USING TECHNOLOGY TO DEVELOP INTEGRATED WATER RESOURCES MANAGEMENT SCHEMES

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ABSTRACT

The State of Florida, like many states and nations around the world, will be facing critical choices regarding the future of its natural resources and economy in the next decade. Manatee County is one of eight (8) Florida counties included in the Southern Water Use Caution Area designated by the Southwest Florida Water Management District in 1992, indicating that the aquifer is under severe overuse. Manatee County is interconnecting three regional wastewater treatment plants to provide a 32-mile distribution system for urban and agricultural irrigation needs called Manatee Agricultural Reuse System (MARS). The Florida West Coast Resource Conservation and Development (RC&D) Council has developed the MARS Farm Connection Grant Program to connect farmers to the main distribution line. In addition to providing funding for connection, the RC&D will demonstrate a farm-scale integrated water resources management system that includes multiple interconnected sources of water to maximize both economic and environmental benefits.

The stress on the Floridian aquifer and the economic pressure on agriculture in Manatee County require new approaches to managing water resources. Minimizing aquifer withdrawals will require the use of alternative sources such as MARS reclaimed water, surface water, and aquifer withdrawals to meet crop and freeze protection demands. However, the quantities, quality, and seasonal availability of these sources of water present a challenging and potentially risky water management scheme for farmers. Using technology and automation in a farm-scale water management system has the potential to facilitate farmer acceptance of the complex integrated water management approach that will be needed to reduce aquifer withdrawals and keep farming viable in our communities.

To integrate various source of water and quantify the use of each water source, wireless data loggers will be installed at the farmer's wells and reclaimed water connections to transmit meter readings to a central computer which will geospatially represent this data. Recent developments in communication technologies and computer hardware/software will allow us to economically gather data and automatically update consumption information. Furthermore, data can be available on real time basis, if such information is needed. The different water sources on the farm can be interconnected through automation

technologies so that the use of water for the farmer is virtually seamless. Remote data collection and analysis will allow water use assessment and assist farmers with problems identification.

Use of technology in assisting farmers and communities with meeting their natural resource management objectives is one step towards facilitating sustainability and understanding barriers to conservation. Information collected will also help agencies develop programs to help farmers better manage their irrigation scheme and adopt efficiencies.

This approach will be part of a demonstration project which can promote an Integrated Water Resource Management Program for sustainable development. The more we understand our natural systems and their limitations, planning for water resource management can be better balanced with population growth, expansion and sustainability.

Quantifying resources through the use of technology and geospatially representing data can be made available to the various agencies and citizens to better see their individual and collective roles in creating sustainable communities where resources will be available for generations to come.

INTRODUCTION

The State of Florida, like many states and nations around the world, will be facing critical choices regarding the future of its natural resources and economy in the next decade. Three interrelated factors are contributing to the urgency of this problem: water use patterns and aquifer depletion, an important agricultural economy, and immense population growth. Although Florida is not typically considered an arid state, there are many complex water resource issues, including areas in the state that have been identified as having water supplies that are at risk due to overuse. Florida ranks number 2 nationally in production of fresh vegetables with 2002 sales of $1.4 billion and number 9 nationally in the value of farm products with $6.85 billion in sales for 2002. Additionally, the U.S. Census Bureau reported in April of 2005 that current projections indicate Florida, California, and Texas will account for 46 percent of the total U.S. population growth between 2000 and 2030, and that Florida will move from the fourth to the third most populous state, behind California and Texas. The Census Bureau also predicts that Florida will add more than 12 million people between 2000 and 2030.

The combination of aquifer depletion, water for food production, and population growth has urged many counties in Florida to plan for sustainable water resources. Manatee County located just south of Tampa Bay, is one such county. Since the mid 1980s, Manatee County has been planning and developing its reclaimed water system, the Manatee Agricultural Reuse System (MARS), to supply farms and landscape areas with reclaimed water. To connect

the farmers to the reclaimed water system, the Farm Connection Grant Program is being implemented by the Florida West Coast Resource Conservation and Development (RC&D) Council.

