks After 100% OB Regression

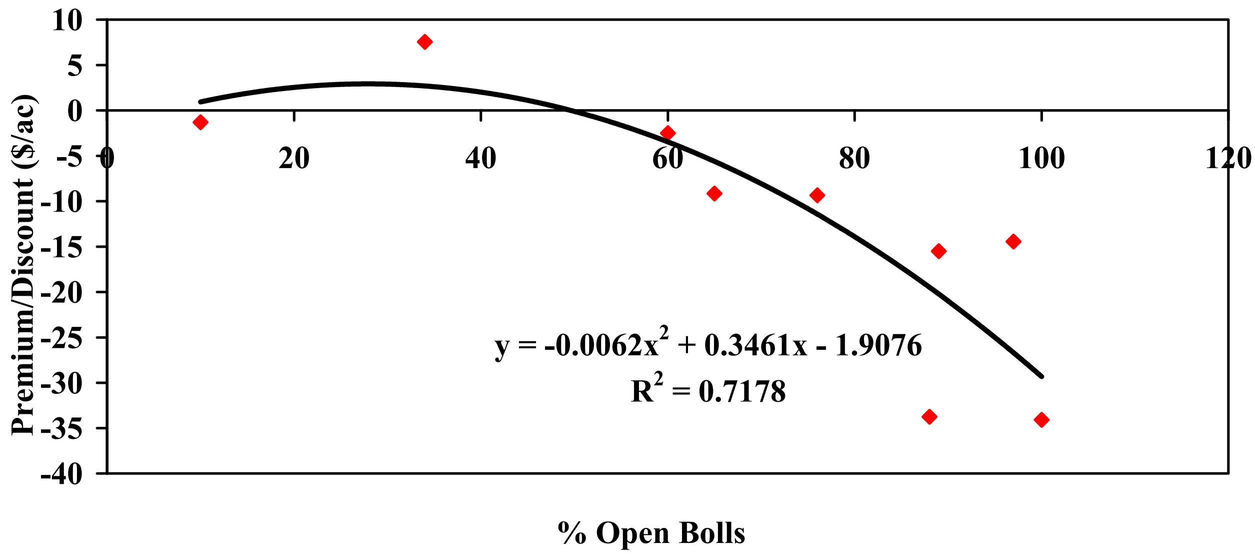

Figure 4.4. OB/Discount or Premium Regression

The -\$28.74 is converted to pounds by dividing it by the price of cotton, in this case \$0.60/pound. The dollars cancel leaving pounds. This amount is subtracted from the previous time-adjusted yield of 1238.12 resulting in a yield of 1227.51lbs (see column F, row T_3T_{14} in appendix A-11). For weeks where harvest runs over 100%OB, the regression in Figure 4.5 is needed to calculate the quality adjusted yield. Again, this is because the percent open bolls will not decrease once all are open.

Figure 4.5 describes the effects of delaying harvest past 100%OB. The regression equation $y = -5.9975x^2 + 23.568x - 61.647$ estimates the approximate discount associated with delaying harvest, where x is defined as %OB. This equation is used for any combination of planting and harvest that runs over 100%OB. Table 4.4 shows the test statistics for this regression. As before, the dollar amount of the premium or discount is converted to pounds by dividing by the price of cotton, and is then added or subtracted from the time-adjusted yield.

Section V: Peanut Calculations

The coefficients for the peanut enterprise are calculated similarly to cotton. The TSW Risk Index uses variable factors to determine an estimated probability that a given field of peanuts will develop TSW. The factors taken into account are variety, planting date, population, at plant insecticide, row pattern, and tillage. Each of these factors has a corresponding level of risk. Table 4.5, below, summarizes the risk index points associated with the "base peanut budget", as set forth by Brown et al (2001). With timeliness being the focus of this research, all of the factors are held constant, with planting date being the changing variable.

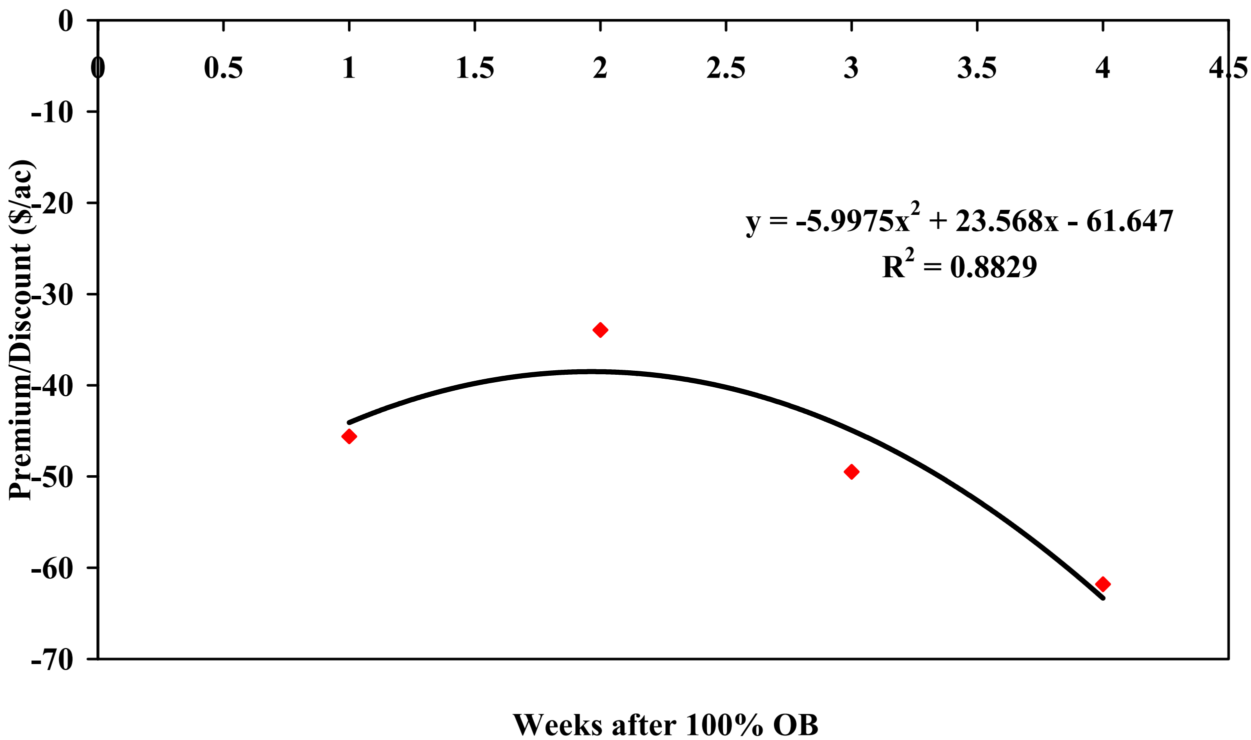

Figure 4.5. Premium/Discount Regression

Considering all of the ratings possible with changing planting dates, the lowest possible rating is a 65. This risk level is assigned as a base rating for the combination that satisfies the planting date requirement-in this case T_4T_{14}. The risk index for the base combination is calculated as follows is in bold in table 4.5.

The amount of time needed to "produce a profitable, high quality yield is approximately 150-160 days" (UGA Extension Service, 1997). This number of days is used to determine the planting/harvest combinations. As stated earlier, planting date is the only factor allowed to vary, so the lowest possible ranking is 65 (planted May 1-20) and the highest possible ranking is 80 (planted either before April 15 or after May 31). Once the range of index ratings is established, a relationship between the index rating and yield is needed.

Raw data from the National Center for Peanut Competitiveness on TSW is used. The data obtained is from research in GA and FLA. The study incorporates various varieties, row spacing, and tillage methods. With planting the only changing factor, only the data associated with conventional twin row production is examined. Of that data, only that dealing with Georgia Green variety peanuts with Thimet is considered. The data from those fields fitting the criteria (variety and spacing) is extrapolated and analyzed. This data is analyzed with the goal of establishing a relationship between index ratings and yield. To be consistent, regression analysis is conducted using all of the extrapolated data with ratings of 55-90.

The trend in Figure 4.6 indicates that as the index rating increases, the yield decreases. This is logical as UGA recommends practices with the lowest index points as a means of increasing yields.

Table 4.5. TSWV Risk Index Points

Factors	Points
Variety	**Georgia Green = 20**
	Flo Runner = 50
Planting Date	Prior to April 11 = 25
	April 11-20 = 20
	April 21-30 = 15
	May 1-20 = 5
	May 21-31 = 10
	After May 31 = 20
Population	< 2 seed/ft. = 25
	2-4 seed/ft. = 10
	> 4 seed/ft. = 5
At Plant Insecticide	None = 15
	Thimet = 5
	Other = 15
Row Pattern	**Single (32-38") = 15**
	Twin (7-10") = 5
Tillage	**Conventional = 15**
	Strip-till = 5

* The risk point intervals above are adjusted to reflect the two-week time periods set forth in the research.

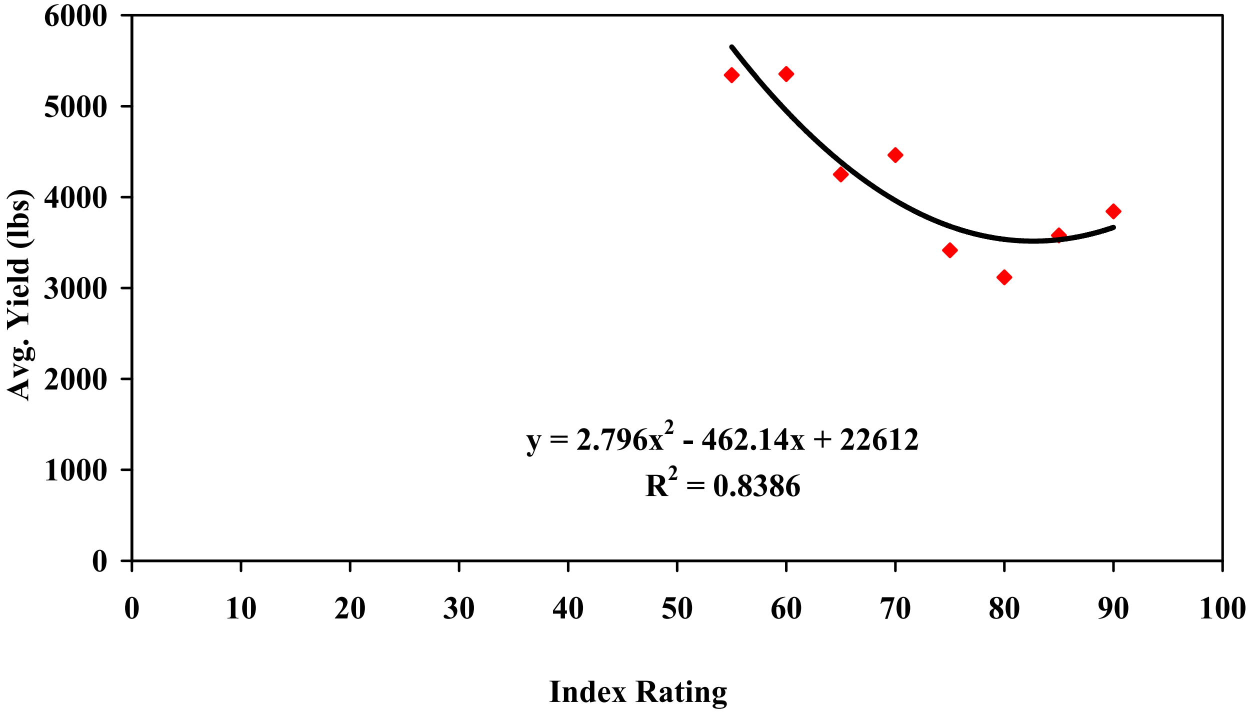

Figure 4.6. TSWV Regression

possible rating. The regression equation $y = 2.796x^2 - 462.14x + 22612$ is used to estimate the index related yield, where x is represents the different index ratings. Table 4.4 shows all of the variables in the regression to be significant at a level of 0.01. This quadratic form of the equation is a general estimator of yield.[1]

The downward trend indicates that as the index rating increases to higher severities, yield declines. One problem with this trend line is that at approximately 90%, the line curves upward indicating that yield increases with more severe wilt problems. Severity of TSW will not increase yield, therefore the only portion of the line that should be considered is that in the range of 55-90. Once the optimal yields for ratings 65-80 are determined, a timeliness adjustment is needed. According to the University of Georgia Extension Service (1997), digging 2 weeks early decreases yield by 740 lbs per acre while digging 2 weeks late decreases yield by 540 lbs per acre. Quality adjustments are not made, as sufficient data is not available.

Section VI: Using Data to Establish Constraints

Before proceeding to build the LP model, data supporting the constraints to be implemented are needed. For the most part, constraints placed on the model are labor intensive. The researcher believes labor is one of the most binding resources, if not the most binding. Knowing how much time is available to work on a given day during the two-week intervals over the course of the production season for these crops is vital. In order to determine these coefficients, data is obtained from the Georgia Agricultural

[1] A linear equation is also fit to the data points, and the regression appears in Appendix A-8. The peanut yields estimated by the linear regression are higher than the quadratic form, and would therefore have a higher optimal net return under all scenarios. Also, the linear equation causes a reallocation of resources todifferent periods.

Statistics Service (GASS) that it reports in the "Georgia Weather and Crops Bulletin" published weekly from around March through December.

