International Organization for Standardization
Organisation internationale de normalisation
Международная организация по стандартизации

Ch. de Blandonnet 8 | CP 401, 1214 Vernier | Geneva, Switzerland | T: +41 22 749 01 11 | central@iso.org | www.iso.org

Ref. ISO/TMB IWA

Date 2016-04-22

Invitation to an international workshop on Drip irrigation

Dear ISO Members,

Following approval by the Technical Management Board of a proposal from SII (Israel), we are pleased to enclose the draft program and registration form for a workshop for the purpose of developing an International Workshop Agreement on *Drip irrigation*.

Meeting dates: 2016-08-31 to 2016-09-02

Location: Swedish Standards Institute (SIS),
Sankt Paulsgatan 6 SE-118 80 Stockholm
Sweden

We would be grateful if you could publicize this event in your country.

Yours faithfully,

Sophie Clivio

Secretary to the Technical Management Board

Encl.: - IWA Drip irrigation communication
- Invitation and IWA registration form
- Draft IWA Drip Irrigation

Drip Irrigation: International Workshop Agreement
August 31 - September 2 2016
Stockholm

The International Standardization Organization (ISO) and The Standards Institution of Israel (SII), in agreement with leading drip irrigation industry companies, are planning to hold an international workshop on drip irrigation, in the purpose of advancing worldwide usage of this sustainable irrigation method.

The intention is to hold an intensive international discussion of relevant stakeholders, such as irrigation companies, drip irrigation users, governmental and or standardization / regulation / inspection bodies, sustainability developing organizations, academy representatives and others.

This ISO international workshop is to be held in Stockholm, in parallel to the World Water Week, at the premises of SSI – the Swedish Standards Institute. It is planned to take 2-2.5 days between August 31 and September 2, 2016, by the end of which, a basic consensus in the subject of drip irrigation can be reached and published as an ISO International Workshop Agreement.

Agenda

31 August: Drip Irrigation Workshop

The workshop will be focused on the need of developing countries and, in particular, of small-scale implementations supporting small farmers.

1-2 September: ISO IWA on Drip Irrigation

International discussion on Drip Irrigation and development of an ISO/IWA.

Relevant Professional Material

See draft proposal attached.

We also encourage you to send any related material that can contribute to the development of a Drip Irrigation IWA.

Purpose

- Promoting drip irrigation use as an efficient method preserving water, land and energy resources
- Addressing pressing need of preservation and scarce resources management through standardization
- Reaching an International Workshop Agreement (IWA), to be published by ISO

IWA Process

Participants are invited to submit standards or other existing relevant documents for consideration in advance of the workshop. These documents will be provided to all pre-registered participants for review and comment. At the meeting, activity will focus on the evaluation of the submitted documents, their applicability and subsequent integration for the International Workshop Agreement.

As soon as agreed by the workshop participants, the IWA shall be a framework document for the fundamentals of drip irrigation method and its benefits. It will then be published by ISO and is anticipated to be subject to further evolution into an ISO standard or standards, in addition to standards developed by ISO TC 282 and ISO TC 23 / SC 18.

The IWA will be held in English.

Participation

Participation is open to all experts from organizations involved with water, irrigation equipment, control systems, filtering systems and agriculture, who have an interest in irrigation method application.

To make the necessary meeting arrangements and ensure sufficient space, pre-registration is required.

Registration fee

Participation in Drip Irrigation workshop and IWA is free of charge.

Contacts

Further specifics on the meeting logistics and process for the advance review of existing documents will be sent to registered participants.

Points of Contact at SII are the International Water Standardization Programme Manager Yaron Ben-Ari (email: yaronbenari@sii.org.il | tel: +972-3-6465315) and the International Water Standardization Programme Coordinator Orit Itsik (email: orit_it@sii.org.il).

Relevant Documents

Parties interested in submitting relevant documentation should contact one of SII's points of contact mentioned above.

About Drip Irrigation

The benefits of drip irrigation are increasingly acknowledged: it is a most feasible method to meet worldwide forthcoming challenges such as population growth, water scarcity, food security and rising prices, land degradation and the changing environment.

In response to limited water, land and energy resources available today, drip irrigation can save large amounts of water (depending on the type of crop, in some cases over 50% of water can be saved with the use of drip irrigation), and increase yields. It also requires less labour and energy for operation.

The drip irrigation method can be applied in dry areas, saline soils and steep slopes, where other methods cannot be practiced. It can also function as a delivery system for fertilizers and other agrochemicals.

drip irrigation IWA draft.docx

THE STANDARDS INSTITUTION OF ISRAEL

Standardization Division

Drip Irrigation IWA
Invitation

August 31 – September 2, 2016
Stockholm, Sweden

Dear friend

The Standards Institution of Israel (SII) invites you to attend a Drip Irrigation International Workshop in Stockholm, Sweden.