The Florida West Coast RC&D Council is a local U.S. Department of Agriculture sponsored 501(c)(3) organization specializing in community leadership capacity building in the areas of sustainable economic and community development, natural resources use and conservation, sustainable agriculture, and healthy community food systems. The RC&D Area (Figure 1), authorized by the Secretary of Agriculture in 2001 includes Hillsborough, Manatee, Pinellas and Sarasota Counties, on the central southwest coast of Florida, serving a population of approximately 3 million people (Community Survey of the U.S. Census Bureau, 2003).

Figure 1 – Location of Manatee County, Florida within the Florida West Coast Resource Conservation and Development (RC&D) Area

Sustainability has been at the core of the RC&D concept since the inception of the program by the Department of Agriculture in the 1960s when the USDA program was created to address rural poverty in the United States. Assistance from USDA was provided to help local people build sustainable natural resource-based economies that would improve their quality of life. RC&D is very much like many community or economic development non-governmental organizations around the world, using natural resources, ingenuity, and partnerships to empower people to make their lives better.

The involvement of the Florida West Coast RC&D Council in the MARS project has created an opportunity to implement water resources management schemes on farming operations.

Sustainable Food and Water Balance

The Food and Agriculture Organization (FAO) of the United Nations has reported extensively on the relationship to food production and water resources (UNESCO, 2003). One trend that exists globally and at a local level in Manatee County is that agriculture accounts for up to 70 percent of the world's water withdrawals from surface and groundwater[1]. Up to 300,000 cubic meters (80 million gallons) of water per day are pumped from the Floridian Aquifer for agricultural irrigation in Manatee County (approximately 85% of total usage) and an additional 45,000 cubic meters (12 million gallons) are pumped per day for

[1] In the United States 190 billion m^3/yr (50 billion gallons/yr) of fresh water is used for irrigation; 25 million hectares (62 million acres) are irrigated, 47% by flooding, 46% by sprinklers, and 7% by micro-irrigation.

residential use. Irrigation efficiencies worldwide are approximately 40 percent, with 60 percent of the water drawn being lost to evaporation, deep infiltration, runoff, or weed growth. Irrigation efficiencies in Manatee County vary widely depending on the type of irrigation system, maintenance of the system, and the commitment to irrigation water management to maximize the system's efficiency.

Manatee County is one place where the importance and future of agriculture is in question. Manatee County, like many urban-edge areas, is facing agricultural land conversions to residential and commercial uses. The county's status in the ranks of agricultural production implies that the natural resources situation in Manatee County is favorable for economically viable agriculture and that water resource planning should address the economic importance of agriculture as well as contributing to a local food system. However, state legislation requires regional water management districts around the state to plan for allocation of scarce water resources to meet population needs for potable consumption, natural systems, agriculture and industrial users in that order. Florida counties, under the jurisdiction of regional water management districts, are required to follow these regional plans in planning for their own water supplies.

Non-sustainable Water Resource Consumption

Manatee County is one of eight (8) Florida counties included in the Southern Water Use Caution Area (SWUCA, Figure 2) designated by the Southwest Florida Water Management District (SWFWMD) in 1992. A "water use caution area" is an area where water resources are or will become critical in the next 20 years. The implication of a water use caution area is that the use of water exceeds recharge, or in other words, the use is not sustainable.

The SWUCA is a 5,100-square-mile area in southwest Florida where water resources are already critical. Within the SWUCA, the Eastern Tampa Bay Most Impacted Area (ETB MIA) extends along the coast of southern Hillsborough, Manatee, and northwestern Sarasota counties, where there is the greatest concern for saltwater intrusion as a result of depressed aquifer levels. Depressed aquifer levels not only allow saltwater intrusion, but also contribute to reduced flows in the rivers and lowered lake levels in some areas.

To work towards stabilization of groundwater levels, permitted groundwater withdrawals from the Floridian aquifer in the ETB MIA have not increased since 1990. However, this effort alone is not enough to offset increases in groundwater withdrawals in the Floridian aquifer as a whole, due to increased demand from rapid population growth in the state.

The SWUCA Recovery Strategy, developed by SWFWMD and currently in draft form, is designed primarily to manage groundwater withdrawals to achieve and sustain the Floridian aquifer saltwater intrusion minimum aquifer level. There are numerous sub-strategies in the SWUCA, including the incorporation of water reuse measures and providing financial incentives to develop alternative supplies such as reclaimed water projects. However, very few of the sub-strategies come without actual costs, opportunity costs, or other material and non-material implications.

