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Agricultural Water Conservation Practices-A Review

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Abstract: Water conservation in agricultural sector may be efficiently achieved by applying improved agricultural, irrigation and water harvesting techniques, Approximately 70% of all available water is used for irrigation while remaining 22% is used for industrial purposes and 8% is for domestic purpose. About 40% of all agricultural production depends on efficient irrigation. In conventional agricultural practices only 45% water is effectively used by crops while remaining 55% is lost during transmission to farm, farm distribution and in field applications. Irrigation scheduling involves management of soil moisture. Weather monitoring is used to determine the period of irrigation while soil capacity and crop type is responsible for the determination of quantity of water required. The irrigation techniques commonly employed are used for water conservation and efficient production. Some of the techniques include **"**LEPA (Low Energy Precision Application) and LESA (Low Elevation Spray Application)**,** Flood (furrow) irrigation, Drip Irrigation, Spray Irrigation, Better spray irrigation, Sprinkler irrigation, Localized irrigation, Center pivot irrigation, Lateral move (side roll, wheel line) irrigation, Sub-irrigation, Manual irrigation using buckets or watering cans, Automatic, non-electric irrigation using buckets and ropes, Irrigation using stones to catch water from humid air, Dry terraces for irrigation and water distribution". Preparation of agricultural field is very important in water conservation e.g. Laser Leveling, Furrow diking, Conservation Tillage, Tailwater Reuse, Lining canals with concrete or other liners reduces water loss through seepage by 10-30%. Evaporation in canals can be reduced if irrigation districts provide water on demand rather than keeping the canals continuously filled. Underground conveyance systems eliminate costly evaporation and deep percolation. The high efficient techniques like Drip Irrigation and LEPA Center Pivots reduces water loss to only 2 to 5% while water loss in LESA Center Pivots, Surge Valves with Furrow Application and Furrow with Open Ditch are estimated to around 10, 20 and 40% respectively. The paper reviews the different water conservation approaches in agriculture practices.

Key words: Irrigation water • Water Conservation • Conservation Techniques • Agricultural Techniques • Water Harvesting techniques

INTRODUCTION

The water efficiency practices listed in the paper describe the methods to reduce excess water use through implementation of efficient irrigation technology, effective irrigation scheduling and soil moisture determination and retention. These practices are designed to minimize water losses from evaporation, deep percolation and runoff.

Agriculture uses 70% of total global "blue water" withdrawals, most of which is for irrigation. In developing countries, as much as 80-90% of freshwater is used for agriculture Only 17% of all cropland is irrigated, but this land provides 30-40% of the world's food production. Over 60% of the world's irrigated area is in Asia.

Water is confined as soil moisture, stored water in surface storage like reservoirs, tanks, ponds and in open wells etc., iii) ground water in sub surface, iv) sea water and v) waste water like sewage and treated or untreated industrial effluent.

Agricultural water conservation practices plays key role in estimating the optimum consumption of irrigation water and application of efficient techniques of irrigation. Factors to be considered in water management planning include soil, water quanitiy and quality, crops, climate, available labor and economics. These considerations are all interrelated Soil provides physical support for the plant and serves as a reservoir for nutrients and water. The chosen irrigation method must suit the soil intake

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rate. The feel and appearance of soil vary with texture and moisture content. Soil moisture conditions can be estimated, with experience, to an accuracy of about five%. Soil moisture is typically sampled in one-foot increments to the root depth of the crop at three or more sites per field. It is important to apply water according to crop needs in an amount that can be stored in the plant root zone of the soil. Furrow diking conserves irrigation and rainfall amounts. This conservation management choice reduces runoff and helps in retaining the water on the field. Water is stored in the dikes and infiltrates into the soil. The flow meter, with its high accuracy, can also be used as a water management tool which helps in reducing water costs, preventing over-irrigation and reducing leaching of chemicals and fertilizers into the ground.

