Special Publication SJ95-SP5

MANAGEMENT EFFECT ON IRRIGATION WATER USE FOR POTATO FARMS OF NORTH FLORIDA

Prepared by

University of Florida
Institute of Food and Agricultural Sciences
Food and Resource Economics Department
Gainesville, Florida

Prepared for

St. Johns River Water Management District
Palatka, Florida

1995

Special Publication SJ95-SP5

MANAGEMENT EFFECT ON IRRIGATION WATER USE FOR POTATO FARMS OF NORTH FLORIDA

by

Austin Trippensee
Patrick Byrne
William Boggess
Alan Smajstrla*

July 1995

*The authors are respectively Graduate Research Assistant, Assistant Professor, and Professor, Food and Resource Economics Department, and Professor, Department of Agricultural Engineering, University of Florida.

EXECUTIVE SUMMARY

Approximately 29,500 acres of potatoes are grown in the tri-county area of St. Johns, Putnam, and Flagler counties. The majority of this acreage is located in St. John's county. The major water use in St. Johns County is agriculture with an average daily usage of 35.57 million gallons per day. In 1994, the St. Johns River Water Management District (SJRWMD) identified St. Johns County as a "Water Resource Caution Area" based on findings of the report, "Waste Supply Needs and Sources Assessment." The purpose of this study was to determine key factors that influence water usage among potato farms in this tri-county area. Previous efforts have been limited to analyzing physical characteristics, such as soil type and plant age. This research effort analyzes management and production techniques, as well as the aforementioned physical characteristics, to achieve a more comprehensive understanding of irrigation water use for potatoes.

Information for this study was collected from three sources: 1) SJRWMD Benchmark Farm Project; 2) STATGO soil maps; and 3) a comprehensive potato grower survey where 62 of 69 identified growers were interviewed for the study. Surveys were conducted through a live interview format. The questionnaire contained 77 questions dealing with such topics as: general farm information; farm operator information; pest management and fertilization practices; irrigation management and decision criteria; planting characteristics; general management information; and grower opinions on the future of potato production. Interviews would typically take about 45 minutes each to complete. Individual grower responses were kept confidential.

The survey revealed that potato acreage has increased 10 percent over the last 5 years. Most growers use a seep, semi-closed pipeline distribution system for potato irrigation. Physical characteristics of the actual systems are similar between growers. Most growers use some form of sensory observation (e.g., sight and/or feel) to verify irrigation effectiveness, rather than a mechanical

form (e.g., tensiometer). Specifically, 96.8 percent of growers use soil appearance as an indicator of irrigation effectiveness. The bulk of potatoes (76.5 percent) were planted between the middle of January and the middle of February. Planting dates are driven by variety and market forces, as opposed to irrigation concerns. Growers plant in hopes of harvesting during desirable potato price periods or to fulfill forward contracts.

There were some observed differences between growers with respect to management practices. Many growers do shut off the irrigation system based on rain expectations, but the amount of expected rainfall needed for shutoff and the shutoff timing varied between growers. There were also variations in delay time to restart irrigation after an actual rainfall. In a typical rainfall year, approximately 35 percent of the growers will not start up the irrigation system for at least 30 days after planting, while almost two-thirds of the growers will start up within 30 days. These differences in management practices were of particular interest for analysis of factors that affect water usage on these North Florida potato farms.

Over 40 percent of the growers could not comfortably recall or estimate their electricity expenditures for pumping irrigation water. Water distribution costs represent only 1 to 2 percent of total costs per acre for potato production. As a result, growers view water as a low-cost risk reducing input. Growers are more concerned with the soil drying out to a critical level where yield and plant vigor would be significantly impacted then they are with over-irrigation. Use of water is valuable to the farmer for two reasons: 1) helps minimize yield risk; and 2) improves return potential. Growers are using several water conservation components in their systems, such as furrow and ditch risers, land leveling, and closed pipe distribution. In general, growers do not appear to be very optimistic about the technical feasibility of irrigation alternatives, and they are even less optimistic with regard to the economic feasibility of irrigation alternatives.

The analysis portion of this study demonstrates that water use was significantly affected by soil type, planting date, irrigation start up timing, irrigation shut off and restart criteria, irrigation shut off with respect to harvest, and grower familiarity with energy costs for pumping water. Soil types that required a greater quantity of water represent only 3 percent of the sample acreage. Planting date decisions do not ordinarily rely on irrigation concerns. Also, the shut off timing before harvest is determined by potato type. Delaying irrigation start up to at least 30 days post-plant does significantly reduce water consumption. This decision is frequently based on weather rather than management decisions. Later planting dates result in a warmer growing season that may have higher moisture needs during the early growth stages. Shutting off the irrigation system based on rainfall expectations does reduce the water consumption, as does a longer restart delay after actual rainfall. These decisions are most likely based on specific site characteristics and the grower's level of risk aversion. Finally, growers who are aware of their energy expenditures for pumping irrigation water tend to use significantly less irrigation water than those growers who are not readily aware of these expenditures. While the relative proportion of costs is low, the absolute amount of energy expenditures is estimated to be almost 8 thousand dollars per grower. In summary, some educational efforts may heighten grower awareness of those factors which significantly impact water use, but there would seem to be greater potential benefits to finding a new type of irrigation system or modifications to the current system. This new system or modification would have to be cost-effective and manageable for the grower.

This study also recommends some additional information that should be included in the Benchmark Farm Program to increase future understanding and monitor evolving trends of water usage.

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (cont.)

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the Saint Johns River Water Management District (SJRWMD) for funding this project. Special thanks to Cynthia Moore and Vince Singleton of the SJRWMD for their invaluable assistance and interest in this research effort. We extend our sincere appreciation to Austin Tilton for his time and energy in setting up this project, as well as to Jim Dilbeck and Dan Schrader. Finally, we would like to thank the growers for taking the time to talk with us about their operations and concerns. We appreciate their candor, frankness, and hospitality with respect to this project.

INTRODUCTION

Background

Water resource management has become a major concern in the State of Florida. In response, the Florida Legislature passed the Water Resources Act in 1972. This act provides the framework for Florida's water management system and establishes the water management districts. After a statewide referendum in 1976, the district's governing boards obtained the ability to levy taxes. The Water Resources Act has been amended several times, but the structure has gone mostly unchanged (St. Johns River Water Management District).

The St. Johns River Water Management District (SJRWMD), located in Northeast Florida, is one of the five water management districts in the state. The district consists of all or part of 19 counties. Within the district, there are 3,500 lakes, 56 springs, 12,400 square miles, and an estimated population of 3.3 million people (St. Johns River Water Management District).

The mission of the St. Johns River Water Management District is "to manage water resources to insure their continued availability while maximizing environmental and economic benefits" (Singleton 1990, ii). The district accomplishes this mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management (Singleton 1990).

Over the past few years, conflicts related to water resources in Northeast Florida have increased. Increases in resident population have resulted in an increased demand in water consumption. Also, recent years have had below-average rainfall amounts. These factors have affected the recharge of groundwater resources, causing decreases in the amount of water available.

Residents along the St. Johns River have reported that some wells that were formerly free-flowing artesian now require pumps, and some wells dry up periodically. These concerns have led the water management district to study the users and uses of water in this area. As shown in table 1, the major users of water for the St. Johns River Water Management District are agriculture, public supply, and commercial and industrial self-supply. Within agriculture, the three major crop types were fruit crops (44 percent), ornamental/turf (27 percent), and vegetables (22 percent) (Florence 1995). Table 2 lists the crops included in each crop category.

The potato industry in North Florida is located primarily in St. Johns, Putnam, and Flagler counties. This three county area covers over 1.16 million acres with an average daily water withdrawal of 171.6 million gallons. Agriculture accounts for 35 percent of total water usage (Florence 1995). For the 1994 growing season there were approximately 29,500 planted acres of potatoes in North Florida (Vegetable Summary 1993-1994).

In Flagler County, the major use of water was for agricultural irrigation (8.02 million gallons per day). Agriculture in Putnam County used 17.38 million gallons per day (Florence 1995). In St. Johns County, the major user of water was agriculture with 35.57 million gallons per day.

In 1994, the St. Johns River Water Management District (SJRWMD) completed the "Waste Supply Needs and Sources Assessment." In accordance with the requirements of the *Needs and Source Assessment*, SJRWMD identified "Water Resource Caution Areas" within the District, as areas where future water supply needs may be difficult to meet without incurring undesirable environmental impacts. One of these areas is located in St. Johns County. The major agricultural crop grown in this area is the potato.

Table 1: 1992 Water Use by Category (in million gallons per day), St. Johns River Water Management District.

Category	Total
Public supply	424.63
Domestic self-supply	84.92
Commercial/industrial self-supply	148.20
Agricultural irrigation	624.60
Recreational irrigation	17.44
Thermoelectric power generation	136.43
Abandoned artesian wells	75.67
Total	1511.89

Source: Florence 1995, p. 12.

Table 2: Crops Included in Estimates of Water Use for Agricultural Irrigation

Vegetable Crops	Fruit Crops	Ornamental and Grasses
Cabbage	Blueberries	Ferns
Carrots	Citrus	Flowers and foliage
Cucumbers	Ornamental	Woody ornamental
Peppers	Peaches	Improved pasture
Potatoes	Pecans	Sod
Tomatoes	Strawberries	
Sweet corn	Watermelons	
Watercress	Miscellaneous fruits	
Miscellaneous vegetables		

Source: Florence 1995, p. 7.

In early 1980, the St. Johns River Water Management District initiated a "Benchmark Farm" Program. This program was designed to collect technical data on agricultural water use, including potatoes. To collect information, potato growers were asked to voluntarily participate in the Benchmark Farm program to form a network of potato production water use monitoring sites. At each site, a flow meter was placed on a well and information was collected by St. Johns River Water Management District personnel. There are currently a total of 55 sites for potatoes in the program. These sites are located in Putnam, St. Johns, and Flagler counties (Littell and Portier 1994). Data have been collected for these sites from 1990 through 1994.

In June 1994, Dr. R. Littell and Dr. K. Portier conducted an analysis on four years of data collected in the Benchmark Farm Program for potatoes (Littell and Portier 1994). These data only contained technical and climatic information. The objective of their analysis "... was to quantify the temporal and spatial variability of water pumped and, using statistical analysis techniques, determine whether and what fraction of this variability could be attributed to variation in site (agronomic) or environmental (rainfall) parameters" (Littell and Portier 1994, p. 3). Management practices were not used to explain variations in water consumption. By increasing the amount of information contained in the model, the model could explain more of the variation observed in the amount of water pumped for potato irrigation.

Objectives

The purpose of this study was to determine key factors that influence water usage among potato farms in Flagler, Putnam, and St. Johns counties. Specific objectives were as follows:

1. To collect information from potato growers with regard to management and production techniques, as well as differences in site characteristics.

2. To determine which factors account for variations in irrigation water use.

3. To provide implications and recommendations to the St. Johns River Water Management District as to how management, production, and site characteristic effects may be used to improve the management of available water resources.

THEORY

Irrigation Systems

Currently, growers use a water furrow system to distribute irrigation water to the potato plants. This system is commonly referred to as a sub-irrigation system. Water furrows are typically spaced 60 feet apart between planted rows. There are approximately 16 rows of potatoes between the water furrows. These rows range in height from approximately 8 to 14 inches. The water from the furrows is distributed laterally to the potato beds (Hensel 1964). Moisture reaches the plant roots through capillary movement upward (Fox et al. 1956).

The main requirements for this type of system to be practical and successful are as follows:

1. The surface soil must be of uniform texture, deep, and highly permeable.
2. There must be a natural high water table or a restricting layer in the soil profile upon which a perched or temporary water table can be developed at a reasonable depth below the normal root zone of the crops.
3. The land surface must be smooth with a gentle slope.
4. The restricting layer in the soil profile must be reasonably parallel with the ground surface.
5. During the growing season, the water table must be controlled within certain limits, depending upon the crop-growth cycle.
6. Adjacent farmers must agree as to the desirable position of the water table for different times during the season. Thus, sub-irrigation may require special community cooperation (Fox et al. 1956).

