5. Project description

(a) Introduction

Background

Water resources in southern Florida face unique challenges because of the region's complex hydrologic system which is a consequence of both natural and man-made influences. The routing of water in south Florida has been altered from natural pathways by canals, levees, and other structures to provide flood protection and increased dry acreage for development. Even with man-made drainage structures in place, south Florida still maintains a relatively high water table. This water table has close interaction with surface waters because of their separation by limestone bedrock which is characterized by high infiltration rates. Protection of the surficial aquifer (or groundwater) is essential for Miami-Dade County because of the public's dependence on it for protection of ecological treasures [e.g., Everglades National Park (ENP) and Biscayne National Park (BNP)], drinking water, and agricultural irrigation water. Hence, numerous studies have been conducted [e.g., Comprehensive Everglades Restoration Plan, Combined Structural and Operational Project, Water Management Issues Affecting the C-111 Basin, Dade County, Florida: Hydrologic Sciences Task Force Initial Assessment Report (Graham et al., 1997)] in southern Florida that address such water resource issues as restoring the hydroperiod to the ENP, salt water intrusion, and flooding.

Although water quantity and delivery concerns have been historically prevalent in Miami-Dade County, water quality is becoming an equally important issue (SFWMD, 2003). Local governments have been encouraged to analyze, design, and remedy storm water problems and have been encouraged to incorporate runoff treatment and source control needs into their long-term planning efforts. For some waters, government entities have even proposed water quality targets. One such standard is for phosphorus (P), which is often a limiting nutrient in aquatic ecosystems. A target of 10 ppb P has been adopted for surface waters entering ENP (Florida Senate Bill 0626ER, 2003). Although this is a very low P concentration, minimal perturbations in aquatic nutrient concentrations are of concern because of their ability to substantially alter an aquatic ecosystem. For example, excessive nutrients often shift trophic levels, thereby influencing the community structure of an ecosystem (Rosemond et al., 1993; Biggs et al., 2000). The sensitivity of aquatic ecosystems to P has resulted in the focus of many resources on P abatement, particularly through identification of P sources and transport pathways.

One activity often identified as contributing to P loads in a watershed is agriculture. This is because of agriculture's reliance on fertilizers [nitrogen (N), P, and potassium (K)] to ensure plant growth and yield, and hence continual application of fertilizer on agricultural crops. Nutrients (or fertilizers) that are applied in excess and/or are not readily assimilated by plants often move through the soil profile and into the groundwater by leaching (Hanson and Trout, 2001). Although agricultural nutrient leaching is a concern, many postulate that agriculture still provides the best land use alternative for the ecologically sensitive areas of southern Florida (Schaffer, 1998). This is because the alternatives to agriculture land use, which are urban development and fallow land, impart their own environmental concerns. Urban areas present problems such as heat sinks, noise pollution, and chemical pollution from runoff. Fallow farmland is generally invaded by exotic weed species that threaten the native habitat (which has occurred in areas adjacent to the ENP). Urban planners and land managers in Miami-Dade County and project managers at the South Florida Water Management District realized the critical role of maintaining viable agriculture for restoring the Everglades. Thus in 1998, Miami-Dade County and the South Florida Water Management District jointly funded the Miami-Dade Agricultural Land Retention Study aimed at identifying economic and land use planning strategies to keep agriculture in the area feasible. A critical finding of the report was that best management practices (BMPs) for agriculture must be developed to reduce the potential for agrochemical leaching into the groundwater and potential agrochemical pollution of the adjacent natural areas (Degner et al., 2001). Hence, for agriculture to remain an integral part of the system, environmental as well as economic sustainability will be central. This entails developing and helping farmers adopt economic and environmentally viable production systems and new precision technologies, such as BMPs. Without agriculture in this watershed, water and ecological resources will likely face even greater environmental consequences.

Because of the need to develop innovative BMPs that mitigate nutrient leaching from agricultural land, we have previously coordinated with different agricultural groups to facilitate implementation and education related to BMPs in the Biscayne Bay watershed of southern Florida [e.g., water management (Al-Yahyai et al., 2003; Li et al., 2000a; Muñoz-Carpena et al., 2003a; 2003b; 2003c; Nuñez-Elisea et al., 2001; Zekri et al., 1999] and nutrient management (Li et al., 1999b; Crane and Schaffer, 2001). Results from previous stakeholder surveys and research suggested that incorporation of additional irrigation BMPs and nutrient BMPs would benefit the Biscayne Bay watershed by reducing water usage and optimizing fertilizer benefits for agricultural production (Li et al., 1999b; Muñoz-Carpena et al., 2003b). In response to this, recent studies at University of Florida-Tropical Research and Education Center (UF-TREC) have targeted different agriculture commodities within the watershed for development of BMPs.

A precision irrigation research project, conducted at UF-TREC by Drs. Klassen, Li, and Muñoz-Carpena, used automated feedback control from soil moisture sensors to irrigate tomatoes. This study consisted of multiple irrigation treatments including: traditional farmer scheduling (calendar based), historical evapotransporation, and irrigation based on multiple soil moisture tensions. Fertilizer treatments were included in this, and lysimeters were installed to capture water and nutrient moving through the soil profile. This combination of nutrient and irrigation BMPs indicated that the precision irrigation and fertigation system used less irrigation water and fertilizer and reduced nutrient leaching than traditional irrigation and fertilization practices in the area.

A similar project was conducted at UF-TREC by Drs. Crane and Schaffer using soil moisture monitoring and irrigation management for carambola trees. In the carambola study, irrigation was initiated when soil water depletion (SWD) was estimated (using multi-sensor capacitance probes) to be 0 to 8%, 9 to 11%, 12 to 14%, and 15 to 17%. No significant differences in shoot flushing, extension shoot growth, flowering, fruit yield or fruit quality occurred between treatments. In that study, trees in the lowest SWD treatment (15 to 16% SWD between irrigation events) were irrigated for a total of 10 hrs per year with 890 L (235 gal) of water per tree year applied (Al-Yahyai and Schaffer, unpublished data). This is in stark contrast to commercial carambola growers' practices of irrigating from 3 to 6 times per week and applying as much 908 to 2,226 L (240 to 588 gal) per tree per week (J.H. Crane personal observations). Thus, a tremendous potential exists for reducing nutrient leaching from the soil surface into the aquifer. Also, growers using traditional calendar-based irrigation scheduling often allowed their irrigation systems to run regardless of rainfall events, underscoring the need for soil moisture based irrigation scheduling in south Florida orchards.