Accurate water measurement and soil moisture monitoring are key components of efficient on-farm water management practices. Irrigation flow meters can be used to assist in the calculation of the efficiency of irrigation systems, identifying water loss from leaks in conveyance systems and to accurately apply only the necessary amount of water based on soil moisture levels and weather conditions. Soil moisture monitoring is used in conjunction with weather data and crop evapotransporation (ET) requirements to schedule irrigation. Fields should be designed for efficient water use by grading land with laser equipment, creating furrow dikes to conserve rainwater and by retaining soil moisture through conservation tillage.

Following section describes the various aspects of water conservation practices in agriculture and the different types of irrigation practices.

Improving Water Use and Watershed Management:

- Using more efficient irrigation systems (e.g., drip irrigation)
- Moving towards more precision agriculture
- Boosting rain fed agriculture, upgrading rain fed systems, as well as waste- and rainwater management
- Using conservation agriculture
- Using more water-efficient crops and assessing soil type
- Maintaining year-round vegetative cover of soils
- Using intercropping to maximize uptake of water and crop productivity in the agro ecosystem.

Review of Different Irrigation Techniques: Irrigation has been around for as long as humans have been cultivating plants. Man's first invention after learning the technique of growing plants from seeds was probably a bucket. Ancient people must have been strong from having to haul buckets full of water to pour on their first plants. Pouring water on fields is still a common irrigation method today -- but other, more efficient and mechanized methods are also used.

Efficient Irrigation Systems

LEPA (Low Energy Precision Application) and LESA (Low Elevation Spray Application): LESA irrigation systems distribute water directly to the furrow at very low pressure (6-10 psi) through sprinklers positioned 12- 18 inches above ground level. Conventional high pressure impact sprinklers are positioned 5-7 ft. above the ground and hence are very susceptible to spray evaporation and to wind-drift, causing high water loss and uneven water distribution. LESA systems apply water in streams rather than fine mists to eliminate wind-drift and to reduce spray evaporation, deep percolation and under watering. LEPA irrigation systems further reduce evaporation by applying water in bubble patterns, or by using drag hoses or drag socks to deliver water directly to the furrow. LEPA and LESA systems concentrate water on a smaller area and increase the water application rate on the area covered. Therefore, the application rate must be monitored closely to follow the soil intake curve and furrow diking should be used to prevent runoff. In addition to water savings, these irrigation systems use much less energy (at least 30% less than conventional systems), which reduces fuel consumption and operating costs. Other advantages include reduced disease problems due to less wetting of foliage and easier application of chemicals. Both lateral move (side roll) and center pivot systems can be readily converted to LEPA irrigation. Variable flow nozzles adjust flow from a computer to match microclimate conditions. Correct management of a LEPA system is essential to realize potential water savings. Farmers who replace older irrigation systems with LEPA sprinklers should adjust their management practices so that they do not continue to use excess water. If the pivot system does not have a digital control box showing the amount of water applied, meters should be installed or readings from portable meters should be requested from the local water district to accurately determine how much water is being applied. When managed correctly, LEPA irrigation is 20-40% more efficient than typical impact sprinklers and furrow irrigation. While LEPA systems can be costly, this expense can be offset in 5 to 7 years through reduced energy savings of 35-50%, labor cost reduction of as much as 75% and increased crop yields.