The tri-county area, in which potatoes are grown, is known to have a water table that comes within a couple feet of the surface. The irrigation process works by artificially raising the water level. Water is pumped into the water furrows and allowed to seep out and feed the water table. The depth of the water table should be controlled approximately 9 inches below the bottom of the alley in the middle of the bed between water furrows (Hensel 1964).

For irrigating potatoes in the tri-county area, there are two main system types. Semi-closed pipeline seepage irrigation is the most widely used system in the area. The other type of irrigation system is an open ditch seepage irrigation system.

In a semi-closed pipeline system, water is pumped from a well into a distribution pipeline. This pipeline then carries the water to the individual furrows. At each furrow there is a nozzle or valve through which the water is transferred to an open water furrow. The growers who have installed valves at the water furrows can adjust these valves to control how much water is applied to an individual furrow. An open ditch system uses a well to pump water directly into the ditch which is used to carry water to the individual water furrows.

Drainage ditches around the perimeter of the fields are used to carry off excess water that can occur due to a storm event. On the end of the field opposite where water is distributed into the water furrows is another ditch which has a water control structure. The water control structures aid the grower in maintaining proper moisture levels in the field. Some growers may also build earthen dams, lined with plastic, in the water furrow to control water levels in the field.

The growers use centrifugal, turbine, and submersible pumps to withdrawal water from their wells. All of the pumps use electricity as the power source. The flow rate on a gallons per acre per minute basis is very low (approximately 6 gallons per acre per minute). Because of this low flow rate, most growers operate their pumps 24 hours per day to keep up with the needs of the potato plants.

Factors Affecting Water Use

Factors that affect the quantity of water required by a particular field include site, management, and production characteristics.

The main site specific characteristics include soil and field preparation characteristics. The soil characteristics that affect water usage are the depth, texture, and permeability of the soil. Properties of the soil that affect these characteristics include the content of organic matter, soil texture, bulk density, and soil structure (Soil Survey of St. Johns County 1983).

Field preparation can differ between fields. One factor is the slope of the field. The most important measurement is the slope of the field. As the slope of the field increases, water will pass through the field more quickly and the ability of the water to be retained in the field decreases. This incidence increases the demand for water. Field preparation also includes the spacing of water furrows, the height of the planted rows, the depth of the water furrows, and the design of perimeter ditches.

Management and production factors include the decision rules used by the grower to determine when to turn on and off the irrigation systems, when the grower plants and harvests the fields, and how precisely the grower monitors the inputs required for the production process.

Obviously, the longer a grower operates the pumps the more water they will use. The factors that affect when a grower turns on the system include: the age of the plant; the soil moisture levels in the field, water furrows, and drainage structures; fertilization schedules; pest management procedures; and weather conditions. Factors that would affect when a grower turns off the irrigation system include: expected rainfall; actual rainfall; soil moisture levels in the field, water furrows, and drainage structures; and harvesting schedules.

Another explanation for differences in water usage could be the grower's risk perception. It is known that water is a very critical input in the production process. Irrigation water could be considered a risk-reducing input to the production process.

For the 1994 growing season the average yield was 225 hundred weights (cwt.) per acre for the Hastings area (Smith and Taylor). Using a five year (1988-1993) average of $9.58 per cwt., the average value for an acre of potatoes is $2,155 (Vegetable Summary 1992-1993, 1994). The average pre-harvest costs per acre were $1,623.81, with fixed costs of $436 per acre, and variable costs of $1,188 per acre (Smith and Taylor). Growers spend an estimated $10 to $20 per acre for electricity to operate their pumps, representing only 1 to 2 percent of variable costs.

For profit maximization the grower will maximize the following equation,

$$Y=pq-C(q)-B$$

where

Y = profit
p = output price
q = output
C(q)= variable cost
B = fixed cost.

This equation has the first-order condition

$$p=C'(q).$$

Under perfect competition, the first-order condition requires marginal revenue equal marginal cost.

If one assumes that water is the only input of interest, the profit maximization equation can be represented by the following equation,

$$Y=pf(w)-rw-B$$

where

Y = profit
p = output price
$f(w)$ = production function for potatoes with respect to water
r = marginal cost of water
w = quantity of water.

The first order condition for this equation would be

$$pf'(w)=r.$$

This first order condition implies the price of the output times the marginal product (marginal revenue product) for an input will equal the marginal cost for that input (Robison and Barry 1987).

Since the cost of pumping water is very low when compared to the value of the crop, the profit maximizing level of water use will occur at a point where the marginal product of water is quite low. The marginal product for water decreases as the amount of water pumped increases. Hence, the level of water use will be relatively high under the profit maximization paradigm.

Under yield maximization, the grower will maximize output. The grower will use an input until the marginal product for that input is equal to zero. Therefore it can be shown that under profit maximization or yield maximization the value of the marginal products are similar, indicating that the optimal levels of water use under either maximization strategy are about equal.

An important objective met by pumping water for irrigating potatoes is to reduce the risk associated with output. Under expected utility maximization, a grower will use inputs in combinations that provide the maximum level of utility. The utility for a grower is affected by the amount of profit received by the grower for a level of risk. The level of risk a grower faces is directly related to the amount of variance associated with the output. A grower who is risk averse will accept reduced profits for a decrease in the variability of his profits.

Applying this concept to profit maximization gives the optimal output under risk for a grower as the certainty equivalent. A certainty equivalent can be defined as the return on a risk-free investment, equaled to the expected return on the risky investment less the risk premium (Robison and Barry 1987). The equilibrium point for the certainty equivalent is determined by the tangency between an iso-expected utility line and an expected value-variance set. The expected value-variance set is defined as the choices or sets of choices that provide minimum variance for alternative levels of expected returns (Robison and Barry 1987). The certainty equivalent can be expressed by the following equation,

$$Y_{CE}=pf(w)-rw-\frac{\lambda}{2}p^2f(w)^2\delta_\epsilon^2$$

where

Y_{CE} = certainty equivalent output
p = output price
f(w) = production function for water
r = variable cost for water
λ = measure of risk aversion
δ^2_ϵ = variance of the error.

The first-order condition for the certainty equivalent is

$$pf'(w)-r-\lambda p^2f(w)f'(w)\delta^2_\epsilon=0.$$

So long as the marginal cost for the input is positive the output satisfying the first-order condition under risk will be less than the corresponding output under profit maximization. The difference between the two levels of output will be equal to $\lambda p^2 f(w) f_W \delta^2_\epsilon$ which represents the cost of risk. The cost of risk can be explained as costs the firm would willingly forgo from its expected profits if the difference were received with certainty (Robison and Barry 1987).

Risk can be associated to the moisture levels in the soil. Plant stress as a result of insufficient moisture levels in the soil negatively affects the yield. Growers may use pumped irrigation water as a cheap insurance policy to guard against decreases in yield as a result of stress caused by insufficient moisture levels in the soil. Using water in this manner will decrease the variability in the output causing the utility of the grower to increase. The grower faces little economic incentive to conserve water under the current system.

The amount of risk caused by decreased moisture levels in the soil will be different for every grower. One would expect that if the grower had a large capacity and could replenish the moisture levels in the field rapidly, the risk level would be low. Also, the soil type for a given field will affect the rate water can seep into the soil. If the grower had an irrigation system that could not replenish the moisture level in the soil once the moisture level dropped below a certain level, the grower would have a higher risk level. This higher risk level would cause the grower to pump more water. Consequently risk averse growers will use more water than profit maximizing (risk neutral) growers under this scenario.

Previous Work

The only previous work conducted, with regard to irrigation water usage in potatoes in North Florida, was the work reported by Littell and Portier in 1994. Their analysis used data on potatoes collected by the Benchmark Farm Program over a four year period beginning in 1989.

The Benchmark Farm Program collected data on the amount of water pumped for potatoes using flow meters installed at the well heads. As a back-up, data was collected from the electrical meters for the pumps. This electrical meter data could be used to impute the amount of water pumped, if the flow meter broke or malfunctioned. A data quality variable was inserted into the database to identify readings that were estimated or inaccurate. The Benchmark Farm database also contained information on: the date the field was planted; the date the flow-meter and time-meter were read; rainfall; field soil information, size, and location.

Littell and Portier chose to use a regression technique that analyzed both the time-series and cross-sectional differences between Benchmark Farm sites. The model from their work was

$$W_{it}=f(A_{it},M_i,S_i)$$

where:

W = acre inches of water pumped per acre
t = time period
i = site
A = crop-age
M = month in which the reading was taken
(1=January, 2=February, etc.)
S = soil series dummy variable
(1=St. Johns, 0=other).

The crop-age and month factors included all of the product and cross-product terms. This model was selected as the best model because this combination of variable provided the highest R-square with the fewest amount of parameters (Littell and Portier 1994).

In theory, as the plant gets older the amount of water required by the plant should increase. This increase will cause the crop-age variable to have a positive effect on the amount of water required. As the observation period moves further into the year, the average daily temperature increases along with the amount of daylight. The month variable will have a positive effect on the amount of water pumped for irrigation. Water will pass through and be retained in different soils at different rates. A variable for differences in soil characteristics will account for differences between soils.

The model used by Littell and Portier had an R-square of 0.618 and all of the coefficients except for the one associated with the crop-age squared term were statistically significant. The most significant effect from their model was for the dummy variable for whether the soil series was called St. Johns. The model showed that if the soil series for the field was called St. Johns, the field used 3.07 acre inches of water per acre less per month than the other fields (Littell and Portier 1994).. The Littell and Portier study also demonstrated that planting date had a significant effect on the amount of water pumped for irrigation purposes.

The limitations to this work were that the model did not account for differences in management and production practices. In addition, the Littell and Portier study only had one field that had a soil series called St. Johns. It cannot be said that the effect is due to soil characteristics.

PROCEDURES

Questionnaire Design and Development

The purpose of the questionnaire was to collect management, production, and site information from individual potato growers. The framework for the questionnaire came from a Fernery Management Survey (Boggess et al. 1991). With the help of Dr. Pat Byrne, Dr. Bill Boggess, Dr. Allen Smajstrla, Dr. Dale Hensel, Austin Tilton (Extension Director - Putnam County), Jim Dilbeck (Extension Director - St. Johns County), and Dan Schrader (Extension Director - Flagler County) the fern survey was revised to apply to the potato industry in North Florida. The questionnaire was organized into sections that pertain to general farm information, farm operator information, pest management practices, fertilization practices, irrigation management information, specific field information, farm management information, and information dealing with the future of potato production.

The questionnaire was reviewed by the St. Johns River Water Management District personnel, county agents from the respective counties, and Hastings Research Center Personnel. Two growers were selected to pre-test the questionnaire. The goals of the questionnaire were explained to the growers who were then interviewed using the questionnaire. After being interviewed, the growers were asked to comment on the questionnaire and about how improvements could be made to the questionnaire. After all comments had been noted the questionnaire was finalized. (A copy of the final questionnaire is in Appendix A.)

Interviewing Process

Names, addresses, and phone numbers for potato growers were collected from the county extension offices for the three counties. After identifying relationships between growers, it was determined there were 69 farms or farming operations in the three county area, made up of approximately 90 individuals.

A letter explaining the questionnaire and uses of the information to be collected was mailed to everyone on the revised potato grower list. Approximately two weeks later representatives from the Institute of Food and Agricultural Sciences went to a North Florida Growers Exchange meeting at the Putnam County Extension Office. At this meeting, the representatives discussed with the growers who was conducting the research, for whom the research was being done, who would have access to the information, and what were the goals of the research. The growers asked questions concerning why they should participate and possible effects of the research.

Personal interviews were used to collect the questionnaires from the growers. All interviews were conducted by the same person and in the same manner. The questionnaire was collected by personally interviewing a representative from each farm or farming operation. The interview consisted of the grower identifying the fields he grew potatoes on in the 1994 growing season and answering questions on a written questionnaire. Responses to the questionnaire were recorded by the interviewer.

The St. Johns River Water Management District assisted in the data collection process by providing maps containing all of the potato fields in the tri-county area with field identification numbers and a computer database containing the respective soil characteristics.