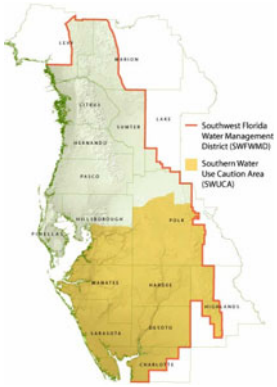

Figure 2 – The Southern Water Use Caution Area (SWUCA) of the Southwest Florida Water Management District (SWFWMD). Graph source: SWFWMD.

Continued development of reclaimed water projects has been established as a priority for the state by the Florida Reuse Coordinating Committee and the Water Conservation Initiative Water Reuse Work Group in their June 2003 report *Water Reuse for Florida.*

The Manatee Agricultural Reuse System (MARS) project is part of this larger regional strategy to reduce aquifer withdrawals through treated wastewater reclamation and recycling, designed to pipe reuse water from urban areas to rural areas for use in agricultural irrigation as an alternative to groundwater use.

The MARS Project

Manatee County has completed interconnection of three regional wastewater treatment plants to provide a 32-mile distribution system for urban and agricultural irrigation needs. Manatee County has been working on the main transmission pipeline for approximately five years with a budget of about $55 million, which includes three booster pumping stations to convey reclaimed water throughout their transmission line.

The RC&D will provide funding and technical assistance to link Manatee County's MARS main transmission line to the farmer's agricultural irrigation system using funds obtained through Congressional direct appropriations, which now total $8.5 million. The RC&D has developed a three phase MARS Farm Connection Grant Program to carry out this objective. The first two phases consist of connecting the farmers to the reclaimed water system and to create a smooth technological transition from fresh or well water to reclaimed water use by the farmers.

Phase III was developed for the RC&D to play a community role through the implementation of demonstration projects and incentives that address reclaimed water quality, seasonality of rainfall and reclaimed water availability, and water conservation.

Presently, connecting farmers and nurseries to the MARS transmission pipe is underway.

Integrated Water Resources Management

Food and Agricultural Organization of the United Nations defines Integrated Water Resources Management (IWRM) as a process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. It is also a political procedure with long-term gains that are vital to the sustainability of the resource base (Global Water Partnership).

Practically all of the materials found on the Internet related to IWRM discuss policies, management, and procedures on the subject of Integrated Water Resources Management issues.

The approach RC&D will be taking in IWRM is two fold: application of technology to maximize efficiency for the management of water and other resources on agricultural land, and to tap into the knowledge and skills of farmers, manufactures, policy makers, water district agents, regulators, governmental agencies, NGOs, and other stakeholders by bringing them together in a partnership towards addressing the many issues related to water resources management.

Farm-Scale Integrated Water Resources Management

The stress on the Floridian aquifer and the economic pressure on agriculture in Manatee County require new approaches to managing water resources. Additionally, many residents, decision-makers, and consumers are not aware of the importance of agriculture to the economy of Manatee County and to the security of the food system in their local area. That places additional pressure on finding ways to assist farms with water conservation as agriculture consumes the largest volume of water, as in most areas of the world.

Minimizing aquifer withdrawals requires the use of alternative sources such as MARS reclaimed water, and surface water, in addition to some aquifer withdrawals to meet crop and freeze protection demands. However, the quantities, quality, and seasonal availability of these sources of water present a challenging and potentially risky water management scheme for farmers. Using

technology and automation in a farm-scale water management system has the potential to facilitate farmer acceptance of the complex integrated water management approach that will be needed to reduce aquifer withdrawals and keep farming viable in our communities.

The different water sources on the farm can be interconnected through automation technologies so that the use of water for the farmer is virtually seamless. Remote data collection and analysis will allow water use assessment and assist farmers with problems identification.

METHODOLOGY

The implementation of the MARS Farm Connection Grant Program provides an opportunity to address integrated water management schemes by using various techniques and technologies to create efficiencies and conserve water and other resources.

One of the goals of the program is to measure the reduction of Floridian Aquifer pumping from agricultural lands where the MARS reclaimed connection will be made. Wireless transmitters will be installed at the master meter reclaimed water connection and at the wells on the farmer's property. The data will be collected on a central computer and geospatially mapped on a Geographic Information System map.

