WATER CONSERVATION TECHNICAL BRIEFS

TB 1 – Irrigation Systems

SAI Platform

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WATER CONSERVATION

TECHNICAL BRIEFS

TB 1 - Irrigation Systems

Irrigation is the replacement or supplementation of rainfall with water from another source in order to grow crops or plants. In contrast, agriculture that relies only on direct rainfall is referred to as **dry land farming** or **rain fed agriculture**. This document provides a review of major technologies used in irrigation such as overhead irrigation, overhead pivot irrigation, centre pivot irrigation, drip irrigation and subsurface drip (SDI) irrigation.
This Technical brief gives the description of the main irrigation systems in used and highlights the major advantages & disadvantages regarding to installation cost, energy use, water efficiency and uniformity, labour.

Since water remains the main issue in agriculture due to increasing water scarcity, one of the central objectives of the SAI Platform is to promote a better management of water use in farming activities. The SAI Platform therefore encourages the adoption of drip irrigation system (surface & subsurface) due to its higher water efficiency and crop productivity compared to other systems.

Obviously, the principal obstacle for farmers to adopt drip systems is currently the important initial investment. However, it is essential to keep in mind that the system will quickly be profitable according to higher crop yield, less pumping cost and less water use.

Although drip irrigation suits to almost all type of vegetables and fruits, the method is generally use for cash crop. Despite this, this technology is currently used to produce cereal (maize, corn).

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Section 1: Irrigation efficiencies

Irrigation Efficiencies	Although there are many definitions of irrigation efficiency, they can be grouped into three main categories: irrigation efficiency, application efficiency and distribution efficiency (or uniformity). In general, irrigation efficiency is related to the percentage of water delivered to the field that is used beneficially. These definitions are more relevant when considering seasonal water allocation or seasonal water use. Where the focus is on the performance of a single event, application efficiency (AE) is most commonly used. In broad terms, application efficiency is the percentage of water delivered to the field that is used by the crop. Distribution uniformity (DU) is an expression that describes the evenness of irrigation water application to a crop over a specified area.

Pressurized irrigation system application efficiencies, AE (%)		
Sprinkler irrigation systems		
System type	Range	Average
Lateral move	60-75	70
Center pivot (high pressure)	65-80	70
Center pivot (low pressure)	75-90	80
Stationary guns	50-60	55
Traveling guns	65-70	70
Drip irrigation systems		
Surface	85-95	90
Subsurface	85-95	90
Surface irrigation		
Flood & Furrow	25-80	50

SECTION 2: OVERHEAD IRRIGATION

Cost	Variable depending on the system.

Description	Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Water is distributed through a system of pipes by pumping and is sprayed above the crop by an impact sprinkler.

Operation pressure & flow	Impact sprinklers (guns) operate at: - pressures of about 5 to 9 bar (70 to 130 psi). - flows of 3 to 76 l/s (10.8 to 273.6 m^3/h ; 39.6 to 1003 gmp). - nozzle diameter of 10 to 50mm (0.39 to 1.96 inch).

Remarks & Recommendations	
The nozzle is that part of a sprinkler which actually distributes the water. The discharge opening or orifice used on a sprinkler to control the volume of discharge, distribution pattern, diameter and droplet size. The volume of discharge from the sprinkler is primarily a function of nozzle size and pressure. Wetted diameter is a function of nozzle size and pressure, but it is also greatly affected by the type of sprinkler.	
Guns also have relatively low initial costs as compared to permanent or portable solid set irrigation systems, and they require less labor than portable multi-sprinkler systems because they must be manually moved between sets.	
Hand-moved (portable) guns are most adaptable to relatively small acreages.	
More water is lost during high evaporative demand periods (hot, dry days) than during low demand periods (cool, cloudy, humid days). Thus, sprinkler irrigation systems usually apply water more efficiently	