<u>Data Handling and Summary Procedures</u>

The responses to the questionnaire were entered into a computer using Questionnaire Programming Language (QPL) software (Dooley 1991). The QPL software created a collection program which facilitated the data entry process. The QPL software was also used to write a program that could be used with Statistical Analysis Software (SAS 1985) to generate summary statistics of the survey results.

In order to statistically analyze variations in the amount of water pumped for irrigation use, the database containing the information from the questionnaire was merged with information from the Benchmark Farm Program and soil characteristics information. Both the Benchmark Farm data and the soil characteristics data were provided by the St. Johns River Water Management District. Information from the Benchmark Farm data included the date the field was planted, acre inches of water pumped per acre, and the data quality. The data quality was either "good", "estimated", or "inaccurate". "Estimated" meant that the meter malfunctioned and the amount of water pumped was calculated using the number of kilowatt hours and the pump specifications. If the data quality was "inaccurate" it meant the flow meter malfunctioned and the kilowatt hour method could not be used to estimate the amount of water pumped.

The St. Johns River Water Management District also provided information about the soil characteristics from a geographic information system (GIS) database containing state soils information called STATSGO (State Soil Geographic Data Base 1991). Soil variables included the map unit identification number (MUID) and number of acres of each map unit for a specific field. The MUID is a number provided by the STATSGO program that represents areas comprised of specific soil types. A specific soil type can appear in more than one MUID. Each MUID has a proportion for each soil type in the unit, as represented in that unit throughout the state.

<u>Statistical Analysis Procedures</u>

The work done by Littell and Portier analyzed the amount of water pumped on a monthly basis. Their model suggested that the age of the crop, the month of measurement, and the soil type could be used to explain differences in the amount of water pumped. This study includes management, production, and site variables which have the same value throughout the growing season. Consequently, this analysis was conducted over the entire growing season.

To adapt the variables used in the Littell and Portier model to a growing season basis, some modifications were made to the model. To capture the crop-age and month variation, a new variable was used in the seasonal model. The new variable was the number of days after December 1 of the preceding year the field was planted. A more specific grouping method for soil differences was created, using the MUID data to create three different categories. These categories would give the proportion of the field contained in each MUID group.

The data collected from the questionnaire were examined with respect to management or site variation. Variables to be included in the analysis were selected based on a three stage process. First, there had to be a theoretical reason for why the variables were believed to be important. Second, there had to be variation in the responses given by the growers. Third, there had to be an adequate number of responses to be used in a model. The model for the seasonal regression was,

$$W=\sum_{i=1}^{k}(A_i*S_i)+\sum_{j=1}^{n}(B_j*M_j)$$

where

W = amount of water pumped per season
k = number of site variables
S_i = i^{th} site variable
A_i = weight for the i^{th} site variable
n = number of management variables
M_j = j^{th} management variable
B_j = weight for the j^{th} management variable.

There are over 20 variables in this model with less than 50 observations for a given season. As a result, initial inclusion of all variables would raise efficiency concerns. Therefore, the variables were added to the base model one at a time. A variable was retained if the estimated coefficient was statistically significant at the .10 level. Variables that explain differences in management practices were then added to the model in a similar manner as the site variables. The same criteria was used for retaining management variables. After all of the significant site and management variables were determined, a final single season model containing the significant variables was estimated. The final single season model was then applied to the five years of Benchmark Farm Data. A dummy variable was used to account for rainfall differences between study years.

POTATO PRODUCTION AND IRRIGATION QUESTIONNAIRE

A total of 62 interviews were completed between September and December 1994. Limited responses to certain questions were most often a result of the perceived sensitive nature of the question or that the information was not readily available. Growers were not given advance notice of the types of information required for the questionnaire. The questionnaire was designed to collect information that the grower uses to make decisions on a day-to-day basis. The assumption is that information that is important to the grower could be recalled. To give the growers advance notice of the types of data being collected would bias the results of the questionnaire.

The questionnaire was broken down into eight sections. These are General Information, Farm Operator Information, Pest Management Practices, Fertilization Practices, Irrigation Management Information, Specific Field Information, Farm Management, and the Future of Potato Production. The results are presented under these headings.

General Information

The objective of this section was to collect general information about the potato industry in North Florida. This included the size and location of the fields for the individual growers, type and size of different operations undertaken by the growers, and information on whether the industry is increasing or decreasing in this area.

Of the growers that responded to the questionnaire, 71 percent are participating in the Benchmark Farm Program. The average grower has been producing potatoes for 24 years. This section also asked for the respondents to indicate their gross acres of potato production and the yield by type, season, and ownership status.

For the Fall 1993 season, four respondents (6.5 percent) grew a fall potato crop. All respondents grew potatoes in the spring 1994 season. Three respondents (4.9 percent) grew only table potatoes, 42 respondents (68.9 percent) grew only chip potatoes and the remaining 16 respondents (26.2 percent) grew both types. The total number of acres reported by interviewed growers represents 27,734 acres and the average number of acres per grower for potato production was 450 acres.

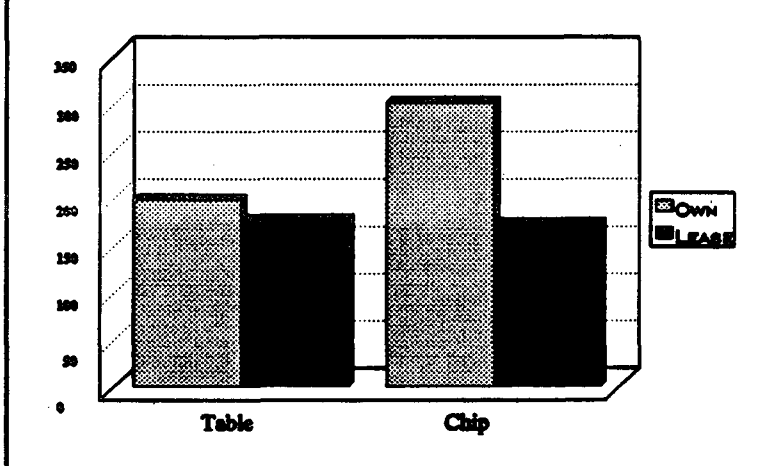

Figure 1 Average Gross Acres of Potato Production

Overall, growers commit a larger portion of their acreage to chipping potatoes. Of the nearly 84 percent of the growers who grow chipping potatoes, the average acreage size was 302 acres owned (figure 1). Over 69 percent of the growers lease land for chipping potatoes as well. The average amount of acres for this purpose was 174. For table potatoes, 27.4 percent grow on their own acreage with an average of 199 acres and nearly 13 percent lease an average of 178 acres for table production. Yields are higher for chipper potatoes with yields averaging 230 cwt/ac for leased land and 234 for owned land. Reported yield averages for table potatoes ranged from 182 cwt/ac for leased land to 201 for owned land (figure 2). Table potatoes usually bring a higher market price than chipping potatoes, but there is also a thin market associated with this type. Even though the yields for table potatoes are lower, it is not known if the water requirements are lower as well.

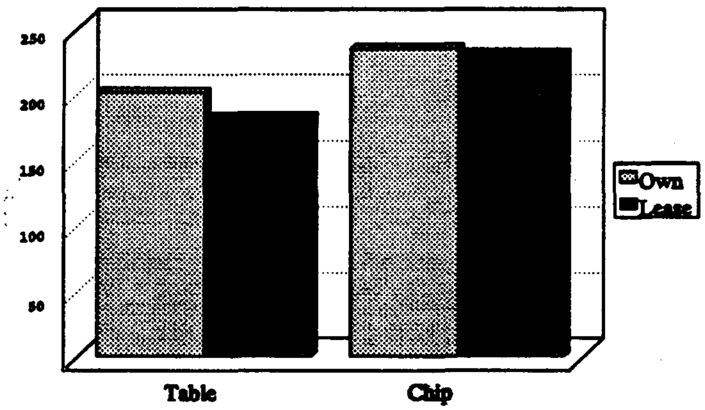

Figure 2 Average Yields (cwt/ac) by Potato Type

Over the last 5 years, almost 42 percent of the current growers have increased their planted potato acreage, while only 14.5 percent have decreased the acreage planted (figure 3). On average, growers who increased acreage did so by about 164 acres. The average change for growers who reduced their acreage was almost 126 acres (Table 3).

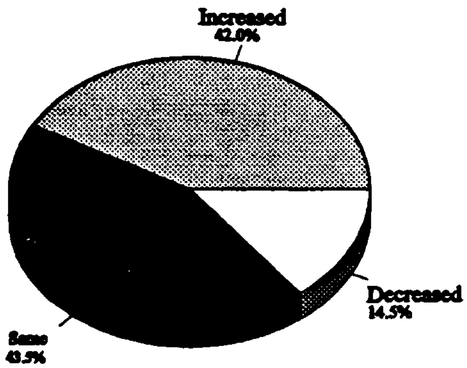

Figure 3 Potato Farm Acreage Today vs 5 Years Ago by Grower

Table 3: Average Change in Potato Acreage over the Last 5 Years

Change	Frequency	Mean	Min	Max
Increase	25	163.76	30	500
Decrease	9	125.56	30	400

Farm Operator Information

Of the persons interviewed, all respondents were men. The average age was 48 years with a range from 29 to 73 years. The respondents highest level of education was broken into four categories: a) less than high school (4.8 percent); b) high school graduate (53.3 percent); c) some college (30.6 percent); and d) college graduate (11.3 percent) (figure 4). Of those who responded they had some college, the average number of years completed was 1.82 years with a range from 1 to 4 years.

Growers were asked to identify, in no particular order, up to three sources that they consider to be important information resources. The number of responses from each grower ranged from one to three sources. Vendors were most frequently identified as a key information resource (72.6 percent), followed by IFAS (50 percent (figure 5). Private consultants were only identified by 12.9 percent of the growers. Under the "other" category, most growers responded with "other growers", as an important source of information; however, two growers responded that literature was an important source, while two other growers identified potato processors as "other" sources for information.

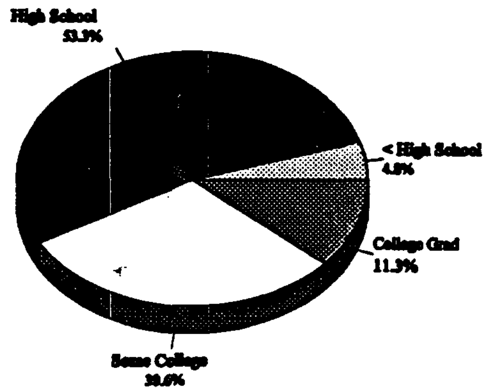

Figure 4 Highest Level of Education Attained by Grower

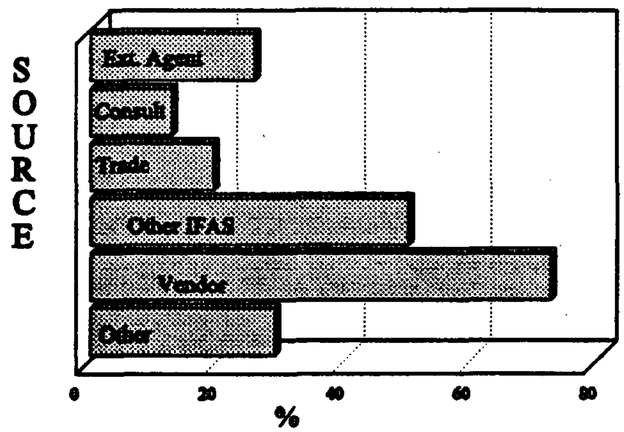

Figure 5 Grower Sources for Information

Frequently, growers live on or next to one or more of their potato field sites. The respondents were asked for a weighted average of the distances for all sites. However, if the respondent lived on or next to a site and all sites border each other, then the respondent was considered to live zero miles from the sites. The average distance was 3.25 miles with a range from 0 to 20 miles. Over 90 percent of the respondents indicated that the owner was responsible for overseeing irrigation management. In almost every situation, there are no automatic controls for pumping irrigation water. Manual systems are more effective if the sites are readily accessible. Further, owners would be more motivated to check the system than hired labor.

