EFFECTS OF EVERGLADES RESTORATION ON SUGARCANE FARMING IN THE EVERGLADES AGRICULTURAL AREA

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
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This thesis is dedicated to my parents, Carlos and Janet, and my sister, Carmen.

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Sugarcane production is a $700 million business in the Everglades Agricultural Area. Beginning in the 1920s, this portion of the Everglades region of South Florida was drained, leaving rich muck soils to be used by agriculture. Productivity led to diminishing water quality until, in 1994, the Everglades Forever Act called for the wetland to be restored. As part of the larger Comprehensive Everglades Restoration Project (CERP), the current drainage system in Florida Everglades is being altered or removed and best management practices require that less water be drained out of the area to reduce phosphorus loads. It is expected that maintaining a higher water table lowers sugarcane production for an EAA farm and that the EAA sugarcane operation will experience economic losses under the changed water conditions.

The analysis assumed a hypothetical 640-acre sugarcane farm with a high level of management, operating to maximize profit, and independent of processors. Using an approach based on agronomic yield models, this analysis estimated yield and profit

change for this "typical" farm under four scenarios. Functions from a 2002 study on sugarcane cultivar response to water tables were used to determine an expected yield function that included a parameter for flood events along with historical distributions for water table depth. That function, along with acreage, overhead cost, variable cost, and price, was then simulated using Simetar, varying the input factors.

The mean values for yield changes, and consequently for profit changes, in the simulations were significantly different across the baseline and post-restoration scenarios. A zero-profit estimation found that water table depth of 31.83cm with 6 flood cycles resulted in a yield of 31.1 tons per acre, just a 7 % difference from the historical mean. All post-restoration simulations resulted in average losses over the estimated period including a decrease in yield to approximately 27 and 24 tons per acre. If basing decisions on the mean values of these scenarios, one would expect that the 640-acre farm, even keeping all acreage in production, would see an average loss of up to $135,000 for the year.

CHAPTER 1
INTRODUCTION

Agriculture is one of Florida's largest industries and a major sector of the economy. This industry alone accounts for over six billion dollars annually. Perhaps most well known commodities are citrus and sugarcane, vegetables, berries and melons While farmland may not be as expansive as in other states, much of it is in use for these types of high value crop production. Much of this production takes place in south Florida, which includes the Everglades Agricultural Area (EAA).

For many, the Florida environment is just as valuable as its industries. Florida has diverse ecosystems including lakes and rivers. Citizens and lawmakers alike have worked to restore fragile wetlands and greenways. Programs such as "Florida Forever" set aside vulnerable parcels of land so that natural areas can be preserved. Public awareness has influenced initiatives for protected wildlife, sensitive land, and water resources in many forms, but perhaps none greater than the task of restoring the Florida Everglades. With strong citizen support, state and federal agencies came together to develop the Comprehensive Everglades Restoration Plan (CERP). It is this multi-stage effort that is bringing about great challenges in balancing the interests of producers, environmentalists, and developers.

It was the establishment of agriculture that motivated the creation of a system for flood control and began the series of changes in the Everglades area. Later on, population booms and urban growth further changed the landscape of the state. This expansion put further pressures on water quality and management. Construction and land development show no signs of slowing, and thus water management will continue to be an issue for the foreseeable future.

Due to these changes, current producers have a number of immediate concerns: keeping production profitable, adjusting their practices to meet environmental standards, and making decisions with an uncertain future in their industry. The EAA is just a small piece of the larger picture. This area represents jut one sector of one of the most complex and long-range wetland restoration projects ever undertaken. Within this area, the primary concerns are maintaining flood control, while also ensuring water availability, and controlling runoff into the Everglades Protection Area.

The case is unique as the EAA falls within a particular watershed, is home to crops that may not be produced in many areas, and has been subject to specific water management measures for so many years. However, Florida is not the only state trying to balance agricultural and environmental interests, nor is South Florida the only region struggling to manage development and water needs as well as wanting to preserve as much of the natural beauty as possible. As these challenges are approached, the results of these programs will surely serve as indicators for future projects around the country.

Geography and Land Use

The Florida Everglades region is historically known as one of the most unique and productive ecosystems in the world . Marjory Stoneman Douglas describes the region in her 1947 book, <u>Everglades: River of Grass</u>:

> The grass and the water together make the river as simple as it is unique. There is no other river like it. Yet within that simplicity, enclosed within the river and bordering and intruding on it from each side, there is a subtlety and diversity, a crowd of changing forms, of thrusting teeming life. All that becomes the region of the Everglades.

It is the defining ecosystem of South Florida, a hydrological network of saw grass plains and swamps that once covered nearly three million acres (USGS 2002).

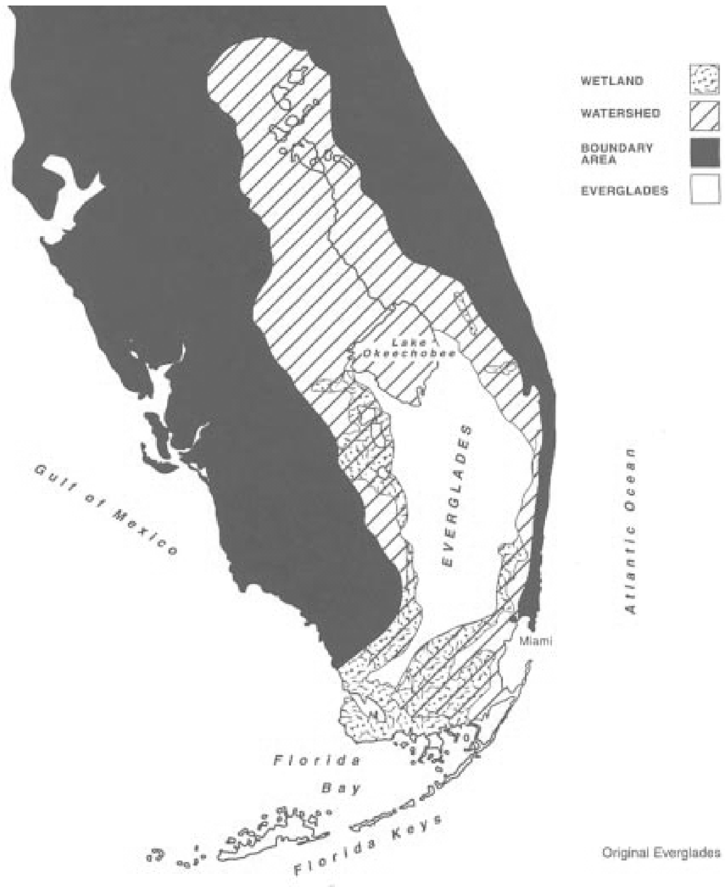

Figure 1-1. Original Everglades, surrounding wetlands, and south Florida watershed. Source: USGS.

From the extensive Everglades marsh, approximately 700,000 acres were drained to provide rich farmland (Bottcher and Izuno 1994). This area is now known as the Everglades Agricultural Area (EAA) and sits in Hendry and Palm Beach counties between Lake Okeechobee to the north and the Everglades Protection Area to the south.

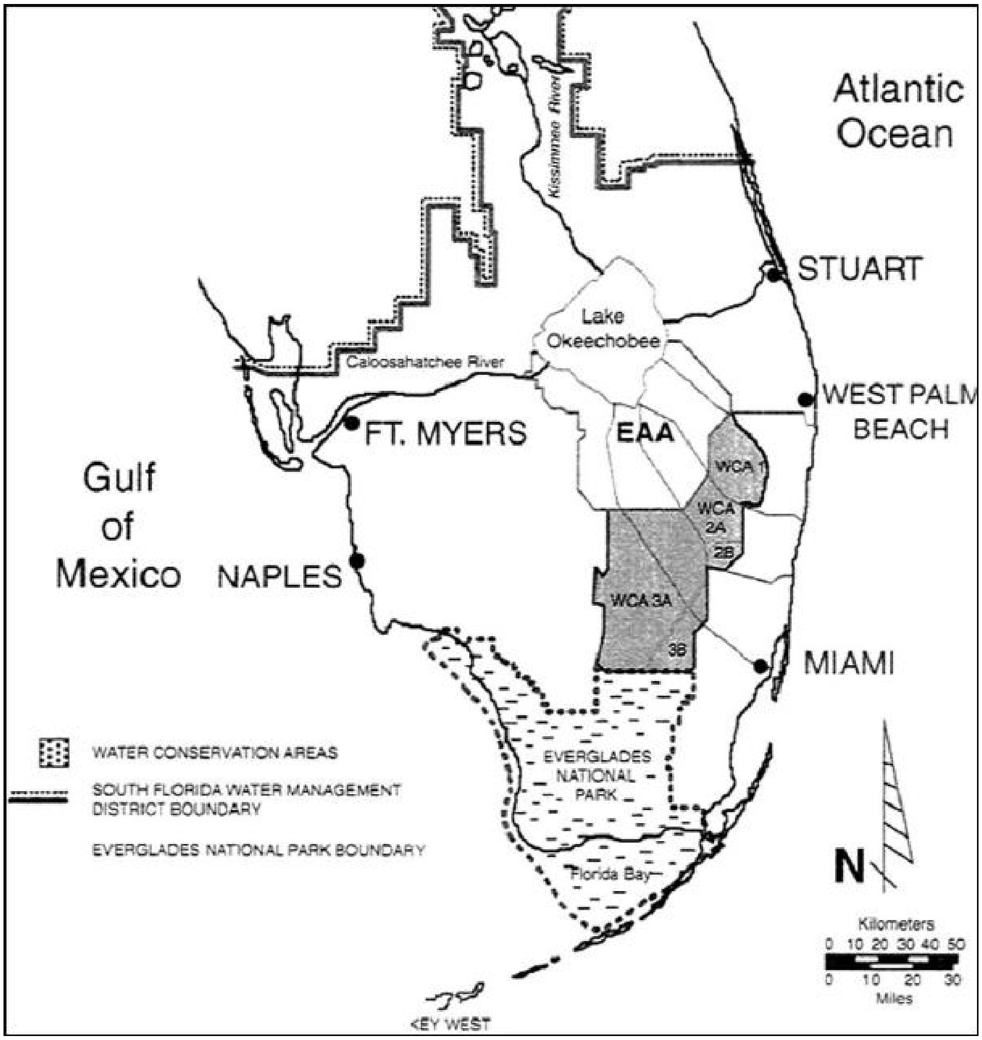

Figure 1-2. Current map of the Everglades region, including the Everglades Agricultural Area. Source: IFAS

Agricultural development of the area was made possible by the establishment of a drainage and irrigation system to regulate the amount of water available, especially during the wet and dry seasons. The area receives enough annual rainfall to sustain its crops, however, most of that rainfall comes in June through September, while winter and spring are dry (EREC 2005). The irregularity of these rainfall patterns makes water management the EAA=s greatest challenge.

The EAA has been able to regulate its water levels by using a system of canals, pumps, and levees first put in place in the 1920's. Currently, approximately 80% of the area pumps its excess water into storm water treatment areas and water conservation areas and a few drainage districts still drain runoff into Lake Okeechobee (FFWP). While agriculture thrived over the decades, the water quality of the Everglades diminished with nutrient levels steadily increasing.

Economic Characteristics: EAA

The EAA is still one of the most productive agricultural areas in the country. The agricultural industries occupying the EAA are responsible for an estimated $1.5 billion of sales each year (Aillery et al 2001). As of 1997, Palm Beach and Hendry counties had over 730,000 acres of cropland making up approximately 1200 farms. The leading crops in production are sugarcane, rice, sod, and winter vegetables. By 2002, the EAA had about 500,000 acres in production, with 90% of its acreage in Palm Beach County. Over 5,000 people in this area are employed either directly in agriculture or in associated businesses as reported in the 2000 census (USACE and SFWMD 2003.)

Sugarcane dominates production in the EAA covering 86% of its acreage and bringing in sales of over $762 million in 2001. Nearly a quarter of domestic sugar is produced in the region. The EAA also boasts a rice industry with sales of over $9 million. Winter vegetable production is also a profitable practice in the EAA, second only to sugarcane. Row crops cover over 16,000 acres and represent about 16% of EAA sales in 2001 (USACE and SFWMD 2003).