at night (and early mornings and late evenings) than during the day.
More water is lost by sprinklers that discharge water at high angles, over great distances, and at great heights above the ground surface because of greater opportunity time for evaporation. In addition, greater water losses occur from systems which discharge a greater proportion of small droplet sizes because small droplets are more readily carried by wind and they expose more surface area to the atmosphere for evaporation.
Application efficiencies will be reduced if water falls between widely spaced plants or outside the crop root zone, as in the cases when irrigating young crops.
Sprinkler irrigation application efficiencies are reduced by non uniform water application. Non uniform application causes some areas to be over-irrigated (and lose water and nutrients to deep percolation) while other areas are under-irrigated (reducing crop yields). Thus, **system design** affects application efficiency. Non uniform water application occurs when sprinklers are not properly selected nor properly matched to the sprinkler spacing and operating pressure used.
Non uniformity also occurs if pressure losses within the irrigation system are excessive (due either to friction losses or elevation changes).
Other causes of non uniformity such as clogged nozzles or enlarged nozzles from abrasion by pumping sand also reduce application efficiencies.
Sprinkler water application patterns must overlap sufficiently (typically about 50%) to apply water uniformly. Because of this need for overlap, non uniformity occurs at the edges of fields where overlap is not possible
Part-circle sprinklers can be used at the edges of fields to improve uniformity, but they are more mechanically complicated and more expensive than full-circle sprinklers.

Advantages(+) / Disadvantages(-)	
+	Low labour and maintenance with fixed irrigation sprinklers.
+	Guns irrigation system are flexible, they allow irrigation of oddly-shaped fields (but wheel sprinkler can be used with a maximum of 15^{o} slope rate).
+	Can be used for frost control.
-	Relatively high pumping costs
-	Incorrect operating pressure, and component wear or failure can still distort application patterns and reduce uniformity and application efficiency leading to important water and chemicals loses.
-	Gun irrigation systems require large energy inputs per unit of water delivered because of their high operating pressures.
-	Relatively high labor requirements, both to move the portable guns between sets and to set up the self-propelled (travelling) guns.
-	During water applications, sprinkler irrigation systems lose water due to evaporation and wind drift. More water is lost during windy conditions than calm conditions.
-	Wet leaves from irrigation favours foliar diseases.
-	Apparition of white leaves spot if irrigation water contains bicarbonate.
-	Can damage fruit close to harvest.

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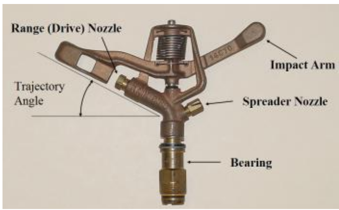
Pictures	



Impact sprinkler (gun)

Rotary irrigation sprinklers

Lateral sprinkler move irrigation (sprinkler wheel)

Travelling big gun

SECTION 3: CENTRE PIVOT IRRIGATION

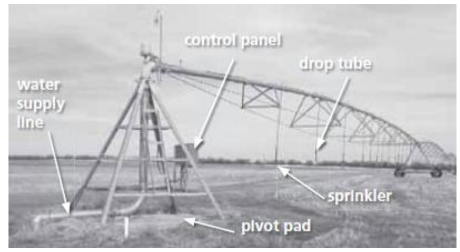
Description	**The centre pivot irrigation is a form of overhead sprinkler that apply small amount of water at frequent intervals to a unit area of crop. It consists of a span of pipe which is supported on wheeled frame towers and is self propelled around a central pivot point. Water is usually delivered to the pivot point through a buried mainline pipe.**

Technical information	Centre pivot irrigation operate at: - pressures 0.7 to 5.5 bar (10 to 80 psi). - center pivot systems are either electric or oil-drive. - the system may vary in length from approximatively 60m to 790m and is capable to irrigate a circular area up to 200 ha (500 acres).

Remarks	It exists 3 main types of centre pivot irrigation system: - high pressure sprinklers - low spray sprinklers - LEPA system (Low Energy Precision Application) (For more informations on their specific performances, see paper: Optimal performances from center pivot sprinklers systems).

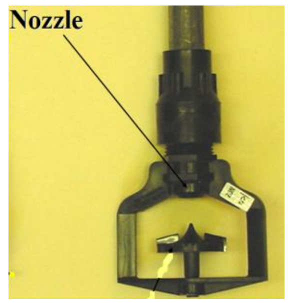
Pictures	

Central pivot irrigation in action with spray pad sprinklers



Central pivot irrigation system

Aerian view of central pivot irrigation in Kansas



A spray pad sprinkler

SECTION 4: DRIP IRRIGATION

Description	Drip irrigation is sometimes called trickle irrigation and involves dripping water onto the soil at very low rates (2-20 liters/hour) from a system of small diameter plastic pipes fitted with outlets called emitters or drippers. Water is applied at frequent intervals near the root zone of plant over a long period, so that only part of the soil in which the roots grow is wetted.