Pest Management Practices

Questions in this section pertained to experiences and practices with respect to blight, as well as diseases prevention. Almost 68 percent of the interviewed growers reported reduced potato yields due to blight in 1994. The average reduction in yields were estimated to be 30 percent for affected fields. For those affected growers, the average acreage affected for each grower was 40 percent. Less than one half of the growers (48.4 percent) stated that they use the telephone blight cast advisory (figure 6). Blight advisory

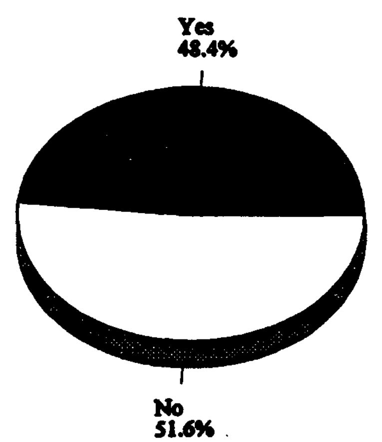

Figure 6 Proportion of Potato Growers that Use the Telephone Blight Advisory

recommendations are usually followed by 83 percent of those that use the advisory.

All of the growers, except one, stated that they fumigated their entire potato acreage prior to planting. The exception only fumigated 50 percent of that operation's acreage.

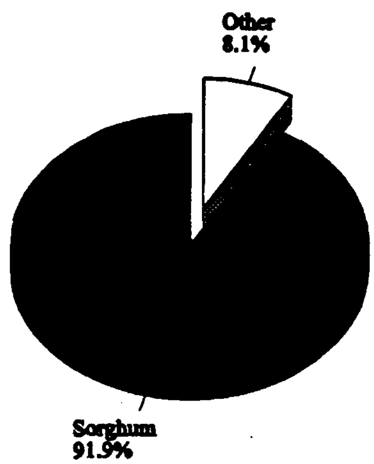

Figure 7 Proportion of Acreage Maintained with Cover Crop

Cover crops are frequently used in potato production to reduce disease incidence for the following season. The overwhelming choice (91.9 percent) for 1994 was the use of sorghum as a cover crop during the off-season (figure 7). Other fields were maintained in the summer with a corn cover, which could be used for silage.

Fertilization Practices

Responses in this section concern timing, frequency, and types of fertilizer applications used by the potato growers. Some growers were concerned with revealing certain types of fertilizer information, especially with regard to fertilizer analysis. In these cases, growers indicated that these practices involve their own "trade secrets." Lime applications were not included in the information, since this is not usually an annual practice. Fertilizer analysis was given with respect to nitrogen (N), phosphorous (P), and potassium (K).

The mean values are provided in table 4. The "n*" column gives the number of growers who gave fertilizer analysis information. Means were calculated based on complete information

Table 4: Fertilizer applications.

Application Date		Frequency	N	P	K	n*
Prior to Planting	5-6 weeks	12	2.11	9.22	31.67	9
	3-4 weeks	29	5.64	12.00	24.84	25
	1-2 weeks	12	5.11	8.44	17.00	9
	< 7 days	7	22.00	7.50	3.50	6
After Planting	2-4 weeks	54	28.45	0.66	3.48	44
	5-6 weeks	28	29.32	0.00	2.52	25
	> 6 weeks	21	24.93	0.14	5.43	14

*=frequency of responses for N, P, K.

observations only. In general, fertilizer is applied once prior to planting. The key components of this application are P and K. Higher nitrogen analysis is observed when application occurs within 7 days of planting. Applications after planting are related to the timing chosen for the pre-plant application. For instance, if application occurs weeks before planting, then the grower is likely to fertilize again soon after planting. Some growers apply two applications or more after planting. Nitrogen is the key component for post-plant applications.

Irrigation Management Information

The purpose of this section was to determine how the respondents regulate their irrigation systems, the type of system, and attributes of the planted rows. Sub-irrigation provides moisture from the bottom, opposite of the overhead system. As such, visual checks may have some differences. Growers mostly use soil appearance as an indicator of irrigation effectiveness (96.8 percent) (figure 8). Plant appearance (58.1 percent) is also used as a check by the majority of the potato growers. To a lesser degree, growers evaluate their systems based on water levels in the furrows and ditches, 14.5 and 11.3 percent respectively. Less than 5 percent of the respondents indicated that they use a tensiometer to determine the moisture content of the soil.

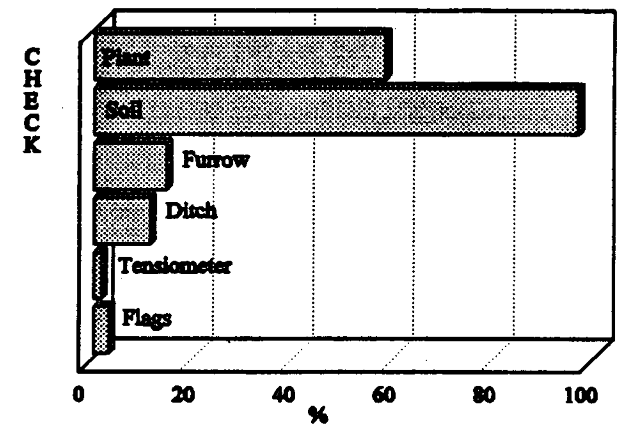

Figure 8 Potato Irrigation Check Systems

Soil appearance evaluations appear to be based on experience as opposed to mechanical measurement. Approximately sixty percent of the respondents indicated that the soil appearance is acceptable if the top is dry, but the soil lower than one inch from the top is moist (figure 9). Another method for evaluating soil appearance used by growers is the clumping of soil in the alley. This "rule of thumb" is based on a handful of soil taken from the alley. If the soil clumps in the hand, then

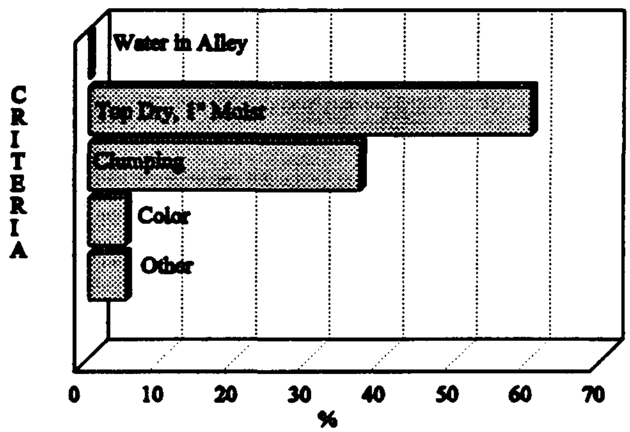

Figure 9 Soil Appearance Criteria for Irrigation Check

moisture is considered adequate. This method is used by 36.7 percent of the growers. Surface color and other methods are only used by 5 percent of the growers.

The most popular irrigation system used for potatoes in this North Florida area is the seep, semi-closed pipeline water delivery system (figure 10). Ninety-seven percent of the potato acreage in North Florida uses this system. The seep, semi-closed pipeline water delivery refers to a system which distributes water by using a pipe from the well to an open water furrow in the field. This system allows the grower to control, with better accuracy, the amount of water delivered to each water furrow. This system also does not have a long delay between water being pumped from the well and delivered to the water furrow.

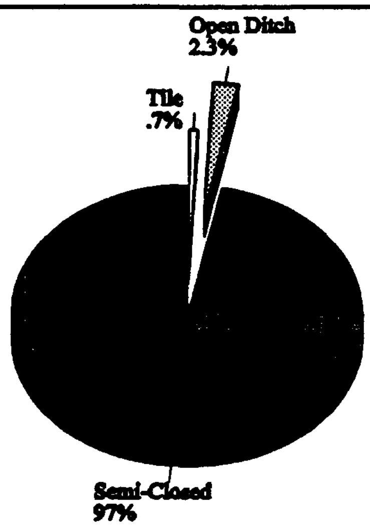

Figure 10 Potato Irrigation Systems in North Florida

The seep, open ditch water delivery refers to a system where the water is carried from the well to the field in an open ditch or furrow. The other system that was found was a tile system. The tile system consists of a network of perforated pipe buried approximately three feet below ground level.

On average, growers have 13 wells over four inches and use 12 of these wells for potato irrigation. Over 70 percent of the growers responded that at least one of their wells are "free-flowing" at some time during the year. In this context, "free-flowing" refers to wells where water would flow without mechanical assistance at any time during the year. This does not mean that pumps are not required for the irrigation season.

Centrifugal pumps were the most common choice (71.4 percent) for irrigation wells (figure 11). The "other" category represents wells that did not use any pump and accounted for only 1.3 percent of the irrigation wells.

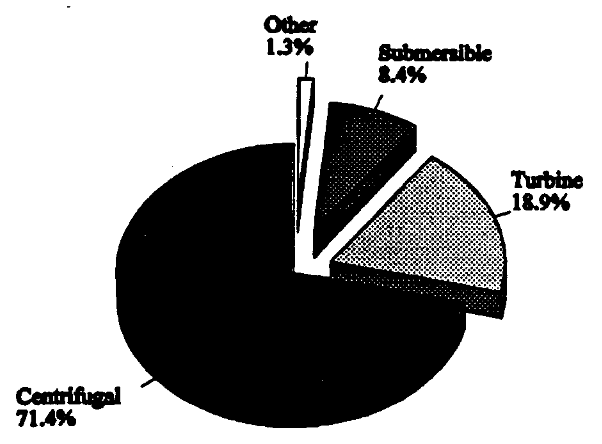

Figure 11 Types of Pumps for Potato Irrigation

Electricity was the power source for all of the pumps. Growers were asked if they could recall their energy expenditures for their pumps over the 1994 growing season. Growers were not given advance notice that this question would be asked. The purpose of this question was to determine if growers knew this answer without having to check their records. If energy expenditures for pumping water were an important component for the operation, then it was assumed that growers would be more likely to recall the amount. If energy expenditures were not an important management component for the potato operation, then the grower presumably may be less likely to recall this information. Only 9 growers (14.3 percent) knew the exact amount spent on electricity for their pumps; however, 24 respondents (38.1 percent) could make a rough approximation of their energy expenditures for the 1994 growing season. In all, over 52 percent of the growers had some notion of their energy expenditure. Combining the actual figures with the estimations, the average amount spent on irrigation by each grower was $7,945.47 ($n$=33) with a range from $1,000 to $30,000.

For the growers who knew exactly what their expenditures were, the average was $4,520 per grower. The average amount spent per acre was $11 with a standard deviation of $4.62. For the growers who could make an estimate, the average was $9,373 per grower. The average amount spent per acre was $18 with a standard deviation of $8.10. Energy expenditures for pumping water represented about 1 percent of estimated costs of production. The average size of a farm for growers who knew their expenditures exactly was 428 acres versus 495 acres for those growers who estimated their usage.

Specific Field Information

Specific information was gathered for one field belonging to the respondent, in order to gain insight into the differences in growing techniques used by the growers. For the purposes of this questionnaire, a specific field was defined as a field being irrigated by one well or one irrigation system. If the grower participated in the Saint John's River Water Management District (SJRWMD)

Benchmark Farm Program, then that field was used as the specific field. If the grower did not participate in the Benchmark Farm Program, then a field was randomly chosen from the field maps provided by the SJRWMD.

The average field size was 41.25 aces (n=60) with a range from 10 to 167 acres. All of the fields used the seep, semi-closed pipeline water delivery system, except for one field which used a tile system. The average slope was 7.38 inches per 1,000 feet (n=34) with a range from 0 to 20 inches. Slope information was not readily known by many of the growers.

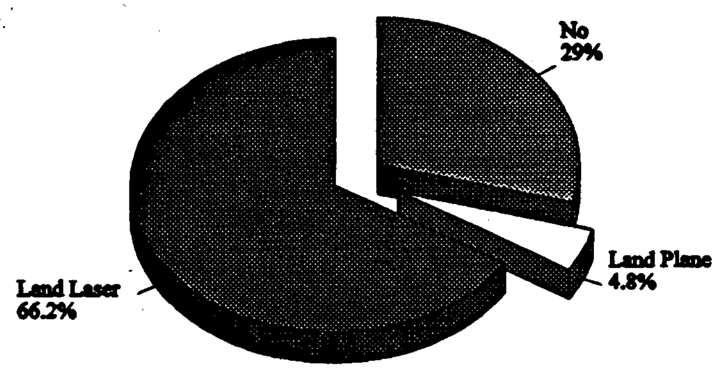

Figure 12 Specific Field Slope Verification Procedures

Field slope was most commonly verified with a land laser technique (66.2%), but 29 percent of the growers responded that they did not verify the slope of this specific field (figure 12). About 5 percent of the respondents used a land plane to verify field slope.