In addition to tomatoes and carambola, a papaya soil moisture based irrigation project was recently initiated by Dr. Fred Davies at the University of Florida in Gainesville and by Drs. Crane, Muñoz-Carpena, Schaffer, and White at UF-TREC. The project consists of 5 treatments: traditional farmer irrigation scheduling (calendar based), historic ET based irrigation, and soil water tension at 10 cbars, 15 cbars, and 25 cbars. The anticipated outcome of this 3-year project is that the amount of water applied can be substantially reduced without negatively impacting fruit yield or fruit quality.

As well as precision irrigation BMPs, precision fertilization BMPs have been investigated by UF-TREC faculty. Fertilization of agricultural soil is often performed with little information on the actually quantity needed by the plants. One BMP suggested for assessing the plant nutrient needs and more precise application of fertilizers is soil and plant tissue sampling. This consists of taking a soil and plant sample, analyzing it for nutrient content, assessing plant needs, and applying fertilizer based on plant needs and soil limitations. Soil sampling based methods for determining fertilizer needs minimizes the use of nutrients in excess, thereby reducing nutrients available for leaching into groundwater during infiltration of rainfall or irrigation waters. Nutrient leaching studies have been integrated into irrigation research at UF-TREC in efforts to understand nutrient transport. Nutrient leaching from soils has been evaluated using different methods. One method often employed is to install and monitor lysimeters. Lysimeters placed in the root zone collect water moving through the soil profile. The lysimeter samples are then analyzed for constituents (Li et al., 2002). Another mechanism for monitoring nutrient transport is monitoring wells. Standard monitoring wells (5 m deep) were used in two water quality research projects at UF-TREC. Bi-weekly water quality sampling from crop fields (i.e., tomato, corn) showed nutrient leaching into groundwater during raining summer and early crop season (Munoz-Carpena and Li, 2004). Previous data collected from groundwater monitoring wells in avocado, lime, and carambola orchards and tomato, squash, and bean fields indicated that there was significant leaching of nitrates into the groundwater at certain times of the year from vegetable fields and occasional leaching from lime orchards. The amount and timing of leaching varied considerably among crops and among different plantings of each crop indicating that agricultural management in the area is closely coupled with groundwater leaching of nutrients (Schaffer et al., 2001).

Results from previous research on precision irrigation and fertilization indicated that nutrient leaching from agriculture in the Biscayne Bay watershed could be reduced by expanding these BMPs to a target audience. A target audience of high-return stakeholders is essential because of the limited resources available for BMP development and implementation. High-return agricultural producers are producers that (1) have longevity in the watershed, (2) are interested in development, implementation, and continued use of BMPs, and (3) currently use irrigation and fertilizer practices that could be improved to reduce nutrient leaching. Fruit orchards were selected as one of the high-return agricultural commodities in the watershed for implementing BMPs because of the longevity of orchards as a crop in the watershed and because of the current irrigation practices found in fruit orchards. Co-PIs, Drs. Crane, Li, and Schaffer, have both reported excessive irrigation as common in local fruit orchards. Nearly 75% of all orchards in Miami-Dade County are irrigated and almost all growers base irrigation rates and frequency on experience and observation of crop growth and yield rather than on quantitative scientific information. This suggests that irrigation and fertilizer rates may be excessive and could, thus, lead to leaching of nutrients into the groundwater. Current research indicates that by implementing a BMP that provides a test for when irrigation occurs on fruit orchards, lower nutrients loads will enter groundwater and water quality will improve. Landscape nurseries were also selected as a high-return agricultural commodity within the watershed for implementing BMPs. Landscape nurseries were identified because of their economic viability which has resulted in rapid expansion in south Florida. In addition, landscape plants are very high input plants that are grown with excessive nutrients and few, if any, BMPs are used in growing landscape plants. The influence landscape nurseries have on water quality in south Florida is unknown. Hence, monitoring of nutrient leaching from such nurseries is paramount to protecting groundwater water quality. Implementation and evaluation of BMPs in landscape nurseries that reduce nutrient leaching will assist in protecting water quality in the watershed. Soil moisture based irrigation has been identified as a BMP that will result in more precise application of irrigation and therefore less nutrient leaching in commercial nurseries (Newman et al., 1991).

Our proposed project will expand previous and on-going research efforts to improve water quality of the Biscayne Bay watershed (Figure 1) by increasing water-use and nutrient efficiencies thereby reducing the potential leaching of nutrients into the groundwater. In addition, our proposal targets high-return stakeholders so that the most economical and environmental viable BMPs are evaluated.