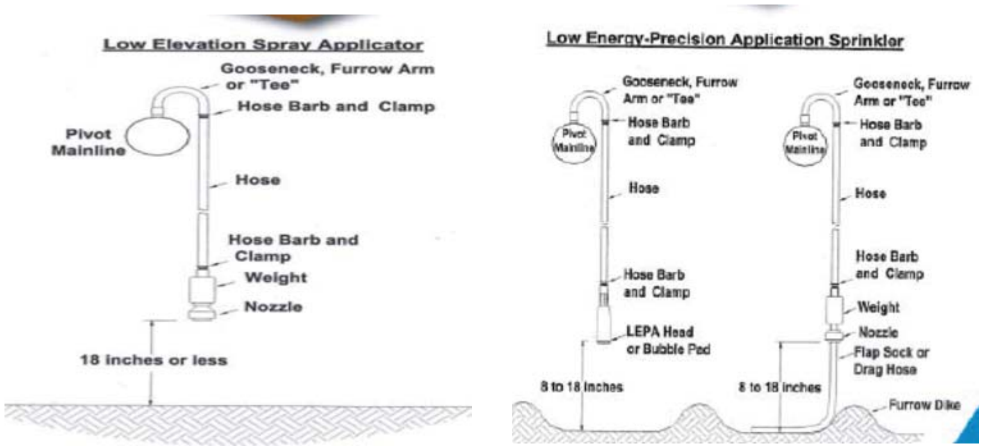

Fig.1: Methods of Spray Irrigation

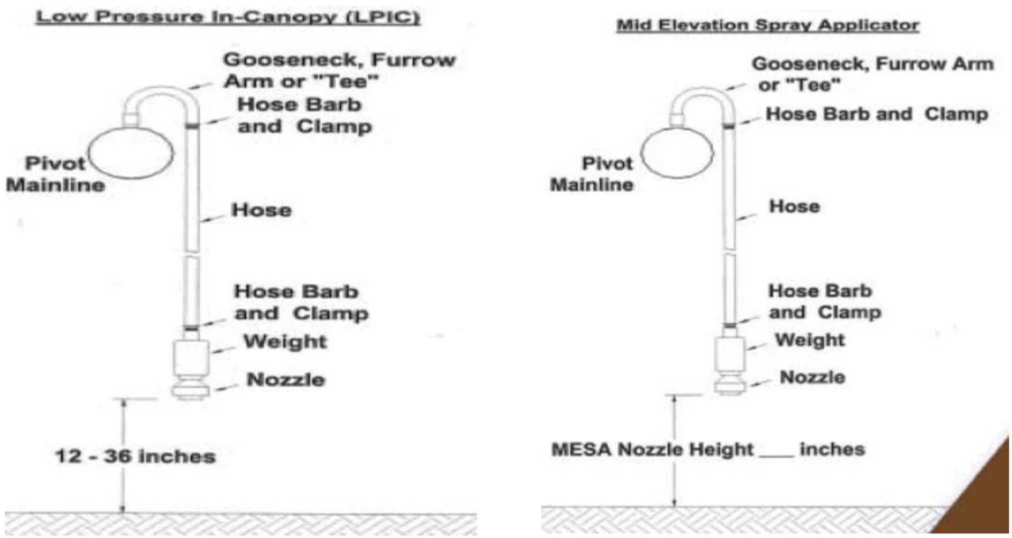

Fig. 2: Low Pressure In Canopy (LPIC) and Mid Elevation Spray Application (MESA) Irrigation systems

Spray Irrigation: Spray irrigation is a more modern way of irrigation, but it also requires machinery. Large scale spray irrigation systems are in use on large farms today. These systems have a long tube fixed at one end to the water source, such as a well. Water flows through the tube and is shot out by a system of spray-guns (traveling gun).

Efficient Spray Irrigation: In traditional spray irrigation, water is sprayed through the air onto the fields. In the dry and windy air of the western U.S., a lot of the water sprayed evaporates or blows away before it hits the ground. Another method, where water is gently sprayed from a hanging pipe uses water more efficiently. This method increases irrigation efficiency from about 60% (traditional spray irrigation) to over 90%. This also reduced electricity requirement. Figure 1 shows different methods of spray irrigation.

Low Pressure In Canopy (LPIC): For optimum efficiency, circular rows should be used with center-pivot systems and straight rows should be used with linear systems. When farming in a circle pattern, straight rows can be utilized near the center of the center-pivot systems for ease of farming operations. The land slope for a LPIC system should not exceed 3.0% on more than 50% of the field. Field runoff should be controlled. Tillage and/or residue management should be utilized as necessary to control excessive translocation of applied irrigation water.

These could include furrow diking or pitting, in-furrow chiseling, or residue management such as limited or not tillage. Terraces may be needed on steeper slopes (> 2%) to control rainfall and irrigation induced erosion.