Restoration and Conservation History

Regulation of the Everglades region began in 1934 when Congress authorized the acquisition of land for a park that would preserve natural conditions in south Florida

(SFWMD 2004). After thirteen years, President Truman officially dedicated the Everglades National Park in December of 1947 (ENP), the same year Douglas published her account of the wetlands.

Florida continued to grow, however, and in order to establish a system for flood control, agricultural and urban water supply, and preservation of wildlife, Congress in 1948, set forth the Central & Southern Florida (C&SF) Project. Reaching from central Florida to the Florida Keys, it took the form of canals, levees, storage areas and other water control structures. The drainage projects for controlling flooding were begun by the State of Florida and eventually continued by the Corps of Engineers (USACE and SFWMD 1999). Successful drainage of the area made the land south of Lake Okeechobee suitable for agricultural development, creating the EAA.

However, this control system altered the natural ecosystem to such an extent, that even the protected area was being damaged by changes in water flows and the phosphorus running off of the agricultural lands. In 1991, the State of Florida established the Douglas Everglades Protection Act (F.S. 373.4592, 1991) which called for a Surface Water Improvement and Management (SWIM) plan and a change in regulatory procedures for the EAA. Many felt there was not enough available information to make such decisions and lawsuits began, delaying the restoration efforts.

In 1994, the Florida state legislature passed the more comprehensive "Everglades Forever Act" which established new storm water treatment areas and Best Management Practices (BMP) for the EAA in an effort to restore the natural flow of the Everglades as well as improving water quality (Bottcher and Izuno 1994). Combining short and long term projects, this plan includes more research and monitoring in the decision-making process than previous laws had allowed. The state followed up with the Water Resources Development Act (WRDA) of 1996, authorizing the Corps of Engineers to develop a plan by 1999 that would encompass all aspects restoration. The Water Resources Development Act of 2000 set forth the parameters for the final restoration project and laid out the key points of the comprehensive plan.

Comprehensive Everglades Restoration Plan

The Comprehensive Everglades Restoration Plan (CERP) was the result of the WRDA of 2000. With a budget of $7.8 billion, the plan includes thirty years of construction and an additional twenty years of maintenance. There are more than sixty components of the plan, being carried out by both the SFWMD and the Corps of Engineers. The costs are to be evenly divided between the state and federal governments.

The primary goals are to develop ecological values as well as increasing economic and social values. By restoring a more natural hydrological flow, it is expected that water quality would be improved throughout the area and threatened and endangered species would also see improvement in their habitat. Under CERP, new water quality treatment facilities will be established along with over 200,000 acres of reservoirs and wetland water treatment areas being constructed.

Agricultural concerns have been considered a major part of the plan, because of the proximity of natural and agricultural areas. In November of 1999, the South Florida Action Plan for the Applied Behavioral Sciences, drafted to bring socioeconomic concerns into the restoration planning process brought these concerns to light. A number of CERP projects take place within or adjacent to current agricultural areas. Though there are pockets of agriculture spread over south Florida, the area concentrated around

Lake Okeechobee, including the EAA, would be the most affected by CERP implementation (USACE and SFWMD 2001).

Focus of Present Work

This study seeks to provide insight into the role that the Everglades restoration program will have on the immediate area, specifically, sugarcane farming in the EAA. EAA farms are crucial to Florida's agricultural industry and indeed are major contributors to the greater economy.

Problem Statement

Under CERP, some major drainage canals will be removed and more water is being retained as part of BMP. In light of these conditions, a sugarcane producer in the EAA is likely to face higher water tables and longer flood durations, as pumping is limited both voluntarily and by regulation. To examine these conditions requires looking at many parts of the situation: options for modeling agricultural production, the relationship between agriculture and the Everglades restoration effort itself, the economics of water use, and previous work on sugarcane yields.

By examining the current status of sugarcane production in the EAA and the current strategies in water management, this study aims to provide an informed picture of the impacts CERP will have on the agricultural industry in the long run. Looking at the impacts of water on those crops will assist in filling in some of the gaps in information

Hypotheses

Maintaining a Higher Water Table Lowers Average Sugarcane Production for an EAA Farm.

Though each year brings a season of heavy rain to South Florida, farmers have been able to manage their risk by planting alternate crops or letting the land lie fallow during the rainy season. Under the restoration plan, it is expected that there will be a significant difference, as more water is being kept on the land to reduce nutrient loading in addition to removal of some of the drainage system. Assuming that producers are currently operating at an optimal level, increasing the available water would hinder yield. Some crops, such as rice, require flooding and as such may not show a decreased yield. In the case of sugarcane, lower yield among the current cultivars is anticipated and in response new cultivars are being bred for water tolerance.

The EAA Sugarcane Operation Will Experience a Reduction in Profit Under the Changed Water Conditions.

Maintaining more water on farmland is a strategy being employed by sugarcane growers in order to reduce soil subsidence as well as limiting phosphorus loads, major objectives of the restoration effort. Literature suggests that production is constrained not only by the amount of water applied, but also by limitations on the amount of water that can be pumped out of the system under a certain time. The producer, having to choose which fields to drain, may find that less acreage can be harvested. The consequential decline in production cuts into the profits of that operation.

Research Objectives

The first objective of the analysis is to provide a descriptive framework for analyzing changes in sugarcane production for a representative farm in the Everglades Agricultural Area. This includes determining the current production practices in the area as well as estimating future production possibilities. In particular, the focus of the work is to describe the crop response to water management such that a producer would have knowledge of how changes in those practices could affect his operation. This requires not only gathering information on the crop yield itself, but also determining how much water is coming in and out of the system.

The other major objective is to gauge the economic impact of the water flow change. In order to meet this objective, there must first be a determination of future production. By simulating the production relationship, a range of possibilities can be outlined. Along with future estimations, there must also be a determination of cost structure. Once these factors are combined, the resulting analysis can be useful for a producer in weighing future decisions.

CHAPTER 2
PRODUCTION THEORY AND ITS APPLICATION TO FLORIDA AGRICULTURE

Theory of the Firm

As modern economic theory developed, there developed a need for specific definitions and assumptions. The focus of analysis shifted in the early twentieth century from industry perspective to that of the individual unit. Coase, specifically, set forth his Nature of the Firm (1937) in order that continued analysis would have a well-defined and consistent basis when performed at firm level. At the same time, it was hoped that the resulting definition would be both realistic and useful within the analytic methods of the time. Any definition, he stated, would need to conform to the "most powerful economic instruments" of economics: the ideas of marginal analysis and substitution.

An initial step in creating the basic assumptions is differentiating the firm from the larger economic system. The basics of the system are well defined and lead the economist to assume that resources will be allocated based on prices and that the system will continue working on its own through market transactions. When the perspective changes to the firm level, however, there is not an internal market to allocate resources. Instead the firm has to have a coordinator, someone who will be the decision-maker and direct production. Through this coordinator, the firm avoids the costs that come with operating a market. The firm is then defined as a system of interactions in which resources are allocated by a particular "entrepreneur."

Among the most important characteristics of the theoretical firm are that it has an upward sloping cost curve and that it will not pay to produce output beyond the point at which marginal cost is equal to marginal revenue. Additionally, the firm will continue to grow until the marginal cost of creating a transaction within the firm is equal to the cost of having that transaction in the marketplace.

Alchian and Demsetz (1972) do not refute Coase's definitions, but take a more specific look at what constitutes a "classical firm". They examine the structure and lay out six major qualifications of a firm. First, it must produce using joint inputs. Second, these inputs come from a number of input owners. Next, all the contracts for joint inputs have a party in common. That party must also have the authority to renegotiate the input contracts independent of each other. Additionally, that party holds claim to the residuals and finally, must have the right to sell the central contractual residual status.

Similar to Coase, Alchian and Demsetz see the existence of a central decision-maker as imperative to the existence of the firm. This decision-maker is owner and employer. They feel that this structure is the result of necessity. That is, that in attempting to align productivity to the marginal costs of inputs, the most efficient method is to operate as a classical firm.

Interrelationships of Economic and Agronomic Concepts

Agricultural decision-making involves combining both economic and biological factors in order to maximize outcome. This combination becomes crucial in examining yield responses, optimal output, and the overall input-output relationship (Redman and Allen, 1954). What is considered "optimal" they find, is greatly influenced by the particular concepts being employed. That is, when constants are changed, other factors (e.g., the factor-product price ratio) may become more or less important in determining the most profitable choice.

Crop yield is certainly one area in which these two schools of thought intersect. Agronomic production functions give the economist a quantitative look at the changes in production under various conditions. Yield is a result of numerous factors, from the plant itself to the soil in use, to the surrounding climate, to nutritional inputs. Early theorists concentrated on the "food" of plants: water, nitrogen, earth, fire. As agronomy has developed however, there is a more clear understanding of plant processes such as photosynthesis, which incorporates energy into the relationship. Some of these basic factors, however (water, nitrogen, and other fertilizers) are still the subject of economic analysis, especially under changing conditions.

The "Law of the Minimum" argued by von Liebig was one of the earliest models of production and still carries some influence, even if it no longer stands alone. Von Liebig began with the concept of a minimum factor, the factor of yield that is most scarce. In this theory, yield will change only when this minimum factor is changed. Consequently, the production curve would increase at a constant rate until it reached the limit determined by the minimum factor. At that point, von Liebig's curve becomes horizontal, as adding more of the other factors does not change yield.

While von Liebig's concept resonated with early farm economists, it was not an especially accurate model of plant response. Later experiments provided data that would be used to modify the concept, moving away from the idea of a linear relationship with constant returns to scale.

In trying to improve the production model, Mitscherlich assumed that there was a maximum yield under ideal conditions and that it was the shortage of any one factor that would cause yield to decrease proportionally. His result was a curve concave to the given factor axis such that

$$dy/dx = (A - y)\ C$$

where y is the yield while x is the factor in question and A is the maximum yield. Though an improvement over the von Liebig equation, Mitscherlich's model still did not adequately represent possible yields since each factor had its own constant, C and did not account for factors influencing each other. Baule expanded this model to include variable growth factors, making the case that yield is dependent upon the interaction of many factors. Overall yield is then expressed as

$$Y = (1\text{-}10c1x1)(1\text{-}10c2x2)\ldots(1\text{-}10cnxn)$$

with c representing the effect of the corresponding x factors.

At the same time, Spillman was developing another estimation of yield. Basing his model on the expectation that increments of a growth factor could be the terms of a geometric series. Using the example of fertilizer application, Spillman expressed the yield relationship as:

$$Y= A(1-R^{x})$$

In this expression, R would indicate the ratio of increments in yield and suggests a sigmoid curve. Both Mitscherlich and Stillman agreed that the law if diminishing increment would not apply once the input quantity was large enough to damage the plant.

Redman and Allen in their overview of these principles raise the concern that economists must be careful in using data from farm crops on the basis that the functions drawn from these data are not necessarily true of all plant growth. Fixed factors and decision-making may be different for separate sets of data and as such, the economist attempts to find an expression of "best fit." Once such an expression is created, it can then be used under various scenarios to forecast the profitability of choices.

Diminishing Returns

One of the most relevant parts of the economics/agronomic relationship is the theory of diminishing returns. This idea was first set forth in the 18^{th} century by Turgot. In describing expenditures and production, he noted that while returns initially increased, effects would eventually diminish. Early in the 19^{th} century, Malthus, Ricardo, West, and Torrens all described the same phenomenon in their publications on land rent. Ricardo was perhaps most accurate in describing the phenomenon within intensive farming. His analysis however was indicative of diminishing average returns and not explicitly marginal returns. Malthus tried to use the diminishing returns concept to make his arguments regarding population growth, specifically, that the food supply was limited to arithmetic growth. The concept remained part of economic thinking of the time, even incorporated into the "four propositions" stated by Senior as he began the study of political economy.

It was not until the twentieth century drew near that the distinctions were made between average and marginal products. Clark presented a paper that applied the idea of diminishing returns to all factors of production. His major assumption was that all factors of production remain permanent except for one factor that would be changed. Under these assumptions, if more units of the one varying factor were added, the marginal and average products associated with that factor would eventually decrease.