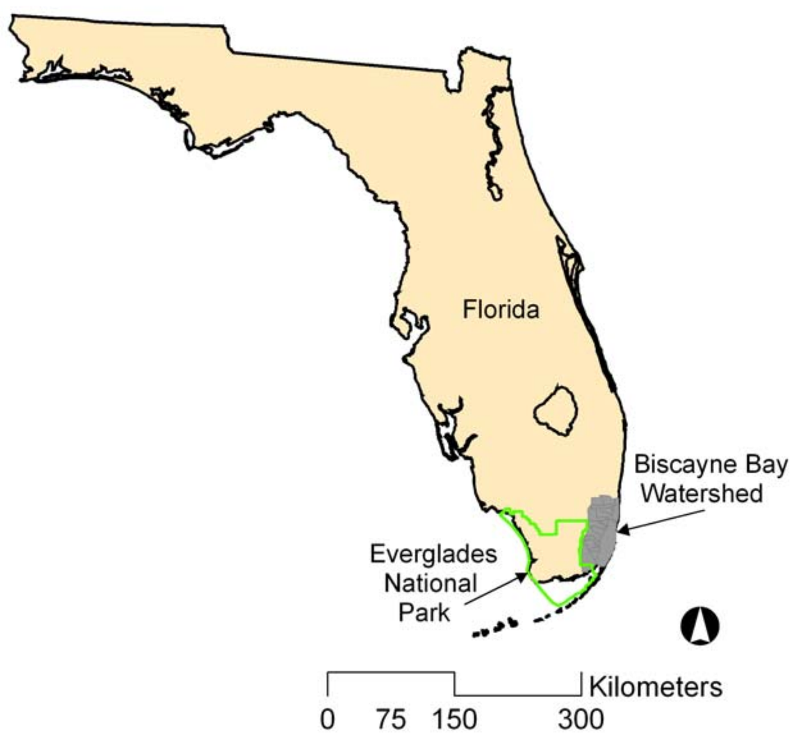

Figure 1: Biscayne Bay Watershed in southern Florida

Our results will expand the understanding of nutrient transport from high-return stakeholders (fruit orchards and landscape nurseries) in the Biscayne Bay watershed and how different BMPs reduce the movement of these nutrients into the groundwater. This project will provide funding for additional development and implementation of practices on stakeholder land, extended outreach and education, and development of guidelines for integrated BMPs into the watershed. Our project is consistent with restoration objectives for Everglades National Park and Florida Bay as described by the Florida State Legislature in the Everglades Forever Act, Section 373.4593 (2), F.S., and complements the C-111/South Dade County Project Modifications. In addition, this project will coordinate with efforts being made by UF-TREC, County Extension, and Florida state agencies to develop a BMP manual specific to southern Florida agriculture. Drs. Crane, Edwards, Li, Schaffer, and White have been selected to participate in the development of this BMP manual and BMP efforts from this project will substantially enhance the BMP manual produced. Information from other projects [C-111 Spreader Canal project (South Florida Water Management District (SFWMD)), Frog Pond (UF-TREC and Miami-Dade County Soil and Water Conservation District), South Florida Initiative – Water Quality Research (UF-TREC), Developing Management Practices to Prevent or Reduce Flooding Damage in Vegetable Crops (UF-TREC and SFWMD); Historical Changes in Salinity, Water Quality, and Vegetation in Biscayne Bay (USGS)] will assist our efforts in conducting this research, education, and extension project.

The UF-TREC researchers have a long-standing working relationship with Biscayne Bay watershed stakeholders that will facilitate implementation of the goals laid out in the proposal. All agricultural stakeholders will be involved in all aspects of this project which will include implementation of BMPs on stakeholder lands, demonstration/field days, computer training, Internet postings, an interactive web board, and economic analysis for stakeholders implementing practices (see Long Term Goals). The multi-disciplinary team of scientists at UF-TREC provides a unique group of expertise (Agricultural and Biological Engineering, Food and Resource Economics, Horticultural Sciences, and Soil and Water Sciences) in research and extension. Recent research and outreach projects with stakeholders include: Field demonstrations and evaluation of citrus tristeza tolerant rootstocks suitable for 'Tahiti' lime and calcareous soils (Dr. Crane); Precision irrigation: quantified soil moisture-based irrigation control system for vegetable production (Dr. Muñoz-Carpena et al., funded by a USDA Sustainable Agriculture Grant); Irrigation and fertilization optimization project to extend best management practices to the South Dade Basin (Dr. Schaffer, funded by U.S. EPA 319 grant, the South Florida Water Management District and the Florida Department of Agriculture and Consumer Services); Optimizing BMPs, water quality, and sustained agriculture in the Lincoln Lake Watershed (Dr. White, funded by EPA 319/Arkansas Soil and Water Conservation Commission); Conducting economic analyses of technologies generated as well as on-farm economic assessment of conservation practices (Dr. Evans). In addition, members of the research team are familiar with GIS technology which provides the ability to build databases, perform mathematical functions, modify data through programming, and develop detailed maps of information contained in or derived from the databases. GIS tools have been used extensively to estimate various environmental concerns because of their spatial capacity and application flexibility (Lee et al., 2003; Hughes et al., 2004; Paz, et al., 2004).

The range of expertise, mission of the research and education center ("…to develop information and technology to increase efficiency of vegetable, tropical fruit and ornamental plant production; develop sustainable practices for south Florida with minimal negative environmental impact; disseminate this information through publications and the Cooperative Extension Service; develop the abilities of graduate students to conduct scientific research investigations and to function effectively as successful members of the scientific community…"), and the established relationship between stakeholders and UF-TREC makes it a unique institution in south Florida and provides a very productive venue for research, education, and extension involving agricultural stakeholders.

Study area

Agriculture in the Biscayne Bay watershed (Figure 2) comprises 11 percent of the area. Other major land uses are urban (36%), water (27%), and wetlands (21%). A survey conducted in 2000-2001 provided a more detailed database of agricultural land use including vegetable fields, fruit orchards, and landscape and ornamental plant nurseries (Minkowski and Schaffer, 2002; Figure 3). Orchards were divided into 16 sub-categories based on fruit crop species planted. Boundaries for the Biscayne Bay watershed are a result of anthropomorphic landscape modifications (canals, levees, structures, etc.) and natural landscape characteristics. Annual average precipitation is ~140 cm with the majority occurring between May and October.