Over the course of the production season, GASS publishes information entitled *days suitable for fieldwork* and *crop progress reports*. In order to get a good estimate, data from 1997-2001 are analyzed. The days suitable for fieldwork data are entered into spreadsheet form to determine the amount of days suitable for fieldwork during each two-week period. In appendix A-9, the data is broken down into two-week periods. In 1997, the first report is for week ending March 16. The report shows there to be 4.8 days suitable for fieldwork. This number is divided by 7, as there are seven days in a week. The result is 0.6857 or almost 7/10 of a day for fieldwork. The days are then converted to hours by multiplying the days by the number of hours worked a day times the number of laborers (3 in this case). While it is impossible to model the exact number of hours a producer will be in the field, this study assumes an eight-hour day. The total number of hours available for fieldwork represents the right-hand side of the many of the labor constraint equations. One problem for building these constraints is that data is not available for most of December. Therefore, these hours are estimated.

In 1997 and 1998, days suitable are reported through December 6. Years 1999, 2000, and 2001 ended around November 25. Missing data for each year missing through December 31 is estimated. To begin estimating these coefficients, the data missing through December 6 is estimated using the relationships of the last reported coefficients for the previous two years—1997 and 1998.

Referring to appendix A-9, column 3 (1999), November 29 is the first missing entry. Therefore, the data from the previous two years is used to estimate the third year on that day. This is done by first averaging the entries for 1997 and 1998. For example, the figures for November 29 for 1997 and 1998 are 0.7143 and 0.8857, respectively. These numbers are determined by taking the days suitable for fieldwork reported for the seven-day period ending November 28 (5.0 days in 1997) and dividing by seven (days in a week). The quotient times 8 (for an 8 hour work day) indicates that, on the average, there are approximately 5.71 hours each day available for fieldwork.

The average of 0.7143 and 0.8857 is 0.8000. Next, this number is adjusted by the percent of the current year's most recent observation in relation to the previous two years. In 1999, the most recent observation was 0.7571 on November 28. This number is then divided by the average of 1997 and 1998's reported figure, the 0.8000 in this case. This quotient is 0.946. Multiplying that quotient by the average of the previous two years (0.800 x 0.946) results in an estimate 0.7568. Multiplying again by the 8-hour day, there are approximately 6.05 hour available for work November 29, 1999. For the 30th of November through December 6, this process is utilized as a means of estimating the needed coefficients.

There are no data available for December 7-31 in any of these years. Therefore, it is estimated as well. This is calculated by comparing the change in days available for the last two weeks that data is available ending December 6 for 1997 and 1998. For example, in 1997 the last week decreased 22 percent. This percent is calculated by dividing 0.5571 (week ending Dec. 6, 1997) by 0.7143 (week ending Nov.19, 1997). The quotient is 0.78. This number, as a percent, is subtracted from 1, or (100-78) and the difference is 22. Therefore a 22 percent increase is evident. This same kind of arithmetic is done for 1998 and there is a 6.5 percent decrease. This is an average decrease of 7.75

percent. Subtracting from 100%, this is approximately a 92% decrease. Therefore, the estimated coefficient for December 7-13 is 92 percent of 0.5571, which is equal to 0.5215. Therefore, December 14 is assumed to be 92 percent of that for December 13. All of the other missing coefficients are estimated in this manner.

Now all of the coefficients needed to initiate Solver are available. It is important to keep in mind throughout this research and optimization, that only the variable costs are being considered. Without fixed costs being added into this model, profit itself is not being maximized. Rather, the net return above variable costs is being maximized. The methodology for maximizing profit still applies, but the difference should be noted.

In order for a producer to grow BtRR cotton, he/she must agree to produce x number of acres as a refuge requirement. In this case, the 95/5 embedded refuge option is used. This means that for every 100 acres, 95% will be BtRR and the other 5% will be conventional cotton. The refuge is an Integrated Pest Management (IPM) approach to prevent Bt resistance in tobacco budworms and cotton bollworms.

CHAPTER 5

THE MODEL

Section I: Mathematical Description of the LP

As stated earlier, LP models are useful in decision-making where numerous resources are available and efficient allocation becomes more difficult. With a timeliness study, equipment availability and labor availability tend to restrict productivity during a given period, such as harvest. The LP will use a base budget, and a series of partial budgets to maximize net return in order to establish the optimal farm plan. This optimal farm plan defines the best combination of the number of acres to produce, when to plant them, and when to harvest them. With the various factors affecting productivity, LP optimally determines the best allocation of the resources for planting and harvesting.

In Chapter 3, Chiang (1984) describes how to formulate the objective function for the longhand LP model. With the use of Excel and Solver, the objective function is basically the same. First the base objective function to be maximized is defined. Next, the imposed constraints for this typical South Georgia farm are defined as well. This system of equations then tells what is to be optimized, and the limits or constraints that are to be imposed in determining the optimization. Note that the objective function is what is being maximized, subject to the given constraints. This system of equations looks like this:

$$\text{Maximize } \Pi = \sum_{i=1}^{21} r_i * a_{\cot i} + \sum_{j=1}^{15} r_j * a_{pnutj}$$

subject to :

$$\sum_{i=1}^{21} L_{ip} * a_{\cot i} + \sum_{j=1}^{15} L_{jp} * a_{pnutj} \le Labor_p \text{ for } p = 1,\ldots,19$$

$$\sum_{i=1}^{21} PL_{ip} * a_{\cot i} + \sum_{j=1}^{15} PL_{jp} * a_{pnutj} \le Planter_p \text{ for } p = 3,\ldots,7$$

$$\sum_{i=1}^{21} CH_{ip} * a_{\cot i} \le C.Harvester_p \text{ for } p = 11\ldots,19$$

$$\sum_{j=1}^{15} PC_{jp} * a_{pnutj} \le P.Combine_p \text{ for } p = 13,\ldots,19$$

$$\sum_{j=1}^{15} PD_{jp} * a_{pnutj} \le P.Digger_p \text{ for } p = 12,\ldots,19$$

where,

r_i and r_j are net revenues per acre for rotations i for cotton and j for peanuts, respectively, a_{coti} and a_{pnutj} are acres of cotton rotations i and peanut rotations j, respectively, L_{ip} and L_{jp} are hours of labor per acre used by rotations i and j in period p, $Labor_p$ is labor hours available in period p, PL_{ip} and PL_{jp} are hours of planter time per acre used by rotations i and j in period p, $Planter_p$ is planter hours available in period p, CH_{ip} are hours of cotton harvester per acre used by rotations i in period p, C.Harvester is cotton hours available in period p, PC_{jp} are hours of peanut combine per acre used by rotations j in period p, P.Combine is peanut combine hours available in period p, PD_{jp} are hours of peanut digger per acre used by rotations j in period p, and P.Digger is peanut digger hours available in period p.

The base LP described above was modified to allow the hiring of additional labor. Since labor is defined in this model to include an hour of worker time combined with an hour of tractor time, increasing the amount of labor available requires increasing both the number of worker and tractor hours. Rather than modeling the custom hiring of both labor and tractor time, we took advantage of the hours of tractor time that become available when the self-propelled cotton harvester is used. In any period p in which the cotton harvester is employed, we allowed labor to be hired such that the maximum number of hours of labor that can be hired is equal to the number of hours the cotton harvester is used (equal to the number of tractor hours freed up to combine with hired labor). The following modifications were made to the above model to allow the hiring of labor during selected time periods when the cotton harvester is being used:

$$\begin{aligned}
&\textit{new constraint for hours of hired labor}:\\
&HL_p \le \sum_{i=1}^{21} CH_{ip} * a_{\cot i} \;\; \textit{for } p = 12,\ldots 15\\
&\textit{revised labor availability constraint}\\
&\sum_{i=1}^{21} L_{ip} * a_{\cot i} + \sum_{j=1}^{15} L_{jp} * a_{pnutj} \le Labor_p + HL_p \;\; \textit{for } p = 12,\ldots,15\\
&\textit{revised objective function}\\
&Maximize\ \Pi = \sum_{i=1}^{21} r_i * a_{\cot i} + \sum_{j=1}^{15} r_j * a_{pnutj} - \sum_{p=12}^{15} w * HL_p
\end{aligned}$$

where HL_p is the number of hours of labor hired in period *p*, *w* is the wage rate per hour for hired labor, and all other variables are as previously defined.

Section II: Constructing the LP Model in Excel

Appendix A-7 shows the layout of the LP model in Excel. At the top of each column, the time period combinations are entered below each crop heading. The other rows are labeled according to their purpose. Looking at appendix A-7, columns A:V are for cotton and columns W:AK are for peanuts. Columns AL:AO represent the cotton harvester hours used in each two-week time period at harvest. Columns AP:AS represent the number of hours that could be hired during harvest. Notice in this scenario, 16.66 hours are being hired for September 1-15, cell AL4.

The time period combinations are listed in row 2, cells B2:AK2 for example. Next the changing cells (where the solution occurs) are in cells B4:AK4. Cells in rows 5 and 6, like B5 and B6, are simply for breaking the final acreage down into the number of BtRR acres and conventional acres. The conventional acreage is assumed to be 5 % of the solution acres, while BtRR is considered to be 95% of the solution acres (from the 5% embedded refuge option).

Row 8 is the row for the objective function. The numbers in cells, B8:AK8 for example, are the net revenues for each plant/harvest combination. The total net revenues are calculated by multiplying the BtRR net revenues, from the partial budgets, by .95. Next, the net revenue for conventional cotton, from the partial budget, are multiplied by .05, and added to the net revenue for BtRR. These net revenues are multiplied by their respective factors to comply with the refugee requirement for BtRR cotton. The objective function equation is entered into cell AM8 at the end of the objective function row. The objective function equation is entered in as the summation of the solution acres multiplied by the net revenue (ie. B4 x B8) for each combinations. Summarized this is

(B4 x B8)+(C4 x C8)+…(AK4 x AK8). This goes hand in hand with the system of equations in section 1. The target cell is where the optimal net return for the farm is calculated.

The cells at the bottom of the sheet are all of the constraints, rows 11-68. The coefficients in the cells such as B15 are the amount of time required to do each job for each plant/harvest combination during a given period. For instance, cell B16 is the coefficient for planting during T_3T_{11} in April 16-30. Like the constraints explained in Section I, these are multiplied by the solution acres and summed across and entered into one cell, like cell AL15. The same format was used for each constraint, and represents the left-hand side (LHS) of the constraint. The RHS is simply the hours available during each two-week period, which came from the days suitable data discussed earlier. Therefore, the LHS must be less than or equal to the RHS. Ragsdale (1998) explains how to set up LP models in *Excel*© and other programs. Constraints were constructed in *Excel*© according to the constraint equations in Section I.

Once the original model is established, it is used as the base scenario for creating all other scenarios. Once established, only the RHS of the constraints are adjusted accordingly as the partial budgets are employed. Sensitivity and answer reports are available for each scenario providing sensitivity information for increasing net returns.

CHAPTER 6

RESULTS

Solver is a great optimization tool not only because it eliminates working through the simplex method longhand, but it also provides answer and sensitivity reports useful for analyzing the results of the optimization. However, there are other benefits of computerized, linear programs. In total, seven scenarios are created and optimized to determine the most profitable position a typical producer should take in South Georgia. While labor is binding in most cases, increasing labor was not necessarily the most profitable decision to make. Here, each scenario will be mentioned, while only the most profitable ones will be explored. The results of each scenario are in Appendix A-7.

Section I: The Initial Model

The initial model was created using the specifications of the typical South Georgia farm defined in Appendix A-1. The crew size included the farm operator and two full-time employees. The typical farm also includes one two-row digger and one two-row combine, one four-row digger and one four-row combine, and one cotton picker. For the typical farm, approximately 1000 acres of cotton and peanuts are produced. Once all of the calculations from Chapter 5 are figured into the model, as well as entering the constraints into *Solver*, optimization was possible.

Optimization of the initial model (scenario 1) results in a net return of $331,736.81. Under this model, a total of 1000 acres are planted and harvested. Of the 1000 acres, 881.06 acres of cotton are planted. This breaks down into 837.01 acres of BtRR, stacked gene cotton, and 44.05 acres of conventional cotton--as an embedded refuge. The other 118.94 acres are planted with peanuts in time period T_5T_{15}. Harvest for these peanut acres occurs October 16-31.

In the time combination T_3T_{11}, cotton planting begins with 11.54 acres being planted April 16-30, and continues through June 1-15. The initial harvest date is T_{11} (August 16-31). Harvest is carried out in consecutive weeks through T_{17} (November 16-30). Harvest was not allowed to carry over into December as the majority of cotton harvest is completed by the end of November (USDA, 1997). Table 6.1 breaks down the planted acreage for the optimal solution of scenario 1 into time-periods for each crop. Only 118.94 acres of peanuts are planted in scenario 1. They are planted May 16-31 and are harvested October 16-31. This forces the producer to harvest both cotton and peanuts during the T_{15} time-period (October 16-31). Therefore, cotton harvest is discontinued at some point during that two-week period to harvest peanuts. Once peanut harvest is complete, cotton harvest is resumed.