Operation pressure & Flow rate	Drip irrigation system operate at: - Pressures typically range from 0.2 to 2 bars. Emitter discharges are in the form of small streams or individual drops, with flow rates ranging from 1 l/h to 7 l/h, but most commonly being 3.5 l/h (0.013 gmp)

Cost of installation	Conventional drip irrigation systems cost between $1,200 and $3,000 per hectare (10,000 m^2) Remarks: - The low-cost drip systems available from International Development Enterprises cost less than $500 per hectare and are available in a variety of sizes (http://www.ideorg.org) - The cheapest alternative is to use a bucket drip irrigation (see paper: bucket drip irrigation).

Advantages(+) / Disadvantages(-)	
+	High water application efficiency ~ 85% - prevent losses due to evaporation or run-off, and if the flow rates are set correctly, water losses due to deep percolation (i.e. water penetrating the soil below the root system and flowing into the water table) can be minimized.
+	Highly uniform distribution of water.
+	Usually operated at lower pressure than other types of pressurized irrigation => reduce energy costs.
+	Improved fertilizer and pesticide management – Precise and more timely application of fertilizer and pesticide result in a higher efficacy, and may also reduce their use.
+	Less water quality hazards - runoff into stream is reduced or eliminate and there is less nutrient and chemical leaching due to deep percolation.
+	Smaller and more frequent irrigation application may reduce salinity hazards and minimize soil erosion.
+	Drip irrigation can be use on hilly land.
+	Water efficiency not affected by windy conditions, hot and dry days.

+	Foliage remains dry thus reducing the risk of diseases.
+	Programmable system – Automatisation possible.
+	Drip irrigation also allows the grower to customize an irrigation program most beneficial to each crop.
+	Drip can provides an ideal moist environment for the roots which optimize growth and thus can increase crop yield.
+	Drip allow to control where the water is applied which help minimizing weed growth.
-	High initial investment.
-	Timely and consistent maintenance and repairs are a requirement.
-	Filtrations issues - Clogging of water emitters if water is not properly filtered and the equipment not properly maintained.
-	Longevity of the system is variable. The PVC lines are often damage by roots.
-	Application efficiencies of drip systems are primarily dependent on the design of the systems and on their maintenance and management.
-	Need to be trained to the system.

Remarks & Recommendation	
Length of lateral lines should not exceed the manufacturer's recommendations for the specific tape used. Excessive length of laterals will result in poor uniformity and uneven water application. As a result, the amount of water applied by the emitters in the last section of the lateral will be significantly reduced when compared with the amount of water applied by the emitters close to the lateral entrance.	
All delivery lines (mains and submains) should be sized to avoid excessive pressure losses and velocities. Since the flow rate of the emitters is usually a function of the pressure, the water application at the beginning of the line may be very different from the water application at the end of the line which results in poor application uniformity.	
The maximum size of the zones depends on the flow rate from the well. The water flow rate from an existing water pump limits the maximum size of the irrigation zone.	
Zones should be approximately the same size. Variation in crop zone sizes will reduce the efficiency of pumpoperation. When all zones are of the same size, pipe sizes and system cost will normally be minimal.	
Pressure regulators may be required if the pressure produced by the pump is too large or if zones vary greatly in size.	
Drip irrigation systems require filtration. Selection of filters depends on water source and water quality. Surface water normally requires sand media filters to trap organic materials such as algae, bacteria, and other organic debris. Screen or disk filters are usually sufficient for well water.	
An irrigation system should include an injection port to allow for injection of fertilizer and also of chlorine or other chemicals to clean the pipes (to avoid clogging).	
Any irrigation system that will be injecting fertilizers or toxic chemicals is required to be equipped with proper backflow and anti-siphon equipment to prevent the chemicals from contaminating the water source.	
When preparing chemicals to clean the pipes**, DO NOT MIX ACIDE AND CHLORINE IN THE SAME CONTAINER.**	
Flowmeters and pressure gauges should be used to help manage the system. Sudden changes in water flow rates or pressures indicate system problems. These problems usually require immediate attention. For example, an increase in flow rate may be a sign of a broken pipeline, whereas, a gradual decrease may indicate plugging problems. Flowmeters are also a necessary tool for proper irrigation scheduling. It	

