Irrigation Conservation Practices Appropriate for the Southeastern United States

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PROJECT REPORT 32

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ABSTRACT

Irrigation system efficiency and water conservation characteristics were investigated for the primary irrigation systems present in the southeastern United States and, in particular, Georgia. These recommendations take into account the humid region and the differences between this area and water conservation potential in arid regions. Although the most efficient irrigation systems are currently being used throughout the region, many systems have been in place for 20 years and are in need of upgrades and improvement.

The potential for a tax incentive or regulatory program to encourage irrigation system upgrades to more efficient and conservation-oriented alternatives produced five (5) primary recommendations. Firstly, an irrigation audit is suggested for all systems considering a change to be sure recommended changes are appropriate. Although no direct water savings are associated with an irrigation audit, the characterization of needs is a primary consideration. Secondly, a properly operating end gun shutoff is recommended for the estimated 2,000+ center pivot systems that are in need of such repair/installation. The estimated water savings are ≈ 2,851 million gallons at a cost/benefit ratio of ≈ $351/million gallons saved in an average year. Thirdly, repair of the water delivery system on 80 psi traveling gun systems (older ones still in use) is estimated to save ≈ 2,585 million gallons of water in an average year on the estimated 1600 systems in need of such repairs. The cost/benefit ratio of such repairs is estimated at ≈ $2,166 per million gallons saved in an average year. Fourthly, use of a preferred irrigation scheduling technique on orchard drip systems (estimated that ≈ 500 systems, primarily on pecan, would benefit) would translate to ≈ 1,996 million gallons of water saved in an average year. The cost/benefit ratio of such improvements is ≈ $376 per million gallons saved. Fifthly, the replacement of old sprinkler packages with new, more efficient sprinklers is estimated to save ≈ 4,181 million gallons in an average year on the ≈ 4,400 systems in need of such replacement. The cost/benefit ratio of such replacement is ≈ $631 per million gallons saved in an average year.

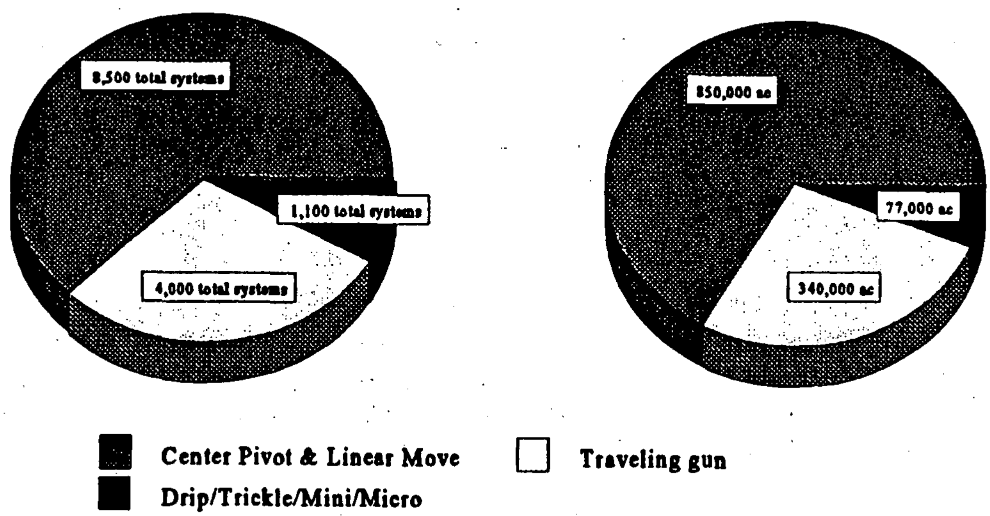
The above scenarios represent less than 15% of the recommendations indicated in this report. The choice of particular improvements is based on the characteristics of individual systems and the desire to be more efficient and conservation minded. The suggestions in this report are not designed to be all inclusive, nor cover new alternatives which may be available in the future. However, water conservation in irrigation systems will continue to be a priority in considerations for existing and new irrigation systems (and permits) in Georgia.

INTRODUCTION

General:

Irrigation is an essential part of a full crop management program, whether in arid or humid areas. Irrigation in humid areas reduces part of the risks of growing crops by not relying totally on Mother Nature to supply plant water needs. In 1997 there were over 1.3 million acres of irrigated cropland in Georgia (Harrison and Tyson, 1997). The majority of irrigation in Georgia is associated with three primary classifications: center pivot and linear move, traveling gun, and drip/trickle/mini/micro. The number of systems associated with each type and the estimated land area under each classification are indicated in Figure 1. This acreage is expected to increase in the future as profit margins on dryland crop production decrease and farmers attempt to reduce risks. Irrigation remains the life-blood of many of Georgia's agricultural operations and will continue to be required to meet future food and fiber needs.

Figure 1. Irrigation Systems in Georgia



The prevalence of irrigation in Georgia and surrounding states and the amount of water associated with this practice has generated interest about the quantity of water used in irrigation. The estimation of how much water is actually used in agricultural irrigation became extremely important when the tri-state water dispute between Georgia, Alabama, Florida surfaced in the early 1990's. Since then, several projects have studied water use (including irrigation water use) in the major basins associated with Atlanta in order to estimate how changes in water allocation might impact Alabama, Florida and other parts of Georgia. Water use concerns associated with salt-water intrusion and pumping along the east coast have also increased the need for good quality data on agricultural water use.

Unfortunately, agricultural water users have not been required to report their water use in Georgia, so current data and analysis are crude estimates at best. Whether these estimates are good or bad, they are, in fact, estimates. Since no firm data were available to indicate how much water was being used, it was impossible to determine whether water was used wisely.

Irrigation of agricultural crops has received "bad press" because problems in water application are usually easily identified. Traveler systems which are spraying water over roads, irrigation sprinklers which have failed and are shooting "geysers" of water into the air, and spray drift during high winds are occasionally observed and reported by the general public who travel near irrigation systems. Even though agricultural irrigation systems operate correctly most of the time, public opinion is often based on these rare events.

The undeserved poor reputation for agricultural irrigation has created a need for better assessment of how well we are actually irrigating and what steps can be taken to improve those practices. The primary purpose of this report is to document the most prevalent irrigation practices currently being used in Georgia and indicate alternatives, which may be implemented to improve agricultural water use efficiency. Alternatives are suggested based on a particular type of irrigation system. Water savings and efficiency improvements associated with a change in irrigation type are also presented. Some improved management alternatives are suggested which can be applied to most agricultural irrigation situations. However, the scope of this report is limited in that only those practices most prevalent in Georgia and the southeastern United States are included. The practices in this report are also dated. New irrigation practices and management alternatives are being developed continuously. In all cases where older irrigation systems are replaced, new more efficient systems and/or components will hopefully be used.

Irrigation practices discussed in this report relate to application efficiency and irrigation conservation. The *application efficiency* is the ratio of water being withdrawn from a particular resource to the water available for target plant production. *Irrigation conservation* is the process of **improving** the application efficiency. The term "improving" implies that an effort is made to reduce losses by a particular management or system change. In all irrigation systems, some water loss will occur (i.e., all water withdrawn from a source will not reach the target plant roots). However, some losses can be legitimately minimized or eliminated. When these losses have been minimized on a particular system, then the application efficiency is maximized for that system.

Application Efficiencies:

Application efficiency, as indicated above, is a term used to define the difference between the water taken from a water source and the water reaching a position where the target plants can use the water (usually at the plant roots). At this point the differences between humid area irrigation and arid area irrigation diverge. In the application of water, if the water is not reaching the soil or remaining in the soil where roots are located, then this water is lost. This loss directly reduces the efficiency of the irrigation system. Of course, there are other uses for irrigation besides meeting crop needs (seed bed preparation, seed germination, softening a soil crust during emergence, frost protection, salt removal, etc.; Burt, et al., 1997). In this report the primary use of irrigation in Georgia's humid region is associated with *consumptive use*, where the water is taken up by the plant. All other uses are either tied to arid conditions; or they are usually minor components of overall irrigation applications in the southeast, and will not be extensively addressed in this report.

In an irrigation system, *losses* may occur at any position in the water's pathway. Application efficiencies are affected by system leaks, system water pressure (decreased droplet size), evaporation rate, wind speed and direction, uniformity of application, canopy interception, deep percolation, and other factors. Application efficiencies can vary widely by crop and the particular type of irrigation system. For the most part, irrigation systems that expose water to the atmosphere for a long period of time are subject to decreased application efficiency. In the southeast, and particularly in Georgia, the majority of the irrigation systems being used are already the most efficient available for the particular crop and land conditions. Very little if any surface (including furrow, level basin, flood, ...) irrigation is used. Water table management (WTM, also know as sub-irrigation) is used extensively in North Carolina and Florida, but few systems have been installed in other states (Shirmohammadi, et al., 1992). Surface and WTM are usually less efficient irrigation alternatives. The predominate use of center pivot, drip/trickle, traveler, and solid set irrigation results in relatively high application efficiency *potential.* We say potential, because poor management and design of a particular system can result in poor application efficiency even though the average system is efficient.

In irrigation system design, application efficiency and uniformity are critical factors. *Uniformity* implies how consistently emitters/sprinklers apply water across the irrigation system. In most irrigation systems all the sprinklers or emitters do not apply the same amount of water. Those near a mainline tend to emit more water than those at the end of lines due to pressure losses. Sprinklers and emitters may not wear evenly and some variation exists in manufacturing. As a result, water application often varies significantly across a field. Obviously, a system with high uniformity is desirable to ensure the entire crop is receiving the same amount of water.

In many irrigation system evaluations, the characteristics of application efficiency are based on the output from the low quarter emitters. The definition of low quarter emitters or sprinklers is the quarter of the emitters or sprinklers producing the least amount of water in the irrigation system. The following are considered "reasonable" application efficiencies from two different sources.

