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Adoption of Energy and Water-Conserving Irrigation Technologies in Florida[1]

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ENERGY USED FOR IRRIGATION IN FLORIDA AGRICULTURE

Florida is a leading producer of many valuable crops such as citrus, vegetables, and ornamentals. These crops are critically dependent upon supplemental irrigation and other energy-intensive inputs such as fertilizers and chemicals. Florida's total irrigated area ranks 8th in the U.S., with 2.03 million acres.

Energy for pumping irrigation water in the U.S. accounts for 23 percent of total on-farm energy use in the United States. Irrigation represented 32 percent of total primary energy consumption for citrus production in Florida in 1980. Fossil fuels are the primary energy source for irrigation and chemical inputs to crop production systems. Costs for fossil fuels have remained relatively inexpensive, with prices declining in real terms during the 1980s. However, a finite supply of these nonrenewable energy sources means that energy costs will inevitably increase. Ultimately, use of these energy sources may become unsustainable within the next generation. Additionally, imports of petroleum contribute to an unfavorable balance of trade for the United States, and are vulnerable to disruption by political instability.

Beyond the direct energy costs for irrigation pumping, agricultural water use is associated with large, indirect energy costs. Energy is required for manufacture of irrigation machinery and equipment, and for water supply infrastructure. For example, use of electric power for irrigation poses needs for additional public utility system capacity because agricultural water needs are often greatest at peak load times, such as during winter freezes and hot, late afternoons.

POTENTIAL BENEFITS OF CONSERVATION IRRIGATION

Technologies

A large share of Florida's irrigated acreage in fruit crops, vegetable crops, and ornamentals is suitable for application of microirrigation technology. Microirrigation and other water-conserving irrigation technologies have the potential for conserving large amounts of energy, both directly and indirectly. Direct energy savings for microirrigation technologies come about through reduced operating pressure as well as reduced pumping volumes. Water application efficiencies for microirrigation systems may be higher than for sprinkler or gravity flow irrigation systems. Direct energy costs for microirrigation in Florida citrus groves were estimated at only one-third to one-sixth of those for sprinkler or seepage irrigation

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systems. Substantial indirect energy savings in terms of reduced fertilizer use were demonstrated for micro-irrigated vegetable production as compared to seepage irrigation.

Other potential benefits offered by microirrigation technologies may include improved fruit yield and fruit quality. Fertilizer and chemical use may be reduced if the microirrigation system is operated properly, because leaching is minimized for lower irrigation water volumes applied. Improved fruit and vegetable quality may result from avoiding frequent wetting of the crop plants' foliage, thus eliminating conditions for growth of plant pathogens. Fertilizer or chemical costs, however, may not be reduced if more expensive soluble forms are used, or if the system is not managed properly.

Tail-water recovery systems are a new technique for water conservation in some intensive irrigation systems, with surface runoff collected in ponds constructed near fields. Tail-water recovery may recapture up to 40 percent of water applied from overhead sprinklers during continuous pumping for freeze protection or plant establishment. Energy savings from tailwater recovery may be significant due to reduced pumping heads.

CONSTRAINTS TO ADOPTION OF CONSERVATION IRRIGATION TECHNOLOGY

Florida's agricultural industry has not adopted water conservation technology to the degree technically or economically feasible. Approximately 40 percent of suitable crop acreage in Florida was under microirrigation in 1991. Microirrigation has been adopted strongly by the citrus industry (51 percent), and is now universally installed in new groves because it provides cold protection, and installation costs are lower than for sprinklers. However, microirrigation is used very little on Florida's large commercial vegetable acreage (11 percent).

Reasons for these differences in rate of conservation technology adoption among various agricultural industry groups are poorly understood, and further information is needed. Factors that may affect adoption of conservation irrigation technology include crop characteristics (cultural requirements), financial situation of the farm, resource situation (energy, soil and water), grower characteristics (education, experience, managerial abilities), farm structure (sole proprietorship vs corporate, own vs lease), costs (installation, operation, maintenance), and institutions (laws, rules, regulations, customs, traditions) affecting how the farmer is influenced by community standards for action. Different areas of Florida are affected by Water Management District rules pertaining to efficiency of agricultural water use. Initial costs for new microirrigation systems may range from $500 per acre for field crops to $40,000 per acre for intensive greenhouse crops. This cost may be 20 times higher than a conventional irrigation system for closely spaced crops. Labor requirements and management needs for ongoing maintenance may also be greater due to elaborate filtration systems required in some areas. Some crops require use of sprinkler irrigation for plant establishment or freeze protection, so installation of microirrigation systems represents some duplicated capital costs.