Section II: Sensitivity Reports

Once optimized, *Solver* provides answer and sensitivity reports. The sensitivity report makes analysis of the model possible by providing different pieces of information. The sensitivity report for scenario 1 is found in Appendix A-10. First, it reports the

Table 6.1 Scenario 1 Optimal Solution

	Cotton			Peanut
Period	**Total Acres**	**BtRR**	**Conventional**	**Acreage**
T_2T_{11}	********	********	********	0.00
T_2T_{12}	*********	********	********	0.00
T_2T_{13}	*********	********	********	0.00
T_3T_{11}	**11.54**	10.97	0.58	********
T_3T_{12}	**135.18**	128.42	6.76	0.00
T_3T_{13}	**60.96**	57.91	3.05	0.00
T_3T_{14}	**0.00**	0.00	0.00	0.00
T_3T_{15}	**0.00**	0.00	0.00	********
T_3T_{16}	**0.00**	0.00	0.00	********
T_4T_{12}	**0.00**	0.00	0.00	********
T_4T_{13}	**113.86**	108.17	5.69	0.00
T_4T_{14}	**82.85**	78.71	4.14	0.00
T_4T_{15}	**0.00**	0.00	0.00	0.00
T_4T_{16}	**0.00**	0.00	0.00	*******
T_4T_{17}	**0.00**	0.00	0.00	*******
T_5T_{13}	**0.00**	0.00	0.00	*******
T_5T_{14}	**98.41**	93.49	4.92	0.00
T_5T_{15}	**108.32**	102.91	5.42	118.94
T_5T_{16}	**36.42**	34.60	1.82	0.00
T_5T_{17}	**0.00**	0.00	0.00	*******
T_6T_{14}	**0.00**	0.00	0.00	*******
T_6T_{15}	**97.59**	92.71	4.88	0.00
T_6T_{16}	**0.00**	0.00	0.00	0.00
T_6T_{17}	**135.92**	129.12	6.80	0.00

*Note T_pT_h, where T_p is the planting period and T_h is the harvest period.

final value (the optimal solution) for each time-period combination and a reduced gradient. The reduced gradient can be considered a shadow price. A shadow price indicates that if a certain activity occurs in a given time-period combination, or in this case if acres are planted and harvested in a given time-period combination, in general, can increase or decrease by the shadow price amount per given unit. For example, on the report in Appendix A-10, looking in the "cell" column in row F4, if one additional acre of rotation T_3T_{15} is put into production during that time-period, net returns would decrease by $31.65 as an acre of a more profitable rotation is removed from production. Therefore, if one acre of production takes place in the time-period combination T_3T_{15} - (planting April 16-30 and harvest October 16-31), net returns would be reduced by $31.65 for each acre entering into the solution.

The lower part of the report contains the most useful information. The lower part analyzes how the solution reacts to the imposed constraints. For instance, it tells how net returns would adjust if more land were available. Table 6.2 defines the constraints for scenario 1. Looking at the Table, the first binding constraint is on land. The constraint is said to be binding because the left-hand side (LHS) of the constraint is equal to the right-hand-side (RHS). In this case, land cannot exceed 1000 acres. Since 1000 acres (LHS) are being produced, the LHS equals the RHS thereby binding that constraint.

Looking at page one of Appendix A-10, the Lagrange Multiplier (LM) column is useful for determining various pieces of information. For the land example, the number 273.37 is reported for the LM. Since land is a binding constraint, the production of more land would alter the profitable solution. The LM is positive meaning that increasing land

Table 6.2 Defining the Binding Constraints for Scenario 1

Land	**LHS**		**RHS**
	1000	<=	1000
Labor Hours:			
March 16-31	65.5725	<=	171.0461
April 1-15	162.1747	<=	279.8352
April 16-30	180.7353	<=	279.222
May 1-15	168.3579	<=	285.9451
May 16-31	281.8948	<=	324.5486
June 1-15	212.0219	<=	272.2882
June 16-30	78.0821	<=	263.9822
July 1-15	248.0767	<=	285.8045
July 16-31	166.4475	<=	314.8157
Aug 1-15	153.1139	<=	304.1851
Aug 16-31	93.0503	<=	335.3846
Sept 1-15	**298.2178**	<=	**298.2178**
Sept 16-30	228.9568	<=	280.3574
Oct 1-15	**290.6894**	<=	**290.6894**
Oct 16-31	**330.2174**	<=	**330.2174**
Nov 1-15	**281.7573**	<=	**281.7573**
Nov 16-30	**269.2774**	<=	**269.2774**
Dec 1-15	**225.8808**	<=	**225.8808**

Dec 16-31	29.5169	<=	191.1864
		<=	
Planter Hours:		<=	
April 16-30	**51.0873**	<=	**93.0741**
May 1-15	**49.0735**	<=	**95.3150**
May 16-31	**60.6581**	<=	**108.1829**
June 1-15	87.9213	<=	90.7427
June 16-30	**0.0000**	<=	**87.9941**
Picker Hours:		<=	
Aug 16-31	**6.1703**	<=	**111.7949**
Sept 1-15	**72.2602**	<=	**99.4059**
Sept 16-30	**93.4525**	<=	**93.4525**
Oct 1-15	**96.8965**	<=	**96.8965**
Oct 16-31	**110.0725**	<=	**110.0725**
Nov 1-15	**19.4702**	<=	**93.9191**
Nov 16-30	**72.6570**	<=	**89.7591**
Dec 1-15	**0.0000**	<=	**75.2936**
Dec 16-31	**0.0000**	<=	**63.7288**
		<=	
Combine Hours:		<=	
Sept 16-30	**0.0000**	<=	**186.905**
Oct 1-15	**0.0000**	<=	**193.793**
Oct 16-31	**0.0000**	<=	**220.1449**

Nov 1-15	**14.7002**	<=	**187.8382**
Nov 16-30	**179.5183**	<=	**179.5183**
Dec 1-15	**0.0000**	<=	**150.5872**
Dec 16-31	**0.0000**	<=	**127.4576**
		<=	
Digger Hours:		<=	
Sept 1-15	**0.0000**	<=	**198.811**
Sept 16-30	**0.0000**	<=	**186.905**
Oct 1-15	**0.0000**	<=	**193.793**
Oct 16-31	**0.0000**	<=	**220.1449**
Nov 1-15	**66.7592**	<=	**187.8382**
Nov 16-30	**0.0000**	<=	**179.5183**
Dec 1-15	**0.0000**	<=	**150.5872**

available by one acre would increase net returns. Note that no numbers in the LM column will be negative. Negative effects on net returns occur in the reduced gradient column. The 273.37 in the land row means that for every one acre of land produced over the 1000 acres constraint will increase net returns by 273.37 per acre. This is the highest number in the LM column, indicating that, if allowed, can potentially have the greatest influence on the net revenues.

The second largest number in the LM column is the constraint on the cotton picker. Looking at row AL48 (Appendix A-10n weeks September 1-15, the LM is 87.57. This implies that net returns can be increased by $85.75 by making one additional hour available on the RHS of the cotton picker constraint. The only way to increase the availability would be to increase the picker capacity, which is only possible by adding a second cotton picker. With only one cotton picker available at harvest, the picker and two tractors are being used. Assuming one person per tractor, another person could be hired during the harvest period because one person would take over the picker. However, further information from the sensitivity report in Appendix A-10 is needed to determine if hiring more labor will negatively impact the net returns.

Allowing additional picker capacity would have another affect on the farm. Additional labor is not desirable if there is not an equipment compliment—meaning that if additional labor is hired, there should be a tractor or other equipment available. In this scenario, 99.41 hours are available for picking cotton during September 1-15. Of these hours, only 72.26 are utilized. If another picker were added, this would have the same effect of increasing tractor availability by 99.41 hours. This is due to the fact that the additional picker has 99.41 hours available, and represents that numerical increase in tractor hours available for another person. This fact supports the previous paragraph in having one extra tractor once someone takes over the picker.

Looking at the LM for labor, various assumptions can be made. Continuing down the LM column, row AL26 has a value of 34.24. This value makes labor the third binding constraint. The value in the cell indicates that for every hour of labor that is made available during that time period, net returns will increase by $34.24 per hour. On the other hand, the meaning could be interpreted as a wage rate per hour cap. In this scenario, additional labor is assumed to cost $9.00 per hour. This wage rate is significantly less than $34.24. Therefore, more labor should be hired to increase net returns.

Section III: Other Economic Uses of the Model

Scenario 2—Adding an Additional Cotton Picker

The sensitivity report for scenario 1 identifies the capability of the producer to move to a more profitable position by relaxing constraint with the highest shadow price—cotton picker availability. Scenario 2 is similar to scenario 1 with the exception of adding an additional cotton picker. In any case where additional resources are made available, net returns only increase because the binding constraints are relaxed. Therefore, the addition of the cotton picker should only allow profits to increase because the picker constraint is being relaxed compared to that of scenario 1.

The simplest way to add the cotton picker would be to adjust the RHS of the cotton picker constraints. Basically, doubling the RHS of the constraint increases the available picker hours allowed in scenario 1. Looking at Appendix A-11, doubling value of the cells in column AV in the constraints section is equivalent to adding the additional cotton picker. The reason the adjustment is made this way, and not by adding the picker (and additional costs) through the budget is that only net returns above variable costs are being assumed.

Under the conditions of scenario 2, land still has the largest shadow price. Here, if more than 1000 acres were available for production, net returns could be increased by \$322.14 for each additional acre. Again, this being the largest number in the LM column, it is potentially the biggest net revenue constraining factor. This constraint is the biggest obstacle preventing the farm from producing at a more optimal level. In this scenario net returns increased \$742.84 to \$332,479.65. Referring back to the sensitivity report for scenario 1, the shadow price indicated that if more picker hours were made available, that net returns would increase.

The second largest net revenue constraint, other than land, is peanut combine availability. Comparing the results of scenario 1 and 2, the yields do not change for either cotton or peanuts. Rather, the amounts produced in the different time periods are increased or decreased according to the constraints—a reallocation of resources. This demonstrates how LP model move from point to point on the PPC or product transformation curve reallocating resources to maximize net returns or profit.

Scenario 3—Hiring additional Labor

In this scenario, Solver is allowed to hire extra labor in the harvest periods as needed--as those periods were the only binding periods. In the scenario, net return is increased by $406.80. As in scenario 2, production acreage does not change, and peanut harvester (combine) availability continues to be the next largest LM binding constraint. The sensitivity report for scenario 3 implies that additional peanut combine hours will allow net returns to increase by $35.62. Therefore, if an additional picker can be made available for $35.62 or less per acre, then one should be added.

The model is allowed to hire additional labor by the addition of columns AP:AS. The model in Appendix A-7 displays these columns and the amount of labor hired in cells AP4:AS4. In cases were it is optimal to hire labor, *Solver* will do so provided the cost of labor does not exceed the shadow price. The price of labor, as shown in the objective function row, is $9.00 or –9.00 in the row 8. In scenario 1, a laborer is hired to work a total of 16.66 hours during September 1-15. While additional labor is added to September 1-15, the report indicates that labor continues to be binding September 16-30 through December 1-15. However, more labor could have been hired for that period, but it is not profitable to do so. Otherwise, it would have been added in this optimization.

Scenario 4—Adding both a Second Cotton Picker and Hiring Additional Labor

Scenario 4 is identical to scenario two with the exception of allowing additional labor to be hired. Additional labor is allowed to be hired as scenario 3 explains. Again, 16.66 hours are hired in September 1-15. Net Return does not increase compared to scenario 2, and only increased slightly compared to scenario 3 by $336.04. Production acreage for cotton and peanuts does not change, but does change the distribution, or allocation of resources during the different periods. Again, peanut combine availability continues have the largest shadow price than any other constraint based. Therefore, the next scenario will incorporate an additional combine into scenario one.

Scenario 5—Adding an Additional Peanut Combine

In all of the previous scenarios, combine availability is continuously binding. Referring back to the original model, scenario 1, an additional peanut combine is incorporated into the model to create scenario 5. The net returns that did increase relate to scenario 1, and the additional combine alone did not rank first for increasing net returns. The additional availability increases profits by $482.96. Under the program, 40.37 additional acres of peanuts are produced compared to scenario 1. (Keep in mind the word additional is not the same as "additional peanuts" grown under the 1996 Farm Bill.) One difference that does not occur in the other scenarios is that the addition of the third combine causes availability of the planter to become binding June 1-15. Having an additional planter would now increase net returns by allowing for additional cotton or peanuts to be produced. The additional peanut combine is added to the combine availability by multiplying the RHS (cells AV57:AV63) of the combine constraint by 3 rather than 2.

Scenario 6—Adding an Additional Peanut Combine and Hiring Labor

By far, compared to the original, this is the most profitable position that a producer could take based on the assumptions in this research. Profit increased to $334,078.41—an increase of $2,341.60. Allowing for both resources to be relaxed, labor again has the largest shadow price compared to the other constraints--during harvest.

Under the circumstances though, it is not profitable to hire more than the 95.22 hours of labor that was hired for September 1-15. With that in mind, planter availability is the next binding constraint that could be addressed. Both of these are allowed to enter into the model by adjusting the RHS of the constraints as previously explained.

Scenario 7—Price Changes

When it comes to prices, LP does not forecast prices. The only way to accomplish sensitivity analysis with price is to simply run scenarios while changing the price manually. Looking at the sensitivity report for scenario 1 in Appendix A-10, in no column is price a variable. The only way to obtain sensitivity analysis of price changes is to allow price fluctuations in the model and optimize the solution using each price. As an example, consider scenario 7.

In this scenario, the price is allowed to change from 60 cents per pound to 52 cents per pound—the marketing loan rate. All of the other coefficients are the original coefficients from scenario 1. Under the price of the new scenario, the optimal solution to the new program is $267,567.93 – a decrease of $74,509.14 compared to scenario one. Under the new program, 1000 acres are still in production with 632.17 acres being cotton. The cotton acreage includes 600.56 acres of BtRR and 31.61 acres of embedded refuge. With additional resources available, the model allows 367.83 acres of peanuts to enter into the solution. Considering this, and a scenario if the price was the current futures price of 46 cents per pound, peanut production increases only with reduced cotton prices. Table 6.3 is a good illustration of the shift of production and resources in cotton production due to the price decrease. Peanut production only changed by growing 99.77

more acres in the T_6T_{16} time period. Notice that with the price decrease to \$0.52, the optimal, efficient allocation of resources changes. Comparing the time periods for each scenario, the acres produced in one period are then produced in another.

In some periods like T_4T_{14} through T_5T_{16}, the cotton acres produced in scenario one are not produced in scenario 7—or were reduced. Instead, those acres are used to produce additional peanuts in various time periods. Prices changes could also be made in peanuts just as cotton prices were allowed to change. Scenarios with peanut price changes are not constructed, as \$355 per ton is the guaranteed price of peanuts under the 2002 Farm Bill. However, these types of scenarios could easily be made by simply adjusting the price of peanuts—and assuring the price carries throughout the model.