Meeting schedule and location	The meetings will take place on August 31 - September 2 2016 at **The Swedish Standards Institute** **Sankt Paulsgatan 6** **SE-118 80 Stockholm**
Registration:	Please register at SII: Tel: +972-3-7454459 | E-mail: orit_it@sii.org.il | yaronbenari@sii.org.il

Drip Irrigation IWA
Registration Form

August 31 – September 2, 2016
Stockholm, Sweden

Participation in Drip Irrigation Workshop Is Free of Charge

Please type or print in block letters and return to:
The Standardization Division, SII, 42 Chaim Levanon st., Tel-Aviv 69977
Tel: +972-3-6467675 | E-Mail: orit_it@sii.org.il or yaronbenari@sii.org.il

Surname________________________ First Name ____________________________

Full Mailing address____

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E-mail address____

Company/Organization:____

Country: ____

Tel: ______________________________ Fax: ________________________________

E-Mail:____

Name(s) of accompanying person(s) _______________________________________

THE STANDARDS INSTITUTION OF ISRAEL

Standardization Division

Draft

4/21/2016

Drip Irrigation

Contents

Forward

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TMBG, *Technical Management Board Groups.*

Introduction

Declining vital natural resources such as land and water, and increasing world population, pose a constant threat that could develop into a future food and water crisis. Given the limited water and land resources available, the amount of food grown today should be increased to meet the demands of tomorrow. Reduction of available water for human consumption should be addressed. As direct consumption of fresh water by populations cannot be decreased, the amount of water needed for agricultural uses should be reduced, in order to allocate it for domestic uses or irrigate larger areas.

The drip irrigation method addresses water scarcity and other environmental considerations. The use of drip irrigation can save large amounts of water (depending on the type of crop, in some cases over 50% of water can be saved when using drip irrigation), and can increase yields.

Drip irrigation addresses not only the need to reduce water consumption and increase yield but also requires less labor and energy for operation, and contributes to the reduction of cost to farmer, due to a lower requirement of labor, fertilizers and other chemicals.

Drip irrigation relates to sustainability agriculture issues, and can be used in dry areas, saline soils and saline water and steep slopes, where other irrigation methods cannot be practiced.

Drip irrigation is easy to handle and operate once installed. It is suited for automation and remote operation by computer or mobile phone. The simplicity of the system makes it easy to fix and repair.

Other than irrigation, drip irrigation is used as a delivery system for fertilizers and other agrochemicals. The advantage of drip irrigation as a delivery system is the small amount of fertilizers required and the fact that it is distributed exactly where it needed, in the root zone, while minimizing fertilizers release to the environment.

Adoption of drip irrigation can help achieve sufficient fresh water for domestic uses and sufficient food quantity and quality for reasonable prices, while increasing farmers' income with yield increment and cost reduction.

Drip irrigation

1 Scope

This document reviews major irrigation methods available and practiced today by farmers worldwide, while comparing those methods to drip irrigation. The document reviews the benefits of drip irrigation, such as increased yield, reduced water consumption, reduced energy consumption and reduced labor.

The document also reviews some of the limitations of drip irrigation.

Drip irrigation qualities referred to in this document apply to drip irrigation systems manufactured in accordance with ISO 9261.

This document is designated for agricultural policymakers, infrastructure authorities, water authorities and food cooperatives interested in developing agricultural policies to preserve natural resources and funds. This document is also designed for farmers and small holders interested in applying an economic agricultural method .

2 Normative references

ISO 9261: 2004, Agricultural irrigation equipment – Emitters and emitting pipe – Specification and test methods

ISO 16075 Part 1 (FDIS) Guidelines for Treated Wastewater Use for Irrigation Projects – Part 1: The Basis of a Reuse Project for Irrigation

ISO 16075 Part 2 (FDIS) Guidelines for Treated Wastewater Use for Irrigation Projects – Part 2: Development of the Project

ISO 16075 Part 3 (FDIS) Guidelines for Treated Wastewater Reuse for Irrigation – Part 3: Components of a Reuse Project for Irrigation

ISO 16075 Part 4 (CD) Guidelines for Treated Wastewater Reuse for Irrigation – Part 4: Monitoring

ISO AWI 20419 Irrigation Equipment Adaptation to Treated Wastewater – Guidelines

EN 15099-1: 2007 Irrigation Techniques – Relmote Monitoring and Control for Irrigation Systems – Part 1: General Considerations

3 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

3.1
chemigation
injection of agrochemicals such as pesticides or herbicides to the irrigation system together with irrigated water