CASE STUDY IN CONSERVATION IRRIGATION TECHNOLOGY ADOPTION: THE FLORIDA STRAWBERRY INDUSTRY

The Florida strawberry industry is comprised of approximately 4,700 production acres located primarily in the Hillsborough County area. Florida strawberries are grown in raised beds covered with black polyethylene mulch. Farmers who use drip irrigation lay the drip tubing underneath the plastic mulch. Bare-root plants are watered with overhead sprinklers for about 2 weeks, 6 to 8 hours each day, for plant establishment, regardless of whether drip irrigation is used. Overhead sprinklers are also used intermittently for cold protection during the winter months. After strawberries are harvested in the spring, some growers plant vegetables in the same fields and use the same plastic and drip tubing, thus avoiding these costs for a second crop.

In a survey conducted to investigate why farmers adopt conservation irrigation technologies, 44 Florida strawberry farmers were personally interviewed. They were asked questions about their farming practices and attitudes towards technologies.

CONSERVATION TECHNOLOGIES AND PRACTICES

Conservation technologies used by Florida strawberry growers sampled in this study are shown in Table 1. Drip irrigation was used by 86 percent of growers sampled, and was used on 90 percent of the sampled acreage. Tailwater recovery systems were installed by 48 percent of sampled farmers and operated on 45 percent of sampled acreage. Total industry acreage for drip irrigation was estimated at 4,236 acres, and tailwater recovery systems were installed on 2,108 acres.

Another conservation practice in the strawberry industry is to change sprinkler nozzles during plant establishment in order to reduce water volumes applied. The survey found that 61 percent of growers followed this practice. It was also found that nearly all farmers (95 percent) managed their irrigation system themselves, rather than delegating this responsibility to family members, employees, or others. Drip irrigation systems were used for fertilizer application (fertigation) on 98 percent of drip-irrigated acreage.

Table 1. Number of firms and acreage for drip irrigation and tailwater recovery systems, sampled Florida strawberry growers, 1992.

System	Percent of Farms Sampled	Percent of Average Sampled	Total Industry Acreage
Irrigation Type			
Drip and overhead	84.6%	90.1%	4,236
Overhead only	13.6%	9.9%	464
Total	100%	100%	4,700
Tailwater Recovery Systems Installed			
Yes	47.7%	44.8%	2,108
No	52.3%	55.2%	2,592
Total	100%	100%	4,700

The history of adoption of drip irrigation and tailwater recovery is shown in Figure 1. Crop acreage has increased steadily since the early 1970s. However, adoption of drip-irrigation and tailwater recovery systems did not begin until the middle of the 1980s. Drip irrigated acreage has since continued to increase steadily to the current level, while very few tailwater recovery systems have been installed recently.

ENERGY CONSUMPTION AND EFFICIENCY FOR STRAWBERRY IRRIGATION

Energy consumption for drip and overhead sprinkler irrigation in strawberry production was estimated as shown in Table 2, based upon water use and irrigation system operating parameters. Irrigation system heads were calculated from survey data on operating pressures and pumping depths, with a drawdown of 10 feet and 10 percent pipe friction loss assumed.

Energy required for crop maintenance irrigation averaged 382 water horsepower-hours (whp-hr) per acre per year for sprinkler irrigation, and 307 (whp-hr/a/yr) for drip systems (Table 2).

The 20 percent greater energy efficiency for drip systems was due to the reduced operating heads (pressure and depths), rather than any savings in water volumes applied for crop maintenance. On an industry-wide basis, mechanical energy requirements for irrigation averaged 451 water horsepower-hours per acre.

Energy sources for strawberry irrigation were electric power, diesel fuel, and both electricity and diesel. Electric power was used as the sole energy source on 15 percent of acreage, diesel engines were used on 60 percent, and both electric and diesel power were used on 25 percent of acreage. Gasoline engines were not used by any growers. A greater share of drip-irrigated acreage was served by electric power (27 percent) than was non-drip irrigated acreage (10 percent), presumably due to the greater control and convenience offered by electricity. Diesel power plants were usually provided for frost/freeze watering, either alone or as back-up units in case electric power is disrupted.