Table 6.3 Price Decrease Effects on Production

Scenario 1		Scenario 7	
Period	**Total Acres**	**Period**	**Total Acres**
T_2T_{11}	********	T_2T_{11}	********
T_2T_{12}	*********	T_2T_{12}	*********
T_2T_{13}	*********	T_2T_{13}	*********
T_3T_{11}	11.54	T_3T_{11}	94.22
T_3T_{12}	135.18	T_3T_{12}	89.29
T_3T_{13}	60.96	T_3T_{13}	76.78
T_3T_{14}	0.00	T_3T_{14}	64.15
T_3T_{15}	0.00	T_3T_{15}	0.00
T_3T_{16}	0.00	T_3T_{16}	0.00
T_4T_{12}	0.00	T_4T_{12}	0.00
T_4T_{13}	113.86	T_4T_{13}	98.04
T_4T_{14}	82.85	T_4T_{14}	0.00
T_4T_{15}	0.00	T_4T_{15}	18.01
T_4T_{16}	0.00	T_4T_{16}	0.00
T_4T_{17}	0.00	T_4T_{17}	0.00
T_5T_{13}	0.00	T_5T_{13}	0.00
T_5T_{14}	98.41	T_5T_{14}	39.87
T_5T_{15}	108.32	T_5T_{15}	0.00
T_5T_{16}	36.42	T_5T_{16}	0.00
T_5T_{17}	0.00	T_5T_{17}	0.00
T_6T_{14}	0.00	T_6T_{14}	0.00
T_6T_{15}	97.59	T_6T_{15}	90.16
T_6T_{16}	0.00	T_6T_{16}	17.01
T_6T_{17}	135.92	T_6T_{17}	44.65

CHAPTER 7

IMPLICATIONS AND CONCLUSIONS

Section I: Implications

In producing cotton and peanuts, there exists an optimal, feasible solution for allocating resources such that maximum net returns are realized. In this research, seven different scenarios are considered: the original model, the original plus an additional cotton picker, the original with additional hired labor, the original with both an additional picker and hired labor, the original with an extra peanut combine, the original with both an extra combine and hired labor, and the original with a cotton price reduction. Of these, scenario 6,with the additional peanut combine and hired labor, demonstrates the highest optimal solution. Table 7.1 is a summary of the scenarios and optimal values.

As a result, production does change as a result of adding the extra combine and labor. The acreage allocation includes the production of more peanuts and less cotton, though the difference is only about 40 acres. The increase in net returns is due to the reallocation of resources throughout the growing season. Since fixed costs are not introduced, the addition of the combine would only allow the activities in the given periods to change, which increased the net returns.

The optimization of these scenarios where cotton harvest is initiated while delaying peanut harvest is not the norm for most producers. Typically, cotton harvest is not initiated in Georgia until the majority of peanut production is complete.

Table 7.1 Scenario Comparison

Scenario	1	2	3	4
Net Return	$331,736.81	$332,479.65	$332,143.61	$332,479.65
Total Acres	1000	1000	1000	1000
Total Cotton	881.06	881.06	881.06	881.06
BtRR	873.01	837.01	837.01	837.01
Conventional	44.05	44.05	44.05	44.05
Peanuts	118.94	118.94	118.94	118.94

Table7.1 Continued

Scenario	5	6	7
Net Return	$332,219.77	$334,078.41	$257,227.67
Total Acres	1000	1000	1000
Total Cotton	840.69	840.71	632.17
BtRR	798.66	798.68	600.56
Conventional	42.03	42.04	31.61
Peanuts	159.31	159.29	367.83

Producers, not realizing potential variations of profits, may be experiencing yield reductions or quality discounts for leaving the cotton in the field while completely harvesting peanuts. On the other hand, assumptions of quality and yield are made from limited data, therefore the quality and yield adjustments may be slightly off target. However, they are for setting a foundation in this area of research in Georgia.

Another production flaw of typical production may be the acreage allotted to each crop enterprise. According to the typical farm description (Appendix A-2), producers allot 700 acres for cotton and 300 acres of peanuts. The optimal solution here suggests planting only 119 acres of peanuts and 881 acres of cotton. Producing more peanuts, which do not appear to be as profitable as cotton, may be the profit-minimizing alternative. Producers may need to reconsider their enterprise objectives and management strategies.

Section II: Summary and Conclusions

Cotton and peanut production continues to be traditional rotation crops for South Georgia producers. The 2002 Farm Bill promises to keep producers profitable, allowing them to stay in business. With increasing costs and decreasing prices, producers are banking on what the government is telling them. Profit maximization continues to be a challenge as the limited availability of resources constrains producer's positions on the product transformation curve.

Traditional production of cotton and peanuts may not be the best practice in this day and time. Innovation demands evolution of the industry as times change and technology advances. It is possible for Georgia agriculture to be profitable, and for family farms to maintain its position in the structure of the industry. As more and more family farms continue to fall victim to the evolving industry, economic tools of the type presented are needed to indicate how to compete in the marketing loan system

Linear programming models like this one are necessary for producers to attempt to model their production tendencies to determine if they are optimally utilizing their resources. There exists a need for them to have this and other information currently not readily available. Research in the area of harvest timeliness is of particular concern, as labor and equipment availability tends to reduce their ability to efficiently harvest crops. Currently, no model of this type exists for Georgia producers or agriculturalist in the research field. While other states have this type of information, Georgia has failed to identify the need for this type of research. As technologies continue to improve producer's efficiency at planting and maintain their crop enterprises, harvest efficiency has been overlooked.

This research is the first of its kind to address the harvest-timeliness issue in Georgia. The lack of available literature required many assumptions be made based on where adequate data does not exist. Research by Shurley and Bednarz is the basis for this research, and several assumptions from regression analysis are necessary to obtain some of the coefficients. While additional literature would have further substantiated the validity of this research, this presentation is a good beginning for Georgia agriculture. Perhaps this study will serve as a foundation for future research in the area of harvest-timeliness and resource allocation.

This study is limited in that weather and other uncontrollable phenomena are not simulated in the model. Further research needed in this area should consider weather trends, and attempt to incorporate those types of variables into the model. Also, Future researchers should incorporate fixed costs into the model, as well as trying to determine weather patterns and the impacts on yield and quality.

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APPENDICES

A-1

Oral Discussion Questions for Meeting With County Agents and Producers

I. Introductions
II. Welcome and reiterate the purpose of the meeting
III. Questions:
1. What would you say is the average farm size of a typical farm for your county in acres, and what would be produced?
2. Of each enterprise produced, how many acres of each will be irrigated?
3. What are the normal yields for each enterprise?
4. What percentage of the land in production is rented, and at what cost?
5. For peanuts, do you rent quota from other owners? If so, for how much?
6. What pieces of equipment would you use in producing these commodities?
7. What tasks would you perform in producing these crops, and in which months would these tasks be completed? (planting, spraying, harvesting, etc.)
8. What chemical and other inputs would you use and at what rates?
9. What percentage of capital is borrowed?
10. What are the typical land taxes in your respective counties?
11. Does your family have an off farm income? If so, how much?
12. How much labor is hired for farm work and at what rate?

These are the typical types of things being asked. Questions other than these did arise.

A-2

Typical South Georgia Farm

Farm Size: 1200 acres
Operator Age: 50-55

Crop	Acres	Irrigated	Base	Program Yields
Cotton	700	350	300	500 lbs./acre
Peanuts	300	150		
Corn	100	75	200	50 Bu./acre
Wheat/Rye	100			35 Bu./acre
Tobacco	50-55			

Land: Owned = 30%
Rented = 70%
Sale Values: Irrigated = $1500-$2500/ acre
Dry= $1200/acre
* A farmer will buy 70-100 acres at a time
Rent Values: Irrigated = $135-$150/acre
Dry = $40-$90/acre
Peanut Quota: Owned = 30%
Rented = 70%--$0.10/ pound
Sold = $0.60/ pound

Crop	Irrigated	Yield/Acre
Cotton	Yes	950 lbs.
Cotton	No	600 lbs.
Peanuts	Yes	3500 lbs.
Peanuts	No	2000-2500 lbs.
Corn	Yes	150 bu.
Corn	No	75 bu.

Other Income: Hunting Lease Income = $3-$5/ac

Off Farm Income = $20k-$30k
Irrigation Pivot Loan Term: 7 years

Cotton Growing Season: Irrigated Conventional RR

--Six row equipment

--Time Table

Late-Feb/March: Harrow—200HP+
Fertilize—30-40 lbs ph.
70-100 lbs p.
10-12 lbs s.

April: Ripper Bedder—200-220HP

May: Plant—Bed Knocker
Vaccum Planter—Cotton 8-9 lbs/ac
Peanuts 110-125 lbs/ac
Herbicide/Insect App.: Treflan
Prowl (1.5 pts)
Temik (3-4 lbs)
Staple (8 oz)

Late-May: Spray Roundup (1qt)—Tractor Mounted Sprayer (12 row)

June: Layby (Directed Spray)—Caperall (1 qt)
MSMA (2 & 2/3 pts)
Fertilze

Late-June: Boron/Solubor (1.5 lbs) @ prebloom
Pix (6 oz)

Mid-July: Boron & Pix (6 oz)
2 Insects Sprays
Insecticides: Karate, Fury, Ammo, Decis

August: Insect spray (for Stink Bugs) & Urea (10#)
App. 4 Units of Nitrogen

September: Defoliate—Finish, Dropp, Prep
(By plane = $3.50-$4.00/ac)

Other: Cost BWEP-- $4.00/ac
Scouting-- $ 7.00/ac
Crop Insurance—65% coverage

Harvest: 4 Row Picker
Module Builder (Gin Owned)
Boll Buggy—small tractor (120-150 HP) (2)

Cotton Equipment Summary:
2—Harrows—12 and 21ft.
1—Ripper Bedder—6 row
2—Planters—6 row
1—Directed Sprayer (Hooded)
2—Rotary Mowers—4 row (10-12ft)
1—Tractor Mounted Sprayer

Tractors: 2—220 HP
1—150 HP
1—87+HP
(Lease = 900 hours; 300/yr)

High-boy—1

Peanut Equipment Summary:
2--Harrow—Cutting
1--Moldboard Plow—4 row—220 HP
1—Bed Shaper—4 row—150 HP

May: Plant (220 HP)
--6 rows; single
--Inputs: Sonalan (1 qt)
110# lbs. Seed
Thimet (Phorate)—5#

Late-May: At Cracking—Herbicide Spray
--Gramoxone (5oz)
--Storm (1 pt)
--2,4 DB (8oz-1pt)
--Bravo

June: Bravo App.

1st July: Land Plaster--$24/ton applied

Early/Mid July: Folicur (7.2oz), Basagran, & Oil

Late-July: Folicur (7.2oz), Classic (.5oz)

August: Folicur (7.2oz), Poast, and Oil

September: Bravo

Inverter (digger)—One 4 row; Two 2 rows
Combines—4 Row and 2 Row

All Corn is Custom or Sillage

Money Borrowed: 80%
Labor: 1 or 2 full-time workers--$20k/yr each
Family Living Expenses: >= Off farm Income

Peanut Equipment Summary:
1—6 Row Combine
1 or 2—4 Row Combine
3—Inverters (1-4 row; 2-2 row)

A-3

Budget for Irrigated, BtRR Conventional Cotton in South Georgia

For Initial Model – Scenario One

Expected Income	**Yield/Acre**	**Price**	**$ Per Ac**	**Total**
Cotton Lint	1000 lbs.	0.60	600.00	**600.00**
Variable Costs	**Amount/Acre**	**Price**	**$ Per Ac**	**Total**
Land Rent	0 acres	0.00	0.00	0.00
Fertilizer:				**55.75**
Custom 5-10-15	400 lbs	0.08	32.00	
Liquid 28-0-0-5	250 lbs	0.09	22.50	
Boron	0.5 lbs	2.50	1.25	
Lime	0.33 tons	22.00	7.26	
Seed	7.5 lbs	1.25	9.38	**9.38**
Technology Fee	1 acre	29.50	29.50	**29.50**
Herbicides:				**18.69**
PPI Treflan	1.5 pts	1.88	2.82	
Early Post OTT Roundup	1.5 pts	4.19	6.29	
Layby Post Dir. Caparol	1.3 pts	3.34	4.34	
MSMA	2.7 pts	1.94	5.24	
Insecticides:				**17.39**
In Furrow Temik	3.5 lbs	1.88	2.82	
Worms, etc. Pyrethroid	4.7 oz	1.48	6.96	
Growth Regulator:				**9.76**
First Bloom Pix	8 oz	0.61	4.88	
Second Treatment Pix	8 oz	0.61	4.88	
Irrigation:	6 inches	4.50	27.00	**27.00**
Defoliation:				**17.40**
Def	5 oz	0.31	1.55	
Dropp	0.125 lbs	52.35	6.54	
Prep	1.33 pts	7.00	9.31	
Scouting:	1 acre	7.00	7.00	**7.00**
Labor:	3.44 hours	9.00	30.96	**30.96**
Fuel and Lube:				**17.35**
Tractors	1.18 hours	8.99	10.61	
Sprayer	0.16 hours	5.40	0.86	
Picker	0.30 hours	12.04	3.61	
Trucks and Misc.	1 acre	2.26	2.26	
Repairs and Maintenance:				**30.71**
Tractors	1 acre	6.87	6.87	
Implements	1 acre	7.32	7.32	
Sprayer	1 acre	3.81	3.81	