Another goal of the program is to demonstrate by integrating the various water conservation techniques the reduction in water consumptions and address water quality issues. To achieve these goals, RC&D is utilizing technology and automation means to develop on farm integrated water resources management schemes.

Water Meter Data Collection

For RC&D to be able to quantify the reduction of aquifer withdrawal, a remote meter readings program is being implemented. Flow meters installed downstream of the reclaimed water connections and those next to the farmer's well will be collecting and forwarding this data to a central computer wirelessly.

Presently, as it is in most other parts of the world, water meter data is read by the farmer and forwarded to a monitoring agency or it is read by a county/water authority representative, usually once a month.

The technology for remote meter reading already exists. Utility departments across the country are using Automatic Meter Reading (AMR) technologies to read water, electric and gas meters. Currently, approximately 20 percent of the water utility market in the U.S. is engaged in using the AMR technology.

A drive-by meter reading was developed several years ago whereby a meter transmits a low frequency signal to a drive-by utility personal. Once the data is collected from an area, the information is downloaded to the utility department's computer for processing and billing.

A more recent technological development is a fixed area network method, where meters transmit data to a collector, in a grid wide network using low power radio transmitters. The data collector forwards this information to a central computer using land line or cellular technology. Other than the advantage of reducing the collection costs associated with reading meters, it creates a medium for an efficient and continuous transfer of meter reading data into central software for billing purposes.

Similar technologies can be adapted at regional levels to collect water consumption readings for agricultural water meters at wells, lakes, reservoirs and rivers to monitor pumping volumes. Data can be transmitted using a cell phone, land lines, or satellite transmission to a central location where the information is stored, and managed by computer networks. Having continuous and real time access to this type of data can assist in developing security strategies for the protection of the water resource as well.

Having a remote meter data collection network in place, addition of a rain tipping bucket and a soil moisture sensor at farms can provide an added advantage to the farmer, who will be able to evaluate water consumption and can address control measures for water conservation. Other than being able to monitor their water consumption, farmers will be able to log on to their account and evaluate if a given rain event has adequately recharged to the desired soil moisture levels, and only apply the balance of irrigation water needs for their crop. In this way farmers become partners in reducing their water consumptions as a result of data availability to decide how much irrigation water is needed for their crops.

Data collected from water meters and rain tipping buckets can be interfaced with Geographic Information System (GIS) software for planning, evaluation and analysis. GIS mapping provides the users with the advantage of spatial data management and its mapping. Historic data can be analyzed, and geographic patterns can establish relationships between features. The results of this analysis can be displayed as a map, values in a table, or in a chart format. Water consumption and rain fall data mapped in GIS will provide the data needed to implement conservation practices.

For the MARS farm connection program, a number of AMR systems have been evaluated and are being installed on an experimental basis. A coordinative effort between Manatee County and RC&D is being developed for both parties to have access to the meter reading data. The goal is not only to collect, map and report reclaimed water consumption and aquifer pumping data for program evaluation

purposes, but also to take the program to another level by demonstrating the use of technology for water consumption data collection in farming operations.

Having access to continuous and accurate flow of data from water meters, as opposed to once a month reading, with possible inaccuracies, can open new doors towards water resources management and conservation program development.

MARS Demonstration Sites

Observing farming practices in Southwest Florida indicates that isolated efforts are made by the farmer to improve irrigation efficiencies. Rain sensors may be used to shut down irrigation once a pre-defined rain event is reached, weather stations may be used to gather hydrological data, soil moisture sensors may be used to determine moisture levels, drainage improvements may be adopted to control water table and convey water away from a portion of a farm, runoff collection ponds may be constructed to reduce nutrient loadings and recalculate water on the farm, and poor water quality may be treated with chemicals.

One of the objectives of the MARS demonstration sites is to demonstrate by integrating the various efforts and use technology and techniques to reduce water consumption and conserve resources. In this way sustainable resource management programs are developed in partnership with the farmers.

To achieve this objective a continuous system of monitoring and real time evaluation will need to be set up so that irrigation decisions are made based on existing variables and conditions, and resource are efficiently allocated to respond to demand. Examples of such an approach are discussed below.

Water Quality Issues

Water sources available on farms in the Manatee County can consist of deep well aquifer water, shallow well brackish water, municipal treated reclaimed water, storm water runoff, and tail water collection system. Since it is the goal of the Manatee County's MARS program to reduce pumping from the Floridian Aquifer and use reclaimed water in its place, the quality and availability of reclaimed water has to be taken into consideration.