Electric power units were estimated to consume 347 kw-hours per acre per year for crop maintenance drip irrigation and 432 kw-h/A for sprinkler irrigation. Diesel power units consumed 27 gallons per acre for crop maintenance with drip systems, and 35 gal/A for sprinkler systems. On an industry-wide basis, irrigation pumping for all purposes was estimated to consume 139 thousand gallons of diesel fuel and 652 thousand kw-h of electricity annually.

ATTITUDES AND BELIEFS AFFECTING ADOPTION OF CONSERVATION IRRIGATION TECHNOLOGIES

Attitudes and beliefs toward conservation were found to have a strong influence on the decision to adopt drip irrigation or tailwater recovery systems. These values and beliefs were measured with a series of scales relating to "how important" a value was or "how likely" an outcome was. Generally, all surveyed farmers had similar attitudes toward the technologies, and placed a high degree of importance on earning more profit, being

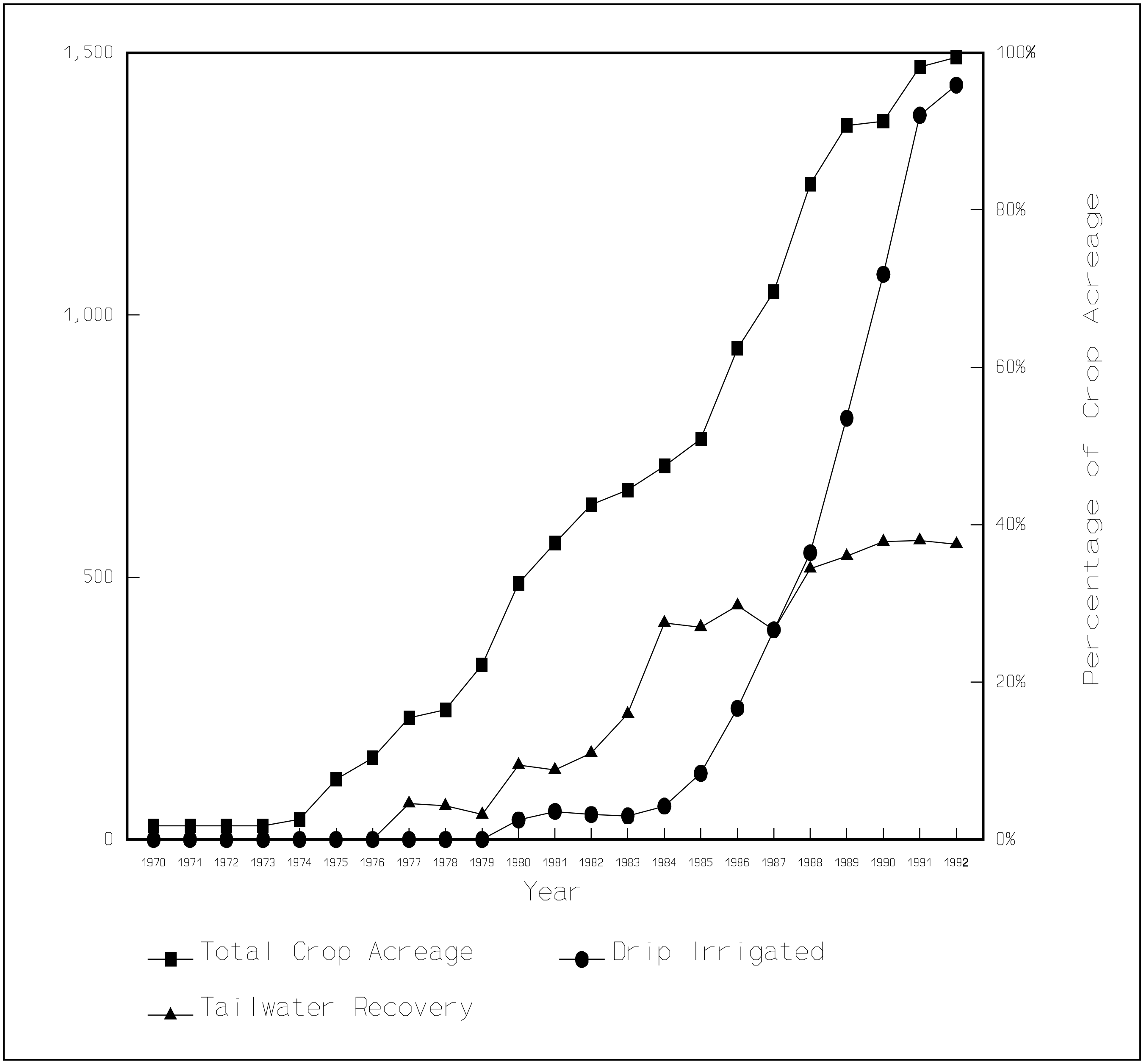

Figure 1. Cumulative crop acreage, drip-irrigated acreage, and tailwater recovery system acreage of sampled Florida strawberry growers, 1970-1992.

independent, and having free choice in the selection of technologies, without coercion.

Security of access to energy and water was the value that most significantly differentiated between adopters and non-adopters of drip irrigation systems.
Adopters of drip irrigation systems were more influenced by perceived norms favorable to drip irrigation from the family, the water management district, the state energy office, and other farmers. The most important information sources for Florida strawberry growers were other growers and equipment dealers. Adopters of drip irrigation believed that current energy consumption was much less likely to have a negative impact on the environment.

Adopters of tailwater recovery systems expressed stronger beliefs and values that these systems will result in improved community relations, and put significantly more weight on community recognition. They put less weight, however, on being self-reliant and independent. Community recognition, respect and admiration relative to the farming operation were also more valued by adopters than non-adopters of tailwater recovery systems.

Table 2. Estimated energy and water consumption for Florida strawberry irrigation, 1992.

		Crop Maintenance Irrigation		
	Units	**Drip**	**Sprinkler**	**All Irrigation***
Crop Area	acres	4,236	464	4,700
Water Depth Applied Annually	inches	16.54	16.41	22.17
Total Water Used	acre-inches	70,085	7,611	104,199