Keller and Bliesner (1990) state:

> "Average application efficiencies are based on full crop canopies and systems that are well-designed and carefully maintained. The values are estimates and should be considered accordingly. Under conditions where poor management, poor design, or conditions are not suited for irrigation, values may be much lower ..."

Allen (1991) reports the following potential application efficiencies of low quarter emitters/sprinklers:

	Range (%)	Average (%)
Sprinkler		
Solid Set	60 - 75	70
Center Pivot	70 - 85	75
Linear Move	65 - 85	75
Big Gun	55 - 65	60
Traveler	60 - 80	70
Trickle	70 - 95	

Keller and Bliesner also (1990) provide the following other efficiency information:

	Efficiency %
Moving or set systems with excellent uniformity in cool or humid climates and low winds.	85
Moving systems in most climates and winds; and set systems with medium to high application rates and good uniformity.	80
Average set system in most climates and winds	75
Travelers	70
Gun or boom sprinklers	60 - 75
Periodic-move laterals	70 - 85
Fixed lateral	70 - 88

In defining application efficiencies which correspond to crop type in Georgia, the predominate irrigation system used for crops such as corn, cotton, peanut, soybean, sorghum, and wheat is the center pivot system. For tobacco, the predominate system type is traveler. For peaches, the systems are split between drip/trickle and traveler. For pecan, the systems are split between drip/trickle and sprinkler. For vegetables, the predominate irrigation system used is drip/trickle. Watermelon and Vidalia Onions, two of Georgia's largest acreage horticultural crops, are predominately under center pivot. In practically all cropping situations, a different type irrigation system than mentioned above is probably being used on some acreage. Therefore, recommendations for improvement need to be addressed for each individual system.

It is important to note that all recommendations indicated below will not work for every situation. The ranges and averages imply that the savings and efficiency increases are not the same for every system. Care should be taken to evaluate each system independently and determine the best alternatives for water savings. The overall goal of this report is to encourage our producers to improve irrigation efficiency. "Poor" systems can be improved greatly while our "good" systems may only require minimal improvements.

PROCEDURES

A workshop approach was used to develop these irrigation conservation practices. Irrigation specialists from the southeast region were brought together to evaluate each individual alternative as a group in two sets of workshops. Initial categories and characteristics were defined in the first workshop and final numbers and ranges were consolidated in the second. The combined "professional years" of design, recommendation, or other irrigation activity (following graduation) of the report authors is well over 100 years. The desire was to obtain the best input possible on the recommendations to be sure the values presented are reasonable. In some cases extensive discussion occurred in order to determine an alternative range of water savings. Published resources from other states and related activities from the participants were also used in developing the information. The final results are based on a "compendium of opinion" from those participating. The qualifications of the individuals participating only implies that these values are reasonable, but do not imply that they are "absolutely right" in all cases.

The documentation for this report was reviewed by the authors twice, followed by submission to the following list of irrigation specialists and interested parties both inside, see following listing of individuals, and outside Georgia for their comments and input.

James Lee Adams, Farmer and Member, Southwest Georgia Agribusiness Association

Gary Black, Georgia Agribusiness Council, Norcross.

Jimmy Bramblett, Agricultural Economist, NRCS, Athens.

Cecil Burke, Georgia Farm Bureau, Macon.

Lamar Ortega, Lindsay Manufacturing, Dothan, Alabama

Elton Sharp, Sharp Systems, Leslie, Georgia

Garland Mears, Garland Mears Irrigation, Americus, Georgia

Allen Smajstrla, Professor and Extension Specialist, Agricultural and Biological Engineering, University of Florida, Gainesville. Specialist in irrigation applications in Florida.

Glenn Smith, Georgia Cattleman's Association, Macon.

Ted Tyson, Extension Agricultural Engineer and Associate Professor, Auburn University, Alabama. Specialist in irrigation design and management and liquid animal waste management.

Kurt Webster, Suwanee River Water Management District, Live Oak, Florida

The base information in this report is designed to apply across the southeast region. The tables and numbers are directed toward Georgia. It is anticipated that reports will be developed with similar specific recommendations for potential water savings in the other states in the region. These anticipated reports will provide a reference/resource for the most logical approaches to improving efficiency of water use in agriculture and potential for water savings through conservation.

The final reports from these efforts are designed to be working documents, with changes and recommendations occurring in the future. The authors welcome input from anyone who has knowledge or information for improvement.

DESCRIPTION OF WATER EFFICIENCY TABLES

Tables 1 through 5 summarize estimates of water savings associated with different changes in irrigation practices. Below is a description of the categories in the tables.

<u>Comparison:</u> Each Comparison is "labeled" for reference purposes. The text will describe reasons for the indicated differences based on these labeled comparisons.

Current Base System: This category indicates a summary of the baseline system configurations in the comparison. For each change/improvement in irrigation, the system used before the change must be identified.

Proposed System Change: This category is a summary of the potential changes which may or may not provide a water savings. Proposed system changes are presented for the majority of the categories which may have been considered in the past for water or energy savings.

Estimated water savings range: This column describes the range in potential savings for a proposed system change. Water savings are positive, while increased water usage would be indicated by a negative value. The range is provided because the proposed changes will not be as effective for all systems. While negative responses indicate an increase in total water usage, water use efficiency is improved so that overall, the change has net benefits. The units of "%" imply percent of total water usage during irrigation.

Estimated water savings average: This is an arithmetic average within the water savings range. In some cases the average may be ""skewed" to indicate more systems may benefit from a change than others (or vice versa).

Potential number of irrigation systems affected: This number is only associated with Georgia at this time. Similar numbers are expected to be included for neighboring states in future reports. The number reflects input from irrigation specialists and irrigation dealers about the number of systems which are "eligible" for the indicated system change.

Average system size: This number is the average size for the particular irrigation system of interest in the state of Georgia (rounded to the nearest 5). The average system size is used to estimate the total potential water savings and the estimated cost per system.

Average Year, total potential gallons saved if fully implemented (million gallons): This number is an estimate of how much water will be saved if all systems suitable for improvement were to implement the proposed system changes. Average year is based on 7 inches of annual water application. Irrigation amounts indicated are not specific for a particular crop or type of irrigation system. Obviously, vegetables with plastic mulch would use more than 7 inches of water in an average year. The calculation is based on the average system size, 7 inches of water applied, and the average estimated water savings.

Dry Year, total potential gallons saved if fully implemented (million gallons): This number estimates how much water will be saved if all systems suitable for improvement were to implement the proposed system changes during a dry year. An "average dry" year criteria (12 inches of water application) is designed to provide estimated conservation effects during those periods when water availability may be critical. Obviously, other dry year criteria can be determined with higher values of water application. The long-term impact of water conservation practices is based on long-term average application values.

Estimated cost for implementation on an average system (1998 $): This is an estimate of the cost per system based on the average size for implementing the indicated change in 1998 dollars.

Statewide costs for full implementation (Million $, 1998): This is the potential number of systems multiplied by the estimated cost for improvement. The potential tax loss, for the indicated tax incentive value, is reflected in this figure (1998 $).

Cost per unit water saved in an average year (1998 $/Million gallon): This value is calculated from the estimates for water saved and total statewide cost figures (in 1998 $). This number provides a value to represent the cost/benefit ratio. Obviously, practices with a lower cost per unit of water saved are more desirable. *One important aspect of this value is that no amortization is used. All costs are indicated within one year.* Essentially, the cost/gallons saved values are presented for amortization in the first year. Obviously, the cost in the second year for similar water savings may be greatly reduced if all outlays were for capital expenses and no yearly charge is required.

COMPARISON OF IRRIGATION PRACTICES

The following narrative comparisons are associated with Tables 1-5. As indicated above, all cost figures are in 1998 dollars. The benefit of the narrative descriptions is to find a comparison, which has application to a particular system of interest. The narrative comparison will then help explain what irrigation system conditions contribute to the different levels of water savings within a particular range. As in any of the analysis, columns to the right are based on the average savings values. For an individual system, the water savings may be more or less than the average. Cost figures do not include changes that may be necessary to improve water supplies (i.e., well re-working, new pumps or power units, etc.) if the recommended system change requires a different flow rate. These type changes could increase the cost for potential modification. The reader needs to be aware that these average cost figures will not apply to all systems.

Center Pivot and Lateral Move Systems (Table 1):

The following comparisons are listed in Table 1 and are associated with center pivot and lateral move systems. In Georgia, the average system size of this type is 100 acres. There are approximately 8,500 systems in this category.

Comparison 1: From No end gun shutoff to *end gun shutoff*

The base system is a center pivot or lateral move system. Typically, the system will have an end gun. The end gun will apply water outside the target area and not be equipped with a working mechanism to turn the end gun on-and-off at desired locations.

Estimated water savings are between 5 and 10%. The low end is associated with systems which are already using good practices and throwing little water into off-target areas. The high end is associated with systems which operate continuously through 24 hours in very open areas and a large percentage of the water is thrown in off-target areas. The average estimated water savings is ≈ 7.5%.

Of the 8,000+ center pivot systems currently in the state of Georgia, 2000 are estimated to be candidates for this type improvement. The potential water savings from this practice alone would be ≈ 2,851 million gallons during an average year. The cost to implement such a change is ≈ $500 per system. The estimated statewide costs for full implementation is $1.0 million. The cost per unit water saved is estimated to be ≈ $351 per million gallons of water saved.

Comparison 2: From poorly uniform system to new sprinkler package (same as original)

The base system is a center pivot or lateral move system with a sprinkler package performing below the accepted standard of 80% uniformity. Typically, the system will have an end gun. The suggested alternative is to install a new sprinkler package that is the same as the original package.

Estimated water savings are between 0 and 10%. No savings are associated with systems which are already using good practices and have uniformity coefficients that will not improve significantly. The high end savings are associated with systems which have uniformity coefficients well below the standard and are therefore over-applying water in some areas. The average estimated water savings is ≈ 5%.