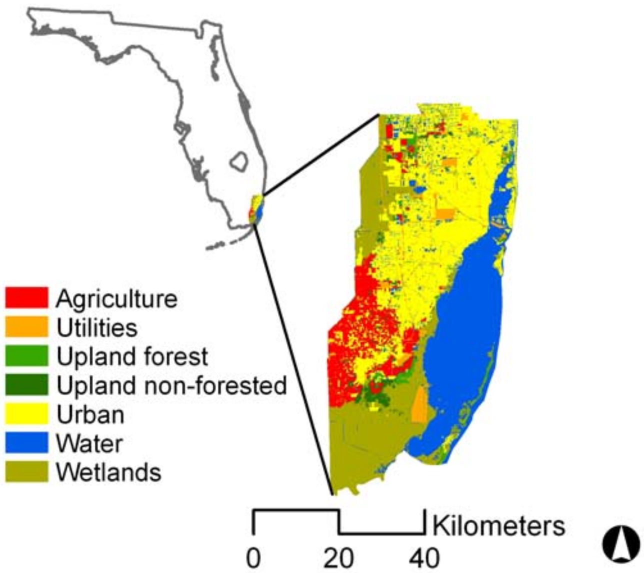

Figure 2: Outline of Biscayne Bay watershed with 1999 land use (SFWMD, 2005).

Two dominant soil types are present in the watershed: a very gravelly loam soil and a marl soil. The gravelly soil is Krome, very gravelly loam. It is classified as a loamy skeletal-carbanatic, hyperthermic, Lithic Udorthents (Nobel et al., 1996) with an alkaline pH of 7.4 to 8.4, a very gravelly texture (34 to 76% limestone fragments), low water holding capacity (0.08 to 0.12 cm cm^{-1} of soil), rapid permeability (1.5 to 5.1 cm hr^{-1}), and low cation exchange capacity (16 to 37 $cmol_c$ kg^{-1} soil). Biscayne marl is a typical marl in the basin. It is described by an alkaline pH of 7.4 to 8.4, a low water holding capacity (0.15 to 0.20%), and rapid permeability (1.5 to 15 cm hr^{-1}) (Li and Klassen, 2001).

Agriculture in Miami-Dade County not only serves as a buffer between protected lands (e.g., ENP), but also is a significant contributor to the economy of the state of Florida. Miami-Dade County is often referred to as the nation's "Salad Bowl" and "Winter Bread Basket" because of its long history of vegetable production in the winter months for exports to the northern areas of the country. In 2002, the market value of agriculture production in the area was estimated at $578 million. The agricultural industry in Miami-Dade County employs over 15,000 people and has a one billion dollar impact on the state's economy (Degner et al., 2001). The primary agricultural commodities in Miami-Dade County can be broken into three groups: vegetable, fruit, and ornamental nurseries. It is speculated that future agriculture in the Biscayne Bay Watershed of Miami-Dade County will be dominated by fruit orchards and landscape nurseries (Degner et al., 2001).

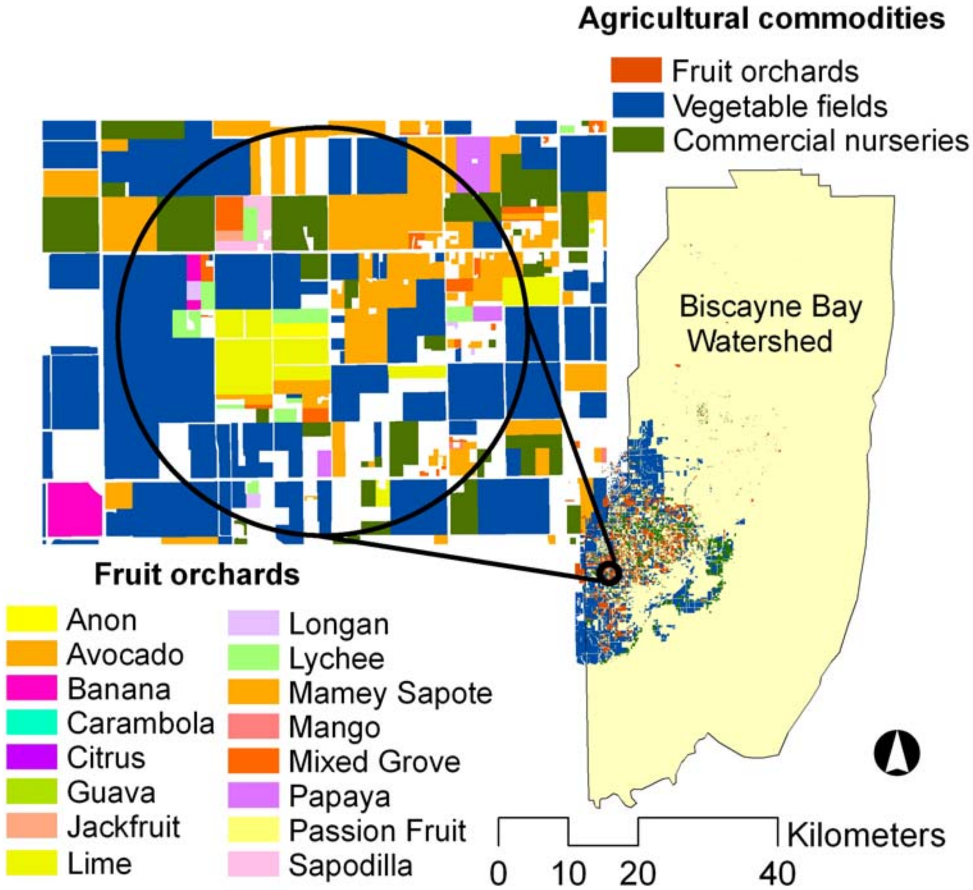

Figure 3: Agriculture types identified in a 2000-2001 study (Minkowski and Schaffer, 2002)

b) Objectives

The long-term goal of this proposed project and its respective objectives address three of the CSREES identified topical themes for NIWQPs: nutrient management, watershed management, and water conservation and agricultural water management. These themes are integrated throughout our objectives and are described as follows:

The long-term goal of this project is to improve water quality in ENP and Biscayne Bay Watershed by reducing agricultural nutrient leaching into groundwater through use of precision irrigation and precision fertilization BMPs. Two high-return agricultural groups will be target for implementing irrigation and fertilization BMPs because of their influence on current and future water quality.