3.2
fertigation
injection of soluble fertilizers to the irrigation system together with irrigated water

3.3
irrigation efficiency
application efficiency
fraction of water volume applied to a farm or a field consumed by crop, in relation to the volume of water applied; Effective Use of Water (EUW)

3.4
transpiration
water evaporating through the plant

4 Global environmental changes

4.1 Water scarcity

Climate changes on a global scale in the past years cause extreme conditions such as strong storms with heavy precipitations on one hand, and long and dry periods of elevated temperatures on the other. One major consequence of these global climate changes is the constant reduction of fresh water availability worldwide. Water scarcity already affects every continent around the world. Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical scarcity, and 500 million people are approaching this situation. Another 1.6 billion people, or almost one quarter of the world's population, face economic water shortage (where countries lack the necessary infrastructure to take water from rivers and aquifers). Water scarcity is among the main problems to be faced by many societies and the world in the current century. Water use has been growing at more than twice the rate of population increase in the last century, and although there is no global water scarcity as such, an increasing number of regions are chronically short of water.

Water scarcity is both a natural and a human-made phenomenon. There is enough freshwater on the planet for seven billion people but it is distributed unevenly and too much of it is wasted, polluted and unsustainably managed. Figure 1 shows the available water worldwide whereby some countries have enough water to support proper life while others suffer from severe water scarcity.

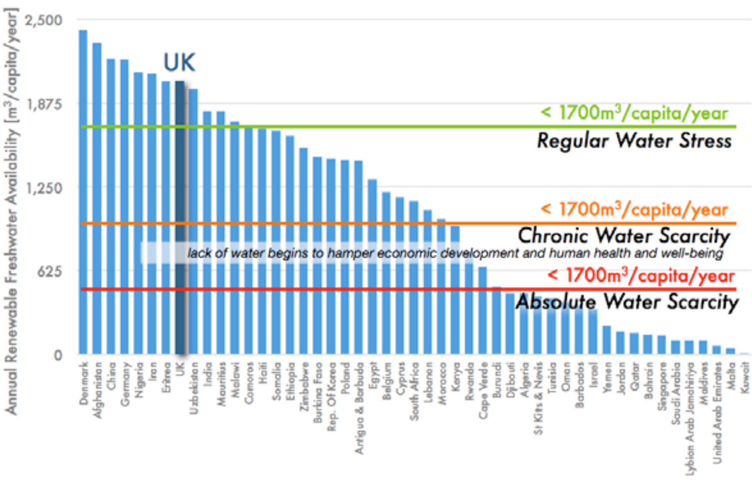


Figure 1: water availability at selected countries world wide

As illustrated in Figure 2, most available water is being consumed by agriculture. For this reason, major acts to save water should be performed in this sector. A more efficient irrigation system can have a positive effect on global water availability.

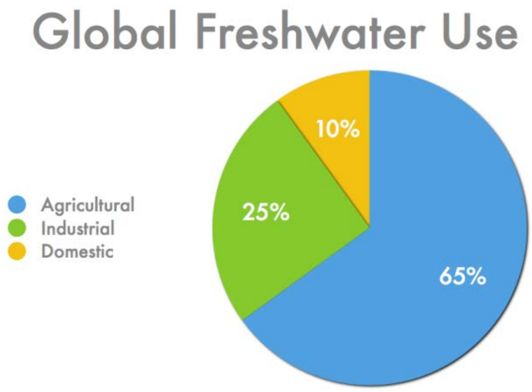


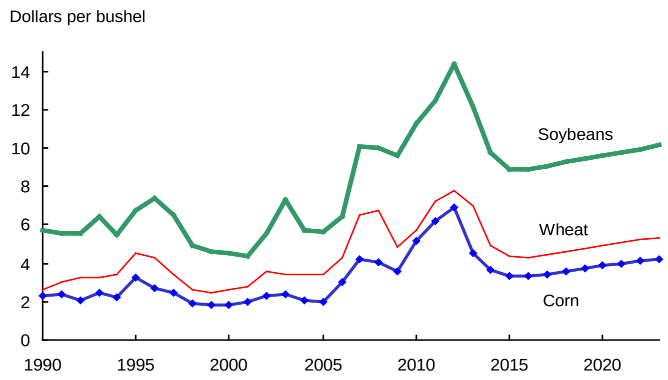
Figure 2: global water consumption by sector

4.2 Food scarcity and prices

By the middle of the 21st century, as the world's population grows to around 9 billion, global demand for food, feed and fiber will nearly double, while increasingly, crops may also be used for bioenergy and other industrial purposes. New and traditional demand for agricultural produce will thus put growing pressure on already scarce agricultural resources. And while agriculture will be forced to compete for land and water with sprawling urban settlements, it will also be required to serve on other major fronts: adapting and contributing to the mitigation of climate changes, helping to preserve natural habitats, protecting endangered species and maintaining a high level of biodiversity. Furthermore, in most regions fewer people will be living in rural areas and even fewer will be farmers. They will need new technologies to grow more from less land, with fewer hands.