Of the 8,000+ center pivot systems currently in the state of Georgia, 4400 are estimated to be candidates for this type improvement. The potential water savings from this practice alone would be ≈ 4,181 million gallons during an average year. The cost to implement such a change is between $0 and $1,000 per system. The low end cost is associated with a system that needed only sprinkler adjustments that used farm labor available at no cost. The high end cost is associated with a complete sprinkler change. The average cost for this comparison is $250 per system. The estimated statewide costs for full implementation is $2.2 million. The cost per unit water saved is estimated to be ≈ $526 per million gallons of water saved.

Comparison 3: From 23 degrees impact sprinklers on top of boom to *reduced angle sprinklers on top*

The base system is a center pivot or lateral move system operated with 23 degree angle impact sprinklers on the top of the pivot. The operating pressure is in the high range (> 80 psi). Typically, the system will have an end gun. The new alternative is reduced angle impact sprinklers on top of the pivot.

Estimated water savings are between 5 and 15%. The low end savings is associated with systems which are already operating at night and using good practices. The high end is associated with systems which operate continuously through 24 hours in very open areas. The average estimated water savings is ≈ 10%.

Of the 8,000+ center pivot systems currently in the state of Georgia, 850 are estimated to be candidates for this type improvement. All systems with 23 degree impact sprinklers on top of the pivot are not candidates for the change due to the limitation on soil intake rates. The reduced angle impact sprinklers will apply slightly more water in a smaller area than the impact sprinklers at a higher pressure. If the soil is not capable of handling the additional input rate, irrigation water would runoff and be ineffective. This is also the sprinkler package recommended for wastewater application so those systems will remain 23 degree impact sprinklers. The potential water savings from this practice alone would be ≈ 1,616 million gallons during an average year. The cost to implement such a change will range from $500 to $2,000 per system depending on the outside labor required. The estimated statewide costs for full implementation is $1.02 million (using a $1,200 average). The cost per unit water saved is estimated to be ≈ $631 per million gallons of water saved.

Comparison 4: From 23 degree impact sprinklers on top of boom to *low pressure sprinklers on top*

The base system is a center pivot or lateral move system operated with 23 degree angle impact sprinklers on the top of the pivot. The operating pressure is in the high range (> 80 psi). Typically, the system will have an end gun. The suggested alternative is to change to low pressure spray nozzles on top of the pivot boom with a reduction in water pressure (15- 25 psi).

Estimated water savings are between 5 and 15%. The low end savings is associated with systems which are already operating at night and using good practices. The high end savings is associated with systems which operate continuously through 24 hours in very open areas. The average estimated water savings is ≈ 10%.

Of the 8,000+ center pivot systems currently in the state of Georgia, 200 are estimated to be candidates for this type improvement. All systems with impact sprinklers on top of the pivot are not candidates for the change due to the limitation on soil intake rates. The spray nozzles will apply more water in a smaller area than the higher pressure sprinklers. If the soil is not capable of handling the additional input rate, irrigation water would run off and be ineffective. The potential water savings from this practice alone would be ≈ 380 million gallons during an average year. The cost to implement such a change is ≈ $3,500 per system if a booster pump is required. The estimated statewide costs for full implementation is $0.7 million. The cost per unit water saved is estimated to be ≈ $1,841 per million gallons of water saved.

Comparison 5: From 23 degree impact sprinklers on top of the boom to *low pressure sprinklers on drops*

The base system is a center pivot or lateral move system operated with 23 degree angle impact sprinklers on the top of the pivot. The operating pressure is in the high range (> 80 psi). Typically, the system will have an end gun. The suggested alternative is to change to low pressure spray nozzles on drops with a reduction in water pressure (10- 20 psi).

Estimated water savings are between 5 and 25%. The low end savings is associated with systems which are already operating at night and using good practices. The high end savings is associated with systems which operate continuously through 24 hours in very open areas. The average estimated water savings is ≈ 15%.

Of the 8,000+ center pivot systems currently in the state of Georgia, 200 are estimated to be candidates for this type improvement. All systems with impact sprinklers on top of the pivot are not candidates for the change due to the limitation on soil intake rates. The spray nozzles will apply more water in a smaller area than the higher pressure sprinklers on top. If the soil is not capable of handling the additional input rate, irrigation water would run off and be ineffective . The potential water savings from this practice alone would be ≈ 570 million gallons during an average year. The cost to implement such a change is ≈ $4,000 per system if a booster pump is required. The estimated statewide costs for full implementation is $0.24 million. The cost per unit water saved is estimated to be ≈ $421 per million gallons of water saved.

Comparison 6: From reduced angle impact sprinklers on top of boom to *low pressure sprinklers on top*

The base system is a center pivot or lateral move system operated with reduced angle impact sprinklers on the top of the pivot. The operating pressure is in the medium range (20-50 psi). Typically, the system will have an end gun. The suggested alternative is to change to low pressure spray nozzles on top of the pivot with a reduction in water pressure (15- 25 psi).

Estimated water savings are between 0 and 5%. No low end is associated with systems which are already operating at night and using good practices. The high end is associated with systems which operate continuously through 24 hours in very open areas. The average estimated water savings is ≈ 2.5%.

Of the 8,000+ center pivot systems currently in the state of Georgia, 700 are estimated to be candidates for this type improvement. All systems with reduced angle impact sprinklers on top of the pivot are not candidates for the change due to the limitation on soil intake rates. The spray nozzles will apply more water in a smaller area than the impact sprinklers at a higher pressure. If the soil is not capable of handling the additional input rate, irrigation water would run off and be ineffective. The potential water savings from this practice alone would be ≈ 333 million gallons during an average year. The cost to implement such a change is ≈ $1,000 per system. The estimated statewide costs for full implementation is $0.7 million. The cost per unit water saved is estimated to be ≈ $2,105 per million gallons of water saved.

Comparison 7: From reduced angle impact sprinklers on top of boom to *low pressure sprinklers on drops*

The base system is a center pivot or lateral move system operated with reduced angle impact sprinklers on the top of the pivot. The operating pressure is in the medium range (20-50 psi). Typically, the system will have an end gun. The suggested alternative is to change to low pressure spray nozzles on drops with a reduction in water pressure (10- 20 psi).

Estimated water savings are between 0 and 10%. No low end is associated with systems which are already operating at night and using good practices. The high end is associated with systems which operate continuously through 24 hours in very open areas. The average estimated water savings is ≈ 5%.

Of the 8,000+ center pivot systems currently in the state of Georgia, 700 are estimated to be candidates for this type improvement. All systems with impact sprinklers on top of the pivot are not candidates for the change due to the limitation on soil intake rates. The spray nozzles will apply more water in a smaller area than the higher pressure sprinklers. If the soil is not capable of handling the additional input rate, irrigation water would run off and be ineffective. The potential water savings from this practice alone would be ≈ 665 million gallons during an average year. The cost to implement such a change is ≈ $4,000 per system if an end gun booster pump is required.

The estimated statewide costs for full implementation is $2.8 million. The cost per unit water saved is estimated to be ≈ $4,209 per million gallons of water saved.

Comparison 8: From reduced angle impact sprinklers on top of boom to LEPA nozzles on drops

The base system is a center pivot or lateral move system operated with reduced angle impact sprinklers on the top of the pivot. The operating pressure is in the medium range (20-50 psi). Typically, the system will have an end gun. The suggested alternative is to change to LEPA (low energy precision application) type spray nozzles with a reduction in water pressure (5- 10 psi).

Estimated water savings are between 0 and 10%. No low end is associated with systems which are already operating at night and using good practices. The high end is associated with systems which operate continuously through 24 hours in very open areas. The average estimated water savings is ≈ 5%.

Of the 8,000+ center pivot systems currently in the state of Georgia, 50 are estimated to be candidates for this type improvement. All systems with impact sprinklers on top of the pivot are not candidates for the change due to the limitation on soil intake rates. The spray nozzles will apply more water in a smaller area than the higher pressure sprinklers. If the soil is not capable of handling the additional input rate, irrigation water would run off and be ineffective. Another problem with the adoption of this sprinkler package is the growers requirement to adopt a different tillage practice called "furrow diking". Not all individuals will adopt this tillage change. The potential water savings from this practice alone would be ≈ 48 million gallons during an average year. The cost to implement such a change is ≈ $4,500 per system if a booster pump is required. The estimated statewide costs for full implementation is $0.225 million. The cost per unit water saved is estimated to be ≈ $4,735 per million gallons of water saved.

Comparison 9: From low pressure sprinklers on top of boom to low pressure sprinklers on drops

The base system is a center pivot or lateral move system operated with low pressure sprinklers on the top of the boom. The operating pressure is in the medium range (20-50 psi). Typically, the system will have an end gun. The suggested alternative is to change to low pressure sprinklers on drops with a reduction in water pressure (10-20 psi).

Estimated water savings are between 0 and 10%. No low end is associated with systems which are already operating at night and using good practices. The high end is associated with systems which operate continuously through 24 hours in very open areas. The average estimated water savings is ≈ 5%.

Of the 8,000+ center pivot systems currently in the state of Georgia, 2,550 are estimated to be candidates for this type improvement. The potential water savings from this practice alone would be ≈ 2,423 million gallons during an average year. The cost to implement such a change is ≈ $1,500 per system. The estimated statewide costs for full implementation is $3.83 million. The cost per unit water saved is estimated to be ≈ $1,578 per million gallons of water saved.

Comparison 10: From low pressure sprinklers on drops to LEPA nozzles on drops

The base system is a center pivot or lateral move system operated with low pressure sprinklers on drops. The operating pressure is in the low range (10-20 psi). Typically, the system will have an end gun. The suggested alternative is to change to LEPA type spray nozzles with a reduction in water pressure (5- 10 psi).

Estimated water savings are between 0 and 3%. No low end is associated with systems which are already operating at night and using good practices. The high end is associated with systems which operate continuously through 24 hours in very open areas. The average estimated water savings is ≈ 1%.