Picker	1 acre	12.71	12.71	
BWEP:	1 acre	4.25	4.25	**4.25**
Crop Insurance:	1 acre	20.00	20.00	**20.00**
Ginning:				**39.63**
Ginning	1000 lbs	0.09	90.00	
Storage	1000 lbs	0.004	4.00	
Less value of cotton seed	1450 tons	0.0375	-54.38	
Marketing and Promotions:				**26.00**
Classing, State and National	1000 lbs	0.0100	10.00	
Warehousing	1000 lbs	0.0160	16.00	
Net Returns to Land, Management, And General Overhead				**207.04**

A-4

Budget for Irrigated Peanuts in South Georgia

For Initial Model – Scenario One

Expected Income		**Yield/Acre**	**Price**	**$ Per Ac**	**Total**
Cotton Lint		1.74 tons	355.00	621.25	**621.25**
Variable Costs		**Amount/Acre**	**Price**	**$ Per Ac**	**Total**
Land Rent		0 acres	0.00	0.00	0.00
Fertilizer:					**40.35**
Phosphate (18-46-0-0)		20 lbs	0.25	32.00	
Potash (60%)		40 lbs	0.14	5.60	
Boron		0.5 lbs	2.50	1.25	
Lime		0.5 tons	45.00	22.50	
Inoculant		6 bls	1.00	6.00	
Seed		100 lbs	0.80	80.00	**80.00**
Herbicides:					**47.00**
Burndown	Gramoxone	1 qt	9.12	9.12	
PPI	Sonalan	1 qt	5.73	5.73	
At Cracking	Starfire	11 oz	0.29	3.19	
	Storm	1 pt	9.36	9.36	
	2,4 DB	1 pt	2.24	2.24	
Other:	Classic	0.5 oz	11.00	5.50	
	Poast	1.5 pts	7.91	11.87	
Insecticides:					**11.05**
In Furrow	Thimet	5 lbs	2.21	11.05	
Fungicides:					**71.73**
At Cracking	Bravo	2 pts	4.72	9.44	
	Bravo	2 pts	4.72	9.44	
	Folicur	7.2 ozs	2.01	14.47	
	Folicur	7.2 ozs	2.01	14.47	
	Bravo	2 pts	4.72	9.44	
Irrigation:		5 apps	5.25	26.25	**26.25**
Labor:		3.647 hours	9.00	32.82	**32.82**
Fuel and Lube:					**29.16**
Tractors		2.75 hours	9.14	25.18	
Sprayer		0.03 hours	5.31	0.17	
Trucks and Misc.		1 acre	3.80	3.80	
Repairs and Maintenance:					**19.76**
Tractors		1 acre	7.36	7.36	
Implements		1 acre	12.37	12.37	
Sprayer		1 acre	0.03	0.03	

Peanut Company				**54.25**
Cleaning	1.75 tons	10.00	17.50	
Drying	1.75 tons	21.00	21.00	
GPC & GPPA	1.75 tons	3.00	3.00	
Marketing Assessment (65%)				**6.95**
Net Returns to Land, Management, And General Overhead				**182.07**

A-5

PARTIAL COTTON BUDGETS

A	B	C	D	E	F	G	H
	T_3T_{11}	T_3T_{12}	T_3T_{13}	T_3T_{14}	T_3T_{15}	T_3T_{16}	T_4T_{12}
Adj. Yield	1141.20	1234.10	1228.72	1227.51	1162.38	1085.21	1140.90
Ginning cost	102.708	111.069	110.5848	110.4759	104.6142	97.6689	102.681
Storage	4.5648	4.9364	4.91488	4.91004	4.64952	4.34084	4.5636
Classing S&N Boards	11.412	12.341	12.2872	12.2751	11.6238	10.8521	11.409
Warehousing	18.2592	19.7456	19.65952	19.64016	18.59808	17.36336	18.2544
Cotton Seed Revenue	42.795	46.27875	46.077	46.03163	43.58925	40.69538	42.78375
Total Costs	439.33	450.47	449.83	449.68	441.87	432.61	439.29
Cost/ac	439.3257	450.4737	449.8281	388.4826	382.6209	375.6756	380.6877
Cost/lb.	0.384968	0.365022	0.366095	0.31648	0.32917	0.346178	0.333673
Net Returns	**288.19**	**336.27**	**333.48**	**332.90**	**301.59**	**262.11**	**288.84**

G	H	I	J	K	L	M	N	O
T_4T_{13}	T_4T_{14}	T_4T_{15}	T_4T_{16}	T_4T_{17}	T_5T_{13}	T_5T_{14}	T_5T_{15}	T_5T_{16}
1234.10	1228.72	1227.51	1162.38	1085.21	1140.90	1232.88	1228.72	1227.51
111.069	110.5848	110.4759	104.6142	97.6689	102.681	110.9592	110.5848	110.4759
4.9364	4.91488	4.91004	4.64952	4.34084	4.5636	4.93152	4.91488	4.91004
12.341	12.2872	12.2751	11.6238	10.8521	11.409	12.3288	12.2872	12.2751
19.7456	19.65952	19.64016	18.59808	17.36336	18.2544	19.72608	19.65952	19.64016
46.27875	46.077	46.03163	43.58925	40.69538	42.78375	46.233	46.077	46.03163
450.47	449.83	449.68	441.87	432.61	439.29	450.33	449.83	449.68
389.0757	388.5915	388.4826	382.6209	375.6756	380.6877	388.9659	388.5915	388.4826
0.315271	0.316257	0.31648	0.32917	0.346178	0.333673	0.315494	0.316257	0.31648
330.68	**333.68**	**332.90**	**301.59**	**262.11**	**285.95**	**332.18**	**333.64**	**332.90**

A-5 CONTINUED

P	Q	R	S	T	U	V	W
T_5T_{17}	**T_5T_{18}**	**T_6T_{14}**	**T_6T_{15}**	**T_6T_{16}**	**T_6T_{17}**	**T_6T_{18}**	**T_6T_{19}**
1162.38	1085.21	1140.90	1234.10	1228.72	1227.51	1162.38	720.05
104.6142	97.6689	102.681	111.069	110.5848	110.4759	104.6142	64.8045
4.64952	4.34084	4.5636	4.9364	4.91488	4.91004	4.64952	2.8802
11.6238	10.8521	11.409	12.341	12.2872	12.2751	11.6238	7.2005
18.59808	17.36336	18.2544	19.7456	19.65952	19.64016	18.59808	11.5208
43.58925	40.69538	42.78375	46.27875	46.077	46.03163	43.58925	27.00188
441.87	432.61	439.29	450.47	449.83	449.68	441.87	388.79
382.6209	375.6756	380.6877	389.0757	388.5915	388.4826	382.6209	342.8112
0.32917	0.346178	0.333673	0.315271	0.316257	0.31648	0.32917	0.476094
301.59	**262.11**	**285.95**	**332.77**	**333.68**	**332.90**	**301.59**	**86.83**

A-6

PARTIAL PEANUT BUDGETS

A	B	C	D	E	F	G	H
	T_2T_{11}	T_2T_{12}	T_2T_{13}	T_3T_{12}	T_3T_{13}	T_3T_{14}	T_4T_{13}
Adj. Yield	2791.2	3531.2	2991.2	2795.2	3535.2	2995.2	2939
final adj. Yield	1.3956	1.7656	1.4956	1.3976	1.7676	1.4976	1.4695
Mkt. Asses.	5.540532	7.009432	5.937532	5.548472	7.017372	5.945472	5.833915
Cleaning	6.978	8.828	7.478	6.988	8.838	7.488	7.3475
Drying	14.6538	18.5388	15.7038	14.6748	18.5598	15.7248	15.42975
GPC and GPPA	4.1868	5.2968	4.4868	4.1928	5.3028	4.4928	4.4085
Cost/ton	255.56022	206.7137	239.9752	255.2267	206.5053	239.6847	243.8383
Cost/acre	356.65984	364.9737	358.9068	356.7048	365.0187	358.9518	358.3204
Adj. Rev.	138.77816	261.8143	172.0312	139.4432	262.4793	172.6962	163.3521

I	J	K	L	M	N	O	P
T_4T_{14}	T_4T_{15}	T_5T_{14}	T_5T_{15}	T_5T_{16}	T_6T_{15}	T_6T_{16}	T_6T_{17}
3679	3139	3646	4386	3846	3222.6	3962.2	3422.6
1.8395	1.5695	1.823	2.193	1.923	1.6113	1.9811	1.7113
7.302815	6.230915	7.23731	8.70621	7.63431	6.396861	7.864967	6.793861
9.1975	7.8475	9.115	10.965	9.615	8.0565	9.9055	8.5565
19.31475	16.47975	19.1415	23.0265	20.1915	16.91865	20.80155	17.96865
5.5185	4.7085	5.469	6.579	5.769	4.8339	5.9433	5.1339
199.3119	229.7339	200.9125	170.8059	191.6331	224.3571	186.6721	212.5598
366.6343	360.5674	366.2635	374.5774	368.5105	361.5066	369.816	363.7536
286.3882	196.6051	280.9015	403.9376	314.1545	210.5049	333.4745	243.7579

A-7
Linear Programming Model

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1												COTTON										
2		T3T11	T3T12	T3T13	T3T 14	T3T15	T3T16	T4T12	T4T13	T4T14	T4T15	T4T16	T4T17	T5T13	T5T14	T5T15	T5T16	T5T17	T6T14	T6T15	T6T16	T6T17
3																						
4	**Acres**	**0.00**	**146.72**	**60.96**	**0.00**	**0.00**	**0.00**	**0.00**	**113.86**	**82.85**	**0.00**	**0.00**	**0.00**	**0.00**	**98.41**	**108.32**	**25.11**	**0.00**	**0.00**	**97.59**	**11.31**	**135.92**
5	BtRR	0.00	139.38	57.91	0.00	0.00	0.00	0.00	108.17	78.71	0.00	0.00	0.00	0.00	93.49	102.91	23.86	0.00	0.00	92.71	10.74	129.12
6	Conventional	0.00	7.34	3.05	0.00	0.00	0.00	0.00	5.69	4.14	0.00	0.00	0.00	0.00	4.92	5.42	1.26	0.00	0.00	4.88	0.57	6.80
7	Rev. Btrr Alone	288.19	336.26	333.48	332.90	301.59	262.11	288.84	330.68	333.68	332.90	301.59	262.11	285.94	332.18	333.64	332.90	301.59	285.94	332.77	333.68	332.90
8	**Obj. Fn.**	**280.81**	**328.28**	**325.53**	**324.96**	**294.04**	**255.05**	**281.45**	**322.77**	**325.73**	**324.96**	**294.04**	**255.05**	**278.59**	**324.25**	**325.69**	**324.96**	**294.04**	**278.59**	**324.83**	**325.73**	**324.96**
9																						
10	**Constraints**																					
11	Total Acres	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12																						
13	**Labor Hrs:**																					
14	March 16-31	0.16215	0.16215	0.16215	0.16215	0.16215	0.16215	0.16215	0.16215	0.16215	0.16215	0.16215	0.16215									
15	April 1-15	0.42039	0.42039	0.42039	0.42039	0.42039	0.42039	0.18017	0.18017	0.18017	0.18017	0.18017	0.18017	0.16215	0.16215	0.16215	0.16215	0.16215				
16	April 16-30	0.24946	0.24946	0.24946	0.24946	0.24946	0.24946	0.24022	0.24022	0.24022	0.24022	0.24022	0.24022	0.18017	0.18017	0.18017	0.18017	0.18017	0.16215	0.16215	0.16215	0.16215
17	May 1-15	0.05757	0.05757	0.05757	0.05757	0.05757	0.05757	0.24946	0.24946	0.24946	0.24946	0.24946	0.24946	0.24022	0.24022	0.24022	0.24022	0.24022	0.18017	0.18017	0.18017	0.18017
18	May 16-31	0.49892	0.49892	0.49892	0.49892	0.49892	0.49892	0.05757	0.05757	0.05757	0.05757	0.05757	0.05757	0.24946	0.24946	0.24946	0.24946	0.24946	0.24022	0.24022	0.24022	0.24022
19	June 1-15	0.05757	0.05757	0.05757	0.05757	0.05757	0.05757	0.49892	0.49892	0.49892	0.49892	0.49892	0.49892	0.05757	0.05757	0.05757	0.05757	0.05757	0.24946	0.24946	0.24946	0.24946
20	June 16-30							0.05757	0.05757	0.05757	0.05757	0.05757	0.05757									
21	July 1-15	0.11514	0.11514	0.11514	0.11514	0.11514	0.11514	0.11514	0.11514	0.11514	0.11514	0.11514	0.11514	0.49892	0.49892	0.49892	0.49892	0.49892	0.05757	0.05757	0.05757	0.05757
22	July 16-31													0.11514	0.11514	0.11514	0.11514	0.11514	0.30703	0.30703	0.30703	0.30703
23	Aug 1-15	0.05757												0.05757	0.05757	0.05757	0.05757	0.05757	0.30703	0.30703	0.30703	0.30703
24	Aug 16-31	1.60367	0.05757					0.05757														
25	Sept 1-15	0.21716	1.60367					1.60367	0.05757					0.05757					0.05757	0.05757	0.05757	
26	Sept 16-30		0.21716	0.05757				0.21716	1.60367					1.60367	0.05757				0.05757			0.05757
27	Oct 1-15			1.60367	0.05757				0.21716	0.05757				0.21716	1.60367				1.60367	0.05757		
28	Oct 16-31			0.21716	1.60367	0.05757				1.60367	0.05757				0.21716	0.05757			0.21716	1.60367		
29	Nov 1-15				0.21716	1.60367	0.05757			0.21716	1.60367	0.05757				1.60367	0.05757			0.21716	0.05757	
30	Nov 16-30					0.21716	1.60367				0.21716	1.60367	0.05757			0.21716	1.60367	0.05757			1.60367	0.05757
31	Dec 1-15						0.21716					0.21716	1.60367				0.21716	1.60367			0.21716	1.60367
32	Dec 16-31												0.21716					0.21716				0.21716
33																						
34	**Planter:**																					
35	April 16-30	0.24946	0.24946	0.24946	0.24946	0.24946	0.24946															
36	May 1-15							0.24946	0.24946	0.24946	0.24946	0.24946	0.24946									
37	May 16-31													0.24946	0.24946	0.24946	0.24946	0.24946				
38	June 1-15																		0.24946	0.24946	0.24946	0.24946
39	June 16-30																					
40																						
41	**Cotton Harvester:**																					
42	Aug 16-31	0.53456																				
43	Sept 1-15		0.53456					0.53456														
44	Sept 16-30			0.53456					0.53456					0.53456								
45	Oct 1-15				0.53456					0.53456					0.53456				0.53456			
46	Oct 16-31					0.53456					0.53456					0.53456				0.53456		
47	Nov 1-15						0.53456					0.53456					0.53456				0.53456	
48	Nov 16-30												0.53456					0.53456				0.53456
49	Dec 1-15																					
50	Dec 16-31																					
51																						
52	**Peanut Harvester:**																					
53	Sept 16-30																					
54	Oct 1-15																					
55	Oct 16-31																					
56	Nov 1-15																					
57	Nov 16-30																					
58	Dec 1-15																					
59	Dec 16-31																					
60																						
61	**Peanut Digger:**																					
62	Sept 1-15																					
63	Sept 16-30																					
64	Oct 1-15																					
65	Oct 16-31																					
66	Nov 1-15																					
67	Nov 16-30																					
68	Dec 1-15																					
69																						
70	**Harvester Hours**																					
71	Sept 1-15		0.53456					0.53456														
72	Sept 16-30			0.53456					0.53456					0.53456								
73	Oct 1-15				0.53456					0.53456					0.53456				0.53456			
74	Oct 16-31					0.53456					0.53456					0.53456				0.53456		
75																						
76	**Hire Labor**																					
77	Sept 1-15																					
78	Sept 16-30																					
79	Oct 1-15																					
80	Oct 16-31																					