The productivity of rice is projected to dip by 17% and the productivity of maize is projected to drop by 6% by the middle of the 21st century. An International Food Policy Research Institute report has stated that food prices will rise even without climate change, but that the global warming will make the problem worse. "Prices are useful single indicator of the effect of climate change on agriculture", the report said.

Wheat prices are projected to grow by almost 40% without climate change, but with climate change, the rise could be as steep as 194%, according to the IFPRI report. Rice prices are projected to rise by 60% without climate change and up to 121% with climate change. Maize prices are expected to surge 60% without climate change but up to 153% with climate change. Figure 3 shows projected prices of some commodity crops in the US.



(adopted from the USDA website)

Figure 3: U.S. farm level prices of corn, wheat and soybean.

4.3 Land degradation

Land degradation is a combination of several processes such as soil erosion, soil salinity, chemical contamination, desertification nutrient depletion and water scarcity.

Land degradation has been occurring for a long time, and continues to affect soil worldwide, in areas more sensitive and vulnerable, such as Tropical and South Africa, Southeast Asia, south China, North-central Australia, Central America, Southeast Brazil, Alaska, Canada and Eastern Siberia. Some of the causes of land degradation are natural processes: man-made or natural processes with humanity as accelerator. Due to recent climate changes, the world has experienced longer drought periods and stronger rain and storm events. These cause gradual reduction in natural vegetation that helps stabilize soil during water runoff, but with the absence of vegetation and stronger water runoff, soil is subjected to erosion forces by water and wind. Afforestation, toxic chemical soil contamination and soil salinity are an example of man-made causes for soil degradation that reduces available cropland for food production. So far 18% of the degraded land is cropland, 25% is central forests and 17% are north forests.

5 Irrigation

5.1 General

Fresh water and fresh healthy food are the basic human resources that should be provided everywhere, at all time, for everyone. In the world today, wide dry regions suffer from water shortage, while others suffer from food scarcity and some suffer from both. Food and water scarcity is becoming one of the main concerns for developed and developing countries, global organizations and many individuals worldwide experiencing droughts and hunger.

Agriculture is the clear relation between the two main areas of concern - water supply and food supply. Food production requires crops, crops production requires water, more water is related to more crop production. Water supply-crop production relation is not one-dimensional. A given crop production can be achieved by less irrigated water: for the same water applied, higher yield can be achieved (i.e. water use efficiency). Increased water use efficiency can be achieved by simple, efficient irrigation practices.

In all irrigation methods, water applied in the field is not being 100% transferred into plant biomass. Some of it spreads in the soil by deep percolation or runoff. Some of it evaporates from the soil surface or the wetted leaves and the remaining water captured in the root zone is used by the plant for biomass production - this is effective water (see Figure 4). The rate of transpiration is related to the plant canopy cover and air evaporation conditions. When less water is lost as runoff, deep percolation and evaporation, the relative portion of effective water is increased and higher effective use of water is achieved.

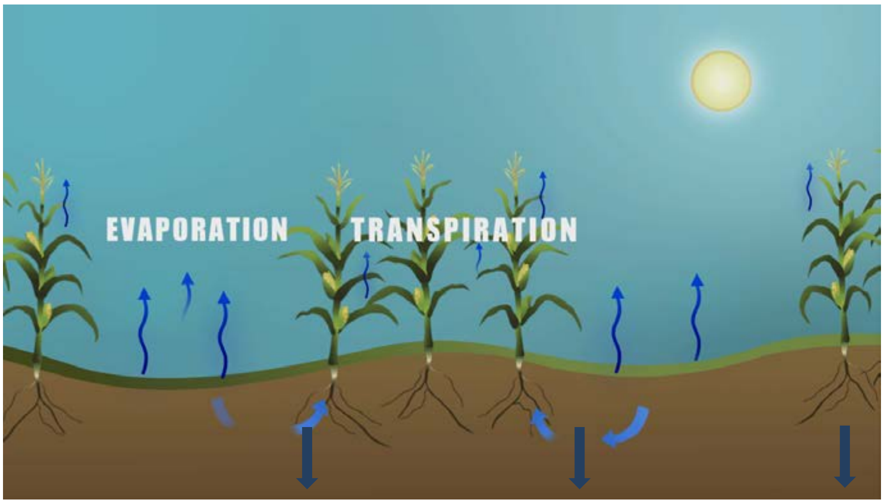


Figure 4: Water evaporation and transpiration in the field.