Edgeworth in 1911 assumed that land was a fixed input and created a table that included variable levels (referred to as "doses" of the other inputs and their resulting output. Though he was arguing that these concepts would apply to any industry (in this case, railways), his work was based on agricultural examples. Citing his observation that at some point there is a transition from increasing to diminishing returns, Edgeworth was one of the first recognize the marginal product of the input as well as the average product, creating columns for each in his table.

Modeling Production

Thompson 1988 describes the flexible functional forms (FFF) as a way to relax the restrictions one gets when using Cobb-Douglas functions. They can be expressed as quadratics, Box-Cox, and numerous other forms. It is important that empirical studies state clearly the reasons a particular form was chosen.

FFF are very useful when using duality theory. If the function satisfies certain conditions (convexity, monotonicity, homogeneity), there is no longer a need for a self-dual function. It is also possible to derive supply or demand from these functions and to use them for comparative statics. Additionally, these functions can be used to estimate equations (or systems) that are nonlinear in their parameters.

One of the main problems with the FFF is collinearity. Also, it is often difficult to meet the above conditions over the entire set of observations. Estimating nonlinear systems also limits interpretation, as much statistical theory assumes linearity in the parameters.

Deiwert (1973) defines flexibility as a local property. Using an arbitrary function, he makes a second order approximation. The parameters of the FFF then must give it first and second derivatives equal to those of the arbitrary function. This definition of flexibility is often applied because the conditions are easier to meet than those of other definitions.

Another measure of flexibility is the Sobolev norm, which is a global definition. This approach measures the average error of approximation and consequently estimates elasticities very close to the true elasticity. This also gives the model nonparametric properties including "small average bias approximations (Gallant 1981); consistent estimations of substitution elasticities (Elbadawi, Gallant, Souza 1983); and asymptotically size α testing procedures (Gallant 1982)."

Many FFF can be looked at as derivations from mathematical expansions, but the definitions do not limit them to only such derivations. Some commonly used expansions are the Taylor, Laurent, and Fourier expansions. The first two are flexible under the Diewert definition, while the Fourier follows the Sobolev definition. Some functions, like the generalized Mc Fadden and Barnett functions are not derived from an expansion (Diewert and Wales 1987).

In Thompson's analysis, four types of studies were used to look at the various FFF: Monte Carlo, parametric modeling, Bayesian Analysis, and nonnested hypothesis testing. The FFF are useful in both production and consumer applications of the Monte Carlo studies, but depend upon the type of data, the size of the sample, and other properties that vary. The parametric model used Box-Cox testing and therefore could only be applied to some of the FFF. The Bayesian analysis allowed very different models to be compared based on their data on both the production and consumer levels. The nonnested testing includes all the proposed models and is also based on the data. Of these methods, the Bayesian analysis and nonnested testing were the most useful in comparing FFF. It is noted that in either case, it is important to be able to compare models with various transformations of the dependent variable.

One must look at the duality of the behavioral model and test the behavioral assumptions to make sure the data are consistent with the assumptions. The data should then be tested for theoretical properties such as returns to scale. The chosen form should fit the assumptions and can be compared with other forms through Bayesian analysis or nonnested hypothesis testing. After the form has been chosen, it is important that it be compared to other measures (in order to gauge sensitivity of that form).

In an examination of The Cottonwood River Watershed, Apland, Grainger, and Strock (2004) describe a framework for creating a farm model that accounts for both agricultural production as well as water quality concerns. In trying to model these tradeoffs, Apland notes that mathematical programming models can incorporate economic and agricultural factors but become very complex.

A deterministic farm model forms the basis of Apland's work, which is designed to be expanded to include risk. The model is made up of 18 production periods for the year in order to represent harvest and planting activities in all combinations. Land, labor, and machines are held fixed so that the analysis can focus on the various harvesting, planting, and tillage dates and fertilizer application is endogenous.

To carry the model forward, the authors discuss a discrete stochastic programming model (DSP). This type of model is useful in that it can capture alternative practices as part of the risk analysis. Further, risk can be included in the constraints and as par of the sequential decision process. However, this method requires a great deal of data to be useful and can be costly.

Risk is a significant factor in modeling agricultural production. Just and Pope (1979) note that risk affected by price, market phenomena, technology, and policy.

Traditional evaluations of production were drawn from experimental data, but the authors argue that using continuous response functions give better estimates. This analysis uses "neoclassical log-linear production functions".

Some of the specific problems with previously used (and popular) models are that increasing input always has positive marginal effect on output and that it also reduces variability of marginal productivity. In order to separate the effects of input on output and variability, the authors propose that a good stochastic specification has two functions; the first modeling the effects of input on mean output and the second modeling the effects of input on variance of output:

$$y = f(X) + h^{1/2}(X)\theta,\ E(\theta) = 0,\ V(\theta)=1$$

The mean and variance of output can then been seen independently as $E(y) = f(X)$ and $V(y) = h(X)$.

The procedure proposed for such and estimation is a three-step regression. The first is a nonlinear least squares (NLS) regression of yield. Second, the expected error is regressed against X using ordinary least squares (OLS). The final step is a weighted NLS regression of y.

In using experimental data, the authors focus on Cobb-Douglas and translog functions. The basic equation is then modified to include an error term, time, and plot to capture time effects. They conclude that the simple two-part production function remains within the bounds of traditional economic thought while removing some of the constraints that hinder decision-making.

Modeling Production and Cost

In a static situation, Paris and Caputo (2004) state, any estimation of the economic relationships of a price-taking firm should include both primal and dual relations. Their proposed model uses a generalized additive error (GAE) approach to make a nonlinear estimation. Their sample firm is at once risk-neutral and cost minimizing. The system is then represented as a set of equations: the primal production and input price functions, and the dual input demand function.

This analysis does face some challenges. The planning and decision-making data is generally not recorded by producers and thus has to be estimated. Also, the choice of production function can pose additional challenges. The Cobb-Douglas and constant elasticity of substitution approaches have the same functional form as their respective cost functions, but that may not be the case with other forms. Once quantities and prices are estimated using NLS, they are put into a nonlinear seemingly unrelated (NSUR) model.

Economics of Water Use

Water use, an important factor in production, is often modeled as water applied. However, Kim and Schaible (2000) challenge the assumption that water (or any of the variable factors) is completely engaged in crop production. Noting that the production process does not consume not all inputs applied, whether water or fertilizer, the authors seek to provide a measure of the overestimation of economic benefits from water use.

The authors observe that economic benefits in agriculture are often modeled as normalized-quadratic functions, but that the derived factor demands are sometimes linear and sometimes in Cobb-Douglas form. As such, both linear and nonlinear cases are examined. Under both scenarios, the total economic benefits were overestimated when using applied water rather than consumptive water. In the application of these methods to corn production in three Nebraska counties, the overestimation was 28.9% and estimate even higher when looking at agriculture overall.

In one of the most traditional models of water use, the Von Liebig production function as described by Boggess et al (1993), uses evaporation and transpiration to estimate the changes in yield. This type of function describes a linear output relationship until some maximum. From that equation, actual yield can then be estimated as a function of the ratio of actual to potential evapotraspiration.

Similar to Kim and Schaible, Boggess et al make the distinction between effective water, actually used by plants, and the total amount of applied water. In modeling irrigation, they point out that it is fundamental to incorporate the concept of hydrologic balance. The principle of hydrologic balance states that there must be equality between the amount of water that enters a specific area and the amount of water that leaves that area. That is, all water entering the particular area, through precipitation, irrigation, or from the soil, and all water leaving the area whether through evapotranspiration, runoff, or percolation must be considered.

South Florida Agriculture and Ecosystem Restoration

Restoring the water flow of the Everglades will create a need for water retention in the northern part of the watershed. By 1978, over three million acres of land had been drained in South Florida (Weisskoff 2005). This region, especially the Everglades Agricultural Area (EAA) will require a great deal of water to meet needs during the dry season. Development of the EAA created a system if irrigation and drainage that prevents most water retention during the wet season. Increasing the amount of water retained may lessen agricultural profitability. Authors Aillery, Shoemaker, and Caswell attempt to model the economic effects of water table management and surface water retention scenarios.

The authors measured the tradeoffs under two conditions, the first being that resource use is determined by agricultural producers alone, the second using joint maximization of agricultural and environmental objectives. Using both objectives resulted in higher marginal costs, but also significantly increased the benefits of lowering the water table (Aillery, et al 2001). Whether the benefits will outweigh the cost is dependent upon the specific agricultural and environmental demands.

Three scenarios of water policy were simulated: water-table restrictions, surface-water development (including land acquisition), and water-retention targets. The first showed an increase in water retention, but at a high opportunity cost and the inability of the soils to retain the desired amount of water. Surface water development also increased water retention, but comes at the cost of production foregone by retiring those lands. A moderate change to a target water-table depth was considered the best option (Aillery, et al 2001).

The authors are up-front about two main concerns with this article. The first is that a true cost-benefit analysis would need more empirical evidence from the agricultural sector and is difficult to generalize. The second is that sugar prices, the major component in estimating agricultural gains reflect price support levels that could change in the future and thus alter these findings.

Sugarcane response to high water tables and flooding

Glaz, et al (2002) note that the EAA is dependent upon the canal system to maintain suitable water levels for sugarcane and other crops. Pointing to a study by Omary and Izuno (1995), ideal water levels fall within 40 and 95 cm below the soil surface. Keeping the water within this range has become more difficult as the farmers are dealing with soil subsidence. As soil is lost, the remaining soil cannot store as much water. Additionally, best management practices put in place to limit Phosphorus entering the Everglades have resulted in farmers pumping less water and thus maintaining higher water levels.

The researchers conducted two experiments, the first being planted in February and harvested in three cycles (plant cane and two ratoon crops). The second experiment was planted in January of the following year and harvested in two cycles. In both cases, two fields were planted and received water treatments from June to October (the months with highest rainfall). The wetter field was treated to have a water level between flooding and 15 cm BSS. The drier field was kept with a water level between 15 and 38cm BSS.

Over the period of study, the researchers found that the soil profile was very sensitive to rainfall. They estimated that for every cm of rain, the soil profile rose 10cm. As a result, even the drier field had some days in which the water level was higher than 15cm BSS, suggesting that during a normal year, fields with the drier target would still see flooding.

For the plant cane crops, the average cane yield for the drier field was 5.8% higher than the wetter field. For the first-ratoon harvests, the drier field average cane yield was 4.3% higher than the wetter field. For the second-ratoon harvest, the average cane yield was 8.4% higher in the drier field.

The researchers also measured the sugar yields from each harvest. The average sugar yield for the plant cane crops was 6.6% higher in the drier field than in the wetter field. The average sugar yield in the first-ratoon crops was 8.3% higher then in the wetter field. In the second-ratoon crop, the average sugar yield was 11.5% higher than in the wetter field.

The project suggests that there are some cultivars that may continue to yield well if the water tables were maintained at a higher level. They suggest that increasing the water table incrementally would be the best option considering profit and the need to reduce phosphorus discharge.

In 2004, Glaz et al published their findings after experimenting with two different sugarcane genotypes. This study was to examine periodic flooding, lasting no longer than one week and then draining to a water depth of about 50 cm below the surface. Flooding was set at 7 days to simulate the longest flood period a commercial field in the EAA might experience. The areas were treated for five and nine cycles in different years. It was noted that in the EAA, it is often difficult to drain to the desired level after a flood.

One of the genotypes developed arenchyma (air cavities) at the roots, which seems to have impacted the yield response. These did not show a significant response to changes in depth over the three years. The other genotype however, showed a 21% cane yield increase and an 18% sugar yield increase in the fully drained case as compared to the flooded specimens in 2000. The 2002 experiment resulted in a 28% increase in both sugar and cane yields in the drained area compared to the flooded plants. The authors point out that using additional flooding periods might result in a nonlinear flood response. Such information would be of use to farmers that are not able to drain all fields at once due to limitations on total drainage to the canals.

Another consideration in sugarcane response is the possible benefit of flooding during certain stages of growth, specifically in trying to control for wireworm (Glaz

2002, 2003). Flooding the seed cane after planting could replace the practice of applying insecticide to the soil. Before the practice could be commercially adopted, however, the feasibility and cost of maintaining the flood condition and then draining would need further examination. There is also a concern that the shortening of the growing season would lead to reduced yield.