Objective 1*) Develop, support, and market economically viable BMPs* *to high-return agricultural stakeholders that address regional water resource degradation as a result of over irrigation and nutrient leaching.* BMPs that will be developed and installed include: (1) a soil moisture based irrigation system for a fruit orchards that will be compared with traditional irrigation systems; (2) incorporation of soil sampling and leaf tissue sampling of fruit orchards to determine fertilizer needs which will be compared with traditional fertilization schemes; (3) a soil moisture based irrigation system with soil sampling and leaf tissue sampling to determine fertilizer needs for fruit crops which will be compared with traditional irrigation and fertilizer methods; (4) a soil moisture based irrigation system in a landscape nursery that will be compared with traditional irrigation systems; (5) incorporation of soil sampling of landscape nursery block to determine fertilizer needs compared with traditional fertilization schemes; and (6) a soil moisture based irrigation system with soil sampling to determine fertilizer needs for a landscape nursery plants which will be compared with traditional irrigation and fertilizer methods. Each BMP will be monitored for water usage, nutrient leaching, plant tissue nutrients, plant growth characteristics, and other relevant parameters (see methods). Develop and use GIS maps that characterize current land use, irrigation, and fertilizer practices spatially, within the agricultural watershed. GIS will also be used to predict current nutrient leaching and potential nutrient leaching if BMPs are kept in place for Biscayne Bay watershed.

Objective 2) *Conduct* ***self-auditing feed back loops*** *to evaluate stakeholder opinion change.* This will consist of two surveys. Initial (or baseline) survey: Conduct a baseline survey to initiate dialogues among all groups participating in the project and to determine the stakeholder familiarity with conservation technologies in irrigation and fertilizer and stakeholder opinion of implementing such technologies. Final (or follow-up) survey: At the end of the project a follow-up survey will be conducted to gauge the relative success of the project in terms of the number of farmers who have or are willing to adopt the practices.

Objective 3) *Provide agriculture stakeholders with information regarding water resources and sustainable agriculture using* ***field days, demonstrations, fact sheets, web postings, and interactive websites.*** Conduct at least 3 field days and demonstrations, develop at least 4 fact sheets, and post project information on the web related to BMPs addressing water quality and water quantity issues. Develop and host an interactive website where people can post questions, concerns, or other information related to sustainable agriculture and conservation techniques. Conduct a computer training session that targets agricultural producers in the area that includes Internet basics, emailing, and navigation through Extension and other relevant websites with information about agricultural BMPs and water issues in southern Florida.

Objective 4) *Develop* ***an economically based, watershed management plan*** *that is a working document for the agricultural watershed to protect water quality and sustain agricultural production.* Perform economic analysis on each conservation method compared to the traditional irrigation and/or fertilizer methods determining the profitability of the proposed BMPs and the conditions under which the farmers would switch to the recommended practices. Compose a management plan using the economic analysis and the GIS maps to provide agricultural producers with a guide to BMPs and their viability in this agricultural watershed.

Objective 5) *Develop a* ***guide for Extension, research, and other applicable groups*** *to use in stakeholder projects that involve integrating new or innovative BMPs into a watershed to protect water resources.* Write a document based on information collected in this project that will provide guidance to others performing similar projects in the future.

From these objectives, the following hypotheses will be tested:

Hypothesis 1
Implementation of soil moisture based irrigation systems will result in significantly lower water volume usage than traditional irrigation methods without negatively impacting agricultural productivity (crop growth, yield, or fruit quality). This will be tested in fruit orchards (avocado and carambola) and landscape nurseries.

Hypothesis 2
Implementation of soil moisture based irrigation and soil and leaf tissue sampling based fertilization will result in significantly lower nutrient leaching in fruit orchards; thereby significantly reducing agrichemical contaminant entering into the south Biscayne Bay watershed and improving water quality. This will be tested in fruit orchards (papaya and lychee) and landscape nurseries.

Hypothesis 3
Implementation of the above BMPs will generate substantial cost savings in the form of reduced quantities of fertilizer used and are profitable over the life of the investment.

(c) Methods

Objective 1) *Develop, support, and market economically viable BMPs.*

General BMP design. BMPs will be developed at UF-TREC and installed in fruit orchards and landscape nurseries at designated stakeholder locations. The BMPs to be used are (1) soil moisture based irrigation scheduling, (2) soil and plant tissue sampling based fertilizer application rates, and (3) a combination of soil moisture based irrigation scheduling and soil and plant tissue sampling based fertilizer applications. Treatments (described below) in orchards and nurseries will consist of 4 single-row replications with a minimum of 4-6 trees (or plants) per row in a completely randomized design. The BMPs will be monitored for a minimum of 2 years.

Measured variables as a function of time will include irrigation frequency, duration and timing; the amount of water applied; nutrient leaching (NO_3, NH_4, PO_4, and total P); weather parameters; fertilizer composition and load; soil water content; soil nutrient composition (N, P, and K); plant growth; fruit yield and quality (in fruit orchards); plant tissue nutrient concentrations (N, P, and K); and production and maintenance costs. Results will be analyzed for significant differences in cash investment, water volume used, amount of applied fertilizer, plant growth, fruit production, and fruit quality among treatment groups.

All information collected will be documented in a field book onsite. This information will also be stored electronically at UF-TREC. Electronic data will be backed up at an additional location to prevent loss of information. Our team will supervise the installation and implementation of treatments and agricultural data collection to ensure the integrity of the experiment.

Soil moisture based irrigation treatments. Soil moisture based irrigation systems will be constructed to periodically measure soil moisture (by a sensor) and initiate or bypass irrigation based on the soil water tension. Treatments in each orchard and landscape nursery will be: (C; control): calendar-based, typical grower applications rates and timing based on surveys of growers, (F1; feedback 1) soil moisture mediated irrigation programmed to keep irrigation valves off unless soil water tension falls below 10 cbars and (F2; feedback 2) the same as F1 but set to irrigate if soil water tension falls below 20 cbar). Soil water tensions of 10 and 20 cbars have been chosen based on water savings from previous irrigation experiments at UF-TREC.