The average row height, as measured at the time of planting, was 10.86 inches (n=50) with a range from 8 to 18 inches. Since water travels to the plant through capillary action, the row height could be used as an approximation of how far the water must travel vertically. In theory, as the row height increases more water would be required for effective irrigation. Higher rows would require more stacking of the water table to provide adequate moisture for the plant. Twelve inch row heights were used by 38 percent of the growers followed by 24 percent for 8 inch rows and 22 percent for 10 inch row heights (figure 13). Only 12 percent of the row heights exceeded twelve inches.

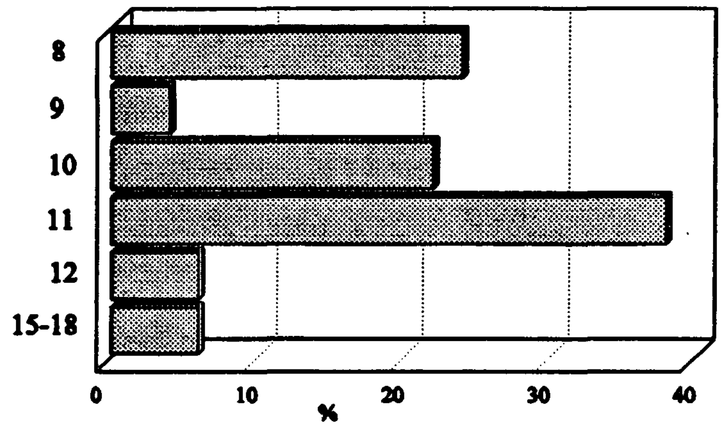

Figure 13 Proportion of Row Heights (in) for Specific Fields

The average number of wells was 1.06 for each specific field with a range from 0.4 to 3.0 wells. Since some wells serve more than one field and some wells serve less than one field, well fractions are appropriate. The most common well diameters were 4 and 6 inches for the specific fields (figure 14). Larger diameters would expectedly be positively correlated with water flow.

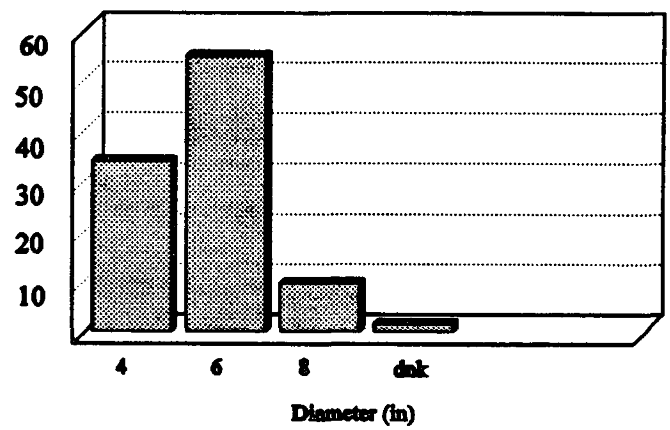

Figure 14 Well Casing Diameters (in) for Specific Fields

Two-thirds of the pumps were centrifugal while 23.3 percent were turbine (figure 15). Only one well did not require a pump since it was a free-flowing well. Horsepower ratings of the pumps varied from

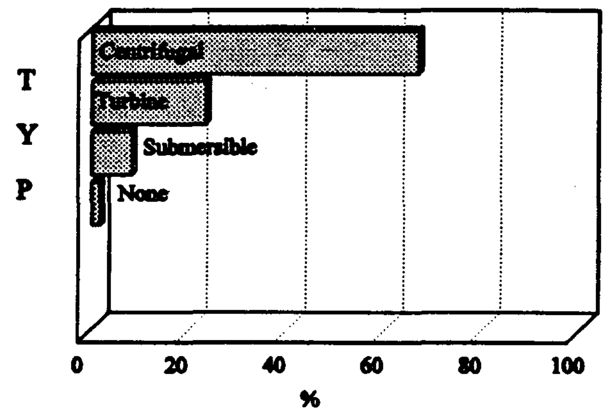

Figure 15 Pump Types for Specific Fields

1.5 to 20 hp with an average of 6.9 hp. Five growers were unsure of the horsepower rating for the field site pump(s). Growers were unsure of the well's discharge capacity, in general. Sixteen growers reported discharge rates ranging from 140 to 800 gallons per minute with a mean of 420 gpm. The small response to this question may suggest that this information is not commonly used by the growers for managing their irrigation activities.

Seventy-five percent of the growers used a 3/4 inch valve at the water furrow. The remaining 25 percent used a 1 inch valve. Larger valve sizes would indicate higher potential flow rates. In most cases, growers have the ability to control the water flow rate at the well and/or water furrow valve. The majority of the growers (62.3) do not adjust the flow rate at the well, while 86.7 percent indicated that they do control the flow rate at the water furrow valve. Their criteria for adjustment closely mirrors the guidelines set forth by the consumptive use permits issued by SJRWMD. These permits state that the discharge is not allowed to overtop the control structures by more than one-half inch. Furthermore, most growers are not allowed any discharge from 1:00 pm to sundown, unless associated with a storm event. (Florida Administrative Code 40C-2 1995).

Planting Characteristics

The bulk of potatoes, 76.5 percent of total acreage, are planted between the 16th of January and the 15th of February (figure 16). Earlier planting dates would have lower irrigation requirements for the season, due to the cooler temperatures. Average seed depth at planting was 3.18 inches with a range of 1 to 7 inches. One common "rule of thumb" mentioned by growers was to use the distance from the first joint on their middle finger to the tip of the same finger for depth measurement. Planting depth may be useful in determining how far the moisture must travel vertically in the soil to reach the plant.

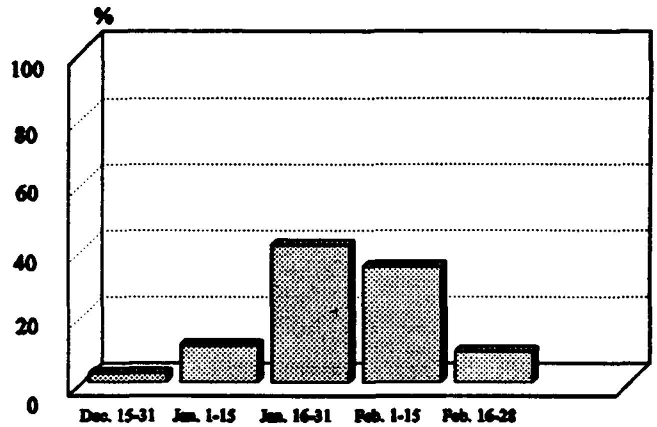

Figure 16 Potato Planting Dates

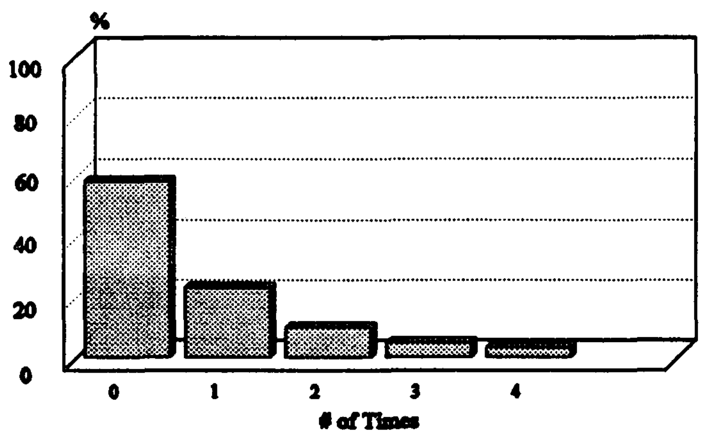

Figure 17 Frequency of Pre-plant Irrigation in Last 10 Years

Over 40 percent of the growers responded that they will irrigate prior to planting during "dry" years. Since "dry" is a rather subjective term, growers were asked to indicate the number of times that they irrigated prior to planting over the last 10 years. Only about 8 percent of the respondents indicated that they irrigated prior to planting more than once during the last 10 years (figure 17). As such, Pre-plant irrigation does not appear to be an important factor in water demand. On average growers wait 3.82 weeks to begin irrigating after planting. Growers indicated that they usually start irrigating when the plant emerges about 2 to 4 inches above the ground. Almost sixty percent of the respondents indicated that they begin irrigating 3 to 4 weeks after planting (figure 18). Premature irrigation is not conducive to the plant's growth. Longer delays would reduce overall water consumption, but the moisture will be necessary after about thirty days.

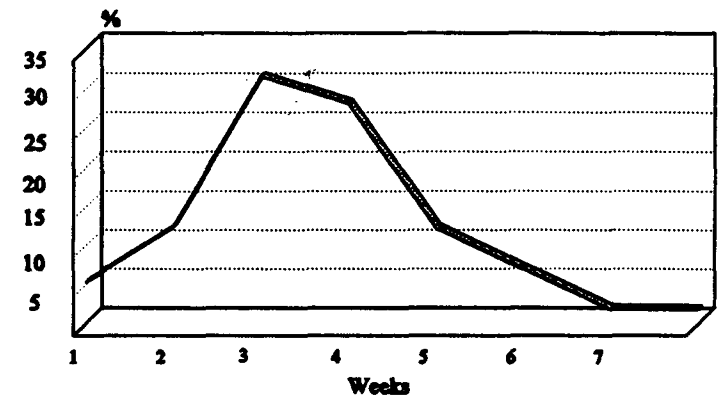

Figure 18 Irrigation Delay After Planting in Weeks

Over 60 percent of potatoes are harvested during the month of May (figure 19). Harvest date information is useful in determining the growing season length when used in conjunction with planting dates. It may also be assumed that potatoes harvested earlier in the year required less irrigation water due to cooler temperatures and rainfall patterns. Water use is expected to have little influence on grower decisions on when to plant and harvest. Planting and harvest dates are driven by other factors, namely production and market window.

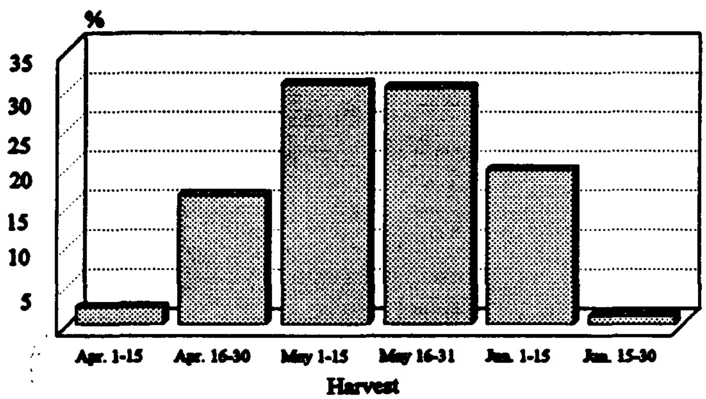

Figure 19 Potato Harvest Dates

Management Information

A key component to good management practices is record keeping. Thorough and up-to-date records can assist managers during the decision-making process. Three key areas for record keeping in potato production are fertilizer application by field, yield by field, and pesticide applications by field. Over 96 percent of the growers indicated that they regularly maintain pesticide application records by field (figure 20). Pesticide operators are required to maintain these records for many pesticides used in potato production. Over 70 percent of the respondents indicated that they also regularly keep records for fertilizer applications and yield information by field.

All of the respondents indicated that they normally irrigate all day (24 hours), however, 81.9 percent of the growers said that they do turn off or delay irrigation based on expected rainfall. Television was identified as the major source for growers to base their rain expectations. On average, an expectation of .94 inches of rainfall was necessary to turn off or delay irrigation, with a range from 0.10 to 2.0 inches.