During the planning stages of the MARS transmission pipe, efforts were made to design the system so that farmers could benefit from the reclaimed water discharged from the three interconnected wastewater treatment plants. Not all farms in the County are located next to the transmission pipe and with the recent expansions in urban sprawl, only pockets of farms and nurseries in the area are candidates for connecting to the MARS pipe. More significantly, the reclaimed water quality may present a challenge to nurseries and crops sensitive to salts and other minerals.

Recent reports are indicating that intrusion of brackish water into the sewage collection system in the coastal areas of Manatee County has resulted in undesirable chloride levels in reclaimed water. Manatee County's wastewater treatment facilities meet the minimum requirements for the State of Florida discharge guidelines. Removal of salts can be a complex process which may require advanced treatment facilities. In lieu of this challenge, it may be possible to mix reclaimed water with other water sources that may be available on a farm. If storm water and/or tail water recovery measures are put in place, it may be possible to mix the incoming reclaimed water in order to improve water quality.

Another measure could be treating part of the reclaimed water with a small onsite reverse osmosis plant and then mixing the higher quality of water with the reclaimed water. Although this approach may be feasible for a small scale farming operation, costs for such a treatment process could be impractical for some of the farms thousands of acres in size. Also, even though reverse osmosis has proved to be a viable alternative for water treatment, especially with the drop in manufacturing costs of membrane production, disposal of the reject water generated by this treatment process may present a challenge to the farmer and permitting agency.

Implementing Irrigation Techniques for Water Conservation

At the heart of an integrated water resources management scheme on farms is the ability to access data on the environmental conditions and address the crop water needs on a real time basis. Many automation and control technologies are presently available to deal with the growing concerns of farmers for irrigation, water resource and environmental management of their crops, albeit, many farmers elect to address some of the issues, given the limitations in understanding the technologies involved and the costs associated with their implementation.

RC&D's goal is to implement, through demonstration, automation techniques that can integrate the many factors involved in water and other resource management, and to provide the farmer with on going support and expertise needed to show their effectiveness. As part of an automation technology, a controller may be able to activate an irrigation cycle by first sensing existing conditions, and then irrigate based on crop water needs, thus effectively reducing aquifer pumping, and conserve energy. As a back up strategy, in times of power failure, solar or battery back up systems can continue with system operation.

The following scenario is an example of a nursery that can benefit from using technology to develop management schemes. Presently, piped fresh water from the County supplies the irrigation needs of the nursery. On the average the nursery pays $5,000 for its monthly water bills. Part of the stormwater runoff is collected on site. Fertilizer enriched irrigation water runoff is also partially

collected on site and is pumped back into the irrigation system after disinfection using chlorine.

The nursery is located next to the MARS transmission line, but the owner is concerned about the quality of reclaimed water and its availability. Also, for propagation purposes, the nursery will need to apply fresh water during the early growing stages of the plants.

As an integrated approach to water quantity and quality for this nursery, water pressure, Electrical Conductivity (EC) and chloride levels at the reclaimed water connection can be measured. Fertigation can be minimized since nutrient rich reclaimed water is being used. If the chloride levels prove to be too high, water from the stormwater runoff can be pumped into the irrigation system. Also, if the incoming reclaimed water pressure is low for the efficient operation of the irrigation system, pumped water from the on site reservoir can boost this pressure.

Tailwater recovery can be extended to collect all of the runoff water from both irrigation and stormwater runoff in the on site reservoir. Since the reservoir and reclaimed water is used in this scenario, nutrient rich irrigation water runoff from the site will be minimized.

Overhead sprayers presently used to irrigate the various horticultural plants can be replaced with pressure regulated in-pot sprayers, thus water is only applied at the root zone level. Pressure regulation will ensure uniformity of water application, resulting in uniform growth of the plants, so long as the soil medium and other conditions remain the same. Soil moisture sensors can be utilized to ensure adequate water is applied as part of the irrigation cycle. Precautionary measures to flush out the excess salt build-ups in the root zone by over irrigating can be considered.

Phase III of the MARS project may also implement solar energy to run electric pumps and controllers to supply desired water quantities and qualities using variable frequency drive pumps to adjust flow and pressure demands automatically, and minimize on site pressure reductions downstream of the system.