. . .

(Peanut rotations)

(Peanut rotations)

	AU	AV	AW	AX	AY
1					
2			**Total Cotton Acres =**		**881.06**
3			**Total Peanut Acres =**		**118.94**
4	**Acres**		Total BtRR =		837.01
5	BtRR		Total Conventional =		44.05
6	Conventional				
7	Rev. Btrr Alone		**NET REVENUE**		
8	**Obj. Fn.**		**$332,143.61**		
9					
10	**Constraints**				
11	<=	1000	**Total Acres**		
12					
13			**Labor Hrs:**		
14	<=	171.046	March 16-31		
15	<=	279.835	April 1-15		
16	<=	279.222	April 16-30		
17	<=	285.945	May 1-15		
18	<=	324.549	May 16-31		
19	<=	272.228	June 1-15		
20	<=	263.982	June 16-30		
21	<=	285.804	July 1-15		
22	<=	314.816	July 16-31		
23	<=	304.185	Aug 1-15		
24	<=	335.385	Aug 16-31		
25	<=	298.218	Sept 1-15		
26	<=	280.357	Sept 16-30		
27	<=	290.689	Oct 1-15		
28	<=	330.217	Oct 16-31		
29	<=	281.757	Nov 1-15		
30	<=	269.277	Nov 16-30		
31	<=	225.881	Dec 1-15		
32	<=	191.186	Dec 16-31		
33					
34			**Planter:**		
35	<=	93.0741	April 16-30		
36	<=	95.315	May 1-15		
37	<=	108.183	May 16-31		
38	<=	90.7427	June 1-15		
39	<=	87.9941	June 16-30		
40					
41			**Cotton Harvester:**		
42	<=	111.795	Aug 16-31		
43	<=	99.4059	Sept 1-15		
44	<=	93.4525	Sept 16-30		
45	<=	96.8965	Oct 1-15		
46	<=	110.072	Oct 16-31		
47	<=	93.9191	Nov 1-15		
48	<=	89.7591	Nov 16-30		
49		75.2936	Dec 1-15		
50		63.7288	Dec 16-31		
51					
52			**Peanut Harvester:**		
53	<=	186.905	Sept 16-30		
54	<=	193.793	Oct 1-15		
55	<=	220.145	Oct 16-31		
56	<=	187.838	Nov 1-15		
57	<=	179.518	Nov 16-30		
58	<=	150.587	Dec 1-15		
59	<=	127.458	Dec 16-31		
60					
61			**Peanut Digger:**		
62	<=	198.812	Sept 1-15		
63	<=	186.905	Sept 16-30		
64	<=	193.793	Oct 1-15		
65	<=	220.145	Oct 16-31		
66	<=	187.838	Nov 1-15		
67	<=	179.518	Nov 16-30		
68	<=	150.587	Dec 1-15		
69					
70			**Harvester Hours**		
71	=	0	Sept 1-15		
72	=	0	Sept 16-30		
73	=	0	Oct 1-15		
74	=	0	Oct 16-31		
75					
76			**Hire Labor**		
77	<=	0	Sept 1-15		
78	<=	0	Sept 16-30		
79	<=	0	Oct 1-15		
80	<=	0	Oct 16-31		

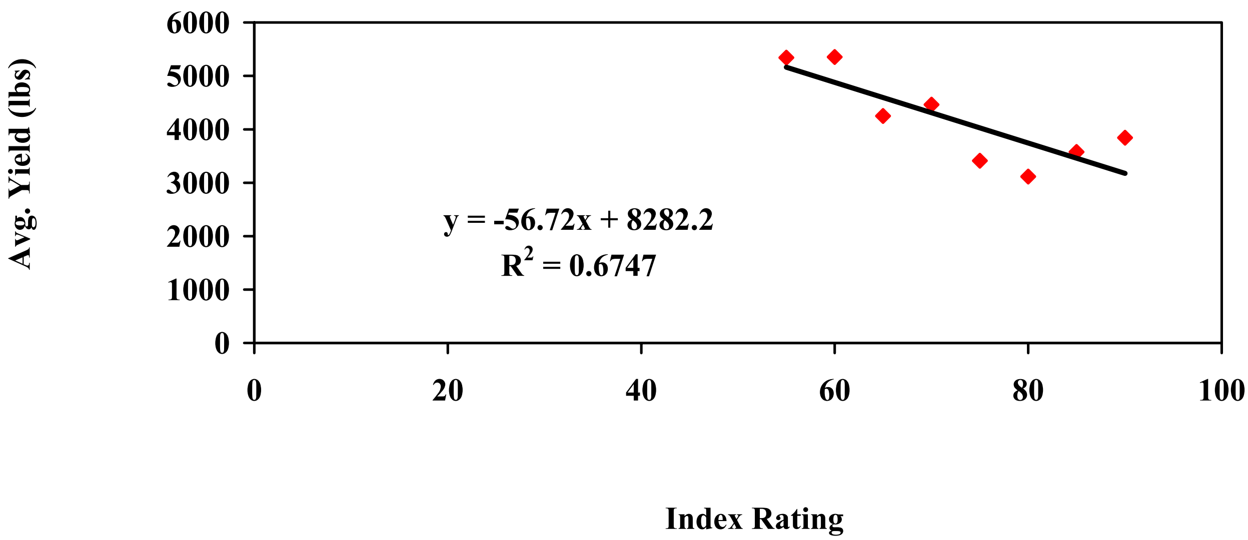
A-7 Continued

(Cotton rotations)

(Cotton rotations)

	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AU	AV	AW	AX	AY
1	PEANUTS																											
2	T2T11	T2T12	T2T13	T3T12	T3T13	T3T14	T4T13	T4T14	T4T15	T5T14	T5T15	T5T16	T6T15	T6T16	T6T17	Cotton Harvest Hrs				Hire Labor						Total Cotton Acres =		881.06
3																1-Sep	16-Sep	1-Oct	16-Oct	1-Sep	16-Sep	1-Oct	16-Oct			Total Peanut Acres =		118.94
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	118.94	0.00	0.00	0.00	0.00	78.43	93.45	96.90	110.07	16.66	0.00	0.00	0.00	Acres		Total BtRR =		837.01
5																								BtRR		Total Conventional =		44.05
6																								Conventional				
7	138.78	261.81	172.03	139.44	262.48	172.70	163.35	286.39	196.61	280.90	403.94	314.15	210.50	333.54	243.76									Rev. Btrr Alone		NET REVENUE		
8	131.84	248.72	163.43	132.47	249.36	164.06	155.18	272.07	186.77	266.86	383.74	298.45	199.98	316.86	231.57	0.00	0.00	0.00	0.00	-9.00	-9.00	-9.00	-9.00	Obj. Fn.		$332,143.61		
9																												
10																								Constraints				
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1									<=	1000	Total Acres		
12																												
13																										Labor Hrs:		
14	0.05757	0.057568	0.057568																					<=	171.046	March 16-31		
15	0.4221	0.422103	0.422103	0.057568	0.057568	0.057568																		<=	279.835	April 1-15		
16	0.24946	0.24946	0.24946	0.422103	0.422103	0.422103	0.057568	0.057568	0.057568															<=	279.222	April 16-30		
17	0.56129	0.561286	0.561286	0.24946	0.24946	0.24946	0.422103	0.422103	0.422103	0.057568	0.057568	0.057568												<=	285.945	May 1-15		
18	0.56129	0.561286	0.561286	0.561286	0.561286	0.561286	0.24946	0.24946	0.24946	0.422103	0.422103	0.422103	0.057568	0.057568	0.057568									<=	324.549	May 16-31		
19	0.56129	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.24946	0.24946	0.24946	0.422103	0.422103	0.422103									<=	272.228	June 1-15		
20	0.56129	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.24946	0.24946	0.24946									<=	263.982	June 16-30		
21	0.56129	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286									<=	285.804	July 1-15		
22	0.56129	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286									<=	314.816	July 16-31		
23				0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286									<=	304.185	Aug 1-15		
24							0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286	0.561286									<=	335.385	Aug 16-31		
25	0.5613									0.561286	0.561286	0.561286	0.561286	0.561286	0.561286					-1				<=	298.218	Sept 1-15		
26	1.50936	0.5613		0.5613																	-1			<=	280.357	Sept 16-30		
27		1.50936	0.5613	1.50936	0.5613		0.5613															-1		<=	290.689	Oct 1-15		
28			1.50936		1.50936	0.5613	1.50936	0.5613		0.5613													-1	<=	330.217	Oct 16-31		
29						1.50936		1.50936	0.5613	1.50936	0.5613		0.5613											<=	281.757	Nov 1-15		
30									1.50936		1.50936	0.5613	1.50936	0.5613										<=	269.277	Nov 16-30		
31												1.50936		1.50936	0.5613									<=	225.881	Dec 1-15		
32															1.50936									<=	191.186	Dec 16-31		
33																												
34																										Planter:		
35	0.24946	0.24946	0.24946																					<=	93.0741	April 16-30		
36				0.24946	0.24946	0.24946																		<=	95.315	May 1-15		
37							0.24946	0.24946	0.24946															<=	108.183	May 16-31		
38										0.24946	0.24946	0.24946												<=	90.7427	June 1-15		
39													0.24946	0.24946	0.24946									<=	87.9941	June 16-30		
40																												
41																										Cotton Harvester:		
42																								<=	111.795	Aug 16-31		
43																								<=	99.4059	Sept 1-15		
44																								<=	93.4525	Sept 16-30		
45																								<=	96.8965	Oct 1-15		
46																								<=	110.072	Oct 16-31		
47																								<=	93.9191	Nov 1-15		
48																								<=	89.7591	Nov 16-30		
49																									75.2936	Dec 1-15		
50																									63.7288	Dec 16-31		
51																												
52																										Peanut Harvester:		
53	1.50936																							<=	186.905	Sept 16-30		
54		1.50936		1.50936																				<=	193.793	Oct 1-15		
55			1.50936		1.50936		1.50936																	<=	220.145	Oct 16-31		
56						1.50936		1.50936		1.50936														<=	187.838	Nov 1-15		
57									1.50936		1.50936		1.50936											<=	179.518	Nov 16-30		
58												1.50936		1.50936										<=	150.587	Dec 1-15		
59															1.50936									<=	127.458	Dec 16-31		
60																												
61																										Peanut Digger:		
62	0.5613																							<=	198.812	Sept 1-15		
63		0.5613		0.5613																				<=	186.905	Sept 16-30		
64			0.5613		0.5613		0.5613																	<=	193.793	Oct 1-15		
65						0.5613		0.5613		0.5613														<=	220.145	Oct 16-31		
66									0.5613		0.5613		0.5613											<=	187.838	Nov 1-15		
67												0.5613		0.5613										<=	179.518	Nov 16-30		
68															0.5613									<=	150.587	Dec 1-15		
69																												
70																										Harvester Hours		
71																-1								=	0	Sept 1-15		
72																	-1							=	0	Sept 16-30		
73																		-1						=	0	Oct 1-15		
74																			-1					=	0	Oct 16-31		
75																												
76																										Hire Labor		
77																-1				1				<=	0	Sept 1-15		
78																	-1				1			<=	0	Sept 16-30		
79																		-1				1		<=	0	Oct 1-15		
80																			-1				1	<=	0	Oct 16-31		