The specifications of this irrigation system are as follows:

- REQUIRED CU (Coefficient of Uniformity) - 90%
- NOZZLE SPACING-Optimum is two crop rows, but drops may be spaced up to 10 feet apart.
- NOZZLE HEIGHT-should be within the planned crop canopy. Lower nozzle heights will require a closer nozzle spacing to insure high distribution uniformity.
- ROW ARRANGEMENT-Any row arrangement
- SLOPE OF FIELD-3% or less

Figure 2. shows the arrangements of LPIC and MESA systems. All materials used in the installation of the sprinkler irrigation including the Low Pressure In Canopy (LPIC) sprinkler nozzle package shall be new and free from defects. LPIC sprinkler systems offer operators a high efficiency alternative application system when LEPA and LESA specification cannot be met.

The LPIC system fills a niche on certain soil types, topography and row arrangement where LEPA and LESA systems are not the best choice.

Mid-Elevation Spray Application (MESA): Water distribution is greatly affected by nozzle spacing and height for MESA irrigation systems. In general, closer spaced nozzles will yield higher uniformity. Nozzle heights should be set above areas of high leaf concentrations. Application rates shall be set such that runoff, translocation and deep percolation are eliminated or additional measures, such as furrow diking, in-furrow chiseling, conservation tillage and/or residue management shall be applied. The specifications of MESA system is as follows:

- REQUIRED CU (Coefficient Uniformity) –90%
- NOZZLE SPACING-Optimum is two crop rows, but drops may be spaced up to 10 feet apart.
- NOZZLE HEIGHT-Above the crop canopy preferably within 3 to 7 feet of the soil surface depending on crop height.
- ROW ARRANGEMENT-Any row arrangement
- SLOPE OF FIELD-3% or less

Surface Irrigation: In surface irrigation systems water moves over and across the land by simple gravity flow in order to wet it and to infiltrate into the soil. Surface irrigation can be subdivided into furrow, border strip or basin irrigation. It is often called flood irrigation when the irrigation results in flooding or near flooding of the cultivated land. Historically, this has been the most common method of irrigating agricultural land.

Where water levels from the irrigation source permit, the levels are controlled by dikes, which usually plugged by soil. This is often seen in terraced rice fields (rice paddies), where the method is used to flood or control the level of water in each distinct field. In some cases, the water is pumped, or lifted by human or animal power to the level of the land.

Localized Irrigation: Localized irrigation is a system where water is distributed under low pressure through a piped network, in a pre-determined pattern and applied as a small discharge to each plant or adjacent to it. Drip irrigation, spray or micro-sprinkler irrigation and bubbler irrigation belong to this category of irrigation methods.

Drip Irrigation: Drip irrigation, also known as trickle irrigation, functions as its name suggests. Water is delivered at or near the root zone of plants, drop by drop. This method can be the most water-efficient method of irrigation, if managed properly, since evaporation and runoff are minimized. In modern agriculture, drip irrigation is often combined with plastic mulch, further reducing evaporation and is also the means of delivery of fertilizer. The process is known as *fertigation.* Deep percolation, where water moves below the root zone, can occur if a drip system is operated for too long of a duration or if the delivery rate is too high. Drip irrigation methods range from very high-tech and computerized to low-tech and labor-intensive. Lower water pressures are usually needed than for most other types of systems, with the exception of low energy center pivot systems and surface irrigation systems and the system can be designed for uniformity throughout a field or for precise water delivery to individual plants in a landscape containing a mix of plant species. Although it is difficult to regulate pressure on steep slopes, pressure compensating emitters are available, so the field does not have to be level. High-tech solutions involve precisely calibrated emitters located along lines of tubing that extend from a computerized set of valves. Both pressure regulation and filtration to remove particles are important. The tubes are usually black (or buried under soil or mulch) to prevent the growth of algae and to protect the polyethylene from degradation due to ultraviolet light. But drip irrigation can also be as low-tech as a porous clay vessel sunk into the soil and occasionally filled from a hose or bucket.