Of the 8,000+ center pivot systems currently in the state of Georgia, it is estimated that none will be candidates for this type improvement. The spray nozzles on drops at ground level will apply more water in a smaller area than the spray nozzles mounted at truss rod height. If the soil is not capable of handling the additional input rate, irrigation water would run off and be ineffective. Another problem with the adoption of this sprinkler package is the growers requirement to adopt a different tillage practice called "furrow diking". Not all individuals will adopt this tillage change.

Improved Irrigation Practices for all Systems (Table 2):

The following comparisons are listed in Table 2 and are associated with all irrigation systems. In Georgia, the average system size assumed for this analysis is 100 acres. There are approximately 13,000 irrigation systems that may be affected.

Comparison 11: From no current method of irrigation scheduling to irrigation scheduling

The majority of irrigation systems do not use a consistent irrigation scheduling method. Typically, irrigation is the last "crop need" met following nutrients and pest control. Many crops are not receiving as much water as the crop actually needs, while in other cases, the crops are being over-irrigated to reduce the potential for drought-related stress (high value crops in particular).

Estimated water savings are between -10 and + 10%. Improved irrigation scheduling on many row crop applications will actually indicate more water is needed by the crop. On the average, the estimated water savings are ≈ 0%.

An estimated 11,700 systems could benefit from an irrigation scheduling method. The average cost for implementation is ≈ $700 which may be as convenient as watching local weather and calculating water needs (book-keeping approach) to installation of soil moisture sensors in the field. Services are also available to help manage crop water requirements.

Although this recommendation does not achieve water savings, the benefits of more efficient water application can be directly tied to improved and/or more consistent crop yields. In addition, the potential for improved water and chemical management can benefit water quality, reduce potential runoff, and reduce potential leaching of nutrients and chemicals.

Comparison 12: From no current method of irrigation scheduling to irrigation scheduling with a Class A Evaporation Pan

This proposed practice has the same potential benefits as Comparison 11. The only difference is the use of a Class A evaporation pan for irrigation scheduling. The evaporation pan provides a method of converting irrigations and water losses almost directly to crop needs (with calculations). The cost of a pan is slightly higher, but if well maintained, the pan can provide an excellent method of determining evaporation losses on a scheduled basis.

Estimated water savings are between -10 and + 10%. Improved irrigation scheduling on many row crop applications will actually indicate more water is needed by the crop. On the average, the estimated water savings are ≈ 0%.

An estimated 11,700 systems could benefit from an irrigation scheduling method. The average cost for implementation is ≈ $1,500 which includes a pan and hook gage (for accurately reading the water level).

Although this recommendation does not achieve water savings, the benefits of more efficient water application can be directly tied to improved and/or more consistent crop yields. In addition, the potential for improved water and chemical management can benefit water quality, reduce potential runoff, and reduce potential leaching of nutrients and chemicals.

Comparison 13: From no uniformity test performed in last 5 years to uniformity test performed

This proposed practice does not directly "save" or "waste" water in itself. The "modifications to the system" to improve uniformity will result in the change in water use. A uniformity test is a procedure to measure the output and distribution of sprinklers, emitters, etc. to determine whether the amount of water estimated to be reaching the crop is actually reaching the crop. Poor uniformity (< 80% Christiansen's coefficient of uniformity) implies that a sufficiently large section of the field is not receiving the "average" water application. As a result, the water that is being applied may be higher in some areas than is expected (encourages deep percolation and runoff) or lower (not meeting crop needs). This practice also affects the efficiency of water use.

Estimated water savings are between -10 and + 10% if improvements are made. Additional water may be required if uniformity is affected by clogged emitters in a drip system. Water savings may be associated with worn sprinklers with larger orifices than in the original new sprinkler. On the average, water savings are ≈ 0%, but water will be used more efficiently.

An estimated 11,700 systems are considered to be at least 5 years old and have not had a uniformity test in the last 5 years. The average cost for a uniformity test on a 100 acre system is ≈ $250. Obviously, the changes in the system to improve uniformity would have associated costs depending on the system needs.

Although this recommendation does not achieve water savings, the benefits of more efficient water application can be directly tied to improved and/or more consistent crop yields. In addition, the potential for improved water and chemical management can benefit water quality, reduce potential runoff, and reduce potential leaching of nutrients and chemicals.

Comparison 14: From no uniformity test, calibration, or major maintenance check in past 5 years to *performance of an irrigation audit*

This proposed practice, as in 13 above, does not directly "save" or "waste" water in itself. The "modifications to the system" to improve uniformity, calibrate operating pressures and supply components, and repair significant leaks, will result in the change in water use. The "irrigation audit" is a full analysis of the entire irrigation system. An audit is essential to determine the most effective and needed recommendations for reducing water use.

Estimated water savings are between -15 and + 50% if improvements are made. Additional water may be required if uniformity is affected by clogged emitters in a drip system or operating pressures have not been sufficient (too many zones in a drip system operated at one time). Water savings may be associated with worn sprinklers with larger orifices than in the original new sprinkler, fixing major leaks, better zone management in a drip system, or end gun shut-offs and sprinkler package changes in sprinkler systems. On the average, the estimated water savings are ≈ 5%, but water and energy will be used more efficiently.

An estimated 11,700 systems are considered to be at least 5 years old and have not had a complete irrigation audit in the past 5 years. The average cost for an irrigation audit on a 100 acre system is ≈ $1000. The statewide costs for full implementation is estimated at $11.7 million. Obviously, the changes required to improve irrigation systems would have additional costs, but this audit provides essential information to determine what, if anything, needs to be changed.

Although this recommendation does not achieve water savings, the benefits of more efficient water application can be directly tied to improved and/or more consistent crop yields. The implementation of a program to encourage irrigation audits across all systems in Georgia where necessary would provide additional information on the efficiency of current irrigation practices and systems. Understanding how much water can potentially be saved is essential to future recommendations on agricultural water use.

Comparison 15: From no major maintenance checks performed in last 5 years to major maintenance check performed

This proposed practice also does not directly "save" or "waste" water in itself. The "modifications to the system" for a more efficient pumping plant, and supply system which does not leak will result in the change in water use. A major maintenance check is a check of fuel use efficiency, meeting pressure requirements, and checking water losses throughout the system. This practice also affects the efficiency of water use but should save water on the average.

Estimated water savings are between 0 and 10% if improvements are made. The largest improvements are based on fixing leaks, repairing gaskets, and so forth. The average estimated water savings is 5%.

An estimated 11,500 systems are considered to be at least 5 years old and have not had a major maintenance check in the last 5 years. The potential water savings from this practice alone would be ≈ 10,929 million gallons in an average year if changes were implemented. The cost to perform a major maintenance check on a 100 acre system is ≈ $500. The estimated statewide costs for major maintenance checks for all appropriate systems is $5.75 million. The cost per unit water saved is not directly applicable, since the costs for improvements have not been added (i.e., the maintenance check does not save water by itself).

Comparison 16: From pressure gages not operating to pressure gages repaired/replaced

A system operating at the correct pressure will operate more efficiently. As in several scenarios above, this proposed practice does not directly "save" or "waste" water in itself. The "modifications to the system" required to ensure proper pressure throughout the system is important.

Estimated water savings are between -5 and + 5% if improvements are made. The largest improvements are based on systems which have been over-pressured. The average estimated water savings is 0%.

An estimated 6,500 systems are considered to not have correctly operating pressure gages, and therefore are most likely not being operated at the correct pressure. The cost to repair/replace gages on a 100 acre system is ≈ $50 on the average. The estimated statewide costs for pressure gage replacement/repair is ≈ $0.33 million.

Traveling Gun Systems Including Cable and Hose Tow (Table 3):

The term "Traveler Irrigation System" refers to either cable tow or hard hose traveling sprinkler systems. The cable tow traveler consists of a single gun sprinkler mounted on a trailer with water being supplied through a collapsible, flexible hose that ranges in length from 330 to 1,320 feet. A steel cable, anchored at one end of the field, is used to guide the gun cart. As the machine moves through the field, dragging the hose behind it, the cable winds around the cable drum. The cable tow traveler was very popular during the early to mid 70's. As a result, many of the machine still in use are old and need repairs.

The hose-drag traveler became popular in the late 70's and consists of a hose drum, a medium-density polyethylene (PE) hose and a gun type sprinkler. The hose drum is mounted on a multi-wheel trailer or wagon. The gun sprinkler is mounted on a wheel or sled type cart referred to as the gun cart. The hose supplies water to the gun sprinkler and also pulls the sprinkler cart toward the drum. The hose drum is rotated by a water turbine, water piston, water bellows, or by an internal combustion engine. Regardless of the drive mechanism, systems should be equipped with speed compensation so that the sprinkler cart travels at a uniform speed from the beginning of the pull until the hose is fully wound onto the hose reel. Many older systems were not equipped with speed compensation and will apply about 30% more water on one end of the field than the other.

Nozzle sizes on gun type travelers are typically 1/2 to 2 inch diameter and require high operating pressures of 75 to 100 psi at the gun for uniform distribution. On most older systems, the gun discharge trajectory angle is 27 degrees. With high discharge angle and operating pressure, water can be thrown as much as 30 feet high and 250 feet from the gun. Compared to other types of systems, travelers have slightly poorer uniformity than center pivots but much better than non-overlapping stationary sprinklers (application uniformity is a measure of the uniformity of water reaching the soil throughout the application area). Travelers tend to have poor application efficiency due to high evaporative losses during application because of their high operating pressure and distance water is thrown. The primary advantage of traveler systems is that they can be easily moved from field to field and are well suited to irregular sized and shaped fields. While travelers tend to have the poorest overall water use efficiency there are numerous applications where they are the system of choice (i.e., more practical than other system options).