The sensors selected for soil moisture based irrigation treatments will be placed in the soil in each treatment row (i.e., one sensor per treatment row). Communication between the sensors and solenoids and irrigation valves will be administered by an irrigation control box and appropriate wiring. An appropriate sensor has already been identified and has been tested for this use by two of the Co-PIs of this project (Drs. Li and Muñoz-Carpena) (Muñoz-Carpena, 2004; Muñoz-Carpena and Dukes, 2004; Muñoz-Carpena et al., 2005). For the soil-moisture feedback initiated treatments, the irrigation system will be pressurized on a set time for both soil moisture feedback treatments, but the valves in each row will only open if soil water tensions fall below the preset values.

<u>Soil sampling and leaf tissue based fertilization.</u> The soil sampling and plant tissue based fertilization BMP will consist of determining nutrient concentrations in collected samples and determining the nutrient needs of the plant-soil system. Soil and plant tissue samples will be collected and transported to Soil Chemistry/Plant Nutrition laboratory, UF-TREC. Soil samples will be analyzed for Organic C, total N, and P at UF-TREC. Total carbon and nitrogen will be analyzed using a CNS analyzer. Inorganic carbon will be measured according to the titration method. Organic carbon will be calculated based on the differences between total carbon and inorganic carbon. Soils will be extracted with 2 M KCl and analyzed for NH_4 and NO_3 using an Auto-analyzer. Soils will be digested with EPA3050 method and analyze for total P. Plant samples will be analyzed for Total C and N using a CNS analyzer. Plant P will be analyzed using EPA3050 method. The soil samples will be logged in immediately on receipt. Soil and plant samples will be collected three times each year from tropical fruit orchards during growth, flowering, and fruiting stages. For landscape nurseries, soil samples will be taken from each block at initial planting and every time growers would traditionally apply fertilizer for the particular plant.

Treatments in each orchard and landscape nursery will be: (C; control): calendar-based, typical grower fertilizer applications rates and timing based on surveys of growers, (F1; feedback 1) soil sample and plant tissue sample based fertilizer application with 3 samplings annually (F2; feedback 2) soil sample and plant tissue sample based fertilizer application using results from 1 sampling annually).

<u>Measuring water use.</u> Each replication within each treatment will be outfitted with water meters and flow meters to record water use. The water meters will provide the total volume of flow. The flow meters will record the flow rate passing through the water line as a function of time. Total water use will be calculated for each plot.

<u>Measuring nutrient leaching.</u> In addition to irrigation and fertilizer practices, all experimental plots (within each treatment and rep) will be outfitted with zero-tension lysimeters to measure nutrient leaching. Lysimeters will be placed below the root zone and will be collected monthly and analyzed for pH, EC, Total P, Ortho-P, TKN, NH_4, and NO_3. The water samples will be collected into cleaned and labeled 500 ml bottles and the date of sampling will be noted on the labels. The samples will be transported to the Soil Chemistry/Plant Nutrition laboratory, UF-

TREC. Water pH will be determined using a pH meter (Orion 501, Orion Research Incorporated, Boston, MA) and EC will be measured using a conductivity meter (Accumet Model 30, Denver Instrument Company, Arvada, CO). Total P, Ortho-P and NH_4 and NO_3 will be analyzed using an Autoanalyzer (AA3, Bran+Luebbe, Buffalo Grove, IL).

Measuring weather parameters. Temperature, precipitation, and relative humidity will be automatically recorded (at minimum) on an hourly time step at all locations were BMPs are being implemented. Weather parameters will be measured and recorded using appropriate sensors and gauges that are placed so that they represent the average conditions experienced by the study plots. A HOBO data logger and HOBO sensors will be purchased for each site that monitors and records temperature, precipitation, and relative humidity (HOBO weather station rain gauge smart sensor tipping bucket and HOBO weather station temperature/RH smart sensor or comparable equipment).

Fertilizer composition & load. Fertilizer rates and composition will be identified. Fertilizer rates and composition for all replications and treatments will be documented.

Measuring fruit yields and plant growth in fruit orchards and landscape nurseries. In orchards, fruit counts from all trees in each replication will be made and where practical fruit will be harvested when mature, counted and weighed. Fruit quality will be determined by measuring the total soluble solid content in a subset of fruit from each replication with a refractometer. In fruit orchards and landscape nurseries, plant growth will be determined by measuring the basal stem diameter 4 cm above the soil surface with a caliper and measuring plant height.

Stakeholder participation. Four stakeholders have indicated interest in this study and have committed to participating by allowing us to install one or more BMP(s) on their orchard or commercial nursery (e.g., soil moisture based irrigation, soil sampling and plant tissue based fertilization, and/or a combination of both).

GIS maps. GIS layers that are available for the Biscayne Bay Watershed will be collected from appropriate agencies and organizations (e.g., SFWMD, USDA-NRCS, US Geological Survey). In addition, a previous study at UF-TREC resulted in detailed 2000-2001 agriculture land use maps for the watershed. An updated land use map will be created by conducting a windshield survey with appropriate GPS equipment and ArcGIS ESRI software. The two maps will be used to assess land use change in the basin over the last 5 years, providing information on land use trends in the basin. The resulting maps will be projected in NAD83 State Plane Florida East. Relevant maps will be available on the interactive website and included in the management plan.

In addition, GIS methods will be used to predict current agricultural contributions to nutrient loads leaving the basin (Elrashidi, et al., 2004) and to predict expected reductions if the irrigation and fertilizer management practices described above in this proposal were implemented throughout the basin. We selected GIS because of the importance of capturing the spatial location and variability of the basin.