Figure 4.6. TSWV REGRESSION—LINEAR



Days Suitable For Field Work Data

Date		Year			
	1997	1998	1999	2000	2001
March					
8					
9		0.3286			
10	0.6857	0.3286			
11	0.6857	0.3286			
12	0.6857	0.3286			
13	0.6857	0.3286			
14	0.6857	0.3286			
15	0.6857	0.3286			
16	0.6857	0.3714			
17	0.7143	0.3714			
18	0.7143	0.3714			
19	0.7143	0.3714			
20	0.7143	0.3714			0
21	0.7143	0.3714			0
22	0.7143	0.3714			0
23	0.7143	0.7571			0
24	0.8	0.7571			0
25	0.8	0.7571			0
26	0.8	0.7571			0
27	0.8	0.7571		0.6413	0.4286
28	0.8	0.7571		0.6143	0.4286
29	0.8	0.7571	0.7571	0.6143	0.4286
30	0.8	0.7714	0.7571	0.6143	0.4286
31	0.8713	0.7714	0.7571	0.6143	0.4286
April					
1	0.8713	0.7714	0.7571	0.6143	0.4286
2	0.8713	0.7714	0.7571	0.6143	0.9
3	0.8713	0.7714	0.7571	0.6857	0.9
4	0.8713	0.7714	0.7571	0.6857	0.9
5	0.8713	0.7714	0.8857	0.6857	0.9
6	0.8713	0.6286	0.8857	0.6857	0.9
7	0.8429	0.6286	0.8857	0.6857	0.9
8	0.8429	0.6286	0.8857	0.6857	0.9
9	0.8429	0.6286	0.8857	0.6857	0.7857
10	0.8429	0.6286	0.8857	0.7571	0.7857
11	0.8429	0.6286	0.8857	0.7571	0.7857
12	0.8429	0.6286	0.8429	0.7571	0.7857
13	0.8429	0.5714	0.8429	0.7571	0.7857
14	0.9	0.5714	0.8429	0.7571	0.7857
15	0.9	0.5714	0.8429	0.7571	0.7857
16	0.9	0.5714	0.8429	0.7571	0.8714
17	0.9	0.5714	0.8429	0.9	0.8714
18	0.9	0.5714	0.8429	0.9	0.8714
19	0.9	0.5714	0.8857	0.9	0.8714

	20	0.9	0.6143	0.8857	0.9	0.8714
	21	0.7	0.6143	0.8857	0.9	0.8714
	22	0.7	0.6143	0.8857	0.9	0.8714
	23	0.7	0.6143	0.8857	0.9	0.9143
	24	0.7	0.6143	0.8857	0.7857	0.9143
	25	0.7	0.6143	0.8857	0.7857	0.9143
	26	0.7	0.6143	0.6857	0.7857	0.9143
	27	0.7	0.6429	0.6857	0.7857	0.9143
	28	0.4857	0.6429	0.6857	0.7857	0.9143
	29	0.4857	0.6429	0.6857	0.7857	0.9143
	30	0.4857	0.6429	0.6857	0.7857	0.9429
May						
	1	0.4857	0.6429	0.6857	0.9143	0.9429
	2	0.4857	0.6429	0.6857	0.9143	0.9429
	3	0.4857	0.6429	0.5857	0.9143	0.9429
	4	0.4857	0.6286	0.5857	0.9143	0.9429
	5	0.8	0.6286	0.5857	0.9143	0.9429
	6	0.8	0.6286	0.5857	0.9143	0.9429
	7	0.8	0.6286	0.5857	0.9143	0.9
	8	0.8	0.6286	0.5857	0.9429	0.9
	9	0.8	0.6286	0.5857	0.9429	0.9
	10	0.8	0.6286	0.7571	0.9429	0.9
	11	0.8	0.8857	0.7571	0.9429	0.9
	12	0.8857	0.8857	0.7571	0.9429	0.9
	13	0.8857	0.8857	0.7571	0.9429	0.9
	14	0.8857	0.8857	0.7571	0.9429	0.9143
	15	0.8857	0.8857	0.7571	0.9286	0.9143
	16	0.8857	0.8857	0.7571	0.9286	0.9143
	17	0.8857	0.8857	0.8857	0.9286	0.9143
	18	0.8857	0.9571	0.8857	0.9286	0.9143
	19	0.8714	0.9571	0.8857	0.9286	0.9143
	20	0.8714	0.9571	0.8857	0.9286	0.9143
	21	0.8714	0.9571	0.8857	0.9286	0.7857
	22	0.8714	0.9571	0.8857	0.8429	0.7857
	23	0.8714	0.9571	0.8857	0.8429	0.7857
	24	0.8714	0.9571	0.8857	0.8429	0.7857
	25	0.8714	0.9143	0.8857	0.8429	0.7857
	26	0.5	0.9143	0.8857	0.8429	0.7857
	27	0.5	0.9143	0.8857	0.8429	0.7857
	28	0.5	0.9143	0.8857	0.8429	0.6429
	29	0.5	0.9143	0.8857	0.9429	0.6429
	30	0.5	0.9143	0.8857	0.9429	0.6429
	31	0.5	0.9143	0.8857	0.9429	0.6429
June						
	1	0.5	0.8286	0.8857	0.9429	0.6429
	2	0.6	0.8286	0.8857	0.9429	0.6429
	3	0.6	0.8286	0.8857	0.9429	0.6429
	4	0.6	0.8286	0.8857	0.9429	0.6
	5	0.6	0.8286	0.8857	0.8857	0.6
	6	0.6	0.8286	0.8857	0.8857	0.6
	7	0.6	0.8286	0.8571	0.8857	0.6
	8	0.6	0.8143	0.8571	0.8857	0.6

9	0.6857	0.8143	0.8571	0.8857	0.6
10	0.6857	0.8143	0.8571	0.8857	0.6
11	0.6857	0.8143	0.8571	0.8857	0.5
12	0.6857	0.8143	0.8571	0.8857	0.5
13	0.6857	0.8143	0.8571	0.8857	0.5
14	0.6857	0.8143	0.7	0.8857	0.5
15	0.6857	0.8571	0.7	0.8857	0.5
16	0.5423	0.8571	0.7	0.8857	0.5
17	0.5423	0.8571	0.7	0.8857	0.5
18	0.5423	0.8571	0.7	0.8857	0.7286
19	0.5423	0.8571	0.7	0.7857	0.7286
20	0.5423	0.8571	0.7	0.7857	0.7286
21	0.5423	0.8571	0.7143	0.7857	0.7286
22	0.5423	0.9143	0.7143	0.7857	0.7286
23	0.7143	0.9143	0.7143	0.7857	0.7286
24	0.7143	0.9143	0.7143	0.7857	0.7286
25	0.7143	0.9143	0.7143	0.7857	0.7
26	0.7143	0.9143	0.7143	0.7286	0.7
27	0.7143	0.9143	0.7143	0.7286	0.7
28	0.7143	0.9143	0.5	0.7286	0.7
29	0.7143	0.9	0.5	0.7286	0.7
30	0.7571	0.9	0.5	0.7286	0.7

July

1	0.7571	0.9	0.5	0.7286	0.7
2	0.7571	0.9	0.5	0.7286	0.7
3	0.7571	0.9	0.5	0.9286	0.7
4	0.7571	0.9	0.5	0.9286	0.7
5	0.7571	0.9	0.7286	0.9286	0.7
6	0.7571	0.8857	0.7286	0.9286	0.7
7	0.8571	0.8857	0.7286	0.9286	0.7
8	0.8571	0.8857	0.7286	0.9286	0.7
9	0.8571	0.8857	0.7286	0.9286	0.8571
10	0.8571	0.8857	0.7286	0.8286	0.8571
11	0.8571	0.8857	0.7286	0.8286	0.8571
12	0.8571	0.8857	0.6429	0.8286	0.8571
13	0.8571	0.7857	0.6429	0.8286	0.8571
14	0.8714	0.7857	0.6429	0.8286	0.8571
15	0.8714	0.7857	0.6429	0.8286	0.8571
16	0.8714	0.7857	0.6429	0.8286	0.9143
17	0.8714	0.7857	0.6429	0.8857	0.9143
18	0.8714	0.7857	0.6429	0.8857	0.9143
19	0.8714	0.7857	0.8143	0.8857	0.9143
20	0.8714	0.8429	0.8143	0.8857	0.9143
21	0.7714	0.8429	0.8143	0.8857	0.9143
22	0.7714	0.8429	0.8143	0.8857	0.9143
23	0.7714	0.8429	0.8143	0.8857	0.7429
24	0.7714	0.8429	0.8143	0.8429	0.7429
25	0.7714	0.8429	0.8143	0.8429	0.7429
26	0.7714	0.8429	0.9286	0.8429	0.7429
27	0.7714	0.8	0.9286	0.8429	0.7429
28	0.6857	0.8	0.9286	0.8429	0.7429
29	0.6857	0.8	0.9286	0.8429	0.7429
30	0.6857	0.8	0.9286	0.8429	0.8286

	31	0.6857	0.8	0.9286	0.6571	0.8286
August						
	1	0.6857	0.8	0.9286	0.6571	0.8286
	2	0.6857	0.8	0.9571	0.6571	0.8286
	3	0.6857	0.9	0.9571	0.6571	0.8286
	4	0.8571	0.9	0.9571	0.6571	0.8286
	5	0.8571	0.9	0.9571	0.6571	0.8286
	6	0.8571	0.9	0.9571	0.6571	0.8286
	7	0.8571	0.9	0.9571	0.8429	0.8286
	8	0.8571	0.9	0.9571	0.8429	0.8286
	9	0.8571	0.9	0.9429	0.8429	0.8286
	10	0.8571	0.8143	0.9429	0.8429	0.8286
	11	0.8286	0.8143	0.9429	0.8429	0.8286
	12	0.8286	0.8143	0.9429	0.8429	0.8286
	13	0.8286	0.8143	0.9429	0.8429	0.8286
	14	0.8286	0.8143	0.9429	0.9429	0.8286
	15	0.8286	0.8143	0.9429	0.9429	0.8286
	16	0.8286	0.8143	0.9286	0.9429	0.8286
	17	0.8286	0.7571	0.9286	0.9429	0.8286
	18	0.8571	0.7571	0.9286	0.9429	0.8286
	19	0.8571	0.7571	0.9286	0.9429	0.8286
	20	0.8571	0.7571	0.9286	0.9429	0.9286
	21	0.8571	0.7571	0.9286	0.8857	0.9286
	22	0.8571	0.7571	0.9286	0.8857	0.9286
	23	0.8571	0.7571	0.8286	0.8857	0.9286
	24	0.8571	0.9286	0.8286	0.8857	0.9286
	25	0.9429	0.9286	0.8286	0.8857	0.9286
	26	0.9429	0.9286	0.8286	0.8857	0.9286
	27	0.9429	0.9286	0.8286	0.8857	0.8571
	28	0.9429	0.9286	0.8286	0.7571	0.8571
	29	0.9429	0.9286	0.8286	0.7571	0.8571
	30	0.9429	0.9286	0.9714	0.7571	0.8571
	31	0.9429	0.7143	0.9714	0.7571	0.8571
September						
	1	0.9429	0.7143	0.9714	0.7571	0.8571
	2	0.9429	0.7143	0.9714	0.7571	0.8571
	3	0.9429	0.7143	0.9714	0.7571	0.7286
	4	0.9429	0.7143	0.9714	0.4571	0.7286
	5	0.9429	0.7143	0.9714	0.4571	0.7286
	6	0.9429	0.7143	0.9143	0.4571	0.7286
	7	0.9429	0.8857	0.9143	0.4571	0.7286
	8	0.8571	0.8857	0.9143	0.4571	0.7286
	9	0.8571	0.85857	0.9143	0.4571	0.7286
	10	0.8571	0.8857	0.9143	0.4571	0.8143
	11	0.8571	0.8857	0.9143	0.8571	0.8143
	12	0.8571	0.8857	0.9143	0.8571	0.8143
	13	0.8571	0.8857	0.9	0.8571	0.8143
	14	0.9289	0.8857	0.9	0.8571	0.8143
	15	0.9289	0.8857	0.9	0.8571	0.8143
	16	0.9289	0.8857	0.9	0.8571	0.8143
	17	0.9289	0.8857	0.9	0.8571	0.9
	18	0.9289	0.8857	0.9	0.5571	0.9

	19	0.9289	0.8857	0.9	0.5571	0.9
	20	0.9289	0.8857	0.8071	0.5571	0.9
	21	0.6857	0.7571	0.8071	0.5571	0.9
	22	0.6857	0.7571	0.8071	0.5571	0.9
	23	0.6857	0.7571	0.8071	0.5571	0.9
	24	0.6857	0.7571	0.8071	0.5571	0.8143
	25	0.6857	0.7571	0.8071	0.8	0.8143
	26	0.6857	0.7571	0.8071	0.8	0.8143
	27	0.6857	0.7571	0.7143	0.8	0.8143
	28	0.7857	0.5143	0.7143	0.8	0.8143
	29	0.7857	0.5143	0.7143	0.8	0.8143
	30	0.7857	0.5143	0.7143	0.8	0.8143
October						
	1	0.7857	0.5143	0.7143	0.8	0.9286
	2	0.7857	0.5143	0.7143	0.885714	0.9286
	3	0.7857	0.5143	0.7143	0.885714	0.9286
	4	0.7857	0.5143	0.7229	0.885714	0.9286
	5	0.9571	0.6286	0.7229	0.885714	0.9286
	6	0.9571	0.6286	0.7229	0.885714	0.9286
	7	0.9571	0.6286	0.7229	0.885714	0.9286
	8	0.9571	0.6286	0.7229	0.885714	0.8714
	9	0.9571	0.6286	0.7229	0.928571	0.8714
	10	0.9571	0.6286	0.7229	0.928571	0.8714
	11	0.9571	0.6286	0.6257	0.928571	0.8714
	12	0.8	0.9286	0.6257	0.928571	0.8714
	13	0.8	0.9286	0.6257	0.928571	0.8714
	14	0.8	0.9286	0.6257	0.928571	0.8714
	15	0.8	0.9286	0.6257	0.928571	0.9143
	16	0.8	0.9286	0.6257	0.957142	0.9143
	17	0.8	0.9286	0.6257	0.957142	0.9143
	18	0.8	0.9286	0.7714	0.957142	0.9143
	19	0.7286	0.9429	0.7714	0.957142	0.9143
	20	0.7286	0.9429	0.7714	0.957142	0.9143
	21	0.7286	0.9429	0.7714	0.957142	0.9143
	22	0.7286	0.9429	0.7714	0.957142	0.9429
	23	0.7286	0.9429	0.7714	0.942857	0.9429
	24	0.7286	0.9429	0.7714	0.942857	0.9429
	25	0.7286	0.9429	0.9429	0.942857	0.9429
	26	0.4714	0.9571	0.9429	0.942857	0.9429
	27	0.4714	0.9571	0.9429	0.942857	0.9429
	28	0.4714	0.9571	0.9429	0.942857	0.9429
	29	0.4714	0.9571	0.9429	0.942857	0.9571
	30	0.4714	0.9571	0.9429	0.957142	0.9571
	31	0.4714	0.9571	0.9429	0.957142	0.9571
November						
	1	0.4714	0.9571	0.8	0.957142	0.9571
	2	0.5143	0.8857	0.8	0.957142	0.9571
	3	0.5143	0.8857	0.8	0.957142	0.9571
	4	0.5143	0.8857	0.8	0.957142	0.9571
	5	0.5143	0.8857	0.8	0.957142	0.9714
	6	0.5143	0.8857	0.8	0.728571	0.9714
	7	0.5143	0.8857	0.8	0.728571	0.9714