Water conservation alternatives for traveler systems are listed in Table 3. There are currently about 4,000 traveler irrigation systems in use in Georgia. System sizes range from 40 to 100 acres with the average system being capable of irrigating about 85 acres per year. Total system replacement cost is approximately $30,000 for a system capable of irrigating 70 to 100 acres.

Comparison 17: Repair the water delivery system for travelers.

A typical traveler irrigation system has a 1,000 ft hose and is operated at 80 psi at the gun. The system is operated about 2,000 feet from the water supply. Many systems have been in operation more than 15 years and continue to use a portable, above ground, aluminum pipe water delivery system. The aluminum pipe is typically in 20 foot lengths with worn or decayed rubber gaskets resulting in significant mainline leakage. On older systems, it is also common to find several repairs in the flexible hose that are also leaking.

Water conservation options range from minor repairs to the water delivery system such as replace gaskets and/or fittings to more costly repairs including replacement of pipe and/or hoses. Water conservation will range from none to over 20% with smaller savings associated with less severe leakage. Simply replacing gaskets in 20 foot aluminum mainline pipe (at a cost of $5/gasket, $500 total for 2,000 ft system) could save about 5% on many older systems. In some cases, total replacement of the aluminum mainline with buried PVC would equate to savings of up to 20%, but the cost of this repair could approach $6,000 (2,000 ft X $3/ft). On very old systems, the flexible hose should be replaced which could also approach $6,000.

It is estimated that 1,600 traveler systems would benefit from major maintenance to repair the water delivery system with an average water savings of ≈ 10%. If all potential systems were repaired, the total annual water savings in an average year would be 2585 million gallons. In a dry year, water savings would approach ≈ 4,431 million gallons. The average cost of these repairs is estimated at $3,500 per system. The statewide costs for full implementation are ≈ $5.6 million. The cost benefit ratio is ≈ $2,166 per million gallons saved.

Comparison 18: Add Speed Compensation to Hard Hose Travelers

The typical hard hose traveler irrigation system has a 1,000 foot hose and is operated at 80 psi at the gun. Many older systems do not have speed compensation. As the hose is wound onto the reel, the effective diameter of the reel changes, thus changing the travel speed of the gun. Most systems are managed to apply the target irrigation amount at the "faster" speed in the cycle. At the slower speed, up to 30% more water is applied, thus wasting 15% on average.

Addition of speed compensation for an existing system would involve retrofitting with a small, 3-5 horsepower, gasoline or diesel engine and subsequent modifications to the drive train (gears, sprockets and pulleys). The average costs of a speed compensation retrofit is ≈ $5,000 and would result in an average water savings of ≈ 10%.

It is estimated that 1,300 hard hose traveler irrigation systems would benefit from the addition of speed compensation. If fully implemented, the statewide water savings would be 2,100 million gallons per year. In a dry year, statewide water savings would approach 3,600 million gallons. The estimated cost for full implementation is ≈ $6.5 million with a water savings cost benefit ratio of ≈ $3,095/million gallons.

Comparison 19: Conversion from standard to low angle gun:

The base system for this comparison includes a traveler system with a 1,000 ft hose. The base system has speed compensation and an efficient water delivery system. A standard 27 degree trajectory gun with a ring nozzle is in use. The suggested alternative is to replace the gun assembly and change to an 18 degree trajectory taper bore nozzle. The lower trajectory will not throw water as high resulting in less evaporation during application. A taper bore nozzle must be used to provide the same overlap and uniformity of coverage at the lower discharge trajectory angle.

Estimated water savings for this alternative range from 0 to 10% with an average of 5%. Greater savings will result if larger nozzles with higher operating pressure are converted. Time of day application would also affect savings with greater savings realized on those systems operated predominately during daylight hours.

Of the 4,000 traveler systems currently in use, approximately 1,200 could benefit from this modification. The potential water savings would be 969 million gallons annually on average, and 1,662 million gallons in a dry year. The average system costs for this modification is $1,500. With full statewide implementation, the total cost for 1,200 systems would be ≈ $1.8 million with a water savings cost/benefit ratio of ≈ $1,857 per million gallons.

Comparison 20: Adjustment to Proper Operating Pressure:

The base system for this comparison includes a traveler system with a 1,000 ft hose. The base system has speed compensation and an efficient water delivery system. The suggested alternative is to determine and adjust, where necessary, the operating pressure. Similar results would be expected for either the standard 27 degree trajectory gun with a ring nozzle or a low angle, 18 degree trajectory gun with taper bore nozzle.

System design including determination of lane spacing for proper overlap is based on manufacturers specifications. These specifications give discharge and wetted diameter specifications for operating pressures at the gun. Many systems do not have functional pressure gages at the gun, instead, the operator relies on a pressure gage at the reel or in some cases at the pumping plant. The result is that many systems are not being operated at design specifications which results in improper overlap and poor application uniformity. System performance should be adjusted to design and manufacturers specifications. In some cases this will require decreasing the operating pressure which will result in less water loss to evaporation (lower pressure results in larger droplets which are less susceptible to evaporation and wind drift). But, in many cases, the operating pressure will need to be increased, resulting in greater water losses. Thus, water savings are estimated to range from -5 (more water use) to + 5%.

The costs of this modification may range from as little as $25 to simply install a pressure gage on the gun to over $6,000 if the pump or pipe needs to be replaced to achieve higher operating pressures. There are no net water savings estimated for this practice. While total water savings from this practice may be small, water use efficiency will improve because operating the system at the proper pressure will result in better application uniformity.

Drip/Trickle/Mini/Micro Irrigation Systems (Table 4):

This class of irrigation systems includes low operating pressure (usually 5 to 20 psi), low volume of output per emitter (or micro sprinkler), and a major distribution system consisting of mains and laterals to place the output devices in the best location for the particular system and plant needs. The major applications in Georgia include buried systems associated with orchards (such as pecan, blueberry, etc.), plastic mulch and drip tape for vegetable or other high value cash crop production, and microspray type sprinklers (spray nozzles) on orchards. Because emitters and spray nozzles under this classification have a much smaller orifice than in other irrigation applications, some filtration of the source water is usually required. The ground area affected by each individual output device as a result of the low emission rate (2 to 12 gallons per hour for emitters vs 3 to 5 gallons per minute per sprinkler device) and is the primary reason for the classification as "trickle" or "drip". Surface areas of between 10 and 100 ft^2 are reasonable assumptions for trickle emitters to spray nozzles, respectively.

In Georgia, about 1,100 systems are in this category. The average system size is 70 acres.

Comparison 21: From old drip system with no pressure control, pressure compensating emitters, or consistent schedule to *improved scheduling for the season (orchard application)*

The base system is an orchard drip irrigation system with buried emitters (most systems of this type in Georgia are on pecans). The system has little or no pressure control and non-pressure compensating emitters. There are currently about 800 systems in Georgia similar to this description.

It is fairly common practice to begin irrigating in the spring when the weather turns dry and to operate the system at its design maximum capacity throughout the growing season without adjusting the water applications to reflect changes in water needs of the crop. Crop water use will vary throughout the growing season as a result of crop growth stage and weather conditions (temperature, relative humidity, wind speed, etc.).

The proposed system change is to vary water applications throughout the season to reflect changes in crop water use. This could be as simple as using daily or weekly pan evaporation rates as reported by the weather service. Other options include using soil moisture sensors, installing a Class A Weather Bureau Evaporation Pan on the farm, or installing an automated weather station with automatic data collection.

Estimated water savings that could be achieved by incorporating these methods range from 20 to 40%. The total estimated water savings in an average year if fully implemented would be approximately 1996 million gallons. The average estimated cost to implement is $1,500 per 70 acre system. The cost per unit water saved is ≈ $376 per million gallons.

Comparison 22: From same system above to _system with better pressure control_

The base system is an orchard drip irrigation system with buried emitters (most systems of this type in Georgia are on pecans.) The system has little or no pressure control and non-pressure compensating emitters. There are currently approximately 800 systems in Georgia similar to this description.

Systems without adequate pressure control will typically have pressure variations which cause areas of high pressure to receive more water than areas of low pressure. In order to supply adequate water to the areas receiving the least amount, other areas tend to get over-irrigated. The recommended design practice calls for no more than plus or minus 10% variation from the average emitter pressure when non-pressure compensating emitters are used.

The proposed system change would be to improve pressure controls to recommended design specifications. This might require installation of pressure regulators at each submain, or on sloped sites it might require the installation of preset pressure regulators at each lateral.

Estimated water savings that could be achieved by improving pressure controls range from 0 to 10%. The total estimated water savings in an average year if fully implemented would be approximately 532 million gallons. The average estimated cost to implement is $1,000 per 70 acre system. The cost per unit water saved is estimated to be $1,503 per million gallons of water saved.

Comparison 23: From same system above to a system which is better maintained, scheduling is used, water meter installed, records maintained, and clogged emitters repaired

The base system has orchard drip irrigation with buried emitters (most systems in Georgia are on pecans.) The system has little or no pressure control and non-pressure compensating emitters. There are currently about 800 systems in Georgia which fit this description. Most systems do not have a water meter to monitor system performance and many are poorly maintained.

The proposed system change would include installation of a water meter, and implementing a regular maintenance program to include repairing leaks, replacing or cleaning clogged emitters and maintaining adequate system records.

These changes will likely result in estimated water savings of between -10 and + 5%, meaning that improving system maintenance may actually result in increased water use. This can be explained by the fact that one of the common maintenance problems with drip systems is emitter clogging. Therefore unless the farmer is aware that the system is partially clogged and adjusts his operating time accordingly, fixing clogged emitters will result in increased water use.

Even though this is a recommended practice that is in the farmer's best interest and will result in better use of water resources it will probably not result in a net water savings.

Comparison 24: From an orchard microsprinkler system to a drip system with improvements from 23 above

The base system is an orchard microsprinkler system typically consisting of one or two microsprinklers per tree with PVC mains and submains and polyethylene laterals. These systems are very similar to drip irrigation system except that the discharge device is a small sprinkler which sprays water over the ground surface as opposed to a drip emitter which discharges water at or below the ground surface.