System Operating Pressure (avg)	psi	47.0	58.1	52.6
	ft	108.6	134.3	121.5
Friction Loss	ft	10.9	13.4	12.1
Depth to Water Table (avg)	ft	33.1	46.3	34.4
Drawdown (est)	ft	10.0	10.0	10.0
Total Head	ft	162.6	204.0	178.0
Mechanical Energy Required	whp-hr	1,301,236	177,278	2,117,836
	whp-hr/acre	307	382	451
Acreage irrigated by electric power	acres	1,235	46	1,281
Electric power used	kw-h	428,597	19,839	652,126
Electric energy efficiency	kw-h/acre	347	432	509
Acreage Irrigated by diesel power	acres	3,001	418	3,419
Diesel power used	gal	83,338	14,438	139,273
Diesel energy efficiency	gal/acre	27.8	34.6	40.7
Conversion factors and constants used				
gallons/acre-inch				27,154
density of water (lbs./gal)				8.326
pressure head (ft/psi)				2.31
pump efficiency (whp/bhp)				0.75
ft-lbs/hp-hr				1.98×10^6
Electric power unit energy efficiency (bhphr/kwh)				1.18
Diesel power unit energy (bhphr/gal)				
* *All irrigation represents plant establishment and frost/freeze protection as well as crop maintenance uses.*				14.75

IMPLICATIONS FOR RESOURCE CONSERVATION EDUCATION AND POLICY

Strawberry growers who were influenced strongly by community norms to conserve energy and water tended to adopt conservation technologies at a higher rate and to a greater extent. Nonadopters were more likely to perceive less individual choice in the matter of switching to conserving technology. They believed that external control was being used to force certain actions by regulatory agencies, and that they simply had less control over the actual decision, due to factors such as insufficient investment capital available.

These findings suggest that attempts by state or other government entities to bring about reductions in energy and water use in agriculture should turn the focus away from regulatory requirements of the "thou shalt" nature and redirect efforts toward defining "thou shalt not" rules worked out in consort with the growers. Growers are more likely to adopt energy and water conserving technologies if they are involved in the process of developing their own solutions within broadly defined limits on what not to do, such as not lowering water tables to the point of substantially affecting neighboring wells. Trends at both the national and state levels toward requiring growers to meet specific technology standards, such as "use of drip irrigation," may be misdirected. Traditional conservation education, technical assistance, and cost-sharing activities of the government and the community is likely to lead to more conservation technology adoption, than will regulatory approaches.