CHAPTER 3
METHODOLOGY

Introduction and Overview of Analysis

The analysis assumed a hypothetical 640-acre sugarcane farm. Using two different approaches, one based on agronomic yield models and historical groundwater levels; the other based on historical yield and rainfall, this analysis estimated profits foregone for this "typical" farm. Both approaches assume that the operation is independent of a processor and profit maximizing.

In the first approach, the agronomic functions measuring response to flooding/high water tables were combined to give an expected yield function that included a parameter for flood events. That function, along with acreage, overhead cost, variable cost, and price were then simulated, varying the input factors. This approach also used a historical distribution along with a range of likely water table levels as described in *Water Management for Florida Sugarcane Production* (2002) and *Agriculture and Ecosystem Restoration in South Florida: Assessing Trade-offs from Water-Retention Development in the Everglades Agricultural Area* (2001).

The second approach utilized historical yield and rainfall, determining relationship between the two based on the most sensitive growth period. Future rainfall will be based on historical records and used to provide possible yields. From the previous Water Management article, the *EAA Storage Reservoir Phase 1 Existing Flood Control Conditions Documentation*, and the 2001 study on drainage uniformity, this approach will assume that the system will drain up to 48% of rainfall.

Agronomic Model

Taking the findings of the empirical research on yield response by Glaz et al (2002), two equations were combined in order to incorporate a parameter for flood events. The results for the two experiments were as follows:

$$Y = 14.6 + 0.16x \qquad (1)$$
$$Y = 17.6 + .25x \qquad (2)$$

The year 2000 experiment with 5 flood cycles (*Eq. 1*) was defined as a base (Z=0) and the 2001 experiment with 9 flood cycles (*Eq. 2*) was defined as Z=1. The following, then, represents flood events, Z, as

$$Z = -1.25 + .25F,$$

where F is the number of flood cycles, and Z is a qualitative variable. The number of flood cycles was simulated as part of the analysis. The simulation of flood cycles was first attempted using a uniform distribution (between 0 and 9), but ultimately, F was determined using a triangular distribution from which pseudo-random numbers were generated. The boundaries of the distribution remained 0 to 9 in keeping with the experimental conditions.

Equations (1) and (2), can then be combined as

$$Y = 14.6 + 3(Z) + .16X + .09(Z)X.$$

Where Y is yield in kilograms per meter squared. Sugarcane yield is historically measured in tons per acre, so the resulting yield (in kg) must be converted by a factor of approximately 4.5 to be expressed in tons per acre (see Table 3-1). In order to translate the empirical data to practical terms, a calibration factor was also included. This factor (0.267) was determined by setting the mean value of the empirical yield data equal to the historical mean yield.

The other key variable in this model is the groundwater level. Table 1 illustrates all key output variables (KOV) and their distributions. In order to simulate the probable range of groundwater levels, the historical data determine the distribution from which the simulated values will be chosen. A normal probability plot suggested that the data were very close to a normal distribution. The ANOVA procedure was used to determine the mean and standard deviation for the groundwater variable based on these data. The mean would be adjusted in order to simulate various scenarios.

Table 3-1. Key output variables and probability distributions for empirical model

Key Output Variables	**Specifications**
Acres	640
Flood Events "Z"	*Z = -1.25 + .25F*
Flood Cycles "F"	Triangular distribution: 0 to 9,
Depth “X” cm	Varied by scenario
Yield (kg per meter sq.)	*Y = 14.6 + 3(Z) + .16X +.09(Z)X*
Yield (tons per acre)	*Y * 4.460947/3.74*
Price (per ton)	$31.70
Variable Cost (per acre)	$760.94
Total Fixed Cost (dollars)	$144,000
Profit	(Price* Yield)-Total Costs

.

Using the Simetar (Richardson, 2001) simulation tool, these data were simulated for 100 iterations for each scenario. The output for each could then be compared in order to determine the effects of new water conditions. Five different scenarios were simulated using this tool.

- Scenario 1: A representation of current conditions, this scenario assumed a mean water table depth of 85.2cm and a standard deviation of 43.23 based on USGS data.
- Scenario 2: Also represents current conditions, but with the mean depth adjusted to 76.2cm as described in *Water Management for Florida Sugarcane Production*
- Scenario 3:A model of post-restoration conditions by raising water table depth to 54.78cm as suggested by Aillery, Shoemaker, and Caswell (Scenario I-5, 2001).
- Scenario 4: Alternative model of post-restoration including a truncated normal distribution for water table depth with mean 50cm, minimum -27.1272cm

(historical minimum), and maximum 92.8cm (95% Upper Confidence Interval for historical data).

- Scenario 5: Identifies conditions under which the hypothetical operation exhibits zero profit.

Rainfall Model

This approach began with the ANOVA procedure on monthly rainfall data over a twenty-year period in order to find variation for further simulation. Also included were the values for pan evaporation (*Evap*) and average temperature (*Temp*) for each month over the same growing period. The data were aggregated such that the annual yields were matched with the previous growing period. For example, Rainfall summed from August of 1990 to January 1991 corresponded to the 1991 production data. Maximum drainage (*Drain*) was set at 48% of the rainfall for each of the months included.

A relationship between total production (*TP*) and these factors was determined by using an Ordinary Least Squares (OLS) regression:

$$\begin{aligned} TP = {} & 2464440.7 - 2947.3Evap - 299037.5AugRn - 333598.7SeptRn - 266891OctRn \\ & - 303408.3NovRn - 309797.5DecRn - 258229.4JanRn - 7455.9Temp + 645862.7Drain \end{aligned}$$

Using this relationship, normal distributions for rainfall were specified for the simulation based on historical mean and variance

In order to represent the changes in drainage practices, the post-restoration scenario changes the percentage of water drained was varied while other climatic factors were held constant. The results of the two scenarios could then be compared to each other and ultimately to the previous model.

The rainfall model was designed to capture the concept of waster balance as presented in the literature regarding water use. It was anticipated that that in defining the amount of water coming into or out of the given system, future water flows could be estimated and consequently changes in production could be predicted. In this case, varying the drainage capacity could give distinct scenarios for comparison.

CHAPTER 4
DATA SOURCES

Empirical Research on Sugarcane Response

Glaz et al (2004) examined water table effects on two sugarcane genotypes in experiments from 2000-2002. Previous research, they noted, was inconsistent regarding sugarcane response to water tables. EAA farmers specifically have to deal with periodic floods (less than a week) and cannot always drain the desired amount of water. To simulate these conditions, the experiment evaluated periodic flooding followed by drainage to depths of 50, 33, and 16 cm below the soil surface (BSS).

To carry out the study, lysimeters made of polyethylene (1.5m x 2.6m x 0.6m) were set up with Pahokee muck soil from an uncropped EAA field. Each lysimeter had well water flowing in each day and a pump to get rid of excess water. Additionally, each had a valve that drained the lysimeter to the target water table level. Two sugarcane genotypes were planted, both being chosen because of high yield and similarity to commercially produced varieties. After planting, the water level remained at 50cm BSS until the actual treatments started. There were four total treatments; one a control and the others being flooded for the first week of a three-week cycle. After the 7 days of flooding, these treatments were drained to the aforementioned depths.

Water height from the actual soil surface up to 2.5cm above the surface was considered a "flood" condition in this experiment. The length of the flood, 7 days, was set to simulate the longest period of flooding one could expect in the EAA. Similarly, the 50cm control depth was based commercial practices. The experiment was repeated for three years; the 2000 experiment used five flooding cycles while the 2001 and 2002 experiments used nine flooding cycles. The resulting response functions were

$$Y = 14.6 + 0.16x \qquad (2000,\ \mathbf{r^2} = \mathbf{0.99})$$

$$Y = 17.6 + .25x \qquad (2001,\ \mathbf{r^2} = \mathbf{0.94})$$

Where Y is equal to cane yield in kg m^{-2} and x is equal to water table depth (cm) during drainage. The difference in flood cycles can then be used as a factor in incorporating the number of floods into the yield response analysis.

Water Table and Flooding Conditions

To be consistent with the cultural practices of the EAA, establishing the possible range of water tables included water table levels as described in Lang et al's *Water Management for Florida Sugarcane Production* (2002). They noted that 30 inches (76.2cm) was optimal depth in terms of sugarcane yield and stated that the recommended target level would be a depth of 23-30 inches (58.42-76.2cm) to the surface. They also noted that variation in EREC studies ranged from 39 inches (99.06cm) to surface level.

Historical water table levels for the area were available from the USGS from October of 1977 to September of 1995. The variation here ranged from a maximum depth of 206.95 cm below the surface to a minimum of just over 27 cm above the surface. The mean depth was just over 85 cm below the surface. The 167 observations, however, are at irregular intervals, which made the information useful only in determining the variation in water table levels. The complete distribution of these data is represented in Figure 4-1. These data were collected from a well at Latitude 26°38'45", Longitude 81°26'07" in Hendry County, Florida.

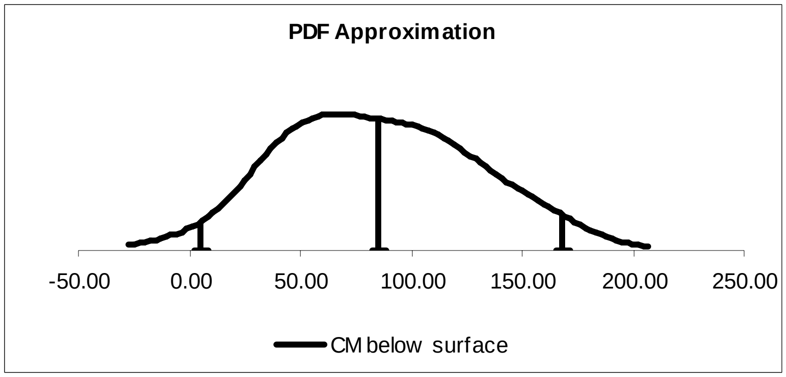

Figure 4-1. Distribution of water level for Hendry County, FL 1977-1995. Source: USGS

Additionally, a more qualitative source of information on water management was a summary of meetings with EAA sugar growers in November 2003 to get a consensus on flooding conditions. Coordinated by the Southwest Florida Water Management District, the *EAA Storage Reservoir Phase 1 Existing Flood Control Conditions Documentation*, provided insight into the growers' major concerns. The participating groups included US Sugar, the Sugar Farms Cooperative, and Florida Crystals, all producers within the EAA. The documentation of the three meetings revealed a number of common points. Some of these key statements included:

- Farmers have not kept regular records of crop losses due to flooding thus far
- The sugarcane crop is most sensitive to flooding during early stages of growth
- Receiving more than 4 inches of rainfall in a 24-hour period is considered problematic

There was also consensus among the growers that heavy rainfall and flooding are of most concern to the areas near the Bolles and Cross Canals which provide water flows to the east and west of the EAA. There was a concern that these canals to no have the capacity to carry water out as needed.

From the 2001 study on drainage uniformity it was noted that sites normally drained an average of only 48% of the rainfall input into the system (Garcia, Izuno, Scarlatos). When looking at the flow of water in and out of the EAA farm system, this average will used to determine how much water is being drained out of the system rather than contributing to the groundwater level.

Historical Production

Through the National Agricultural Statistics Service (NASS), the US Department of Agriculture (USDA) provides historical production information down to a county level. Using the "Quick Stats" website allows users to search production history for all major crops. Under the category Sugarcane for Sugar, county-level data are available for acres harvested, yield per acre and total production. Figure 4-2 illustrates the total annual production for the Hendry County over the past ten years.