Subsurface drip irrigation has been used successfully on lawns, but it is more expensive than a more traditional sprinkler system. Surface drip systems are not cost-effective (or aesthetically pleasing) for lawns and golf courses.

Sprinkler Irrigation: In sprinkler or overhead irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns. A system utilizing sprinklers, sprays, or guns mounted overhead on permanently installed risers is often referred to as a *solid-set* irrigation system. Higher pressure sprinklers that rotate are called *rotors* and are driven by a ball drive, gear drive, or impact mechanism. Rotors can be designed to rotate in a full or partial circle.

Center Pivot Irrigation: Center pivot irrigation is a form of sprinkler irrigation consisting of several segments of pipe (usually galvanized steel or aluminum) joined together and supported by trusses, mounted on wheeled towers with sprinklers positioned along its length. The system moves in a circular pattern and is fed with water from the pivot point at the center of the arc. These systems are common in parts of the United States where terrain is flat. Most center pivot systems now have drops hanging from a u-shaped pipe called a *gooseneck* attached at the top of the pipe with sprinkler heads that are positioned a few feet (at most) above the crop, thus limiting evaporative losses. Drops can also be used with drag hoses or bubblers that deposit the water directly on the ground between crops. The crops are planted in a circle to conform to the center pivot. This type of system is known as LEPA (Low Energy Precision Application). Originally, most center pivots were water powered. These were replaced by hydraulic systems (*T-L Irrigation*) and electric motor driven systems (*T-L, Reinke, Valley, Zimmatic*). Most sprinklers features GPS devices. Reinkes usually have strobe lights and are red. Valleys have a blue label, while Zimmatics' lights are high with either a red or white Zimmatic label.

Lateral Move (Side Roll, Wheel Line) Irrigation: A series of pipes, each with a wheel of about 1.5 m diameter permanently affixed to its midpoint and sprinklers along its length, are coupled together at one edge of a field. Water is supplied at one end using a large hose. After sufficient water has been applied, the hose is removed and the remaining assembly rotated either by hand or with a purpose-built mechanism, so that the sprinklers move 10 m across the field. The hose is reconnected. The process is repeated until the opposite edge of the field is reached. This system is less expensive to install than a center pivot, but much more labor intensive to operate and it is limited in the amount of water it can carry. Most systems utilize 4 or 5-inch (130 mm) diameter aluminum pipe. One feature of a lateral move system is that it consists of sections that can be easily disconnected. They are most often used for small or oddly-shaped fields, such as those found in hilly or mountainous regions, or in regions where labor is inexpensive.

Sub-Irrigation: Sub-irrigation also sometimes called *seepage irrigation* has been used for many years in field crops in areas with high water tables. It is a method of artificially raising the water table to allow the soil to be moistened from below the plants' root zone. Often those systems are located on permanent grasslands in lowlands or river valleys and combined with drainage infrastructure. A system of pumping stations, canals, weirs and gates allows it to increase or decrease the water level in a network of ditches and thereby control the water table.

Manual Irrigation Using Buckets or Watering Cans: These systems have low requirements for infrastructure and technical equipment but need high labor inputs. Irrigation using watering cans is to be found for example in peri-urban agriculture around large cities in some African countries.

Automatic, Non-electric Irrigation Using Buckets and Ropes: Besides the common manual watering by bucket, an automated, natural version of this also exist. Using plain polyester ropes combined with a prepared ground mixture can be used to water plants from a vessel filled with water.

Irrigation Using Stones to Catch Water from Humid Air: In countries where humid air sweeps the countryside, stones are used to catch water from the humid air by condensation. This is practiced in the vineyards at Lanzarote.

Dry Terraces for Irrigation and Water Distribution: In subtropical countries as Mali and Senegal, a special type of terracing is used. Here, a 'stairs' is made through the use of ground level differences which helps to decrease water evaporation and also distributes the water to all patches (sort of irrigation).