5.2 Common irrigation methods

Rain fed agriculture covers 80% of the world's cultivated land, and accounts for about 60% of crop production. Today, irrigated agriculture covers 275 million hectares – about 20% of cultivated land – and accounts for 40% of global food production. This shows the relative importance of irrigation in worldwide global food balance. Irrigation methods available today are surface irrigation, sprinkler irrigation (which includes irrigation machines) and center pivots and micro irrigation methods such as drip irrigation.

Crop irrigation goes thousands of years back in history. Ancient Egyptians flooded their fields from the Nile, and the Persians built a network of tunnels for irrigation water delivered to the field by gravity. Gravity flood irrigation is being used to date and it is the most used irrigation method in developed and developing countries. The major improvement in this method was the invention of pumps that could deliver water farther and higher than water source. A lot of research was invested in surface (flood or furrow) irrigation since the beginning of the industrial revolution and development of agro science in the purpose of improving efficient use of water (EUW). Formulas to calculate irrigation periods, field slopes and furrow structure were developed to design and plan furrow irrigated fields. Surface irrigation has the advantage of simplicity, visibility (the farmer can see the water along the field), surface irrigation is easy to control and excluding pumping costs, it can be a low cost irrigation system.

The next step in agriculture irrigation was the development of sprinklers and similar products such as rain guns and pivots. In these methods, water delivered is used in buried or surface pipes with high pressure and high flow rate. Sprinkler irrigation can be easily installed in the field, used and then relocated at the next filed. Sprinkler irrigation has a uniform water distribution on the soil surface, which can be an advantage to some crops but also irrigate bare soil without any plants (in row crops) which reduces EUW.

Drip irrigation was invented in the mid 1960s by an Israeli developer of a method delivering a small amount of water directly to where it is needed, i.e. the root zone. In drip the irrigation, only a small portion of the soil which is needed for plant water supply is wetted, while the rest of the soil remains dry. Major progress was made in drip irrigation products and knowhow, including better raw materials and other solutions for all crop types. Throughout the years, a trend of emitter discharge rate reduction in drip irrigation systems is evident. If the first emitters had a flow rate of 8 l/h or more, nowadays, flow rates of less than 1 l/h are reached by manufacturers applying the mechanical and functional requirements for agricultural irrigation emitters, specified in ISO 9261, with low probability of emitter clogging. The advantage of flow rate reduction is the reduction of energy needed for system operation, which means a larger area can be irrigated simultaneously.

6 Advantages of drip irrigation

6.1 Crop production

Drip irrigation used at an optimal scheduling in a given field can increase yield by tens to hundreds percents in comparison to other irrigation methods. Reports show increased yield of sugarcane in India by 133% with half of the water used in drip irrigation in comparison to flooded plots, and an increase of 16% in potatoes yield in China with reduction of third of the water in comparison to sprinkler irrigation – due to water management supplying the exact quantity of water at the right timing and in the right place.

Drip irrigation allows not only water delivery into the roots, but fertilizers and other supportive nutrients (see 6.5). High yields require application of a correct amount of water and nutrients to the plant at the right time and in the right place, in accordance with the plant’s needs. In surface irrigation, water quantity applied by each irrigation event is high and the time between two applications may be long (days to weeks).

In surface irrigation, the plant can be subjected to oxygen stress for a few hours at the beginning of the irrigation due to soil flooding, and on the other hand, it could suffer from water stress just before the next irrigation due to large time intervals between irrigations and available water depletion.

In sprinkler irrigation methods, yield can also be relatively high, as water can be applied in much shorter intervals, depending on the farmer's ability to reinstall sprinklers in the field or the center pivot. In sprinkler irrigation methods, time intervals are a matter of days, which allows for an effective irrigation scheduling.

Drip irrigation scheduling allows for short intervals between irrigation events, i.e. irrigation can be applied once every few minutes, several times a day, once a day or every few days. The ability to irrigate in short intervals allows keeping relatively constant water content at the root zone, and preventing over irrigation or water stress for the plant. In drip irrigation, farmers can apply the right amount of water at the right timing according to the plant's needs and immediately react to sudden extreme conditions such as heat that requires additional water.

6.2 Water distribution in the field and irrigation efficiency

One of the factors affecting yield uniformity is water distribution across the field. Field parts receiving less water than other parts have respectively lower yield potential.