The proposed system change is to convert the system into a drip system. This change would involve either simply replacing the microsprinklers with drip emitters or may require replacing the polyethylene laterals in addition to the microsprinklers.

This conversion could potentially result in 5 to 10% water savings for a total potential water savings in an average year of 100 million gallons. The cost per unit of water saved is estimated to be $14,030 per million gallons.

It is unlikely that many of these systems would be converted to drip because the farmer probably had a reason for selecting microsprinklers over drip to begin with.

Some valid reasons for choosing microsprinklers include poor water quality, sandy soils, and ease of maintenance.

Solid Set Irrigation Systems (Table 4):

Solid set irrigation systems include those systems with buried (700 systems) or portable (600 systems) distribution lines, but with sprinklers designed to cover more than 100 ft^2. In most cases, solid set systems will use at least a 30 foot spacing between sprinkler heads. In Georgia, about 1,300 systems fall into this classification with an average field size of 40 acres.

Comparison 25: From 23 degree impact sprinklers on risers, 30+ ft. spacing, poor maintenance and uniformity to a system with a proper sprinkler package, spacing, pressure and uniformity.

The base system for this comparison is a solid set system (may be buried or portable), which has been in operation for a number of years. In these particular cases, sprinkler types may be mismatched and moved to different zones without regard for uniformity and pressure considerations. Some leaks and worn gaskets would be present based on the age of the system.

By improving the sprinkler package (new and matched sprinklers) to match the spacing, pressure and uniformity, the estimated water savings are in the range of 0 to 20%. Average potential water savings are ≈ 10%. An estimated 300 systems fall into the category of benefitting from the above improvements. If these recommended changes were fully implemented, an estimated 228 million gallons of water would be saved in an average irrigation year. In a dry year, water savings may be near 391 million gallons.

The costs to make improvements will range from $600 (portable pipe) to $10,500 (buried) for an average potential cost of $5,500 per 40 acre system. The statewide costs for full implementation would be ≈ $1.65 million for a cost/ benefit ratio of $7,234 per million gallons saved in the first year.

Comparison 26: From 23 degree impact sprinklers on risers, 30+ ft. spacing, poor maintenance and uniformity to a system with good gaskets (portable systems only).

The base system for this comparison is a solid set system as above in comparison 25, but applies to only the 600 portable systems in Georgia. The existing portable systems are essentially all in the "older" category and could benefit from repair and replacement of gaskets.

By repairing/replacing only the gaskets, the estimated water savings are in the range of 0 to 20%. Average potential water savings are ≈ 5% since most systems are not losing as much water due to gasket problems. If these recommended changes were fully implemented on the 600 portable systems, an estimated 228 million gallons of water would be saved in an average irrigation year. In a dry year, water savings may be near 391 million gallons.

The costs to make improvements will be about $500 per 40 acre system. The statewide costs for full implementation would be ≈ $0.3 million for a cost/ benefit ratio of $1,315 per million gallons saved in the first year.

Comparison 27: From 23 degree impact sprinklers on risers, 30+ ft. spacing, poor maintenance and uniformity to a system with fixed leaks (buried systems only).

The base system for this comparison is a solid set system as above in comparison 25, but applies to the 700 buried solid set systems in Georgia. Many of the existing buried systems fall into the "older" category and could benefit from repair and replacement of pipe and fittings.

By fixing leaks, the estimated water savings are in the range of 0 to 20%. Average potential water savings are ≈ 10%. An estimated 150 systems would benefit from leak repair in this category. If these recommended changes were fully implemented an estimated 114 million gallons of water would be saved in an average irrigation year. In a dry year, water savings may be near 195 million gallons.

The costs to make improvements will be about $4,000 on an average 40 acre system. The statewide costs for full implementation would be ≈ $0.6 million for a cost/ benefit ratio of $5,261 per million gallons saved in the first year.

Changing to a Different System (Table 5):

Comparisons 28 through 34 are for general interest and are not necessarily the most cost effective alternatives. Also, the potential impacts of changing from one system to another requires much more specific information about the field conditions, field shapes, etc., than the scope of this publication permits. Irrigators considering complete replacement of an irrigation system should look at the section on New Systems and consult with an irrigation specialist for potential options.

DESCRIPTION OF A NEWLY DESIGNED, PROPERLY MANAGED, WATER EFFICIENT IRRIGATION SYSTEM

Below are several recommendations that we considered as water savings alternatives for new systems. The application of any particular alternative is based on site conditions, and therefore the potential use of other alternatives may be required if soil intake rates, slopes, field shape, water supply, or other limiting factors are present.

Center Pivot or Linear Move:

New systems will fall into one of two categories. The first is a new system that is replacing an existing system (existing system could be center pivot/linear move or other type of system such as solid set sprinkler or traveler). These comparisons are covered in the accompanying Table # 5 with associated water savings for each comparison. The second is a new system being installed on land not previously irrigated. In this case the system will usually have an endgun to reach odd corners of the field. The endgun may/may not need an endgun shutoff to prevent water from being applied outside the target area. If the field conditions indicate the need for an endgun shutoff, one should be used.

The sprinkler package should be selected to match the field conditions. Soil type(s), soil slope, source water quality, and water supply should all be taken into account when selecting sprinklers. As a general rule, the greatest application rate will be at the end of the system. The application rate should not exceed the intake rate of the most restrictive soil type encountered as defined by the current Georgia Irrigation Guide (Note: the Georgia Irrigation Guide can be obtained by contacting the local Natural Resources Conservation Service [NRCS] office). Of course, some logic must be used if the most restrictive soil is extremely small (a clay gall) as compared to the overall pivot area. The most common sprinklers used on new systems will be: reduced angle impact sprinklers (usually 6 degree), low pressure sprinklers on top of the irrigation boom, and low pressure sprinklers on drops (at truss rod height). Each of these options provide potential water savings over high angle impact sprinklers on the top of the irrigation boom. As the sprinkler packages change from reduced angle impact sprinklers to low pressure sprinklers on drops, the soil intake rates and site conditions will become more restrictive. In other words, fewer site conditions will allow low pressure sprinklers on drops as compared to low angle impact sprinklers on the top of the boom.

The sprinkler package will be a small percentage (usually less than 10%) of the total system cost. In the case of adding an irrigation system, no up-front water savings are obvious. The objective is to encourage the owner to install a system that is "water efficient" for the future.

As in all irrigation systems, a method to schedule irrigations is encouraged. Understanding how much water is needed by the crop and when to apply is essential to good water management.

Traveling Gun:

The term "Traveling Gun" or "Traveler Irrigation System" refers to either cable tow or hard hose traveling sprinkler systems. The primary advantage of traveler systems is that they can be easily moved from field to field and are well suited to irregular size and shaped fields. While travelers tend to have the poorest overall water use efficiency among sprinkler alternatives, there are numerous applications where they are the system of choice (i.e., more practical than other system options).

Regardless of the drive mechanism, new systems should be equipped with speed compensation (hard hose systems) so that the sprinkler cart travels at a uniform speed from the beginning of the pull until the hose is fully wound onto the hose reel.

Nozzle sizes on gun type travelers are typically 1/2 to 2 inch diameter and require high operating pressures of 75 to 100 psi at the gun for uniform distribution. Nozzle type (ring versus taper bore) should be selected to match irrigation/precipitation rates to soil intake rates. Guns should be operated in a 300 to 330 degree arc angle to minimize instantaneous precipitation rates. Trajectory angles on new systems for improved water conservation should be less than 27 degree. The lower the angle of trajectory, then the better the water conservation (reduce the impact of wind on evaporation and uniformity). As noted above and in other systems, irrigation application conditions should be consistent with soil types as indicated in the Georgia Irrigation Guide. A preferred method of scheduling irrigations should be used with a traveler. Traditionally, traveler irrigation systems were designed and sized to irrigate throughout the daylight hours. Designing an irrigation system to meet water needs while not irrigating during the hot/windy time of day (noon to 4 p.m.) may increase the cost by requiring a larger system to satisfy the production requirements; but will save water.

Drip Irrigation (Orchard):

Drip irrigation is a low volume, low pressure system and is generally considered a desirable option for orchard irrigation. The system generally consists of buried PVC pipe mains and submains with ½" to ¾" polyethylene laterals. Water application is controlled by point source drip emitters which are either attached to the laterals or are an integral part thereof. The output rate (usually either 1 or 2 gal./hr.) and number of emitters per tree depends on the type of tree, the tree size and tree spacing. Laterals may be on the ground surface, totally buried, or buried with emitters ported to the surface. If non-pressure compensating emitters are used the system should be designed such that emitter pressures do not vary more than plus or minus 10% from the design operating pressure.

These systems are typically designed to operate daily during peak water demand periods. Under recommended operating procedures the system run time is varied throughout the growing season to reflect changes in crop water use. Crop water use can be estimated using daily pan evaporation, by measuring soil moisture directly, or by using published crop water use curves.

Microsprinklers (Orchard):

Microsprinklers are commonly used in orchards as an alternative to drip irrigation. Some reasons for using microsprinklers include water quality concerns, sites with deep sandy soils, and ease of detecting problems such as leaks and clogged emitters. These systems are commonly used on pecans, peaches and other tree fruits. Microsprinkler systems are very similar to drip systems with buried PVC mains and submains and polyethylene laterals. Water application is controlled by a small plastic sprinkler attached to a plastic stake and is supplied from the lateral by a small diameter supply tube. Output rates vary from 5 to 50 gallons per hour. Depending on tree size and spacing there will usually be either one or two microsprinklers per tree. To ensure uniform water distribution, the system should be designed such that microsprinkler pressures do not vary more than plus or minus 10% from the design operating pressure.