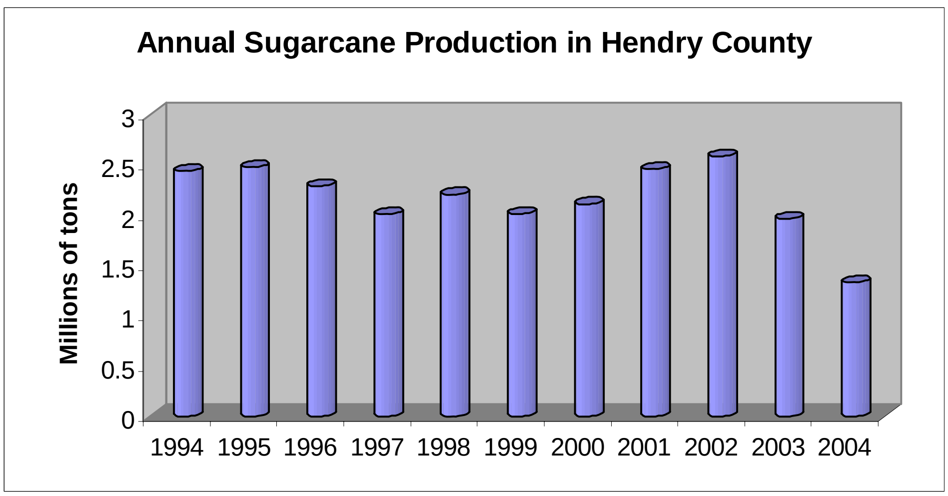

Figure 4-2: Total sugarcane production for Hendry County, FL from 1994-2004. Source: NASS

The production values are listed annually and are available from 1977-2004. For this analysis, however, data from 1980-2004 were considered. The area harvested over that time ranged from 35,000-76,000 acres. The average yield per acre varied from a low of 28.6 tons in 1981 to a maximum of 40.1 tons in 1998. Total annual sugarcane production in the county peaked in 2002 at over 25.8 million tons.

Climatic Data

The Everglades Research and Education Center includes an automated weather station that provides climatological data as a cooperative project of the University of Florida / IFAS and the South Florida Water Management District. The station was provides data on temperature, rainfall, solar radiation, and evaporation at the coordinates 26.6567N and 80.6299W. The time series for rainfall goes back as far as 1924, but for the purposes of this analysis, only data from 1979 – 2000 were considered. The total evaporation and average temperature over the growing season were also noted.

Within the area of interest, Hendry County, FL, sugarcane planting takes place from August through January and this period is considered the most sensitive to excess water. Table 4-1 illustrates the total rainfall for those crucial months.

Table 4-1. Total monthly rainfall in inches for the EAA 1979-2000 .

Year	January	August	September	October	November	December
1979		5.39	14.24	2.24	4.80	2.89
1980	6.09	3.73	7.46	1.02	3.42	0.73
1981	0.68	17.37	4.87	0.67	3.08	0.85
1982	0.63	8.11	12.41	2.75	0.67	0.80
1983	3.91	6.26	6.77	5.16	1.16	4.42
1984	0.23	4.04	8.15	0.40	2.37	0.11
1985	0.75	5.52	9.63	3.39	1.54	2.20
1986	3.59	6.21	4.04	4.50	1.58	3.99
1987	1.18	4.20	4.49	3.14	8.04	0.30
1988	3.02	8.89	2.47	0.11	1.31	0.89
1989	0.97	6.92	8.91	3.49	1.24	1.95
1990	2.47	7.57	2.96	4.22	0.39	1.11
1991	8.24	2.83	6.27	3.54	2.45	0.46
1992	1.20	11.85	10.82	0.69	4.03	0.62
1993	10.16	6.19	5.56	8.00	1.75	0.79
1994	5.60	9.74	5.47	12.16	5.93	7.13
1995	1.91	10.51	8.76	9.60	0.65	0.89
1996	1.35	9.75	3.04	4.23	0.80	0.38
1997	1.23	4.56	5.47	0.65	4.44	5.77
1998	1.47	9.37	11.64	2.20	11.25	1.00
1999	1.95	5.04	8.18	7.69	0.72	0.45
2000	0.74	3.58	7.00	4.77	0.54	0.24

The normal distributions for rainfall during these months, specified through OLS regression, were used to in a simulation to predict the possible rainfall in each of the crucial months (Table 4-2).

Table 4-2. Average EAA rainfall.

Month	Mean Rainfall (inches)	Standard Deviation
January	2.73	2.69
August	7.25	3.45
September	6.87	2.84
October	3.92	3.21
November	2.73	2.77
December	1.67	1.96

Source: EREC Weather

Costs of Production

Cost and Returns for Sugarcane on Muck Soils in Florida (Alvarez and Schuneman) provides a framework for looking at the production costs for farming sugarcane in the EAA. This work provides a number of key assumptions including: a profit maximizing management, independent grower status (non-producer), a small farm unit, and a three-crop cycle, that is, the hypothetical farm crop includes first planting and first and second ratoon crops.

However, cultivation and harvesting practices have changed and the most recent data regarding production costs comes from the USDA Economic Research Service (ERS). These data (see Table 4-2) from the Farm Business Economics Report take into account the additional Everglades Restoration tax that began in 1995. The 1995-1996 values were the final values published in this form. For the purposes of this analysis, it will be assumed that all acreage in the model is harvested.

Table 4-3. Florida sugarcane production expenses

Item	**Dollars per Harvested Acre**	
	1995	1996
Variable Expenses		
Seed	27.95	27.95
Fertilizer	61.33	57.99
Chemicals	59.10	61.15
Custom operations	106.65	104.81
Fuel, lube, electric	21.67	23.79
Repairs	80.12	80.84
Labor	406.54	396.76
Irrigation water purchased	6.70	7.07
Miscellanous	0.56	0.58
Total Variable Expenses	**770.62**	**760.94**
Fixed Expenses		
General farm overhead	114.79	107.45
Taxes and insurance	59.27	59.93
Interest	9.61	9.49
Total Fixed Expenses	**183.67**	**176.87**
Total expenses	**954.29**	**937.81**

Source: USDA, ERS

Sugarcane Prices

The Florida Agricultural Statistics Service (FASS) maintains an annual record of acreage, yield, production, season average price and the overall value of production. From these field crop summaries, prices were recorded from 1980-2003. These prices reflect sales of sugarcane for sugar and seed. As illustrated in Figure 4-3, there has not been a great deal of volatility in price. The maximum price, $39.40 per ton, occurred in 1980 and was followed by a 27% drop to 28.60. After that initial fall, prices have remained close to $30 a ton. In contrast, the lowest season average price was $27.20 in 1999.

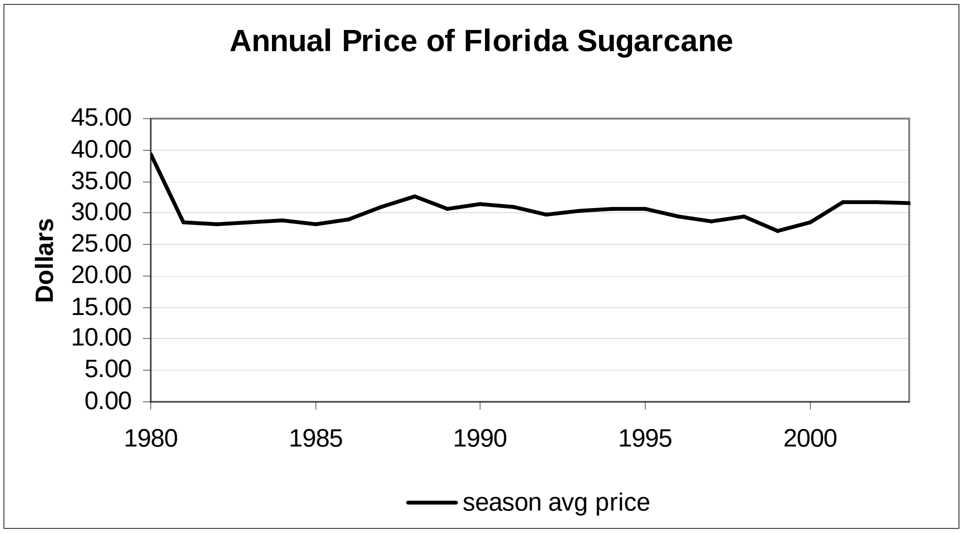

Figure 4-3: Season average price: sugarcane for sugar and seed 1980-2003. Source: FASS

It is likely that a major factor in maintaining this price stability is the tariff-rate quota system in place on sugar imports. This analysis, however assumes that these conditions will not change and thus do not factor into the modeled scenarios.

CHAPTER 5
RESULTS AND DISCUSSION

The analysis involved creating two stochastic models based on agronomic studies and historical data regarding sugarcane production and growing conditions in the Everglades Agricultural Area. Once each model was specified, the key output variables were identified and their respective probability distributions defined. The Simetar simulation application generated pseudo-random numbers, based on the given probability distributions, which were then used to update the model equations 100 times. Each iteration of the simulation generated new values for the every key variable. However, the values for water table depth, yield, and profit (on the basis of hypothetical 640-acre farm) selected as the output of the simulation, as these were of most interest.

Empirical Model Results

Five scenarios using an empirical yield model were completed in order to compare production possibilities with and without the restoration conditions, emphasizing maintenance of a higher water table. These included:

- Scenario 1: Current conditions, assuming mean water table depth and standard deviation based on USGS data.
- Scenario 2: Current conditions, but with the mean depth adjusted to 76.2cm as recommended in *Sugarcane Production* literature.
- Scenario 3: Post-restoration conditions with water table depth to 54.78cm as suggested by Aillery, Shoemaker, and Caswell (Scenario I-5, 2001).
- Scenario 4: Post-restoration incorporating a truncated normal distribution for water table depth.
- Scenario 5: Zero-profit condition

The complete outputs for these simulations are illustrated in Appendices A-D. A summary of the simulated profits is illustrated in Table 5-1, recalling that the fifth scenario was the zero-profit condition. The output series were also compared in pairs in order to determine whether the results were statistically different across the scenarios.

Table 5-1. Summary statistics for simulated model output, profit in dollars*

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Mean	**26,722.33**	**(5,370.24)**	**(85,485.58)**	**(135,442.80)**
Standard Deviation	**215,148.12**	**209,707.29**	**199,273.51**	**142647.91**
Minimum Value	**(378,281.63)**	**(388,859.30)**	**(550,047.54)**	**(383,743.63)**
Maximum Value	**656,710.50**	**642,406.47**	**656,041.87**	**239,375.77**

* For 640 acres of production

In terms of the simulated profits, it was surprising that the mean value for Scenario 2, which incorporated the current conditions, recommended in the *Sugarcane Production* literature. In all other respects, the two base scenarios (1 and 2) were expectedly similar. There is still a large range in the output, potential losses of over $500,000 to profits of over $640,000, but the truncated distribution of Scenario 4 appears to have been most successful in reducing the extreme values. It must be noted, however, that even that scenario exhibits more variation than should be expected.

As the model stands, economic losses are probable. Scenario 5 was indeed a zero-profit scenario, in which the original specifications were solved to determine the point at which total revenue equaled total cost for the sugarcane operation. The zero-profit conditions were: water table depth of 31.83cm, 6 flood cycles (for a Z value of .24), resulting in a yield of 31.1 tons per acre, just a 7 % difference from the historical mean.

The mean yield for Scenario 1, 32.42 tons per acre as stated in Table 5-2, is indeed comparable to the historical average of 33.48 tons per acre produced in Hendry County from 1980-2001. The post–restoration scenarios showed a substantial drop in yield to approximately 27 and 24 tons per acre. However, the variation within this model is still greater than one sees across the historical data. Specifically, the standard deviation is not consistent with the historical standard deviation of 2.67

Table 5-2. Summary statistics for simulated model output, yield in tons per acre*

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Mean	**32.42**	**30.84**	**26.89**	**24.43**
Standard Deviation	**10.60**	**10.34**	**9.82**	**7.03**
Minimum Value	**12.46**	**11.94**	**3.99**	**12.19**
Maximum Value	**63.47**	**62.77**	**63.44**	**42.90**

*Rounded to two decimal places

Regarding the modeling for water table depth, the historical mean and distribution were successful in providing model results that were reasonable considering both the historical information as well as the range suggested in the water management guidelines and literature. In this instance it seems it was successful to maintain variability while adjusting the means.

Rainfall Model Results

As previously discussed, multiple regression using the historical data on production, rainfall during crucial months, evaporation, temperature, along with likely drainage levels resulted in the following relationship between total production (*TP*) and the climatic factors:

$$\begin{aligned} TP = \; & 2464440.7 - 2947.3 Evap - 299037.5 AugRn - 333598.7 SeptRn - 266891 OctRn \\ & - 303408.3 NovRn - 309797.5 DecRn - 258229.4 JanRn - 7455.9 Temp + 645862.7 Drain \end{aligned}$$

The simulation was to provide outputs including yield per acre, total production, and profit for the 640-acre farm. Analysis of this model, however, revealed that it lacked the explanatory power necessary to be of use in decision-making. While it was not unexpected that the historical data would have a great deal of error, selected variables explained only 48% of the variation in total production from 1980-2001. When regressing the same variables against the historical yields, the results explained even less variation, with an R^2 value of approximately .26. Though the historical model was not suitable for this analysis as specified, it may be useful in decision-making if modified.