In surface irrigation, controlling and adjusting water distribution in the field are not trivial and depend on the field's slope and furrows maintenance. Figure 5 illustrates water supplied on one end of the field, flowing on the soil surface towards the other end of the field, while some of it penetrates the soil, available for plant consumption. Because water is applied from a single point, the soil close to the water source becomes wetter than the soil at the end of the row and a large quantity of the water percolates to deep soil layers and ground water. Surface coverage of water by surface irrigation varies according to irrigation method (e.g. surface, border of furrow). In some of the methods there is full coverage of the soil surface with water in crops that are not grown on ridges while in furrow irrigation the channels are filled with water while the ridge stays relatively dry, see Table 1. In both cases, large portion of soil without plants is being irrigated. In addition to waste of water there is also higher water loss to evaporation and boosting of weeds.

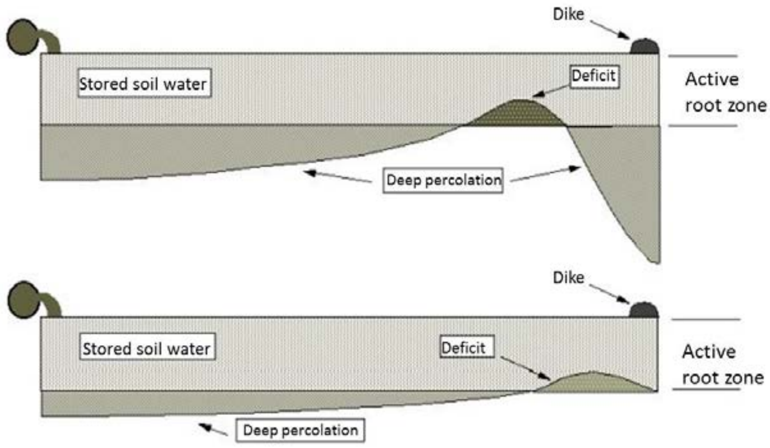


Figure 5: surface irrigation water distribution scheme

Source: University of Nebraska–Lincoln · Lincoln extension

Table 1: irrigation method's efficiency

Irrigation system	Application efficiency (%)
Center pivot	75-85
Solis set	70-85
Furrow	45-65
Basin	60-75
Precision level basin	65-80
Surface drip	85-95
Subsurface drip	>95

Source: University of Nebraska–Lincoln · Lincoln extension

Surface irrigation method relies on gravity flow of water on the soil in accordance with the slope. Surface irrigation methods can only be applied in flat areas that were adequately levelled. This irrigation method is suited for most crops but it is restricted to flat areas such as plains and valleys. In more sloped and steep areas, this irrigation method will not be feasible without major engineering intervention.

Sprinkler irrigation enables a more uniform water distribution across the field in comparison to surface irrigation, with the exception of windy conditions. Wind can dramatically affect water distribution around the sprinkler and strong wind conditions may result in more uneven water distribution across the field. Farmers are then required to operate irrigation only on proper weather conditions that can change from day to day. Due to the full coverage of soil by water there is also boosting of weed growth and water evaporation from the soil. Sprinkler irrigation can be applied in sloped areas such as hills and valleys, as water is applied by pressure. Due to slope, massive water runoff of water can occur during irrigation, as infiltration rate of water is lower than water application rate, which results in free water on the soil surface, subjected to gravity.

Drip irrigation is characterized by uniform water distribution across the field. Basic type of emitters are not pressure compensating and are limited to shorter runs and moderate slopes. Advanced emitter types are pressure compensated, which does not affect flow rate in wide pressure range. This enables longer laterals runs of up to 400 meters without losing flow rate uniformity. One of the major advantages of pressure compensating drip irrigation systems is that it can be used in sloped fields where surface irrigation cannot be applied. Discharge rates of modern emitters are very low (down to 0.4 l/h) which is lower than most of the infiltration rates of most heavy soils and thus runoff is prevented.

Drip irrigation is limited to the close area around the dripper (40-80 cm width wetted area along the laterals) so that no unnecessary soil is irrigated. The result is less weed emergence and less water evaporation.

6.3 Water evaporation from soil surface

Water evaporation from free water table to the atmosphere is larger than water evaporation from bare soil, as soil has capillary forces resistant to water evaporation. The result is that more water is being lost by evaporation from surface irrigation in comparison to drip irrigation, see Table 2. Although drip irrigation intervals are shorter than furrow irrigation intervals, the absence of free water on the soil surface reduces total water evaporation. Furthermore, the total area that is being wetted in furrow irrigation is much larger than drip irrigation, which results in larger evaporation area. Moreover, water content after a furrow irrigation event is much higher than in drip irrigation and the evaporation rate is higher accordingly. For further reduction of water evaporation, subsoil drip irrigation can be applied to keep the top soil dry and prevent water evaporation.