These systems are typically designed to operate daily during peak water demand periods. Under recommended operating procedures, the system run time is varied throughout the growing season to reflect changes in crop water use. Crop water use can be estimated using daily pan evaporation, by measuring soil moisture directly, or by using published crop water use curves.

Drip Irrigation (Vegetables Grown on Plastic Mulch):

Plasticulture is an increasingly popular method of growing certain vegetables including tomatoes, peppers, and melons. This system consists of growing the plants on raised beds that are covered with plastic mulch. The plastic mulch helps to retain soil moisture and control weed growth. The water needs of the plants are supplied through a thin walled drip irrigation tubing or "tape" which has water outlets molded or extruded into the tubing at 12 to 24 inch intervals. The tape is usually installed at the same time the plastic mulch is applied. The tape is installed either on the ground surface directly under the mulch or one to two inches below ground surface. Usually one row of tape is installed per bed with a center to center spacing of five to six feet. The mulch and tape are used for one growing season, for one or two crops, and then taken up and discarded. Typically farmers will also inject fertilizers into the irrigation water to supply the nutrient requirements of the crop throughout the growing season.

These systems are typically designed to operate daily during peak water demand periods. Under recommended operating procedures the system run time or frequency is varied throughout the growing season to reflect changes in crop water use. Crop water use can be estimated using daily pan evaporation, by measuring soil moisture directly, or by using published crop water use curves.

Solid Set:

Solid set systems include both portable pipe and buried systems. Solid set may be the system of choice in turf, vegetable, and other high value cropping situations. For maximum potential water savings, sprinklers should have reduced angle (below 23 degree) trajectory.

A solid set system should be designed to meet crop needs with good pressure control, compatible sprinklers, and desired overlap. As with all systems, the design can include meeting crop needs and site conditions (Georgia Irrigation Guide) without irrigating between 12 noon and 4 p.m. with a preferred irrigation scheduling method. Solid set systems are well suited for irrigating during non-peak evapotranspiration periods using automatic controllers, although larger nozzles or additional system components may be needed to compensate for the non irrigation period. This added cost may be a consideration for water savings in a tax incentive program.

IRRIGATION PRACTICES THAT MAY THE HAVE HIGHEST WATER-SAVING POTENTIAL

Preliminary discussions, when this activity was first being proposed, indicated that creating a tax incentive program would encourage improved irrigation practices. In other words, a tax incentive program would encourage irrigators who need to make changes to improve their systems (not just replace existing components). Later on, during the course of this project, the concept of a tax incentive was dropped with the idea that water savings/conservation should be pursued on its own merits rather than just for tax savings purposes.

The following five recommendations were chosen as a starting point in this type tax incentive program (based on consensus of opinion). These practices have potential for effectively reducing agricultural water use in the near future. These are not the only improvements which should be considered in a program whether tax incentive or other (see all comparisons). As indicated above, the cost/benefit ratios are listed for amortizing the costs within the first year (in 1998 dollars). Subsequent years would benefit from water savings without additional costs (unless a yearly maintenance fee is indicated)..

Irrigation Audit (Comparison 14):

The irrigation audit provides the best starting point for assessing the needs for individual irrigation systems. An irrigation audit does not save water directly, but is essential to good planning for system improvements. In many cases, the audit may indicate a well maintained system, but in most cases, some recommended modifications may be available which will reduce water use or improve irrigation water use efficiency. Without an irrigation audit, some practices which may be installed may not actually save water, if site conditions are not appropriate for the change. The cost for a complete irrigation audit is ≈ $1,000 on a 100 acre system. The statewide costs for the ≈ 11,700 older systems which may benefit from an audit is ≈ $11.7 million. It is recommended that irrigation audits be performed by individuals certified by the Irrigation Association, an internationally recognized organization (represented in Georgia by the Georgia Irrigation Association), or other irrigation specialists who can competently address all aspects of irrigation system design and management (dealers, consultants, etc.). The rigorous requirements for certification can help reduce the potential for poor quality audits.

End gun shutoff, center pivot systems (Comparison 1):

A correctly operating end gun shutoff will effectively eliminate water being applied to areas outside the field which are not in crop production. The water sprayed on roads can be a hazard, while not providing any beneficial use to the crop. On a 100 acre pivot, the water saved is ≈ 7.5% on the average which translates to ≈ 2,851 million gallons in an average irrigation year if fully implemented statewide. In dry years, the water saved is ≈ 4,887 million gallons. An estimated 2,000 center pivot systems would benefit from a correctly operating end gun shutoff. The cost for each system is ≈ $500. Statewide costs would be ≈ $1 million. The cost/ benefit ratio for this practice would be ≈ $351/million gallons saved in an average year.

Repair water delivery system on an 80 psi traveling gun (Comparison 17):

This practice is associated with current water delivery systems (from source to sprinkler gun) on travelers. Many current systems have been in operation for years and still use above ground pipe for transferring water. In addition, small leaks are usually present depending on the length of the system. It is estimated that 1600 systems would benefit from major maintenance to repair gaskets, pipes, hoses and fittings for a water savings of ≈ 10% on the average. If all potential systems were repaired, the estimated water savings would be ≈ 2,585 million gallons per year in an average year if fully implemented statewide. In a dry year, the potential savings may be ≈ 4,431 million gallons. The cost for major repairs is ≈ $3,500 on an average 85 acre. system. However, if a hose is to be replaced, the cost may be near $6,000. The statewide costs for full implementation is ≈ $5.6 million. The cost/ benefit ratio is ≈ $2,166 per million gallons.

Use a preferred irrigation scheduling method on orchard drip systems (Comparison 22):

This practice is associated with the estimated 500 totally buried drip systems (primarily pecan) which are at least 10 years old and do not have pressure control or pressure compensating emitters. For pecan orchard systems, the use of a preferred irrigation scheduling method to change water applications throughout the irrigation season can save between 20 and 40% (average of 30%) of the water applied. In an average year, this translates to ≈ 1,996 million gallons statewide if fully implemented. In a dry year, savings may be near ≈ 4,887 million gallons. The cost on an average 70 acre drip system is ≈ $1,500, but may range from $0 to $10,000 depending on the scheduling method chosen. The statewide costs for full implementation would be ≈ $0.75

million. The cost/benefit ratio is ≈ $376 per million gallons saved in an average year.

Replace old sprinkler package on center pivot and linear move systems where uniformity is ≤ 80% (Comparison 2):

This recommended practice is designed to address sprinkler package problems in uniformity and over-application on an estimated 4400 center pivot and/or linear move systems which have been in place for many years. The need for such a change could be a direct result of a complete irrigation audit. The estimated water savings is ≈ 5% which translates to ≈ 4,181 million gallons saved in an average year if fully implemented statewide. In a dry year, as much as 7,168 million gallons may be saved. The cost to implement a change is between $0 and $1,000 per system with the average cost for this conversion being ≈ $250 per system. The estimated statewide costs for full implementation is $2.2 million. The costs per unit water saved is estimated at ≈ $526 per million gallons of water saved.

SUMMARY

The need for agriculture to demonstrate good irrigation practices is evident in the potential water savings associated with irrigation systems currently in place in Georgia. The age of current irrigation systems, minimal direct cost for water, and the critical time constraints associated with farm operations creates potential for neglect on systems which are not used in some very wet years.

Irrigation conservation and efficiency alternatives are recommended which related to potential water savings on irrigation systems in Georgia. Selected alternatives could be encouraged through a tax incentive program. However, more efficient, water conserving alternatives need to be considered whenever a system change is needed.

In all recommendations, the irrigation audit is considered the first activity. The use of an irrigation audit to determine the current conditions and best/most economical choices for changes is essential to maintaining profitable irrigation practices. The wholesale modification of systems based on the indicated average values is not recommended. Each irrigation system needs to be assessed for the potential benefits of suggested changes.

The alternatives suggested in this report include only those irrigation systems which were commercially available and verified for their application in the southeast region. New irrigation alternatives are expected to be available over time. All new recommendations need to be considered and explored for their potential to reduce water use or improve the efficiency of water application.

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Irrigation Conservation Practices, Estimate of Water Savings, Table 1										
Com-parison	Current Base System	Proposed system change	Estimated water savings range (%)	Estimated water savings average (%)	Potential no. Of irrigation systems affected	Average year[1], total potential gallons saved if fully implemented (million gal.)	Dry year[2], total potential gallons saved if fully implemented (million gal.)	Estimated cost for full implementation on an average system (1998 $)	Statewide costs for full implementation (Million $, 1998)	Cost / Unit water saved, average year (1998 $/ /million gal)
Center Pivot and Linear Move Systems (Average system size = 100 ac, total number of systems in Georgia = 8500)										
1	No end gun shutoff (8000 potential systems)	End gun shutoff	5 to 10	7.5	2000	2851	4887	**$500**	1	351
2	Current sprinkler package has uniformity < 80% (4400 potential systems)	New sprinkler package (same as original)	0 to 10	5	4400	4181	7168	**$250** $0 to $1000 ($1/ft)	2.2	526
3	23 degree impacts on top, high pressure (1700 potential systems)	Reduced angle impacts, medium pressure	5 to 15	10	850	1616	2770	**$1,200** $500 to $2,000 (depending on labor to remove old sprinklers)	1.02	631
4	23 degree impacts on top, high pressure (1700 potential systems)	Low pressure sprinklers on top of irrigation boom	5 to 15	10	200	380	652	**$3,500** $1,000 ($1/ft) + $2,500 booster pump[3]	0.70	1841[illegible]
5	23 degree impacts on top, high pressure (1700 potential systems)	Low pressure sprinklers on drops, 10-20 psi	5 to 25	15	200	570	977	**$4,000** $1,500 ($1.50/ft) + $2,500 booster pump[3]	0.24	421[illegible]
6	Reduced angle impacts, medium pressure (3000 potential systems)	Low pressure sprinklers on top of irrigation boom	0 to 5	2.5	700	333	570	**$1,000** (depending on labor to remove old sprinklers)	0.7	2105
7	Reduced angle impacts, medium pressure (3000 potential systems)	Low pressure sprinklers on drops, 10-20 psi	0 to 10	5	700	665	1140	**$4,000** $1,500 ($1.50/ft) + $2,500 booster pump[3]	2.8	4209
8	Reduced angle impacts, medium pressure (3000 potential systems)	LEPA, drops near ground, furrow diking	0 to 10	5	50	48	81	**$4,500** $2,000 ($2/ft) + $2,500 booster pump[3]	0.225	4735
9	Low pressure sprinklers on top of irrigation boom (2550 potential systems)	Low pressure sprinklers on drops, 10-20 psi	0 to 10	5	2550	2423	4154	**$1,500** ($1.50/ft)	3.83	1578
10	Low pressure sprinklers on drops, 10-20 psi (1300 potential systems)	LEPA, drops near ground, furrow diking	0 to 3	1	0	0	0	n/a	n/a	n/a