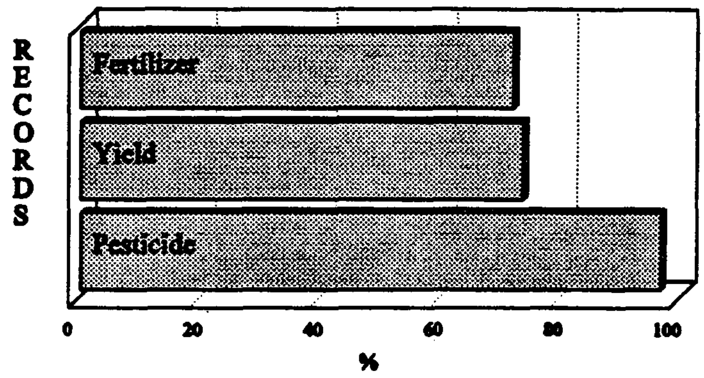

Figure 20 Record Keeping for Fertilizer, Yield, and Pesticides by Field

Growers reported that they would turn off the system at an average of 11.54 hours before the expected rain, with a range from 1 to 48 hours.

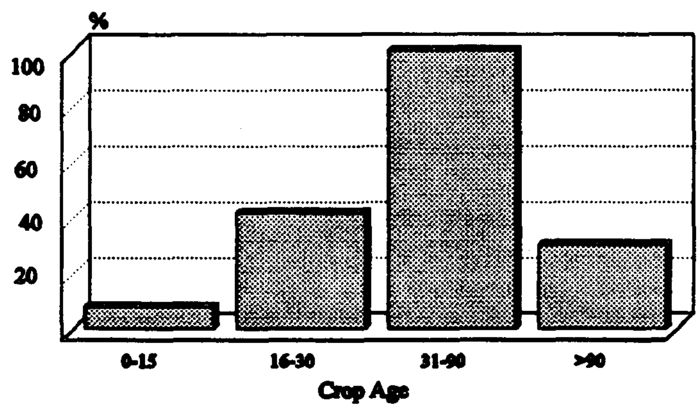

Figure 21 Irrigation and Crop Age

All of the respondents irrigate when the crop is 31 to 90 days old (figure 21). Irrigation is rare when the plants are less than two weeks old, but about 42 percent of the growers do irrigate between 16 and

30 days. Growers were not aware of specific water table levels in the potato fields. Maintenance of water table levels is important for meeting the plant's moisture requirements.

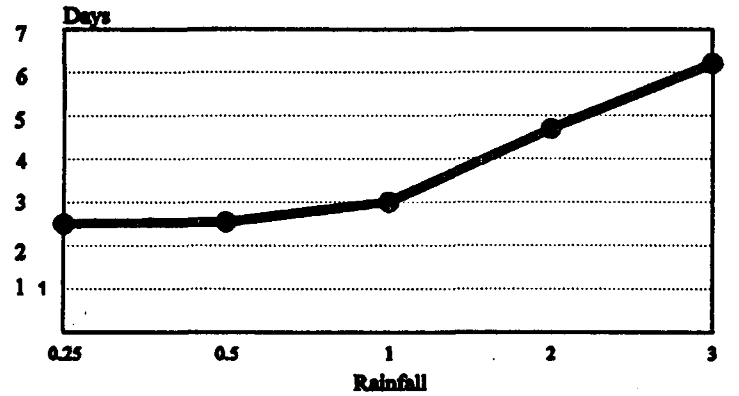

Figure 22 Average Delay in Restarting Irrigation based on Actual Rainfall (in)

Regardless of crop age, growers would turn the irrigation system off with an actual rainfall of at least .8 inches *on average*. All of the growers indicated that they would turn the irrigation system off if actual rainfall event was 1 inch or more, while 70 percent said they would shut the system off if actual rainfall was a half inch. Seventeen percent indicated that they would turn the system off for rainfalls of .1 to .25 inches. Figure 22 shows the average number of days that the growers would keep the irrigation off, given different rainfall amounts. Soil moisture was the number one criteria for turning the system back on according to 72.6 percent of the growers (figure 23). Plant condition was identified as the important criteria by almost 20 percent of the growers. Water level in the furrows, field water table level, and weather conditions were other identified criteria.

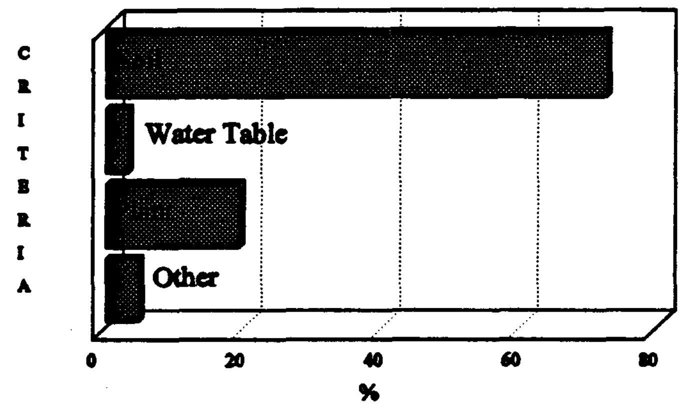

Figure 23 Criteria for Restarting Irrigation

The average time for turning off irrigation prior to harvest was 8.41 days, with a range from the actual day of harvest to 30 days prior to harvest. Potato type, table or chipper, plays an important role in this decision.

As mentioned earlier, the potato growers use the same basic irrigation system. There are some differences in water conservation measures already in use by the growers. Currently, over 80 percent of the growers use risers (furrow and\or ditch), regulate water flow, land leveling techniques, and closed pipeline delivery systems. Other measures include "sub-soiling," tile systems, water recovery, different potato varieties, and a shorter row height. These conservation measures are believed to have a significant impact on water consumption. In fact, over 77 percent of the growers feel their

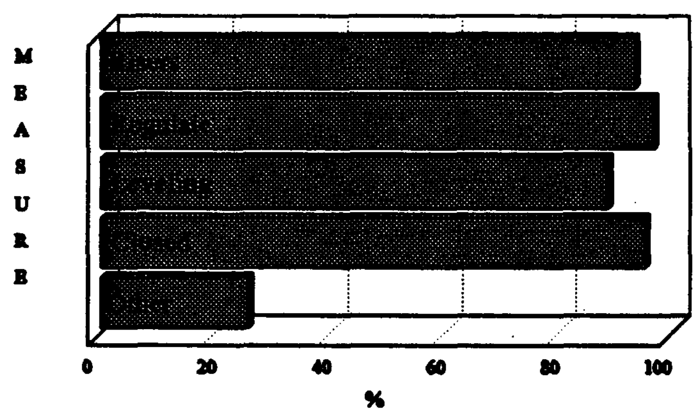

Figure 24 Conservation Measures Used by Potato Growers

operation is cost efficient and over 80 percent feel their water usage is technically efficient.

Growers were asked whether they thought certain conservation techniques were technically and/or economically feasible. Five different conservation methods were discussed with the respondents. First, a water recovery system where water would be recovered after traveling through the field and into the ditch and recycled back to the pump. Second, an automatic irrigation timer or controller that would turn the system off during certain hours or conditions. Third, a computerized water distribution system would control the entire system using sensors for moisture, humidity, et cetera. Fourth, a sub-irrigation system using drip tubing. Finally, moisture sensors in the field that could indicate whether irrigation was necessary. The majority of growers, 71 percent, felt that moisture sensors would be a technically feasible method, but less than half of the growers thought it would be economically feasible (figure 25). Less than half of the growers felt that the other methods were technically feasible. Even less thought that these practices were economically feasible. Of note, less than 10 percent indicated that they thought water recovery, computerized systems, and sub-irrigation were economically feasible. Obviously, the growers are not

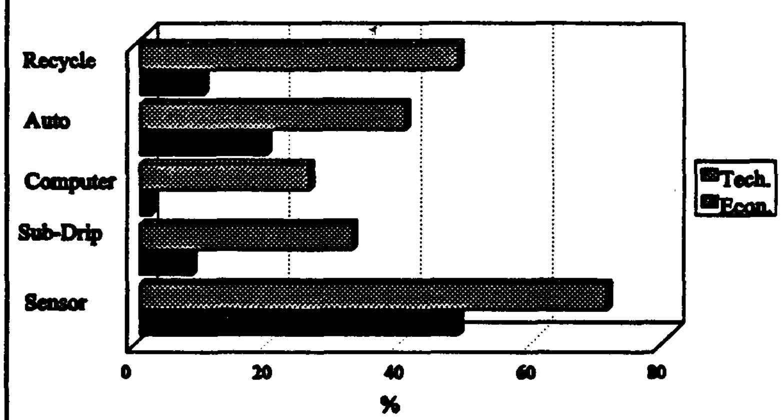

Figure 25 Technical and Economic Feasibility of Conservation Practices According to Potato Growers

convinced that these alternative practices would improve the profitability of their operations. Perhaps they are correct. Further research into these areas would be needed to determine the feasibility of alternative practices for potatoes.

Future of Potato Production

The purpose of this section was to collect information that would identify major concerns of the growers. The growers were asked what they thought the importance of the following factors on the future of Florida potato production would be over the next five years. The growers used a ranking system from 1 to 4, with 1 being most important. Water availability and environmental regulations were consistently considered more important concerns for potato growers than urban development and labor regulations (figure 26). Admittedly, the concerns for water availability may be biased due to this survey instrument at the time, but the results are still evident that water is a real concern to the growers. Growers were asked what did they feel to be a significant obstacle or threat with respect to the profitability and viability of potato production in this tri-county area. Water regulations, environmental regulations, and market conditions were the most frequently discussed threats. Most growers who mentioned water regulations said they

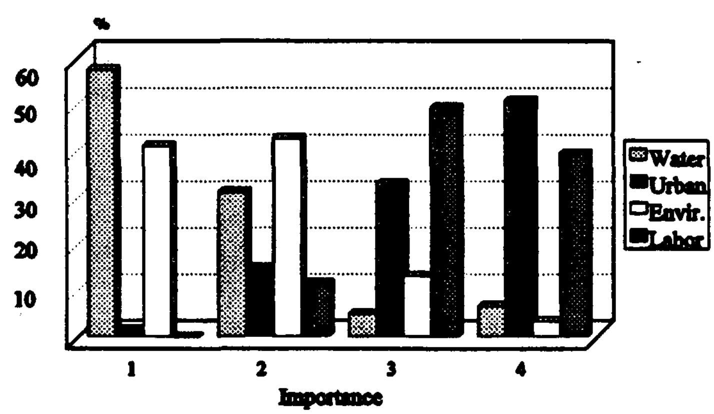

Figure 26 Importance of Various Factors on the Future of Florida Potato Production

felt that water resources in the future may be so limited that they would not have enough water to stay in business. Growers who responded with environmental regulations were referring to the lack of effective pesticides to control blight. The market conditions refer to problems the growers face in marketing their crop and being able to maintain a profit margin.

From the questionnaire, a great deal of information was collected. The questionnaire identified variables that present enough variation and number of observations to be used for evaluating the amount of water pumped for irrigation. Data concerning when a grower turns on and off his irrigation system and how a grower responds to both expected and actual rainfall should benefit the analysis. When a grower plants or harvests his field, although determined by marketing and production influences, should also benefit the analysis. Growers feel they are already implementing conservation procedures and see little value in other alternatives at this time.

WATER USE MODELS AND EMPIRICAL RESULTS

The purpose of this section is to determine and measure the effects of various factors on irrigation water consumption for potatoes in North Florida. Water use can vary between fields for a variety of reasons, such as: type of irrigation system; soil characteristics; planting and harvest decisions; associated costs; and management practices. Irrigation systems are somewhat homogenous for the potato producing area. As such, there are little to no measurable differences in capital outlays and maintenance costs that would account for water usage. For example, other types of systems may be more expensive to operate, motivating the grower to operate the system less to reduce costs. This would result in a difference in water usage due to the type of system. Or, a different type of system may be less efficient in delivering the water to the plants, which would increase water usage.