Comparison of Model Scenarios

While the current and post-restoration scenarios remained linear models, the constraint on the distribution of water levels changed the slope of the trend when comparing water levels with profit for the hypothetical sugarcane farm. The range of simulated values was wider than historically expected across all the scenarios. The change in water table levels, constraining the possible distribution, also had a great impact on the possible production range simulated. The variation in scenarios 3 and 4 was predictably more limited across all variables.

Only Scenario 1 yielded a positive average profit once simulated. It was more surprising, however that the other current scenario, using recommended optimal depth would average in the negative. Compared to the zero-profit case, Scenarios 3, 4, and 5 produced a mean water table that was higher than the zero-profit solution as would be expected.

There remained a great deal of variation within the simulation results across all cases. Even Scenario 4, designed to reign in some of this variation by using a truncated distribution produced results ranging from losses of over \$380,000 to profits of nearly \$240,000. Tracing the variation back to the simulated yield, one must note that Scenarios 1, 2, and 3 resulted in maxima that are far beyond current or historical yield levels. On the other end of the spectrum, Scenario 3 produced a minimum that was similarly improbable, a mere four tons per acre.

Evaluation of Hypotheses

The two hypotheses for this study were analyzed to determine whether there was a significant difference in the mean or variance using a two-sample t-test and an F-test. The tests compared the output series of the simulations from both scenarios of the empirical model. The following hypotheses were tested:

Maintaining a Higher Water Table Lowers Average Sugarcane Production for an EAA Farm.

A distribution comparison of yield results indicated that both the mean and (and in most cases) variance of the base model and the post-restoration scenarios are statistically different. Given a confidence level of 95%, the null hypothesis can be rejected. The two base scenarios, however, were not statistically different from each other in terms of the production results. Additionally, the variances of each base scenario compared with Scenario 3 were not statistically different. Though the difference between scenarios was significant, it is essential to note that the post-restoration scenario did provide some yields at or above the current production levels.

The basic functions used at the beginning of the analysis indicated that yield would be responsive to water changes. Once modified to represent an EAA farm, this model indicated that a shift in the range of maintained water levels affects the possible yields for that farm. The rejection of the null hypothesis in this case indicated that for this type of farm, the adjustment to higher water tables results in lower yield on average. As there is still variation in those water levels, the possibility exists that the farm could achieve greater yields. However, it is more likely that the sugarcane farm, under these conditions, will see lower yields.

The EAA Sugarcane Operation Will Experience a Reduction in Profit Under the Changed Water Conditions.

In examining the assumed sugarcane operation, analysis of the simulation series for profit indicated that these results were also statistically different for both mean and variance across most scenarios. The null hypothesis can then be rejected with a confidence level of 95% except in comparing the mean results between the two base scenarios; that is we can state that there is a significant difference in expected profit between each base scenario and the post-restoration scenarios. It should also be noted that between scenarios 1 and 3 and also between 1 and 4, the F-tests are such that the null hypothesis for variance cannot be rejected.

As in the previous case, though the series are statistically different, they were not mutually exclusive. Of particular importance regarding the difference in profit is that the given simulations kept harvested acreage constant, a variable that directly impacts the costs of production. Similar to the yield hypothesis, it is likely that the operation will experience losses, but not absolutely certain.

Looking at the assumed EAA sugar operation, failure to reject the null hypothesis demonstrates that this “typical” operation will indeed see changes in profit in response to varying water conditions.

CHAPTER 6
SUMMARY AND CONCLUSIONS

Summary

The purpose of this research was to provide an economic perspective in examining the impacts of the Comprehensive Everglades Restoration Plan within in the Everglades Agricultural Area. As sugarcane is the dominant crop in the area, a farm-level analysis was developed in order to examine the impacts of water regime changes on sugarcane production. For the purposes of this analysis, those changes were limited in scope; defined as flood events and a higher average water table. In keeping with previous authors' work on cots of production, the hypothetical farm was modeled assuming that 640 acres in production, the firm employs profit maximizing management, and independent grower status.

The analysis incorporated an empirical water response function and simulations of five scenarios represent the possible water regimes. In order to better align with historical sugarcane production, the empirical data were calibrated. Additionally, the model incorporated historical cost and water distributions based on USGS records. A model based on historical yields and weather data was also developed, but lacked explanatory power and consequently was not used in a simulation. Only one of the modeled scenarios showed an average profit over the course of the simulation.

Conclusions

There was a significant difference between the simulated bases and the post-restoration models, confirmed by a two-sample t-test and an F-test. Upon examining the mean values of these scenarios, one could expect an EAA sugarcane farm to incur monetary losses. Though these results are specific to a small, independent farm, the probable losses are important on a regional scale. These results illustrate the additional costs of CERP implementation beyond construction and planning. This one farm situation is representative of the tradeoffs farmers are facing in the EAA. Best Management Practices help fight soil subsidence and excess nutrient runoff, which are beneficial to all in the long term. However, these immediate losses are considerable.

If this hypothetical operation is indeed indicative of EAA farming, the sheer volume of sugarcane production magnifies the impact. It is important to remember that sugarcane is the primary crop in the EAA, making up 86% of the area's acreage in agricultural production. The EAA generates nearly $800 million in producing nearly 25% of domestic sugar. While this analysis did not attempt to specify total regional implications, it stands to reason that the entire area would be impacted. It is highly unlikely that all farms will experience the same degree of loss, but the high value of this crop and its regional importance suggests that there are many stakeholders who would be adversely affected.

The results of the simulations were not completely negative, however. Even in the constrained post-restoration model, there were profitable iterations. That is, even under changed conditions, part of the range of conditions is such that yields would remain high enough to be profitable. In practical applications, the profit-maximizing producer will do everything in his power to remain in that profitable range. It is also important to remember that while many conditions in the model were fixed, there is a great deal of research going into new cultivars of sugarcane, some of which are being bred for resistance to flooding and/or high water tables. The producer facing a scenario as described would do well to examine the possibility of using such cultivars.

There were, however, a number of limitations on the study. One of the primary limitations was a lack of available, uniform data. In some cases, such as in trying to determine flood information, it was clear that producers did not generally keep records of specific flood events or the resulting damage. Similarly, the analysis would have benefited from having more specific historical yield information rather than relying on and annual average. Additionally, the assumptions made in defining the study farm may hinder the application of information gained. Few sugarcane operations are independent of sugar processors and the division of first planting and consequent ratoon crops is most likely not uniform as in this analysis.

The estimation of production costs is another limitation to the relevance of the study findings. As many of the sugarcane farms are part of vertically integrated production and processing operation, it is difficult to get accurate estimates of production revenue. In order for this analysis to be useful to producers or water management officials, it would be necessary to update the cost portion of the model. A new publication on costs and returns will soon be available (J. Alvarez, personal communication) and those would greatly improve the value of the analysis.

The complexity and scope of issues surrounding production in the EAA make it difficult to incorporate all factors into a single analysis. For example, a more intricate analysis would have to consider the introduction of flood resistant cultivars and the interaction of price supports on domestic sugar. The entire restoration effort is a multidisciplinary project and though the analysis incorporated a variety of perspectives and sources of information, the problem calls for the attention and evaluation of experts from many disciplines.

Implications for Future Analysis

It is intended that this research might be an initial inquiry that could lead to further study by those in water management or perhaps even producers. As a first step, this study sets forth a framework that identifies key variables, such as maintained water level, which are essential in the planning process. By relaxing some of the assumptions and updating certain data, this type of analysis could be easily replicated and used by those most interested in making efficient water management or production decisions.

With updated cost and inputs, additional scenarios can be simulated using the same model, which lends itself to repeated analysis throughout the decision-making process. Water managers could benefit form the additional information when adjusting the capacity for water storage or drainage. With improvements, even the climatic model could be of use to producers looking to analyze the balance of water in the production system, taking into account rainfall, evaporation, and drainage. Such a model would also have to account for irrigation, which was not available for this particular analysis.

It had been hoped that this analysis could capture the current production practices in the area, describing the crop response such that a producer would have knowledge of how changes in those practices could affect his operation. However, the large range of output is an indication that this particular analysis is not yet ready for field application. Considering the economic importance of this industry, it follows that further analysis and continued data collection are warranted.

Over the course of this study, it became evident that decision-makers in the EAA have to make policy and production decisions without complete information. With shared information, such as that from the referenced growers' meeting on flooding, and tools like spreadsheet simulation, future work should be able to better refine the problems to be researched and provide relevant information to all stakeholders.

APPENDIX A
SIMULATION OUTPUT FOR SCENARIO 1

Iteration	"Z"	"F"	X(depth)	Yld tons/ac	Profit
1	-0.14087	4.43652	36.42929	22.99319	-164516
2	0.262596	6.050384	2.020689	18.53983	-254866
3	0.293122	6.172489	88.79114	37.68041	133458.6
4	0.809249	8.236997	99.84259	47.38158	330275.8
5	0.621738	7.486952	136.1192	53.95415	463620.3
6	-0.70749	2.170035	42.67497	19.51556	-235070
7	0.267268	6.069074	71.53518	33.60959	50869.81
8	0.136634	5.546537	24.53701	22.63242	-171835
9	0.003309	5.013236	84.00906	33.03105	39132.38
10	0.551755	7.207022	91.06506	41.58563	212687.7
11	0.098492	5.393969	59.76264	29.39677	-34600
12	-0.44181	3.232743	107.8567	30.87399	-4630.05
13	-0.49417	3.023337	56.77932	23.14934	-161348
14	-0.37266	3.509378	114.7882	32.93913	37267.45
15	-0.59678	2.612878	120.9387	30.19318	-18442.4
16	-0.77456	1.90174	5.295971	15.00526	-326575
17	0.028506	5.114025	38.84618	24.70655	-129755
18	-0.88057	1.477735	54.88547	19.28265	-239795
19	-0.62596	2.496178	82.94403	25.08287	-122120
20	-0.0305	4.877987	145.6574	44.01623	261999.8
21	-0.17373	4.305074	111.1101	35.43426	87888.72
22	-0.32012	3.719529	157.6971	40.38569	188343.3
23	-1.12519	0.499255	81.78061	18.8561	-248449
24	0.456235	6.824941	118.418	46.7976	318428.2
25	0.194742	5.778967	95.76805	37.86543	137212.3
26	0.181085	5.724341	61.69456	30.6116	-9953.39
27	-0.51609	2.935652	109.5618	29.99144	-22535.3
28	-0.65776	2.368975	66.54915	22.74708	-169509
29	0.467112	6.868449	17.3875	22.95801	-165229
30	-0.10347	4.58614	28.54076	21.87101	-187283
31	-0.28159	3.873635	132.7862	37.21858	124088.9
32	0.215671	5.862686	100.8346	39.22092	164712.5
33	-0.39879	3.404844	153.0352	38.11374	142250
34	0.075346	5.301383	48.074	26.87515	-85758.6
35	0.10727	5.42908	77.24882	32.97342	37963.11