[1]Average year is based on 7 inches (180 mm) of water applied during the cropping season

[2]Dry year is based on 12 inches (305 mm) of water applied during the cropping season

[3]Note: booster pump may or may not be required based on individual systems

Irrigation Conservation Practices, Estimate of Water Savings, Table 2										
Com-parison	Current Base System	Proposed system change	Estimated water savings range (%)	Estimated water savings average (%)	Potential no. Of irrigation systems affected	Average year[1], total potential gallons saved if fully implemented (million gal.)	Dry year[2], total potential gallons saved if fully implemented (million gal.)	Estimated cost for full implementation on an average system (1998 $)	Statewide costs for full implementation (Million $, 1998)	Cost / Unit water saved, average year (1998 $/ million gal.)
Improved Irrigation Practices Appropriate for All Systems (assumed average system size = 100 ac, total number of systems in Georgia = 13,000)										
11	No current method of scheduling irrigation applications	Adopt a method of scheduling irrigation applications	-10 to +10	0	11,700	0	0	**$700** $400 to $1,000	8.19	0
12	No current method of scheduling irrigation applications	Irrigation scheduling with Class A Evaporation Pan	-10 to +10	0	11,700	0	0	**$1,500**	17.55	0
13	No uniformity test performed in last 5 years	Uniformity test	?[3]	0	11,700	0	0	**$250**	2.925	0
14	No uniformity, calibration, or maintenance check in last 5 years	Irrigation audit performed	?[4]	?[4]	11,700	0	0	**$1,000**	11.7	0
15	No major maintenance checks in last 5 years	Major maintenance check performed	?[5]	?[5]	11,500	10929	18735	**$500**	5.75	0
16	Pressure gages not operating	Replace/repair pressure gages	-5 to +5	0	6,500	0	0	**$50** $25 to $100	0.33	0

[1]Average year is based on 7 inches (180 mm) of water applied during the cropping season

[2]Dry year is based on 12 inches (305 mm) of water applied during the cropping season

[3]Estimated water savings may be -10 to +10% depending on system needs and implementing changes based on uniformity test. Uniformity improvements will increase efficiency of water use.

[4]Estimated water savings may be -15 to +50% if changes are implemented as a result of the irrigation audit. Irrigation audit effects will increase efficiency of water use across entire system.

[5]Estimated water savings may be 0 to 10% if changes are implemented as a result of a major maintenance check. A maintenance check will help increase efficiency of irrigation system.

Irrigation Conservation Practices, Estimate of Water Savings, Table 3										
Com-parison	**Current Base System**	**Proposed system change**	**Estimated water savings range (%)**	**Estimated water savings average (%)**	**Potential no. Of irrigation systems affected**	**Average year[1], total potential gallons saved if fully implemented (million gal.)**	**Dry year[2], total potential gallons saved if fully implemented (million gal.)**	**Estimated cost for full implementation on an average system (1998 $)**	**Statewide costs for full implementation (Million $, 1998)**	**Cost / Unit water saved, average year (1998 $/ million gal)**
Traveling Gun Systems Including Cable and Hose Tow (Average system size = 85 ac, total number of systems in Georgia = 4000)										
17	80 psi traveler, average leaks (4000 potential systems))	Repair water delivery system	0 to 20	10	1600	2585	4431	**$3,500** $500 to $6,000 (from repair of gaskets to hose)	5.6	2166
18	80 psi traveler, no speed compensation, delivery system repaired (1300 potential systems)	Speed compensation	0 to 30	10	1300	2100	3600	**$5,000** $3,500 to $6,500	6.5	3095
19	80 psi traveler, standard gun, 27° trajectory, ring nozzle, delivery system repaired (1200 potential systems)	Low angle gun, 18° trajectory	0 to 10	5	1200	969	1662	**$1,500**	1.8	1857
20	80 psi traveler, delivery system repaired (4000 potential systems)	Adequate operating pressure	-5 to +5	0	1000	0	0	**$3,500** $25 to $6,000	3.50	??

[1]Average year is based on 7 inches (180 mm) of water applied during the cropping season

[2]Dry year is based on 12 inches (305 mm) of water applied during the cropping season

Irrigation Conservation Practices, Estimate of Water Savings, Table 4										
Com-parison	Current Base System	Proposed system change	Estimated water savings range (%)	Estimated water savings average (%)	Potential no. Of irrigation systems affected	Average year[1], total potential gallons saved if fully implemented (million gal.)	Dry year[2], total potential gallons saved if fully implemented (million gal.)	Estimated cost for full implementation on an average system (1998 $)	Statewide costs for full implementation (Million $, 1998)	Cost / Unit water saved, average year (1998 $/ million gal)
Drip/Trickle/Mini/Micro Irrigation Systems (Average system size = 70 ac, total number of systems in Georgia = 1100)										
21	Orchards, totally buried system, no arches/pressure control, no pressure compensating emitters, 10 years old (800 potential systems)	Operation time and scheduling based on weather and season	20 to 40	30	800	3193	7820	**$1,500** $0 to $10,000 (depending on scheduling method chosen)	1.2	376
22	Orchards, totally buried system, no arches/pressure control, no pressure compensating emitters, 10 years old (800 potential systems)	Better pressure control	0 to 10	5	800	532	912	**$1,000**	0.8	1503
23	Orchards, totally buried system, no arches/pressure control, no pressure compensating emitters, 10 years old (900 potential systems)	Maintain system and schedule, water meter, records, repair clogged emitters	-10 to +5	-2.5	800	-266	-456	**$6,000** $1,900 to $7,100 + $1,750 to $3,500 per year	4.8	-18039
24	Orchards, micro-sprinkler system	Drip system with improvements above	5 to 10	7.5	100	100	171	**$14,000** $7,000 to $21,000	1.4	14030
Solid Set Irrigation Systems (Average system size = 40 ac, total number of systems in Georgia = 1300)										
25	23 degree impacts on risers, 30+ ft. spacing, poor maintenance, poor uniformity (1300 potential systems)	Proper sprinkler package, spacing, pressure, uniformity	0 to 20	10	300	228	391	**$5,500** $600 to $10,500 (from portable pipe to buried)	1.65	7234
26	23 degree impacts on risers as above (600 portable systems only)	Fix gaskets	0 to 20	5	600	228	391	**$500**	0.3	1315
27	23 degree impacts on risers as above (700 buried PVC systems only)	Fix leaks	0 to 20	10	150	114	195	**$4,000**	0.6	5261

[1] Average year is based on 7 inches (180 mm) of water applied during the cropping season

[2] Dry year is based on 12 inches (305 mm) of water applied during the cropping season

Irrigation Conservation Practices, Estimate of Water Savings, Table 5										
Com-parison	Current Base System	Proposed system change	Estimated water savings range (%)	Estimated water savings average (%)	Potential no. Of irrigation systems affected	Average year[1], total potential gallons saved if fully implemented (million gal.)	Dry year[2], total potential gallons saved if fully implemented (million gal.)	Estimated cost for full implementation on an average system (1998 $)	Statewide costs for full implementation (Million $, 1998)	Cost / Unit water saved, average year (1998 $/ million gal)
Comparisons Between Systems (Average system size based on starting system)										
28	80 psi traveller, average leaks, no speed compensation (4000 potential systems)	Center pivot or linear move (average system size applicable = 60 ac)	10 to 20	15	400	684	1173	**$30,000** $25,000 to $35,000	12	17538
29	Overhead sprinkler (orchard application, 300 potential systems)	Drip system (average system size applicable = 70 ac)	20 to 40	30	300	1197	2053	**$35,000** $28,000 to $42,000	10.5	8769
30	Overhead sprinkler (vegetable application, 800 potential system)	Surface drip system (average system size applicable = 70 ac)	-10 to +25	7.5	800	798	1368	**$38,000 + $13,000/yr** $35,000 to $56,000 + $10,500 to $17,500 per year	40.8	51110
31	Solid set, 23 degree impacts on risers, 30+ ft spacing (1300 potential systems)	Center pivot or lateral move (average system size = 40 ac)	10 to 30	20	50	76	130	**$20,000**	1.00	13153
32	Solid set, 23 degree impacts on risers, 30+ ft spacing (1300 potential systems)	Traveller system (average system size = 40 ac)	0	0	n/a	0	0	**n/a**	0.00	??
33	Solid set, 23 degree impacts on risers, 30+ ft spacing (1300 potential systems)	Surface drip irrigation system (average system size = 40 ac)	0 to 40	20	20	30	52	**$15,000**	0.30	9865
34	Overhead sprinkler system (13,500 potential systems)	Subsurface drip irrigation system (average system size = 95 ac)	-10 to +15	2.5	13,000	5868	10060	**$70,000** $45,000 to $95,000	910.00	155070

[1]Average year is based on 7 inches (180 mm) of water applied during the cropping season

[2]Dry year is based on 12 inches (305 mm) of water applied during the cropping season

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