Florida has been coined as the lightening capital of the world since it experiences significant lightening forces during the hot and humid summer months. Many of the automation technologies discussed here will require sensitive electronic and computer equipment that can be damaged every year during the summer irrigation cycles. Auto system shut downs during storms is an important factor in an automation process in Florida so that the farmer can depend on their systems after the passing of storms.

Florida coastal areas, along with other coastal areas around the world, give possibility to use wave energy converters to generate either electricity or desalination of water to be used for agricultural purposes and possibly mixing with brackish water. This concept may be gaining greater attentions in the years ahead and will need to be addressed at a regional policy level.

From RC&D's perspective, use of technology and transfer of technology, the knowledge base, is an important ingredient in the long term sustainability of our projects. The economics and affordability of the technology is also an important element in technology transfer and will have to be taken into consideration during its planning, execution and management stages.

MARS Program Complementing IWRM Strategies

Southern Florida Water Use Caution Area (SWUCA) recovery strategy has been developed by the Southwest Florida Water Management District (SWFWMD) as an integrated strategy to address the diverse issues, policies and management of water resources in the south west region of Florida.

Since the early 1990s, the Governing Board of SWFWMD has been engaging the various stakeholders to address regulatory and non-regulatory components of the recovery strategy. In their recent draft of this strategy (March 2006), they have addressed issues related to the present water supply plans, provides descriptions of the various conservation initiatives and projects that are part of the strategy, discusses existing and planned water resources development projects, provides regulatory components of the strategy and the financial tools available to achieve the goals of their strategy. These integral elements in the water resources management are ingredients for region wide Integrated Water Resource Management (IWRM) schemes.

As part of these schemes, SWFWMD has been funding various projects to promote development and use of reclaimed water by the counties and municipalities in the SWUCA area. Construction of the MARS transmission pipeline and the three pumping stations to supply reclaimed water in Manatee County are being partially funded by SWFWMD as part of their region wide strategy to reduce Floridian Aquifer pumping.

A significant component of the District's effort is to enhance agricultural water use efficiency by funding technology and best management practices (BMPs) research for farm irrigation and management. Along with research, normally conducted by the Institute of Food and Agricultural Sciences (IFAS) at the University of Florida, educational programs are carried out in each county under the extension arm of IFAS.

Phase III demonstration projects that RC&D is planning to carry out may compliment the efforts towards SWUCA strategy. As farmers partner with RC&D

in the Phase III program for demonstrating the techniques and automation technologies, it will be possible to use their operations as sites where the various stakeholders come together to observe results of the water management and conservation schemes.

CONCLUSIONS

Advances in low cost wireless radio communication, computer technologies and sensing equipment provides an opportune time in the field of agriculture to develop technologies that can assist a farmer with managing their water and other interrelated resources in a sustainable manner.

Partnering with the farmers, RC&D's role will be to demonstrate that these technologies can be part of an integrated management of water resources on farms that not only conserve these vital resources, but also address the many complex issues as part of region wide IWRM policies and programs that water agencies and their partners have been developing for decades.

Two goals of RC&D are to develop remote water meter readings and to integrate technologies for the management and conservation of water and other resources on farms connected to the MARS reclaimed water program.

Collection of water meter reading and rain data on a continuous basis can address the goals of IWRM strategies by providing the information a water authority and their partners need to develop area wide realistic goals, establish short and long term plans, and target farming areas to promote water conservation and efficiency improvement programs. Real time and accurate collection of data opens up much possibility for water resources management and conservation planning.

Integrating techniques and technologies to conserve water and other resources will benefit from the research work done by the many institutions worldwide and IFAS at the University of Florida to address the many complex and interrelated concerns of water resources management in Manatee County.

Success of a technologically oriented project can be measured by the sustainability and long term positive effect it will have on a population it is serving. The approach in the three phases of the MARS reclaimed water program will be more than just connecting pipes and instruments and linking them with computers, it will focus on developing partnerships with the farmers, transferring knowledge and putting in place functional systems that will be affordable, economical, and address water conservation issues. This program will also develop a partnership with Manatee County, Southwest Florida Water Management District and other stakeholders in exchange of ideas and lessons learned from the demonstration of integrating water resources management programs on the farms.

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