Soils, on the other hand, do vary from field to field. Organic content, sand composition, and other factors can affect the hydroconductivity (water movement) and moisture retention abilities. Planting and harvest dates also vary somewhat and could potentially impact the demand for water. Plants growing in the cooler season would require less water than plants growing during a warmer time. Rainfall and evaporation measures also differ during the year. Selection of planting and harvest dates are usually based on growing conditions and market expectations, not water requirements. Water is essentially cost-less to the grower except for permit costs. Distribution of water is not cost-less. Expenditures exist for the equipment, supplies, and labor for construction and maintenance of the delivery system; however, there is little reason why these would impact in-season water consumption. Electrical expenditures exist for the actual pumping of water. Here, some growers may be more sensitive to this expenditure than others, resulting in differences in water use.

Other management practices would include field preparation, system operation, and overall level of management. These practices are affected by market expectations, experience, and level of risk aversion.

Data for the analysis were obtained from the grower survey and associated Benchmark Farm information. Only those growers who participated in the Benchmark Farm program were used for the analysis. Further, some observations had to be deleted due to data contradictions and/or incomplete information. As a result, there were 34 fields that were deemed suitable for the analysis.

Base Model

As discussed earlier, the Littell and Portier study modeled water usage as function of crop-age, month, and a zero-one indicator variable identifying whether the soil type was St. Johns or not. Water use was measured monthly rather than for the entire growing season requirement. The analysis for this current study is concerned with total growing season requirements. As such, water use is modeled as a function of planting date (alternative to crop-age) and soil type for the base model. Planting date was represented by the number of days after December 1 that the field was planted, since no planting was reported prior to this date.

To evaluate differences caused by variations in soil characteristics, map unit identification numbers (MUID) were used for soil grouping. There are 8 different MUID numbers for the study area. These numbers were grouped into three groups. Any MUID in which the majority of soils were spodosols were placed in one group. This spodosol group was called FLSUMA and consisted of

MUID FL100, FL103, and FL106. The second group was made up of any MUID which had a majority of soils with high organic content at the surface. This group of organic soils was called FLSUMB and consisted of MUID FL105 and FL107. The third group, FLSUMC, consisted of any MUID which contained a majority of soils that were sandy, low in organic material, and had no clay. The MUID's for the groups in FLSUMC were FL101 and FL113. FLSUMC was used as the base group.

The base model regressed the total number of acre inches of water pumped per acre for the growing season as a function of planting date (PLDATE) and soil differences. In theory, more water will be required by a field the later in the growing season the field is planted. Because the soil group FLSUMC contains heavier soils than FLSUMA and FLSUMB, both FLSUMA and FLSUMB should require less water pumped for irrigation. The actual equation used for the base model was as follows:

$$SACI = \beta_0 + \beta_1 PLDATE + \beta_2 FLSUMA + \beta_3 FLSUMB + \epsilon$$

where SACI refers to the number of acre inches of water pumped per acre for each field; PLDATE is the number of days after December 1, 1993 the field was planted; FLSUMA represents the proportion of the field in soil group FLSUMA; FLSUMB represents the proportion of the field in soil group FLSUMB; and ϵ denotes the error term. Simple statistics for these variables are given in table 5.

Table 5: Descriptive Statistics for Base Model

Variable	N	Mean	Std Dev	Minimum	Maximum
SACI	35	14.9865714	6.4637910	4.34	33.12
PLDATE	35	60.3428571	16.4494642	27	90.00
FLSUMA	35	0.4571442	0.4860359	0	1.00
FLSUMB	35	0.5118065	0.4918651	0	1.00
FLSUMC	35	0.0310493	0.1524890	0	0.89

The average field would use just under 15 acre inches of pumped water and would be planted the end of January. Soil type of the average field would be 46 percent FLSUMA, 51 percent FLSUMB, and 3 percent FLSUMC. None of the study fields could be characterized as 100 percent FLSUMC.

Base Model Results

All estimated coefficients for the base model were statistically significant (table 6). Coefficients indicate that potatoes planted December 1 on a FLSUMC field would use over 21 acre inches of irrigation water. Every 10 days after the first of December would increase water use by 1.72 acre inches. Fields with 100 percent FLSUMA or FLSUMB soil types would use 16.11 acre inches and 18.81 acre inches less respectively compared to the base soil type. The low water retention of the FLSUMC soil types result in higher water usage compare to the other soil categories.

Other site variables were also tried but they did not significantly improve the explanatory power for the model. These variables included: proportion of acreage affected by blight; field slope (when known); furrow length; use of ditch and/or furrow risers; row height; and age of field.

Table 6 Regression Results (standard error) for Water Use Base Model

Variable	Coefficient Estimate
Intercept	21.5657* (6.577)
PLDATE	.1723* (.0579)
FLSUMA	-16.1131* (6.3480)
FLSUMB	-18.8091* (6.2902)
N	34
Adj. R^2	.28
MSE	30.07

* denotes significance at the .10 level

Management Model

The management model includes those variables specified in the base model, as well as management variables. These variables provide indications on timing of irrigation start-up after planting, system shutdown based on rainfall expectations during the growing season, timing of irrigation shutdown before harvest, and ability to recall electricity expenditures. A dummy variable was used to denote whether or not the grower irrigated within 30 days of planting. If the growers wait at least 30 days before irrigation, then water consumption would expectedly be less than for those that began irrigation within 30 days of planting.

Information about expected rainfall was condensed into a single variable by first determining the range for the minimum expected rainfall for the grower to turn off the irrigation system. The range was found to be from 0.1 inches to 2.0 inches with some growers indicating they did not turn off their system based on rain expectations. This indicated rainfall amount was subtracted from 2.1, and indexed by the mean. Fields where growers did not turn off their irrigation were assigned a value of zero. Next, the number of hours prior to the expected rainfall that the grower would turn off his irrigation was indexed by the mean. The variable used in the model was then created by multiplying the two indexes together. The result provides an index that increases in value with grower sensitivity to expected rainfall. Consequently, a higher index value indicates that the grower is either more likely to turn system off based on a lower rainfall expectation, or more likely to turn system off sooner, or some combination of the two than a grower with a lower index number.

Irrigation shutdown was also measured as the days prior to harvest. Electricity expenditures could not be directly specified since most growers were not aware of this expenditure. Instead, a dummy variable was used to indicate whether the grower was familiar with the operation's electricity expenditure for water distribution. If yes, this is hypothesize to indicate that the grower is more sensitive to the costs of pumping water. This sensitivity would expectedly reduce the water consumption since the grower is sensitive to the associated costs.

The last 5 years of Benchmark Farm Program information were used in conjunction with the added management variables to improve the efficiency of the model estimates. Management variables are considered constant for this period. The Benchmark Farm Program data provide the needed planting date and water usage values for each of the five growing season. As a result of adding additional growing seasons, there were 145 usable observations for this portion of the analysis.

Inter-period variations in water requirements were accounted for by rainfall differences. Specifically, rainfall measurement for the month of March at the Hastings station was determined to explain water consumption differences between years. Rainfall information was gathered from the *Climatological Data Annual Summaries for Florida*. Higher rainfall would result in lower irrigation water use, provided the growers regulate water flow.

The management model can be expressed as:

$$SACI = \beta_0 + \beta_1 PLDATE + \beta_2 FLSUMA + \beta_3 FLSUMB + \beta_4 IRR30 + \beta_5 INDEX + \beta_6 FM7 + \beta_7 EEXP + \beta_8 RAIN + \epsilon$$

where IRR30 is 1 if irrigated during first 30 days after planting, 0 otherwise; INDEX is the product of the expected rainfall index and the pre-rainfall expectation shutdown index discussed earlier; FM7 is the number of days prior to harvest which the grower turns off the irrigation system; EEXP is 1 if the grower knew or could estimate expenditures for electricity, 0 otherwise; and RAIN is the inches of rainfall during March for the respective year.

Descriptive statistics for the model are shown in Table 7. About 35 percent of the fields were irrigated within 30 days of planting and the irrigation was turned off an average of 8 days before harvest. Over 59 percent of the respondents were able to recall or comfortably estimate electricity costs. Average March rainfall was 3.59 inches with a range of 1.64 to 6.86 inches.

Table 7: Descriptive Statistics for Water Use Management Model

Variable	N	Mean	Std Dev	Minimum	Maximum
SACI	145	13.6627586	6.5700126	1.92	36.69
FLSUMA	145	0.4942486	0.4863445	0	1.00
FLSUMB	145	0.4717308	0.4889611	0	1.00
INDEX	145	0.8458106	1.7837601	0	8.98
FM7	145	7.9586207	6.6623693	0	30.00
IRR30	145	0.3517241	0.4791635	0	1.00
MONEY	145	0.5931034	0.4929581	0	1.00
RAIN	145	3.5865517	1.7735657	1.64	6.86

Management Model Results

All coefficient estimates were statistically significant at the .10 level and the explanatory power, as measured by adjusted R^2, improved from .28 in the base model to .57 in the management model (table 8). Marginal effects for planting date and soil types decrease in magnitude from those estimates in the base model. A ten day delay in planting date increases the water requirement by one inch , while FLSUMA uses 9.96 inches less and FLSUMB uses 10.90 inches less than the FLSUMC grouping.

Irrigation within 30 days of planting resulted in 2.48 acre inches more than when irrigation did not begin until after 30 days. Sensitivity of system operation to rainfall expectations had a significantly negative effect on water used for the season. A 10 percent decrease in the minimum rainfall expectation or a 10 percent increase in time before expected rainfall for shutoff at the sample means would result in .04 acre inches (-.3806*.1) less water used for irrigation. At first glance, this effect may seem minor, but there is substantial variation in INDEX values. Using the minimum and maximum values reported in table 7 for the variable INDEX, the estimated coefficient shows that the grower with the highest value would use 3.4 acre inches less (-.3806*8.98) of irrigation water than growers with a zero INDEX value. Fields that are irrigated up to the day prior to harvest use 1.26 acre inches more than those that stop irrigation ten days prior to harvest.

Fields used 2.85 acre inches less of water when the operator could recall or comfortably estimate energy costs for pumping water which was consistent with expectations. One inch of rainfall in March reduces pump water used by 1.65 acre inches, indicating a more than proportional reduction in water demand.

In summary, these empirical results show that water demand is significantly impacted by planting date and soil characteristics. Planting date is determined by growing conditions and market expectations; thus, there is little information here that could be used to reduce water requirements. Similarly, it would not be plausible to sufficiently adjust soil characteristics to reduce water needs. With respect to the management practices, certain adaptations may be plausible. Irrigation start-up and shutdown timing have been shown to significantly impact water usage, but shutdown timing does have possible links to potato type and harvest planning. Growers who curtail irrigation due to rainfall expectations use less water; however, growers are reluctant to curtail irrigation due to risk concerns. It is apparent that as grower risk concerns are alleviated, water use will decrease. Further, sensitivity to pumping costs results in less water used for potato irrigation. Still, there would seem to be limited potential for substantially reducing water requirements for this irrigation system under the current environment.

Table 8 Regression Results (standard error) for Water Use Management Model

Variable	Coefficient Estimate
Intercept	25.8690* (3.045)
PLDATE	.0977* (.0240)
FLSUMA	-9.9593* (2.3999)
FLSUMB	-10.9011* (2.3907)
INDEX	-.3806* (.2276)
FM7	-.1258* (.0596)
IRR30	2.4792* (.8394)
EEXP	-2.8480* (.8425)
RAIN	-1.6495* (.2038)
N	145
Adj. R^2	.57
MSE	18.75

* denotes significance at the .10 level

CLOSING COMMENTS

The purpose of this study was to determine key factors that influence water usage among potato farms in Flagler, Putnam, and St. Johns counties. In doing so, information was collected from the potato growers using a questionnaire collected by personally interviewing a representative from each farm or farming operation. Data concerning the demographics of the potato growers, management practices, production practices, and site characteristics were collected and reported. This data was combined with information from the Benchmark Farm Program and soil characteristic information to create a database that could be used for empirical analysis.