	8	0.5143	0.8857	0.9571	0.728571	0.9714
	9	0.3429	0.8	0.9571	0.728571	0.9714
	10	0.3429	0.8	0.9571	0.728571	0.9714
	11	0.3429	0.8	0.9571	0.728571	0.9714
	12	0.3429	0.8	0.9571	0.728571	0.9571
	13	0.3429	0.8	0.9571	0.628571	0.9571
	14	0.3429	0.8	0.9571	0.628571	0.9571
	15	0.3429	0.8	0.9429	0.628571	0.9571
	16	0.6286	0.7429	0.9429	0.628571	0.9571
	17	0.6286	0.7429	0.9429	0.628571	0.9571
	18	0.6286	0.7429	0.9429	0.628571	0.9571
	19	0.6286	0.7429	0.9429	0.628571	0.8429
	20	0.6286	0.7429	0.9429	0.628571	0.8429
	21	0.6286	0.7429	0.9429	0.628571	0.8429
	22	0.6286	0.7429	0.7571	0.628571	0.8429
	23	0.7143	0.8857	0.7571	0.628571	0.8429
	24	0.7143	0.8857	0.7571	0.628571	0.8429
	25	0.7143	0.8857	0.7571	0.628571	0.8429
	26	0.7143	0.8857	0.7571	0.628571	0.8428
	27	0.7143	0.8857	0.7571	0.628371	0.8427
	28	0.7143	0.8857	0.7571	0.628371	0.8427
	29	0.7143	0.8857	0.7568	0.628256	0.8425
	30	0.5571	0.9429	0.7095	0.632043	0.8160
December						
	1	0.5571	0.9429	0.7095	0.632043	0.8160
	2	0.5571	0.9429	0.7095	0.632043	0.8160
	3	0.5571	0.9429	0.7095	0.632043	0.8160
	4	0.5571	0.9429	0.7095	0.632043	0.8160
	5	0.5571	0.9429	0.7095	0.632043	0.8160
	6	0.5571	0.9429	0.7095	0.632043	0.8160
	7	0.512532	0.867468	0.65274	0.581479	0.7507
	8	0.512532	0.867468	0.65274	0.581479	0.7507
	9	0.512532	0.867468	0.65274	0.581479	0.7507
	10	0.512532	0.867468	0.65274	0.581479	0.7507
	11	0.512532	0.867468	0.65274	0.581479	0.7507
	12	0.512532	0.867468	0.65274	0.581479	0.7507
	13	0.512532	0.867468	0.65274	0.581479	0.7507
	14	0.471529	0.798070	0.600520	0.534961	0.6907
	15	0.471529	0.798070	0.600520	0.534961	0.6907
	16	0.471529	0.798070	0.600520	0.534961	0.6907
	17	0.471529	0.798070	0.600520	0.534961	0.6907
	18	0.471529	0.798070	0.600520	0.534961	0.6907
	19	0.471529	0.798070	0.600520	0.534961	0.6907
	20	0.471529	0.798070	0.600520	0.534961	0.6907
	21	0.433807	0.734224	0.552479	0.492164	0.6354
	22	0.433807	0.734224	0.552479	0.492164	0.6354
	23	0.433807	0.734224	0.552479	0.492164	0.6354
	24	0.433807	0.734224	0.552479	0.492164	0.6354
	25	0.433807	0.734224	0.552479	0.492164	0.6354
	26	0.433807	0.734224	0.552479	0.492164	0.6354
	27	0.433807	0.734224	0.552479	0.492164	0.6354
	28	0.399102	0.675486	0.508280	0.452791	0.5846
	29	0.399102	0.675486	0.508280	0.452791	0.5846

30	0.399102	0.675486	0.508280	0.452791	0.5846
31	0.399102	0.675486	0.508280	0.452791	0.5846

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Sensitivity Report for Scenario 1

Adjustable Cells

Cell	Name	Final Value	Reduced Gradient
B4	Acres T3T11	0.00	-0.25
C4	Acres T3T12	135.94	0.00
D4	Acres T3T13	47.56	0.00
E4	Acres T3T 14	0.00	-0.78
F4	Acres T3T15	0.00	-32.05
G4	Acres T3T16	0.00	-70.79
H4	Acres T4T12	0.00	-47.43
I4	Acres T4T13	127.26	0.00
J4	Acres T4T14	71.17	0.00
K4	Acres T4T15	0.00	-0.74
L4	Acres T4T16	0.00	-31.31
M4	Acres T4T17	0.00	-70.79
N4	Acres T5T13	0.00	-44.74
O4	Acres T5T14	110.09	0.00
P4	Acres T5T15	99.50	0.00
Q4	Acres T5T16	37.62	0.00
R4	Acres T5T17	0.00	-31.31
S4	Acres T6T14	0.00	-48.22
T4	Acres T6T15	106.41	0.00
U4	Acres T6T16	0.00	-1.20
V4	Acres T6T17	135.76	0.00
W4	Acres T2T11	0.00	-161.53
X4	Acres T2T12	0.00	-23.43
Y4	Acres T2T13	0.00	-116.42
Z4	Acres T3T12	0.00	-145.80
AA4	Acres T3T13	0.00	-25.98
AB4	Acres T3T14	0.00	-113.69
AC4	Acres T4T13	0.00	-125.10
AD4	Acres T4T14	9.74	0.00
AE4	Acres T4T15	0.00	-187.97
AF4	Acres T5T14	0.00	-24.85
AG4	Acres T5T15	118.94	0.00
AH4	Acres T5T16	0.00	-49.28
AI4	Acres T6T15	0.00	-193.43
AJ4	Acres T6T16	0.00	-29.90
AK4	Acres T6T17	0.00	-74.17

Constraints Cell	Name	Final Value	Lagrange Multiplier
AL11	Total Acres Solution cells (acres of each rotation)	1000.0000	280.9535
AL15	March 16-31 Solution cells (acres of each rotation)	61.9307	0.0000
AL16	April 1-15 Solution cells (acres of each rotation)	152.9802	0.0000
AL17	April 16-30 Solution cells (acres of each rotation)	177.8131	0.0000
AL18	May 1-15 Solution cells (acres of each rotation)	174.0400	0.0000
AL19	May 16-31 Solution cells (acres of each rotation)	275.4567	0.0000
AL20	June 1-15 Solution cells (acres of each rotation)	219.3447	0.0000
AL21	June 16-30 Solution cells (acres of each rotation)	83.6472	0.0000
AL22	July 1-15 Solution cells (acres of each rotation)	253.4819	0.0000
AL23	July 16-31 Solution cells (acres of each rotation)	175.0403	0.0000
AL24	Aug 1-15 Solution cells (acres of each rotation)	160.8085	0.0000
AL25	Aug 16-31 Solution cells (acres of each rotation)	80.0499	0.0000
AL26	Sept 1-15 Solution cells (acres of each rotation)	298.2178	34.4901
AL27	Sept 16-30 Solution cells (acres of each rotation)	250.4945	0.0000
AL28	Oct 1-15 Solution cells (acres of each rotation)	290.6894	2.8400
AL29	Oct 16-31 Solution cells (acres of each rotation)	330.2174	3.9136
AL30	Nov 1-15 Solution cells (acres of each rotation)	281.7573	2.1453
AL31	Nov 16-30 Solution cells (acres of each rotation)	269.2774	28.0665
AL32	Dec 1-15 Solution cells (acres of each rotation)	225.8808	31.3862
AL33	Dec 16-31 Solution cells (acres of each rotation)	29.4816	0.0000
AL39	April 16-30 Solution cells (acres of each rotation)	45.7776	0.0000
AL40	May 1-15 Solution cells (acres of each rotation)	49.5003	0.0000
AL41	May 16-31 Solution cells (acres of each rotation)	64.1007	0.0000
AL42	June 1-15 Solution cells (acres of each rotation)	90.0816	0.0000
AL43	June 16-30 Solution cells (acres of each rotation)	0.0000	0.0000
AL46	Aug 16-31 Solution cells (acres of each rotation)	0.0000	0.0000
AL47	Sept 1-15 Solution cells (acres of each rotation)	72.6695	0.0000
AL48	Sept 16-30 Solution cells (acres of each rotation)	93.4525	88.1575
AL49	Oct 1-15 Solution cells (acres of each rotation)	96.8965	85.7262
AL50	Oct 16-31 Solution cells (acres of each rotation)	110.0725	80.2996
AL51	Nov 1-15 Solution cells (acres of each rotation)	20.1119	0.0000
AL52	Nov 16-30 Solution cells (acres of each rotation)	72.5701	0.0000
AL53	Dec 1-15 Solution cells (acres of each rotation)	0.0000	0.0000
AL54	Dec 16-31 Solution cells (acres of each rotation)	0.0000	0.0000
AL57	Sept 16-30 Solution cells (acres of each rotation)	0.0000	0.0000
AL58	Oct 1-15 Solution cells (acres of each rotation)	0.0000	0.0000
AL59	Oct 16-31 Solution cells (acres of each rotation)	0.0000	0.0000
AL60	Nov 1-15 Solution cells (acres of each rotation)	14.7002	0.0000
AL61	Nov 16-30 Solution cells (acres of each rotation)	179.5183	39.7909
AL62	Dec 1-15 Solution cells (acres of each rotation)	0.0000	0.0000
AL63	Dec 16-31 Solution cells (acres of each rotation)	0.0000	0.0000
AL66	Sept 1-15 Solution cells (acres of each rotation)	0.0000	0.0000
AL67	Sept 16-30 Solution cells (acres of each rotation)	0.0000	0.0000
AL68	Oct 1-15 Solution cells (acres of each rotation)	0.0000	0.0000

AL69	Oct 16-31 Solution cells (acres of each rotation)	5.4667	0.0000
AL70	Nov 1-15 Solution cells (acres of each rotation)	66.7592	0.0000
AL71	Nov 16-30 Solution cells (acres of each rotation)	0.0000	0.0000
AL72	Dec 1-15 Solution cells (acres of each rotation)	0.0000	0.0000

A-11

CALCULATING THE COTTON COEFFICIENTS

A	B	C	D	E	F
	% OB	DAP=X	YIELD	PREMIUM/ DISCOUNT	Q. ADJ. YIELD
T_3T_{11}	50.3	122	1141.2	-0.18	1140.90
T_3T_{12}	83.0	138	1260.60	-15.90	1234.10
T_3T_{13}	98.5	153	1275.39	-28.00	1228.72
T_3T_{14}	99.4	168	1275.42	-28.74	1227.51
T_3T_{15}	100	182	1226.54	-38.50	1162.38
T_3T_{16}	100	196	1190.77	-63.34	1085.21
T_4T_{12}	50.3	122	1141.2	-0.18	1140.90
T_4T_{13}	83.0	138	1260.60	-15.90	1234.10
T_4T_{14}	98.5	153	1275.39	-28.00	1228.72
T_4T_{15}	99.3	168	1275.42	-28.74	1227.51
T_4T_{16}	100	182	1226.54	-38.50	1162.38
T_4T_{17}	100	196	1190.77	-63.34	1085.21
T_5T_{13}	50.3	122	1141.2	-0.18	1140.90
T_5T_{14}	83.0	137	1260.60	-15.90	1232.88
T_5T_{15}	98.5	153	1275.39	-28.00	1228.72
T_5T_{16}	99.4	168	1275.42	-28.74	1227.51
T_5T_{17}	100	182	1226.54	-38.50	1162.38
T_6T_{14}	50.3	196	1141.2	-0.18	1140.90
T_6T_{15}	83.0	122	1260.60	-15.90	1234.10
T_6T_{16}	98.5	138	1275.39	-28.00	1228.72
T_6T_{17}	99.4	153	1275.42	-28.74	1227.51

A-12

CALCULATING PEANUT BUDGET YIELDS

Peanuts	A	B	C	D	E	F	G	H
					Yield			
	Rating	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	T_{17}
T_2	85	2791.2	3531.2	2991.2				
T_3	80		2795.2	3535.2	2995.2			
T_4	75			2939	3679	3139		
T_5	65				3646	4386	3846	
T_6	70					3222.6	3962.6	3422.6