36	-1.07027	0.718925	86.16379	19.85382	-228207
37	0.549071	7.196284	139.9296	53.58913	456214.8
38	0.431603	6.726413	51.2168	30.68115	-8542.42
39	-0.09807	4.607739	147.7863	43.11443	243704
40	-0.69312	2.227535	104.0817	26.68361	-89644.6
41	0.720718	7.882874	19.64739	24.91783	-125469
42	-0.52738	2.890469	53.67027	22.42078	-176129
43	-0.06718	4.731272	85.0789	32.34901	25295.11
44	-0.2085	4.166005	46.29284	24.13256	-141400
45	0.354143	6.416573	92.14386	39.22628	164821.2
46	0.055809	5.223236	58.03419	28.64046	-49943.9
47	-0.46738	3.130461	111.8659	31.04799	-1100.05
48	-0.73816	2.047369	93.28242	24.8395	-127058
49	-0.53983	2.840685	96.63352	27.93762	-64203.2
50	-0.83657	1.653734	113.737	25.55865	-112468
51	0.011686	5.046744	49.76883	26.64755	-90376.2
52	-0.35621	3.575153	125.0916	34.74789	73963.49
53	-0.26709	3.931622	104.7063	32.98205	38138.32
54	-0.80571	1.777173	64.68256	20.99026	-205151
55	-0.25179	3.992828	76.23383	28.60526	-50658.1
56	0.114416	5.457665	31.35745	23.86276	-146874
57	-0.41822	3.327135	44.80873	22.15079	-181606
58	-0.16171	4.353144	51.92192	25.49021	-113856
59	-0.4478	3.208817	95.06784	28.98362	-42981.9
60	-0.11447	4.542103	70.31933	29.1567	-39470.6
61	0.590894	7.363576	108.4223	46.45435	311464.2
62	-0.04915	4.803396	36.6258	23.70666	-150041
63	-0.13121	4.47517	228.228	56.50328	515336.9
64	-0.84268	1.629292	119.9308	26.07675	-101957
65	-0.17774	4.289051	63.22651	27.26075	-77935.6
66	-0.2419	4.032391	97.4099	32.1637	21535.54
67	-0.19304	4.227823	102.9654	33.77226	54169.92
68	-0.31475	3.740993	121.9142	34.95115	78087.31
69	0.027628	5.110511	41.34747	25.17799	-120191
70	-0.00638	4.974475	61.02541	28.59985	-50767.8
71	0.074813	5.299251	168.1759	50.42934	392108.8
72	0.167952	5.671808	78.85104	34.01401	59074.64
73	0.876345	8.505379	130.0185	56.80787	521516.4
74	-0.30126	3.794974	164.6642	41.8564	218181.1
75	0.481129	6.924518	74.93782	36.79808	115557.9
76	-0.60293	2.588292	-14.4811	13.24711	-362244
77	-0.07685	4.692617	142.3177	42.53647	231978.3
78	0.323522	6.294088	80.21285	36.16492	102712.2
79	0.049092	5.196367	116.7473	39.93254	179149.7

80	0.391733	6.566934	124.2045	47.09045	324369.5
81	0.506403	7.025613	127.4007	49.77619	378857.8
82	0.647272	7.589089	177.7241	65.09517	689649.3
83	-0.34571	3.617172	67.47869	26.18819	-99695.6
84	0.311703	6.246812	87.93683	37.73167	134498.5
85	0.413713	6.654852	89.97998	39.51561	170691
86	-0.05331	4.786769	24.34059	21.4327	-196175
87	-0.02132	4.914725	134.8102	42.17295	224603.3
88	-0.38576	3.456948	98.95663	30.40015	-14243.3
89	-0.21773	4.129074	131.0421	38.05372	141032.3
90	-0.56524	2.739034	33.38566	19.46776	-236040
91	0.784015	8.13606	151.4384	61.02104	606993.3
92	0.682643	7.730571	74.06468	38.88077	157811.4
93	-1.00785	0.968586	66.22222	19.01787	-245167
94	0.221046	5.884183	-19.4038	13.85001	-350013
95	0.141384	5.565535	105.6908	39.1524	163322.3
96	-0.92827	1.286927	13.56775	15.12062	-324234
97	0.339725	6.358901	78.25181	35.92004	97744.22
98	0.159975	5.6399	87.26709	35.64601	92184.63
99	0.249983	5.999933	69.48713	32.97794	38054.75
100	0.379602	6.518407	73.04364	35.20149	83166.14

APPENDIX B
SIMULATION OUTPUT FOR SCENARIO 2

Iteration	"Z"	"F"	X(depth)	Yld tons/ac	Profit
1	-0.14087	4.43652	27.37056	21.42314	-196369
2	0.262596	6.050384	-7.03804	16.58278	-294570
3	0.293122	6.172489	79.73242	35.69409	93160.07
4	0.809249	8.236997	90.78386	44.90021	279933.8
5	0.621738	7.486952	127.0605	51.65264	416927.1
6	-0.70749	2.170035	33.61624	18.48899	-255897
7	0.267268	6.069074	62.47645	31.64807	11074.38
8	0.136634	5.546537	15.47828	20.79619	-209088
9	0.003309	5.013236	74.95033	31.32271	4473.455
10	0.551755	7.207022	82.00634	39.35124	167356.3
11	0.098492	5.393969	50.70392	27.59713	-71111.1
12	-0.44181	3.232743	98.79799	29.59259	-30627.1
13	-0.49417	3.023337	47.72059	21.91815	-186326
14	-0.37266	3.509378	105.7294	31.59139	9924.574
15	-0.59678	2.612878	111.88	29.06041	-41423.9
16	-0.77456	1.90174	-3.76276	14.04302	-346097
17	0.028506	5.114025	29.78745	22.97404	-164904
18	-0.88057	1.477735	45.82674	18.42208	-257254
19	-0.62596	2.496178	73.8853	23.97809	-144534
20	-0.0305	4.877987	136.5986	42.34032	227998.8
21	-0.17373	4.305074	102.0514	33.89573	56674.89
22	-0.32012	3.719529	148.6384	38.98756	159978.1
23	-1.12519	0.499255	72.72188	18.23016	-261148
24	0.456235	6.824941	109.3593	44.65483	274955.6
25	0.194742	5.778967	86.70932	35.97347	98828.18
26	0.181085	5.724341	52.63584	28.73274	-48071.7
27	-0.51609	2.935652	100.5031	28.78128	-47087
28	-0.65776	2.368975	57.49042	21.6728	-191304
29	0.467112	6.868449	8.328775	20.8048	-208914
30	-0.10347	4.58614	19.48203	20.26508	-219864
31	-0.28159	3.873635	123.7275	35.7835	94973.99
32	0.215671	5.862686	91.77583	37.30889	125921.1
33	-0.39879	3.404844	143.9765	36.79107	115415.7
34	0.075346	5.301383	39.01527	25.0977	-121819
35	0.10727	5.42908	68.19009	31.16536	1281.158

36	-1.07027	0.718925	77.10507	19.1752	-241975
37	0.549071	7.196284	130.8709	51.35732	410935.6
38	0.431603	6.726413	42.15807	28.562	-51535.7
39	-0.09807	4.607739	138.7276	41.50332	211017.8
40	-0.69312	2.227535	95.02302	25.64324	-110752
41	0.720718	7.882874	10.58866	22.52138	-174088
42	-0.52738	2.890469	44.61154	21.22145	-200461
43	-0.06718	4.731272	76.02017	30.70828	-7992.1
44	-0.2085	4.166005	37.23411	22.62737	-171937
45	0.354143	6.416573	83.08514	37.18143	123335.3
46	0.055809	5.223236	48.97546	26.88176	-85624.5
47	-0.46738	3.130461	102.8071	29.79111	-26599.5
48	-0.73816	2.047369	84.2237	23.84233	-147288
49	-0.53983	2.840685	87.57479	26.75023	-88293
50	-0.83657	1.653734	104.6783	24.65588	-130783
51	0.011686	5.046744	40.7101	24.93116	-125198
52	-0.35621	3.575153	116.0329	33.38438	46300.63
53	-0.26709	3.931622	95.6476	31.53307	8741.292
54	-0.80571	1.777173	55.62383	20.05789	-224067
55	-0.25179	3.992828	67.1751	27.1416	-80352.9
56	0.114416	5.457665	22.29872	22.04784	-183695
57	-0.41822	3.327135	35.75	20.84675	-208063
58	-0.16171	4.353144	42.86319	23.94015	-145304
59	-0.4478	3.208817	86.00911	27.70796	-68862.6
60	-0.11447	4.542103	61.2606	27.56132	-71837.5
61	0.590894	7.363576	99.36356	44.18241	265371.2
62	-0.04915	4.803396	27.56707	22.04863	-183679
63	-0.13121	4.47517	219.1692	54.92395	483295.5
64	-0.84268	1.629292	110.8721	25.17984	-120153
65	-0.17774	4.289051	54.16778	25.72605	-109071
66	-0.2419	4.032391	88.35117	30.69055	-8351.71
67	-0.19304	4.227823	93.90672	32.25224	23331.91
68	-0.31475	3.740993	112.8555	33.54787	49617.67
69	0.027628	5.110511	32.28874	23.44632	-155323
70	-0.00638	4.974475	51.96668	26.9008	-85238.2
71	0.074813	5.299251	159.1172	48.65241	356058.4
72	0.167952	5.671808	69.79231	32.14775	21211.86
73	0.876345	8.505379	120.9598	54.26214	469868.7
74	-0.30126	3.794974	155.6054	40.44018	189448.9
75	0.481129	6.924518	65.87909	34.63143	71600.87
76	-0.60293	2.588292	-23.5398	12.12024	-385106
77	-0.07685	4.692617	133.2589	40.90501	198879.2
78	0.323522	6.294088	71.15412	34.14943	61822.11
79	0.049092	5.196367	107.6885	38.18028	143599.9

80	0.391733	6.566934	115.1458	45.00954	282152
81	0.506403	7.025613	118.3419	47.5853	334409
82	0.647272	7.589089	168.6653	62.76917	642459.2
83	-0.34571	3.617172	58.41996	24.81461	-127563
84	0.311703	6.246812	78.8781	35.72752	93838.36
85	0.413713	6.654852	80.92125	37.41362	128045.9
86	-0.05331	4.786769	15.28186	19.77865	-229732
87	-0.02132	4.914725	125.7514	40.48823	190423.6
88	-0.38576	3.456948	89.89791	29.06499	-41331.1
89	-0.21773	4.129074	121.9834	36.55739	110674.7
90	-0.56524	2.739034	24.32693	18.30474	-259635
91	0.784015	8.13606	142.3797	58.56387	557142.3
92	0.682643	7.730571	65.00595	36.52083	109933
93	-1.00785	0.968586	57.16349	18.27939	-260149
94	0.221046	5.884183	-28.4625	11.93282	-388909
95	0.141384	5.565535	96.63204	37.31162	125976.5
96	-0.92827	1.286927	4.509018	14.30581	-340765
97	0.339725	6.358901	69.19309	33.88902	56538.82
98	0.159975	5.6399	78.20836	33.7874	54477.07
99	0.249983	5.999933	60.4284	31.03299	-1404.32
100	0.379602	6.518407	63.98491	33.13221	41184.76

APPENDIX C
SIMULATION OUTPUT FOR SCENARIO 3

Iteration	"Z"	"F"	X(depth)	Yld tons/ac	Profit
1	-0.14087	4.43652	5.949285	17.71041	-271693
2	0.262596	6.050384	-28.4593	11.95494	-388460
3	0.293122	6.172489	58.31114	30.99701	-2134.3
4	0.809249	8.236997	69.36259	39.03248	160889.4
5	0.621738	7.486952	105.6392	46.21021	306511.2
6	-0.70749	2.170035	12.19497	16.06143	-305147
7	0.267268	6.069074	41.05518	27.00963	-83030.3
8	0.136634	5.546537	-5.94299	16.45405	-297182
9	0.003309	5.013236	53.52906	27.28296	-77484.9
10	0.551755	7.207022	60.58506	34.06754	60160.66
11	0.098492	5.393969	29.28264	23.34149	-157449
12	-0.44181	3.232743	77.37672	26.56245	-92102.7
13	-0.49417	3.023337	26.29932	19.00675	-245393
14	-0.37266	3.509378	84.30816	28.40439	-54733.4
15	-0.59678	2.612878	90.45869	26.38175	-95768.6
16	-0.77456	1.90174	-25.184	11.7676	-392261
17	0.028506	5.114025	8.366183	18.87714	-248022
18	-0.88057	1.477735	24.40547	16.38708	-298540
19	-0.62596	2.496178	52.46403	21.36561	-197536
20	-0.0305	4.877987	115.1774	38.37726	147596.3
21	-0.17373	4.305074	80.6301	30.25753	-17136.8
22	-0.32012	3.719529	127.2171	35.68139	92902.54
23	-1.12519	0.499255	51.30061	16.74999	-291178
24	0.456235	6.824941	87.93798	39.58779	172155.4
25	0.194742	5.778967	65.28805	31.49953	8060.889
26	0.181085	5.724341	31.21456	24.28978	-138211
27	-0.51609	2.935652	79.08184	25.91959	-105145
28	-0.65776	2.368975	36.06915	19.13244	-242843
29	0.467112	6.868449	-13.0925	15.71309	-312214
30	-0.10347	4.58614	-1.93924	16.46751	-296909
31	-0.28159	3.873635	102.3062	32.38994	26125.6
32	0.215671	5.862686	70.35456	32.78748	34190.73
33	-0.39879	3.404844	122.5552	33.66334	51960.25
34	0.075346	5.301383	17.594	20.89457	-207093
35	0.10727	5.42908	46.76882	26.88981	-85461