Sources of Irrigation Water: Sources of irrigation water can be groundwater extracted from springs or by using wells, surface water withdrawn from rivers, lakes or reservoirs or non-conventional sources like treated wastewater, desalinated water or drainage water. A special form of irrigation using surface water is spate irrigation, also called floodwater harvesting. In case of a flood (spate) water is diverted to normally dry river beds (wadi's) using a network of dams, gates and channels and spread over large areas. The moisture stored in the soil will be used thereafter to grow crops. Spate irrigation areas are in particular located in semi-arid or arid, mountainous regions. While floodwater harvesting belongs to the accepted irrigation methods, rainwater harvesting is usually not considered as a form of irrigation.

Problems in Irrigation:

- Competition for surface water rights.
- Depletion of underground aquifers.
- Ground subsidence (e.g. New Orleans, Louisiana)
- Under irrigation or irrigation giving only just enough water for the plant (eg in drip line irrigation) gives poor soil salinity control which leads to increased soil salinity with consequent build up of toxic salts on soil surface in areas with high evaporation. This requires either leaching to remove these salts and a method of drainage to carry the salts away. When using drip lines, the leaching is best done regularly at certain intervals (with only a slight excess of water), so that the salt is flushed back under the plant's roots.
- Over irrigation because of poor distribution uniformity or management wastes water, chemicals and may lead to water pollution.
- Deep drainage (from over-irrigation) may result in rising water tables which in some instances will lead to problems of irrigation salinity.
- Irrigation with saline or high-sodium water may damage soil structure.

Agricultural Techniques for Conserving Water: Irrigation scheduling involves managing the soil reservoir so that water is available to the plants whenever they require. Soil moisture and weather monitoring are used to determine when to irrigate and soil capacity and crop type are used to determine how much water should be applied during irrigation. Accurate water measurement and soil moisture monitoring are key components of efficient on-farm water management practices. Irrigation flow meters can be used to help in finding the efficiency of irrigation systems, identify water loss from leaks in conveyance systems and to accurately apply only the necessary amount of water based on soil moisture levels and weather conditions. Soil moisture monitoring is used in conjunction with weather data and crop evapotransporation requirements to schedule irrigation. Fields should be designed for efficient water use by grading land with laser equipment, creating furrow dikes to conserve rainwater and by retaining soil moisture through Conservation tillage.

Soil Moisture Monitoring: Regardless of the irrigation system used, scheduling irrigation should be based on the crop's water requirement, which is often assessed by monitoring soil moisture. There are many ways to measure soil moisture, each method having its own advantages and disadvantages and varying degrees of accuracy.

Weather Monitoring: Temperature, rainfall, humidity and crop evapotransporation (ET) data should be collected to determine efficient irrigation scheduling.

Soil Capacity: Soil acts as a water reservoir between irrigations or rains. Soil is also a nutrient reservoir and it mechanically supports and stabilizes plants. Each soil type has a different capability to hold moisture based on soil depth, soil texture (ratios of various soil particle sizes), soil structure (soil porosity) and soil water tension. Table 1 gives the variation of type of soil and available water.

Table 1: Variation of Soil Type and Available Water

Soil Texture	Inches of Water Available per Foot of Soil
Coarse Sand	0.50
Fine Sand	0.75
Loamy Sand	1.00
Sandy loam	1.25
Loam	1.50-2.00
Clay or silt loam	1.75-2.50
Clay	2.0-2.4

Table 2: Root Depth of Different Crops

Crop	Approximate Root Depth (ft)	Crop	Approximate Root Depth (ft)
Alfalfa	4-6	Onions	1.5
Citrus	2-5	Potatoes	2-3
Cabbage	1.5 - 3	Peanuts	2-2.5
Corn	2.5-4	Sorghum	2-3
Cotton	3-4	Soybeans	2-3
Grass	3-4	Sugar beet	2-4
Melons	2-3	Sugarcane	4-6
Oats	3-5	Turf grass	0.5 - 2.5
Onions	1.5	Wheat	3-4