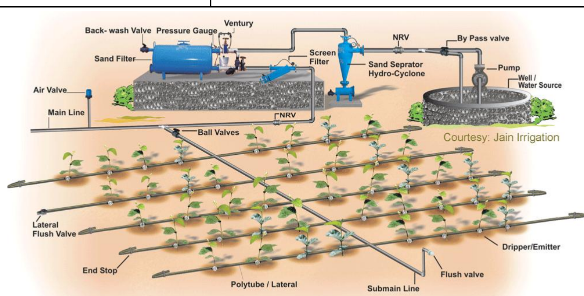
is important to know how much water is applied to each zone with every irrigation cycle. The duration of the cycle may not be sufficient, especially if the flow rate is gradually decreasing due to plugging of emitters.

Air release valve installed at the highest point on the mainline is necessary to avoid suction of soil into the emitters when the system is shut off.

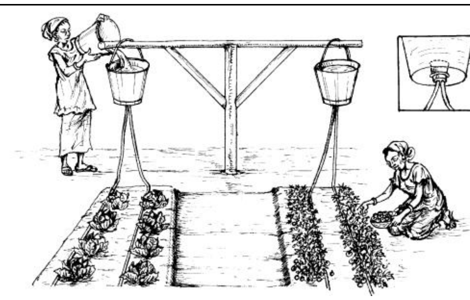
Flush the drip line once a month by opening a portion of the tape at a time and allowing the higer velocity water to wash out the sediment.

Maintain filter station.

Pictures



Schema of drip irrigation system



Schema of basic drip irrigation system

Drip irrigation hose

Drip emitter (dripper)

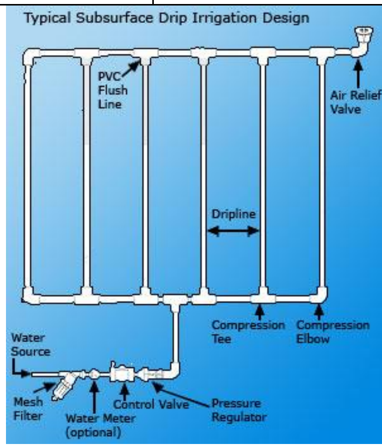
Section 5: Subsurface drip (SDI) Irrigation

Description	Subsurface drip irrigation is the slow frequent application of water to the soil profile (in the root zone) through emitters placed along a delivery line placed beneath the soil surface.

Operation pressure & Flow rate	SDI system operate at: - Pressures typically range from 0.2 to 2 bars. - Emitter discharges are in the form of small streams or individual drops, with flow rates ranging from 1 l/h to 7 l/h, but most commonly being 3.5 l/h (0.013 gmp).

Cost of installation	Conventional SDI systems cost on average 1,000 – 2000 USD per acre (0.4 ha).

Advantages / Disadvantages	Refer to drip irrigation Compared to surface drip irrigation, the main advantage of SDI are: - Many field operations can occur during irrigation events (e.g. ploughing). - Variability in soil water regimes and redistribution are often reduced with SDI. - Hand laborers benefit from drier soils by having reduced manual exertion.

Pictures	
 Typical system design	 Installation of SDI system for tomatoes

SECTION 6: FLOOD & FURROW IRRIGATION

Description	Flood is the oldest method of surface irrigation. A large amount of water is brought to the field and flows on the ground among the crops. In regions where water is abundant, flood irrigation is the cheapest method of irrigation and this low tech irrigation method is commonly used by societies in developing countries. Furrow irrigation is actually a type of flood irrigation in which the water poured on the field is directed to flow through narrow channels dug between the rows of crops.

Cost	Essentially pumping and water costs Pumping cost due to oil consumption may be eliminated in using a **treadle pump** suggested by the International Enterprises in India (http://www.ide-india.org).