Sprinkler irrigation, similarly to surface irrigation, is subjected to high water evaporation due to full area irrigation. Furthermore, in sprinkler irrigation much of the water emitted from the sprinkler lands on the plant canopy instead of reaching the soil, evaporates from the plant and may also cause salt burning on the leafs in irrigation with poor water quality.

Table 2: irrigation efficiencies of different irrigation methods:

Irrigation Efficiencies	Methods of Irrigation		
	Surface	Sprinkler	Drip
Conveyance efficiency	40-50 (canal) 60-70 (well)	100	100
Application efficiency	60-70	70-80	90
Surface water moisture evaporation	30-40	30-40	20-25
Overall efficiency	30-35	50-60	80-90

Source: Sivanappan (1998).

6.4 Dry harvest

Typically, prior to harvest, irrigation is stopped. During the period of time between last irrigation and harvest, soil may be dried and run over with harvest machines and tractors. In continuous harvests e.g. alfalfa, irrigation is continued until harvest, and resumed immediately afterwards.

When surface irrigation is practiced, the soil is not sufficiently dried and 'wet harvest' has to be conducted under mud conditions, which causes operational trouble as well as damages field leveling and furrow shapes are needed for surface irrigation.

In furrow irrigation, a long period of time might be required after the entire field has been harvested - if no damage has been made to furrows and field slop.

In drip irrigation, irrigation can be applied one day prior to the harvest and even during harvest, and the first irrigation following the harvest can be instantly applied. Drip irrigation also allows in season cultivation, and other aeromechanical practices, e.g. spraying, which are hard to execute in furrow irrigation, due to mud.

6.5 Irrigation as a delivery system

The main role of irrigation system is delivering water to the soil and from there to the plant. In addition to water, plants need adequate amount of fertilizers, e.g. N, P, K and micro nutrients.

While all irrigation methods are designed mainly for water delivery to the soil, drip irrigation can also be used as a whole delivery system for wide range of substances, which can generally be referred to as chemigation (chemicals and irrigation).

Fertilizers can be applied in the field can be made by several platforms such as solid fertilizers spread on the soil surface or foliar fertilizer applied directly on the plants' leaves. These two methods require tractors operating in the field, and worker, and the soil needs to be dry for tractors traffic.

Another easy, cost and labor saving method is the application of fertilizers with the irrigation water (dissolved solid or liquid). When applying fertilizers along with the irrigation water in furrow irrigation, an increased amount of fertilizers needs to be added, because not all water applied on each irrigation end up being consumed by the plant: some of it evaporates, some of it is turned to runoff and some of it percolates to deep soil layers and ground water. Considering the fact that irrigation water contains some fertilizer concentration, an environmental risk is caused due to ground and surface water contamination. Moreover, in surface irrigation, distribution of water across the field can be uneven, and if fertilizer application is conducted using water soluble fertilizers, the result would be unevenly distributed fertilizers which may cause spatial variability and loss of yield.

In drip irrigation, the irrigation system can be used as a delivery system. Fertilizers applied through the drip system end up right in the root zone, where it is needed, with minimal losses to deep soil layers. Fertilizers are injected into the irrigation system automatically by a pump located adjacently to the main valve, and the field is fertilized and irrigated at the same time, which saves both time and money, increases fertilizers uptake efficiency and reduces fertilizers losses to the environment.

Not only fertilizers are applied directly to the root zone by drip irrigation systems, essential materials such as mycoriza for plant symbiosis and herbicides and pesticides are applied too, without any impact to the environment, as all chemicals are delivered exactly where they are needed, at the root zone.

6.6 Water infiltration, water budget and the environment

Crop irrigation is a part of the global water cycle. Irrigation water comes from pumped ground water or surface water from rivers, lakes or reservoirs.

Sustainable agriculture is crucial for the future of our ecosystem and for the preservation of our water sources in terms of quantity and quality. Degradation of water bodies, surface and subsurface, occurs when water withdrawal exceeds its refilling rate, or when water quality drops to levels that prevent re-use. Surface irrigation and sprinkler irrigation require large quantities of water, more than plants' requirements, and the result is that large quantities of water need to be pumped from a source, reducing its water budget.

In furrow irrigation, some of the irrigated water is being used by the plant while the rest goes to ground water, surface runoff, back to the stream, or evaporates. The implication is that the amount of water applied exceeds the required amount to adequately supply the plant’s needs. The first direct impact is high pumping costs and high water costs, unless water is free or delivered for a low rate. In drip irrigation, the amount of water delivered to the field is lower, less pumped water and thus smaller pumps are required: the result is energy and water saving.

Two scales should be considered when comparing water balance in surface irrigation and drip irrigation: basin scale and farm scale.