Objective 2) *Self auditing feed back loops.*

Surveys. An initial survey of stakeholders regarding opinions of the BMPs outlined in this proposal will be conducted. The survey will be used to gain insight into stakeholder opinion on implementing water quantity and quality management practices. Surveys have previously been conducted by Co-PIs (Drs. Crane, Li, and Muñoz-Carpena) in this basin (Li et al., 1999a; Li et al., 2000a; Muñoz-Carpena et al., 2003a; Muñoz-Carpena et al., 2003b; Muñoz-Carpena et al., 2003c) on water quantity but not water quality issues. Stakeholders will be identified using the Miami-Dade County/IFAS Cooperative Extension/IFAS Cooperative Extension Service and growers' organizations in Miami-Dade County which have been successful in the past selecting stakeholders to be surveyed. The initial survey instrument will contain questions on the familiarity of stakeholders with specific water quality and quantity BMPs, their opinion of its implementation on their farms, and their suggestions for improving water quality and water quantity other than those we propose. Based on previous surveys in this basin, fruit producers will likely return ~42% of surveys and ornamental nurseries will likely return ~21% (Muñoz-Carpena et al., 2003b). This is an acceptable return rate considering that typically surveys return rates vary between 10 and 50% (Donan et al., 2000). The surveys will provide a tool for evaluating the extension and education activities. A final survey will be conducted at the end of the project to identify changes in stakeholder opinions regarding BMPs and knowledge gained about the role of agricultural BMP in maintaining water quality in the watershed.

Objective 3) *Field days, demonstrations, fact sheets, web postings, and interactive web board.*

Field/demonstration days. Once the BMPs have been installed, field/demonstration days will be organized to visit the different farms. These events will be advertised through web postings, newspaper announcements, email, and other Extension based routes. Similar activities have been organized by our project group (Drs. Crane, Li, Muñoz-Carpena, and White) to sponsor various events that introduced agricultural stakeholders to new technologies in the agricultural and water quality area. Our field/demonstration days will be coordinated with our collaborators at the Miami-Dade County/IFAS Cooperative Extension Service. Field/demonstration days will be held during the project to introduce the conservation technology to stakeholders. In addition, issues of water conservation and water quality will be discussed. Fact sheets will be prepared throughout the project on the BMPs. These fact sheets will be posted on the website, posted on Electronic Data Information Source of UF/IFAS Extension (EDIS; http://edis.ifas.ufl.edu/), circulated during field/demonstration days, and circulated at relevant Extension and community meetings.

Interactive website. Development of a website with a Web log (BLOG) interactive board will begin at the start of the project. A qualified computer technician will design the website with interactive BLOG which will be accessed through the UF-TREC website. Registration and sign on will be requested of all users to evaluate the use of the web board and website. Information relative to this proposed project and relative to agricultural producers in the watershed will be included on the site. As the project progresses, new information will be added as fact sheets. Hosting of the interactive portion will continue throughout the project and past the project end (as long as it is useful). Postings sent to the website will be reviewed initially by a mechanical filter followed by a qualified technician. Postings that request a response from UF-TREC experts will be responded to in a timely manner. All postings and responses will be available for the public; however, the identity of the users that are posting the comments will be kept anonymous. The interactive website also provides us with a log of stakeholder involvement, which will assist us in determining our success in engaging stakeholders.

Computer training. Mid-way through the project, a computer training session will be held. The training session will be located at UF-TREC's state-of-the-art classroom that is designed for such training. To ensure that computer session attendee's receive adequate attention, classes will be limited to 15 people each. Co-PIs (Drs. Crane and White) have previously conducted similar computer training sessions. Training will consist of basic computer skills, navigation to our website, navigation to the EDIS website and other Extension websites, and emailing. In addition, watershed level water quality issues will be investigated using GIS maps. This will enable stakeholders to gain perspective on the potential impact their farm has on water quality in the Biscayne Bay watershed. Each attendee will receive a document that provides detailed steps in performing each computer task. Training will be made available for all who apply; hence, the number of sessions is dependant on the attendance. The training sessions will target agricultural stakeholders in the watershed. The interest and participation in the computer training sessions will indicate the interest of agricultural stakeholders in gaining Extension and research information via the Internet.

Objective 4) *Management plan.*

Economic analyses. The economic analyses will consist of multiple steps. First, the costs of installing and maintaining each BMP will be estimated. Information on costs of control operations for labor, materials, equipment, and administrative overhead will be obtained from discussions with selected farmers and our team. All incremental costs and benefits will be quantified and monetized as possible. Where monetization is not possible for certain benefits and costs, they will be described. Such description will include the magnitude, timing, likelihood of impact, and irreversibility, etc.

Partial budgeting will be used to assess the desirability of the proposed practices relative to the current practice (status quo). Among other things, this will entail determining the farm gate price (value of the crop minus harvesting and marketing costs) for the selected commodities and computing the gross benefits of each practice; determining average annual costs of installing and maintaining BMPs; identifying and quantifying all other costs which will vary due to adoption of the practice; and determining the net benefits by subtracting the total costs which vary from the gross benefits.

Marginal analysis will be used to select from among the alternative practices. This entails calculating the marginal rate of return from using a higher cost practice. For the practice that appears most promising, a more rigorous economic analysis will be conducted focusing on estimating the net present value (NPV) of the stream of benefits and costs to be derived from the practice over the estimated life of the investment. The analysis will also determine the payback period; that is, the number of years it would take for the discounted accumulated benefits to equal the discounted investment and maintenance costs. A farmer may be willing to adopt a BMP if the NPV with the conservation is greater than the NPV without the BMP. BMPs that are not economically viable but have desirable social benefits attached to them would need economic incentives such as subsidies to make them viable. The level of subsidy needed will be computed.

Objective 5) *Guide for Extension, research, and other applicable groups.*

Extension guide. The final task will be to write a guide on methods for implementing and integrating BMPs and how they relate to improving the overall quality of the watershed. The document will provide guidelines for conducting a similar study in any agricultural watershed.

Pitfalls that might be encountered: A major hurricane, a major flood, or exceptionally hard freeze could destroy agricultural crops. However, we will have an alternative plan to fulfill proposed objectives.