Remarks & Recommendations
Flood and Furrow irrigation should be applied only to flat lands that do not concave or slope downhill so that the water can evenly flow to all parts of the field => land levelling is required.
About 50% of the water is wasted and does not get used by the crops. Some of this wasted water accumulates at the edges of a field and is called run-off. In order to conserve some of this water, growers can capture the run-off in ponds and pump it back up to the front of the field where it is reused for the next cycle of irrigation.
Surge flooding: Traditional flooding involved just releasing water onto a field. In using surge flooding, water is released at prearranged intervals, which reduces unwanted runoff.
Flood is generally used in almonds, peaches, walnuts, rice and alfalfa production.
Furrow is generally used in row crops such as beans, tomatoes, corn, sugar beets other vegetable crops.
If drainage (runoff) water is reused, the application efficiency has been observed to be high (70%), while if the excess water is lost, then the application efficiency has been observed to be low (20%).

Advantages(+) / Disadvantages(-)	
+	Inexpensive method (if water is relatively cheap)
+	Very little labour (once land levelling and digging are finished)
+	Large amount of water flush salts of the soil, which is important for many saline intolerant crops
+	Rodent control
-	Use large amount of water with a very low water use efficiency – Even if the runoff can be reused after being stocked in pond, a large part of the water is wasted due to massive loss via evaporation and deep percolation.
-	Flooding causes an anaerobic environment around the crop which can increase microbial conversion of nitrogen from the soil to atmospheric nitrogen, or denitrification, thus creating low nitrogen soil.
-	Land must be levelled or contoured
-	Runoff water can causes problems (river pollution due to chemicals, soil erosion

System of Rice Intensification (SRI)	The SRI is a new approach to produce paddy rice more sustainably. More than 20 countries are now using its methods to raise their rice production, to reduce water and seed use and to reduce global productivity costs. SRI works by changing the management of the plants, soil, water and nutrients utilized in paddy rice production. The basic concepts of SRI are: - Importance of seeding management. - Give plant optimal wider spacing. - Keep paddy soil sufficiently moist but not continuously flooded, mostly aerobic and not saturated (adapted for rice-growing in rainfed with considerable success). - Actively aerate the soil as much as possible to control weeds. - Enhance soil organic matter as much as possible applying compost, mulch, manure, etc. Chemical fertilizers can be used with SRI, but the best results have come with organic soil amendments.

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Pictures	

Flooded field

Furrow irrigation system

Man using a treadle pump

SECTION 8: APPENDIX

Table 3–2 Adapted irrigation methods

Crop	Management depth (ft)	Adapted irrigation methods — Surface — level border	level furrow	graded border	graded furrow	graded corrug.	Sprinkler	Micro-	Subirr.
Alfalfa	5	x	x	x	x	x	x		
Beans, dry	3	x	x	x	x		x		
Beans, green	3				x		x	x	
Cane berries	3	x	x	x	x		x	x	
Citrus	3	x		x			x	x	
Corn, grain	4		x		x		x		x
Corn, silage	4		x		x		x		x
Corn, sweet	3		x		x		x		x
Cotton	3		x		x		x	x	
Grain, small	4	x	x	x	x	x	x		x
Cranberries	2	x					x		
Grass, seed	3	x	x	x	x	x	x		
Grass, silage	3	x	x	x	x	x	x		
Milo (sorghum)	3	x			x		x		x
Nursery stock	0-3	x	x	x	x		x	x	x
Orchard	5	x	x	x	x		x	x	x
Pasture	3	x		x		x	x		x
Peanuts	3		x		x		x		x
Peas	3	x	x	x	x		x		
Potatoes	3		x		x		x	x	
Safflower	5	x	x	x	x		x		
Sugar beets	5		x		x		x		
Sunflower	5	x	x	x	x		x		
Tobacco	3						x	x	
Tomatoes	2		x		x		x	x	x
Turf, sod	2	x		x			x		
Turf	2	x		x			x	x	
Vegetables	1/	x	x	x	x		x	x	
Vegetables	2/	x	x	x	x		x	x	x
Vegetables	3/	x	x	x	x		x	x	x
Vegetables	4/	x	x	x	x		x	x	x

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