Potato growers in North Florida use the same type of irrigation system. The sub-surface seep system raises the natural water table to facilitate capillary movement of water into the potato root system. For the most part, water is delivered to the field from a well through a closed pipe system. Water is delivered to furrows which are located 16 rows apart. A ditch is used at the other end to collect water that passes through the field. No overhead irrigation is used. Variations in water consumption are chiefly due to planting dates, soil type, rainfall, and irrigation practices. Costs of pumping water account for about 1 percent of total production costs. However, growers that are sensitive to this cost use significantly less water. Most management practices are based on growing conditions, market expectations, and yield assurance. As such, growers are more sensitive to plant condition than gallons of water pumped. Most growers do feel that their current irrigation system is efficient, when considering the need for yield assurance and product marketability. A majority of the growers do currently use risers to control water levels in their fields; regulate the water flow either at the well, the furrow, or both; use land leveling techniques; and have a closed pipeline water distribution system.

Since questionnaires were completed for 90 percent of all the farms or farming operations, the results from the questionnaire provide an accurate insight into the farming practices of the growers. The 34 observations used in the analysis accounts for over half of the growers who participate in the Benchmark Farm Program. Therefore, the results can be reasonably applied to the entire population of potato growers.

Limitations

There do exist some limitations to this research. First, many of the management practices studied are quite subjective. These practices are a result of extensive experience, but they are difficult to quantify satisfactorily. For instance, growers often irrigate based on soil "clumping" as opposed to a physical measure of moisture or water table level. Statistical significance is still valid, but the exact marginal effect measures are difficult to ascertain with a high level of confidence.

Another limitation was the number of fields used in the analysis. Previous research indicated that it would be necessary to use 55 of the 169 permits to be able to predict water usage within 20 percent of the actual amount used (Portier 1988). A permit can contain more than one well, but each Benchmark Farm site monitors only one well. Consequently, the 55 wells in the program do not represent the number of wells suggested by Portier; however, it would seem that the 55 Benchmark Farm sites do provide an adequate representation for management practice information, since there are only 69 potato operations.

Finally, there was some uncertainty and reluctance on the part of the respondents. Growers seemed uncertain as to the value to them for providing this information and some were reluctant to reveal practices that they felt were "trade secrets."

Conclusions and Recommendations

With the current environment, there is little motivation for growers to alter their irrigation practices, except for some relatively small savings in pumping costs. Growing conditions, market expectations, and yield assurance are the strong influences on farming practices, not the volume of water. Growers will be reluctant to change their practices unless assurances can be made that it would increase the profitability of the operation. Many growers expressed that these operations have been in the family for generations. They consider water use to be a right rather than a privilege. Growers would be willing to conserve more water only if it would be cost-effective and if they were assured of an equal or improved yield. As a business operation, these concerns and rationale are legitimate, at least in the short run.

Still, the objective of this research was to determine if there are current adjustments that could be made at the grower level which would result in a reduction of water use. The analysis identified several factors that significantly impact irrigation water consumption. First, earlier planting dates significantly reduce the water requirements for the potato growing season; however, planting date decisions are based on market forces rather than irrigation concerns. Thus, there is a low likelihood of altering when growers choose to plant. Second, the soil group FLSUMC was shown to use considerable more water than the other two soil types. However, FLSUMC represents only about 3 percent of the land in potato production. Third, growers who turn off their irrigation system due to rainfall expectations use significantly less water than those that do not turn off based on rainfall expectations. On average, growers who do turn off use .32 acre inches of water less than those who do not. The actual water savings are based on grower risk perceptions. If the growers risk concerns are too high, then education and assurances could raise the average conservation rate. Fourth, pre-harvest irrigation shutoff also will significantly reduce the amount of water demanded, but these decisions are often based on the type of potato (table or chipper) as opposed to water use concerns. Water consumption tends to be higher toward the end of the growing season due to size of plant and environmental conditions. Fifth, post-plant irrigation startup timing impacts water requirements. Growers who wait at least 30 days post-plant will use an estimated 2.5 acre inches less water than those that irrigate within 30 days. Horticultural research should suggest what the optimal timing would be to begin irrigation. Sixth, growers that are aware of the costs associated with pumping water to the fields use significantly less water than those who cannot readily estimate their pumping costs. On a relative basis, pumping costs represent a very minor portion of the overall production expenses, but the average grower still spends thousands of dollars on electricity to pump water. A growing awareness of the absolute rather than relative amount may provide some incentive for growers to conserve energy which would subsequently lead to diminished water use. Finally, the amount of rainfall during the growing season affects the amount of irrigation water needed, but there is little the District or the growers can do to alter natural rainfall. In summary, there are several factors that affect water usage. Changes in certain important characteristics (planting date and soil group) are not plausible. But, there does seem to be potential in certain management practices that could reduce water requirements. Adoption of these practices would require grower education and possibly additional research to raise awareness and/or confidence with respect to how these practices would benefit the grower.

Changes to the Benchmark Farm database would aid research in the future. The site-specific variables that had variation should be added to the collection procedures. These variables include the soil group, potato variety, field slope, furrow length, harvest dates, and rainfall data.

The water management district may also want to add more information concerning the irrigation system itself. This could include actual flow rates and the hours the irrigation system was used each month. Monthly operation calculations would enable projections within season as well. Yield information would help substantiate whether certain management practices were crucial to yield and yield assurance.

Future research should be focused on trying to develop irrigation methods that could improve the efficiency of water pumped for irrigation. Work is currently being conducted in Hastings by IFAS personnel, using sub-surface drip irrigation. Future research may also determine the feasibility of using other modifications to the irrigation system that could recharge the moisture levels more quickly. This would reduce the risk of turning off an irrigation system and the moisture level in the field dropping to a critical point. Growers expressed a higher confidence level , technically and economically, for moisture sensor use in the current irrigation system. Investigation into this area would also be warranted.

The St. Johns River Water Management District may also want to consider implementing some direct (i.e., subsidy) or indirect (i.e., longer duration permits) economic incentives for the growers to manage their water resources more efficiently. Economic incentives would cause the marginal cost of water to increase. The increase in the marginal cost of water would cause the optimal value of the marginal product to increase. If the growers use water as a risk-reducing input, the cost of using water to decrease the variability in output would increase. Growers would either have to accept more variability in their output or adopt new technologies that could reduce the variability of their output.

A collaborative effort between the St. Johns River Water Management District personnel, IFAS research personnel, and growers could be used to help the growers become better managers and producers. To aid in this collaborative effort, the water management district and the growers need to maintain a close working relationship.

Phase II

A Phase II was originally proposed as a potential follow-up to this research. The objectives would be to develop a management index based on scoring key management decisions points and production practices and integrate this index into the Benchmark Farm Program data. Phase II is not recommended at this time for a couple of reasons. First, the management practice information is highly subjective and would require periodic personal interviews. Secondly, subjective data collection is valid for determining which practices have significant impacts, but the marginal effect estimates are not strong tools for forecasting. Additional investigation will be done to determine if the measures can be more objectively determined, resulting in a more accurate index measure.

REFERENCES

Bajwa, Rajinder Singh. "Analysis of Irrigation Potential in the Southeast: Florida, A Special Report." United States Department of Agriculture, Economic Research Service, Natural Resource Economics Division, 1985.

Boggess, W. G., Amy Purvis, R. H. Stamps, Randy Motes, and Sue Ferenc. "Fernery Management for Groundwater Quality Protection: Leatherleaf Grower Survey." University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL, May 1991.

"Climatological Data Annual Summary: Florida 1990." National Climatic Data Center, Asheville, NC, 1991 94(13).

"Climatological Data Annual Summary: Florida 1991." National Climatic Data Center, Asheville, NC, 1992 95(13).

"Climatological Data Annual Summary: Florida 1992." National Climatic Data Center, Asheville, NC, 1993 96(13).

"Climatological Data Annual Summary: Florida 1993." National Climatic Data Center, Asheville, NC, 1994 97(13).

"Climatological Data Summary: Florida, February 1994." National Climatic Data Center, Asheville, NC, 1994(a) 98(2).

"Climatological Data Summary: Florida, March 1994." National Climatic Data Center, Asheville, NC, 1994(b) 98(3).

"Climatological Data Summary: Florida, April 1994." National Climatic Data Center, Asheville, NC, 1994(c) 98(4).

D'Almada, Philip J. *Agricultural Economic Impact from Water Restrictions in South Florida.* University of Florida, Department of Food and Resource Economics, 1984.

Dooley, Kevin. *QPL Reference Manual, Version 3.0.* United States General Accounting Office, Human Resources Division. United States Department of Commerce, Springfield, VA, September 1991.

"Florida Administrative Code 40C-2: The Permitting of Consumptive Uses of Water." Department of State, State of Florida Darby Printing, Atlanta, GA, Volume 14, February, 1995.

Florence, Bruce. "Annual Water Use Survey: 1992." Technical Publication SJ95-2, St. Johns River Water Management District, Palatka, FL, 1995.

Fox, R. L., J. T. Phelan, and W. D. Criddle. "Design of Subirrigation Systems." *Agricultural Engineering*, St. Joseph, Michigan, 1956 37(2):103-108.

Good, J. C., D. S. Harrison, and A. G. Smajstrla. "Performance of Irrigation Pumping Systems in Florida." Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL 1985.

Haman, D. Z., A. G. Smajstrla, and F. S. Zazueta. "Measuring Pump Capacity for Irrigation System Design." Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL 1994.

Harrison, D. S. "Irrigation in Florida Agriculture in the 80's." Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, Fl 1983.

Harrison, D. S. and A. G. Smajstrla. "Measurement of Soil Water Use for Irrigation Management." Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL 1982.

Harrison, D. S., A. G. Smajstrla, and F. S. Zazueta. "Irrigation Systems and Costs Estimates for Row Crop Production in Florida." Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL 1985.

Hensel, D. R. "Irrigation of Potatoes at Hastings, Florida." *Proceedings of Soil and Crop Science Society of Florida*, Florida, 1964 24:105-110.

Littell R. and K. Portier. "Statistical Analysis of Agricultural Water Consumption Data - Potato Crop Analysis." University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL, June 1994 (unpublished mimeograph).

Pitts, Donald and Allen Smajstrla. "Irrigation Systems for Crop Production in Florida: Descriptions and Costs." Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL 1989.

Portier, Ken. "Statistical Sample Survey Design for Estimation of Agricultural Water Use." University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL, October 1988.

Robison, L. J. and P. J. Barry. *The Competitive Firm's Response to Risk*. Macmillan Publishing Company, New York, New York, 1987.

"St. Johns River Water Management District: A Brief Overview." St. Johns River Water Management District, Palatka, FL, (no date).

SAS Institute Inc. *SAS® User's Guide: Statistics, Version 5 Edition*. Cary, NC: SAS Institute Inc. 1985.

Singleton, Vince. "Investigation of Potato Water Use in the Tri-County Area of Putnam, St. Johns, and Flagler Counties, Florida." Technical Publication SJ 90-13, St. Johns River Water Management District, Palatka, FL, 1990.

Smajstrla, Allen G. "Potential Evapotranspiration Probabilities and Distributions in Florida." Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL 1984.

Smajstrla, Allen G. "Basic Irrigation Scheduling in Florida." Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL 1988.

Smajstrla, Allen G. "Efficiencies of Florida Agricultural Irrigation Systems." Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL 1991.

Smajstrla, Allen G. "Florida Irrigation Systems." Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL 1992(a).

Smajstrla, Allen G. "Irrigated Acreage in Florida" Florida Cooperative Extension Service, University of Florida, Institute of Food and Agricultural Sciences, Gainesville, FL 1992(b).

Smith, Scott and Timothy Taylor. "Production Cost for Selected Vegetables in Florida, 1993-94." University of Florida, Institute of Food and Agricultural Sciences. Circular 1146 (no date).

Soil Survey of St. Johns County, Florida. United States Department of Agriculture, Soil Conservation Service. October 1983.

State Soil Geographic Data Base (STATSGO): Data Users Guide. United States Department of Agriculture, Soil Conservation Service, Miscellaneous Publication 1492, August 1991.

"Vegetable Summary 1992-1993." Florida Department of Agriculture and Consumer Services, Florida Agricultural Statistics Service, Orlando, FL, April 1994.

"Vegetable Summary 1993-1994." Florida Department of Agriculture and Consumer Services, Florida Agricultural Statistics Service, Orlando, FL, (to be published in late spring 1995).

Vergara, Barbara. "Water Supply Needs and Sources Assessment 1994." Technical Publication SJ94-7, St. Johns River Water Management District, Palatka, FL, 1994.