36	-1.07027	0.718925	55.68379	17.57048	-274532
37	0.549071	7.196284	109.4496	46.07971	303863.5
38	0.431603	6.726413	20.7368	23.55083	-153202
39	-0.09807	4.607739	117.3063	37.69351	133724.3
40	-0.69312	2.227535	73.60175	23.18308	-160663
41	0.720718	7.882874	-10.8326	16.85445	-289059
42	-0.52738	2.890469	23.19027	18.38539	-257999
43	-0.06718	4.731272	54.5989	26.82841	-86706.7
44	-0.2085	4.166005	15.81284	19.06804	-244149
45	0.354143	6.416573	61.66386	32.34595	25232.97
46	0.055809	5.223236	27.55419	22.72294	-169999
47	-0.46738	3.130461	81.38587	26.81896	-86898.5
48	-0.73816	2.047369	62.80242	21.48434	-195127
49	-0.53983	2.840685	66.15352	23.94239	-145258
50	-0.83657	1.653734	83.25703	22.52108	-174094
51	0.011686	5.046744	19.28883	20.87242	-207542
52	-0.35621	3.575153	94.6116	30.16007	-19114
53	-0.26709	3.931622	74.22633	28.10664	-60774.2
54	-0.80571	1.777173	34.20256	17.8531	-268798
55	-0.25179	3.992828	45.75383	23.68046	-150572
56	0.114416	5.457665	0.877447	17.75609	-270766
57	-0.41822	3.327135	14.32873	17.76309	-270624
58	-0.16171	4.353144	21.44192	20.2747	-219669
59	-0.4478	3.208817	64.58784	24.69138	-130063
60	-0.11447	4.542103	39.83933	23.78873	-148376
61	0.590894	7.363576	77.94229	38.80995	156374.6
62	-0.04915	4.803396	6.145801	18.12787	-263223
63	-0.13121	4.47517	197.748	51.18931	407527.1
64	-0.84268	1.629292	89.45081	23.0589	-163183
65	-0.17774	4.289051	32.74651	22.09695	-182699
66	-0.2419	4.032391	66.9299	27.20698	-79026.4
67	-0.19304	4.227823	72.48544	28.65785	-49591
68	-0.31475	3.740993	91.43423	30.22953	-17704.8
69	0.027628	5.110511	10.86747	19.35141	-238400
70	-0.00638	4.974475	30.54541	22.88303	-166751
71	0.074813	5.299251	137.6959	44.45048	270809.8
72	0.167952	5.671808	48.37104	27.73457	-68322.7
73	0.876345	8.505379	99.5385	48.24223	347736.8
74	-0.30126	3.794974	134.1842	37.09124	121505.4
75	0.481129	6.924518	44.45782	29.50793	-32344.8
76	-0.60293	2.588292	-44.9611	9.455519	-439168
77	-0.07685	4.692617	111.8377	37.04706	120609.2
78	0.323522	6.294088	49.73285	29.3834	-34871.1
79	0.049092	5.196367	86.26727	34.03669	59534.82

80	0.391733	6.566934	93.72455	40.0888	182320
81	0.506403	7.025613	96.92066	42.40447	229300.3
82	0.647272	7.589089	147.2441	57.26882	530868.3
83	-0.34571	3.617172	36.99869	21.56648	-193461
84	0.311703	6.246812	57.45683	30.9883	-2311.01
85	0.413713	6.654852	59.49998	32.44302	27202.42
86	-0.05331	4.786769	-6.13941	15.86732	-309085
87	-0.02132	4.914725	104.3302	36.50434	109598.5
88	-0.38576	3.456948	68.47663	25.90771	-105386
89	-0.21773	4.129074	100.5621	33.01899	38887.7
90	-0.56524	2.739034	2.905657	15.55455	-315431
91	0.784015	8.13606	120.9584	52.75338	439259
92	0.682643	7.730571	43.58468	30.94027	-3285.47
93	-1.00785	0.968586	35.74222	16.5331	-295578
94	0.221046	5.884183	-49.8838	7.399221	-480886
95	0.141384	5.565535	75.21077	32.9587	37664.54
96	-0.92827	1.286927	-16.9123	12.37901	-379856
97	0.339725	6.358901	47.77181	29.08624	-40900
98	0.159975	5.6399	56.78709	29.39231	-34690.4
99	0.249983	5.999933	39.00713	26.43375	-94713.6
100	0.379602	6.518407	42.56364	28.23899	-58089

APPENDIX D
SIMULATION OUTPUT FOR SCENARIO 4

Iteration	"Z"	"F"	X(depth)	Yld tons/ac	Profit
1	-0.14087	4.43652	3.475841	17.28171	-280390
2	0.262596	6.050384	-17.6044	14.30002	-340883
3	0.293122	6.172489	46.1128	28.32226	-56399.7
4	0.809249	8.236997	54.77228	35.0359	79806.66
5	0.621738	7.486952	78.20701	39.24061	165111.9
6	-0.70749	2.170035	8.295705	15.61955	-314112
7	0.267268	6.069074	31.95968	25.04014	-122987
8	0.136634	5.546537	-5.05496	16.63406	-293530
9	0.003309	5.013236	42.24638	25.15521	-120653
10	0.551755	7.207022	47.92933	30.94592	-3170.76
11	0.098492	5.393969	22.16669	21.92781	-186130
12	-0.44181	3.232743	60.72192	24.20654	-139899
13	-0.49417	3.023337	19.69937	18.10973	-263591
14	-0.37266	3.509378	65.57358	25.6171	-111282
15	-0.59678	2.612878	69.60374	23.77391	-148677
16	-0.77456	1.90174	-16.1404	12.72824	-372771
17	0.028506	5.114025	5.318517	18.29427	-259848
18	-0.88057	1.477735	18.13991	15.79186	-310616
19	-0.62596	2.496178	41.37789	20.01357	-224966
20	-0.0305	4.877987	82.48883	32.3297	24903.42
21	-0.17373	4.305074	63.03677	27.26948	-77758.4
22	-0.32012	3.719529	86.58802	29.41068	-34317.7
23	-1.12519	0.499255	40.4265	15.99861	-306422
24	0.456235	6.824941	67.98594	34.86828	76406.07
25	0.194742	5.778967	51.63238	28.64748	-49801.6
26	0.181085	5.724341	23.76982	22.74567	-169537
27	-0.51609	2.935652	61.94307	23.63001	-151596
28	-0.65776	2.368975	27.80888	18.15285	-262717
29	0.467112	6.868449	-9.63148	16.53575	-295524
30	-0.10347	4.58614	-2.29595	16.40427	-298192
31	-0.28159	3.873635	76.4983	28.30146	-56821.5
32	0.215671	5.862686	55.52589	29.65757	-29308.7
33	-0.39879	3.404844	85.17059	28.20479	-58782.8
34	0.075346	5.301383	12.59395	19.9135	-226997
35	0.10727	5.42908	36.69784	24.87971	-126242

36	-1.07027	0.718925	43.99566	16.69489	-292296
37	0.549071	7.196284	80.02718	38.83084	156798.5
38	0.431603	6.726413	15.13879	22.24126	-179771
39	-0.09807	4.607739	83.31895	31.64879	11089.11
40	-0.69312	2.227535	57.96023	21.38671	-197108
41	0.720718	7.882874	-8.23757	17.54096	-275131
42	-0.52738	2.890469	17.14267	17.58472	-274243
43	-0.06718	4.731272	43.11628	24.74866	-128901
44	-0.2085	4.166005	11.16465	18.2957	-259818
45	0.354143	6.416573	48.78549	29.43888	-33745.7
46	0.055809	5.223236	20.73577	21.39918	-196855
47	-0.46738	3.130461	63.56523	24.34639	-137062
48	-0.73816	2.047369	49.68489	20.04039	-224422
49	-0.53983	2.840685	52.30501	22.12717	-182086
50	-0.83657	1.653734	64.85773	20.68745	-211295
51	0.011686	5.046744	13.96295	19.86331	-228015
52	-0.35621	3.575153	72.15883	26.78051	-87678.6
53	-0.26709	3.931622	58.42244	25.57873	-112060
54	-0.80571	1.777173	26.25471	17.03507	-285394
55	-0.25179	3.992828	35.85858	22.08163	-183009
56	0.114416	5.457665	-0.28206	17.52378	-275479
57	-0.41822	3.327135	9.981866	17.13734	-283319
58	-0.16171	4.353144	15.7133	19.29446	-239556
59	-0.4478	3.208817	51.08607	22.79004	-168637
60	-0.11447	4.542103	30.94818	22.22287	-180144
61	0.590894	7.363576	61.12885	34.59313	70823.78
62	-0.04915	4.803396	3.624508	17.66639	-272586
63	-0.13121	4.47517	92.73595	32.88123	36092.71
64	-0.84268	1.629292	68.96274	21.03036	-204338
65	-0.17774	4.289051	25.04319	20.79188	-209176
66	-0.2419	4.032391	52.90587	24.92636	-125296
67	-0.19304	4.227823	57.12919	26.08115	-101867
68	-0.31475	3.740993	70.21656	26.94273	-84387.4
69	0.027628	5.110511	7.256011	18.66104	-252406
70	-0.00638	4.974475	23.21417	21.50799	-194648
71	0.074813	5.299251	89.05367	34.90898	77231.89
72	0.167952	5.671808	38.01983	25.60203	-111588
73	0.876345	8.505379	74.99924	41.3461	207828
74	-0.30126	3.794974	88.33166	29.92277	-23928.5
75	0.481129	6.924518	34.7852	27.19444	-79280.7
76	-0.60293	2.588292	-22.9999	12.1874	-383744
77	-0.07685	4.692617	81.09388	31.51015	8276.34
78	0.323522	6.294088	39.1404	27.02668	-82684.3
79	0.049092	5.196367	66.88735	30.28797	-16519.2

80	0.391733	6.566934	71.62503	35.01225	79327.03
81	0.506403	7.025613	73.51675	36.74413	114463.3
82	0.647272	7.589089	90.55837	42.71363	235572.6
83	-0.34571	3.617172	28.58303	20.2904	-219350
84	0.311703	6.246812	45.42643	28.3267	-56309.5
85	0.413713	6.654852	47.06445	29.55748	-31339.5
86	-0.05331	4.786769	-5.18694	16.04124	-305557
87	-0.02132	4.914725	77.5487	31.52358	8548.78
88	-0.38576	3.456948	54.0955	23.78808	-148389
89	-0.21773	4.129074	75.56196	28.88944	-44892.7
90	-0.56524	2.739034	1.201646	15.33578	-319869
91	0.784015	8.13606	84.63641	42.90109	239375.8
92	0.682643	7.730571	34.06107	28.45922	-53620.9
93	-1.00785	0.968586	27.53662	15.86416	-309149
94	0.221046	5.884183	-24.0274	12.87146	-369865
95	0.141384	5.565535	59.14679	29.69442	-28561.3
96	-0.92827	1.286927	-11.8668	12.83283	-370649
97	0.339725	6.358901	37.52584	26.78903	-87505.8
98	0.159975	5.6399	44.88694	26.95071	-84225.5
99	0.249983	5.999933	30.25548	24.55474	-132835
100	0.379602	6.518407	33.21341	26.10313	-101421

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BIOGRAPHICAL SKETCH

Jennie Varela was born and raised in St. Petersburg, Florida. She was a graduate of the International Baccalaureate Program at St. Petersburg High School where she was named a National Merit Scholar. She continued her education at the University of Florida in Gainesville, Florida. She graduated with a Bachelor of Science in food and resource economics in May 2002 and completed a Master of Science program in the same department in 2005. She has accepted a position as an Agricultural Economist in Dairy Programs for the Agricultural Marketing Service of USDA.