Limitations to proposed procedures: For each of the agricultural commodities for which BMPs are implemented, only one stakeholder will be participating. Therefore, variability associated with a plot's location (such as elevation, initial nutrient content, soil type) will not be considered. The expected overall principals elucidated from this project should have the potential to be rapidly adapted for and adopted by a broad range of stakeholders between and among commodity groups.

d) Cooperation and Institutional Units Involved

Lead institutional unit: Tropical Research and Education Center, IFAS, **University of Florida**, Homestead, FL: Kati White (Hydrologist/Engineer), Jonathan Crane (Horticulturist), Yuncong Li (Soil and Water Scientist), Edward Evans (Food and Resource Economist), Bruce Schaffer (Plant Physiologist), Rafael Muñoz-Carpena (Hydrologist/irrigation specialist)

Collaborating institutional unit: Miami-Dade County Extension Service, Homestead, FL:
Chris Miller (Aquaculture and water science Extension agent)
Joe Carofalo, Ph.D. (Commercial ornamentals Extension agent)
Henry Mayer (Urban commercial horticulture Extension agent)
Carlos F. Balerdi, Ph.D. (Tropical Fruit Crops)

Collaborators: Tropical fruit growers and landscape and ornamental nursery growers.

(e) Facilities and Equipment:

The UF-TREC is located in the farming area of Miami-Dade County, Florida, 48 km west of Miami. The center has 160 acres of subtropical and tropical fruit (including avocado, lychee and carambola) orchards and vegetable fields on calcareous soils and modern laboratory and greenhouse facilities. The center has the necessary farm machinery to maintain orchards, vegetable fields and greenhouse plants including several tractors, mowers, and sprayers. TREC also has a state-of the art teaching building with video-conferencing capabilities, over 15 internet/computer stations, and a computer-projector lecturing platform. Drs. White and Munoz-Carpena's hydrology laboratories are equipped to conduct hydrology and water quality research and are staffed with skilled technicians for field work endeavors. Drs. Crane and Schaffer's laboratories are fully equipped for environmental physiology and horticultural studies of subtropical and tropical fruit trees including glassware, portable pH and SPAD meters, electronic scales, tissue grinders, drying ovens, a colorimeter and several desktop and laptop computers for data analyses. Dr. Li's soil chemistry and plant nutrition laboratory is fully equipped for digesting plant samples for nutrient analysis and extracting and quantifying all macro and micronutrients. The equipment in Dr. Li's laboratory includes drying ovens, a muffle furnace, fume hoods, digestion blocks and an auto-analyzer, CNS analyzer, and a new atomic absorption spectrometer that will be available for use in this project. Dr. Li's laboratory is certified by the National Environmental Laboratory Conference (NELC) for water, plant, and soil nutrient element analysis. Dr. Edward Evans has the facilities and equipment to do all the necessary economic analysis including desktop computers for data analysis.

(f) Project timetable:

Table 1: Project timetable for 3 Years with each

Task	Year 1				Year 2				Year 3			
Months	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12	1-3	4-6	7-9	10-12
Initial survey	■	■										
Final survey											■	■
Field days/demonstrations, fact sheets, web postings			■	■	■	■	■	■	■	■	■	■
Interactive web board	■	■	■	■	■	■	■	■	■	■	■	■
Computer training					■	■						
Implement BMPs	■	■										
Monitor BMPs	■	■	■	■	■	■	■	■	■	■	■	■
Economic analyses									■	■	■	■
GIS maps	■	■	■	■	■	■	■	■	■	■	■	■
Compose management plan											■	■
Extension guide											■	■

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9. Key Personnel

Kati White, Assistant Professor of Agricultural and Biological Engineering, Tropical Research and Education Center, IFAS, University of Florida. She will be responsible for developing and installing the automated irrigation systems, climatilogical and water-use monitoring, developing and maintaining the interactive web board, fact sheets, computer training, implementing BMPs, BMP monitoring systems, GIS maps, and reports. Dr. White has years of experience in Extension including previous collaborative efforts with multi-agency projects.

Jonathan Crane, Professor and Tropical Fruit Crop Specialist of Horticultural Sciences, Tropical Research and Education Center, IFAS, University of Florida. He will be responsible for assisting with surveys, field days/demonstrations, stakeholder events, computer training, assimilation of information, and fact sheets. Dr. Crane has worked extensively as an Extension faculty at TREC with local growers and holds positions on many local commodity boards.

Yuncong Li, Associate Professor of Soil and Water Sciences and Extension Specialist, Tropical Research and Education Center, IFAS, University of Florida. He will be responsible for fertilizer application, collecting and analyzing soil, tissue and water samples, monitoring, involving field days, result interpretation, posting information on EDIS, and reports.

Edward 'Gilly' Evans, Assistant Professor of Food and Resource Economics and Associate Director of the Center for Tropical Agriculture, Tropical Research and Education Center, IFAS, University of Florida. He will be responsible for assisting with surveys, economic analyses, fact sheets, and reports.

Bruce Schaffer, Plant Physiologist, Professor of Horticultural Sciences and Associate Center Director, Tropical Research and Education Center, IFAS, University of Florida. He will be responsible for assisting with collecting plant growth and fruit yield data and report writing.

Rafael Muñoz-Carpena, Assistant Professor, Agricultural and Biological Engineering, IFAS, University of Florida. He will work with Dr. White in developing and installing the automated irrigation systems.

Chris Miller, Water science/aquaculture Extension agent, Miami-Dade County Extension, UF-IFAS. He will be assisting with Extension activities such as field days and demonstrations and stakeholder surveys.

Joe Garofalo, Commercial ornamentals Extension agent, Miami-Dade County Extension, UF-IFAS. He will be assisting with Extension activities such as field days and demonstrations and stakeholder surveys.

Henry Mayer, Urban commercial horticulture, Extension agent, Miami-Dade County Extension, UF-IFAS. He will be assisting with Extension activities such as field days and demonstrations and stakeholder surveys.