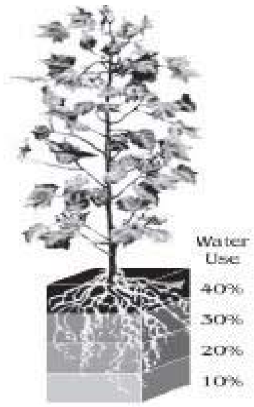

Fig. %age of water Uptake by Plants at Various depths

Crop Type: Plants differ in their ability to withdraw water from soils, their water uptake rate and their ability to withstand soil water stress. When the moisture content in the soil declines to a certain point, plants begin to irreversibly wilt. This point is called the permanent wilting point (PWP) and is measured by soil water tension. Plant available water (PAW) is expressed as the amount of water held between field capacity (FC) and the PWP (FC-PWP=PAW). Each crop and/or crop variety will have a different PWP.

Preparation of Fields for Efficient Water Use

Laser Leveling: Laser-controlled land leveling equipment grades fields to contour the land for different irrigation practices. With sprinkler systems, a perfectly level field conserves water by reducing runoff, allowing uniform distribution of water. Furrow irrigation systems need a slight but uniform slope to use water most efficiently. Laser leveling can reduce water use by 20-30% and increase crop yields by 10-20%.

Furrow Diking: Furrow diking conserves water by capturing precipitation or irrigation water in small earthen dams in the furrows. Water held between the dams can slowly infiltrate into the soil, increasing soil moisture and reducing or eliminating runoff. Furrow dikes can benefit dryland farmers, sprinkler irrigators and furrow irrigators who water alternate rows. Dikes should be made large enough to hold runoff during intense thunderstorms when the soil is not able to immediately absorb the intensity of rainfall. If the field has a slope, furrow diking is especially important to reduce excessive runoff. It is also an important part of LEPA irrigation systems, especially on less permeable soils. Water is applied directly to furrows by drop lines from the sprinklers.

Conservation Tillage: Conservation tillage helps preserve soil moisture by leaving at least 30% of the soil surface covered with crop stubble, thereby decreasing wind and water erosion. The crop stubble layer reduces evaporation in the soil profile by one-half compared to bare soil. Conservation tillage can also reduce pollution caused by runoff and enrich the soil with organic matter.

Tail water Reuse: Tail water, or runoff water, should be minimized as much as possible through soil monitoring and irrigation methods that reduce runoff, such as surge flow irrigation and furrow diking. However, if field runoff is present, it should be captured at the lowest end of gravity-irrigated rows and reused. Reuse of runoff water works best with laser leveling and is effective with soils that have high water holding capacity. It is not recommended for areas where soils contain high concentrations of salt and may spread chemicals, diseases and weed seeds.

Conclusions and Recommendations: There are three basic types of irrigation: surface (gravity), sprinkler and drip irrigation. Using surge flow valves and reusing tailwater can increase water use efficiency (WUE) of gravity irrigation systems. Modifying older high pressure sprinkler systems using the LEPA or LESA methods can increase sprinkler WUE by 20 to 40%. Drip irrigation is a very water efficient method of irrigation that can be effective with certain crops and on uneven terrain.

Lining canals with concrete or other liners reduces water loss through seepage by 10-30%. Evaporation in canals can be reduced if irrigation districts provide water on demand rather than keeping the canals continuously filled. Using underground conveyance systems eliminates costly evaporation and deep percolation.

Using the methods outlined in this brochure will not only conserve water, but will preserve water quality, reduce or eliminate drainage problems, conserve energy, often increase production and save money. The stress of droughts, higher expenses and low commodity prices will continue to make efficient water management practices a necessary tool for farmers who wish to remain competitive in today's market. Efficient agricultural water conservation practices are essential to ensure the viability of agricultural industry.

REFERENCES

1. http://ga.water.usgs.gov/edu/irmethods.html
2. http://www.extension.org/mediawiki/files/a/ab/NRCS_Center_Pivot_Irrigation.pdf
3. http://en.wikipedia.org/wiki/Irrigation