Water balance at basin scale in surface irrigation is supposedly even, as infiltrating water can be later pumped, and runoff returned to the stream, where a following farm can capture and use it. Still, water quality degradation resulting from use should be considered: while the first farm upstream receives fresh water, the last farm receives water pesticides/herbicides and other fertilizers that were inserted to the water in farms up the stream, along with elevated salinity. This refers to surface water as well as ground water.

In surface irrigation at farm scale, as farmers apply more water than needed by the plant, high water and energy costs are required, due to water percolation and runoff.

In both basin scale and farm scale high evaporation rate causes considerable water losses to the atmosphere in comparison to other irrigation methods.

In drip irrigation, most of the water applied to the field is used by the plant for evaporation and biomass production. Using the same amount of water, larger areas can be irrigated in drip irrigation in comparison to other methods.

Sustainable agriculture also relates to the reduction of human activity footprint in the environment. Chemicals are applied daily in the field for different uses, such as pesticides, weed control and fertilizers, with the purpose of supporting plant development. Some of these chemicals can exceed their target area of impact and reach the environment — soil, ground water and surface water. The main vector transporting those chemical into the environment is water. Wherever water flows it carries many types of dissolved materials, such as salts and chemicals that in surface irrigation or sprinkler irrigation can be rapidly leached to the ground water and contaminate it, as well as water used by other consumers downstream.

Because in drip irrigation less water is required in comparison to other irrigation methods, and as water is applied directly where it is needed -- at root zone – quantities of chemicals used and applied are drastically lower. Furthermore, in drip irrigation, there is almost no deep drainage of water from the root zone (with the exception of intent leaching of salts) so that chemicals do not exceed the root zone and environment contamination is avoided. The use of fewer chemicals in drip irrigation practice allows to reduce chemicals manufacturing, reduce environmental damage and costs to farmer.

6.7 Soil and water salinity

When water evaporates from the soil surface, contained salt accumulates on the surface and may later be dissolved back into the water, reach the root zone and cause salinity stress to the plant. In every irrigation method, salt gets accumulated on the soil surface, but the amount and location of salt in relation to the plant varies.

In sprinkler irrigation, 100% of the surface is wetted. The wetting front moves as a piston carrying salts away from the root zone. A sufficient amount of water should be applied to ensure the removal of salts down in the soil profile.

Furrow irrigation is usually considered a good method to prevent salt accumulation, due to large, deep percolation that can wash salts away from the root zone. However, furrow irrigation can promote salt accumulation on the furrows' edges and ridge between two furrows, see Figure 8. Furthermore, salt can accumulate on the edges of the wetting front in the soil profile, right over the root zone. Hence, the flushing of salts in furrow irrigation occurs only beneath the furrow and not in the entire soil profile.

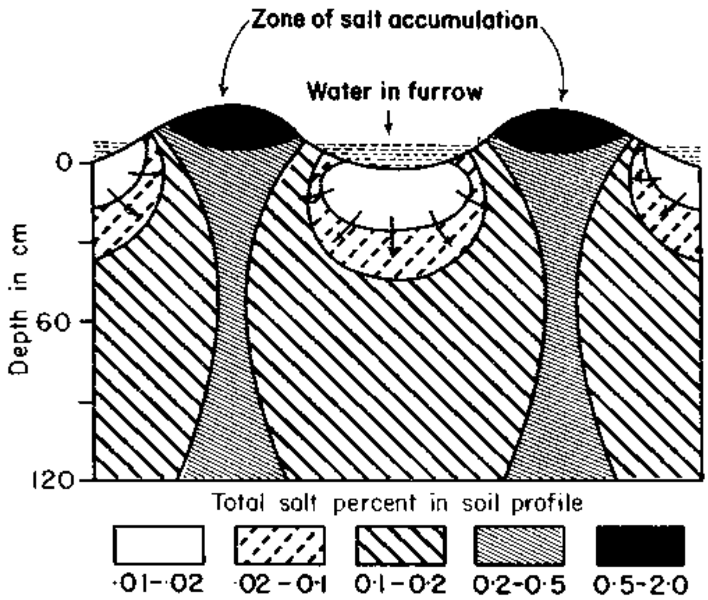


Figure 6: Salt accumulation in soil profile in furrow irrigated field (adopted from the FAO website).

In drip irrigation too, salt accumulates on the edges of the wetted 'bulb' under the dripper. Still, the roots are kept inside the borders of the wet area and away from the salty soil. Furthermore, drip irrigations' high frequency keeps the soil relatively moister, and thus salt levels are relatively lower, whereas the low frequent irrigations in the furrow method cause higher salinity levels in the soil as presented in Figure 7.

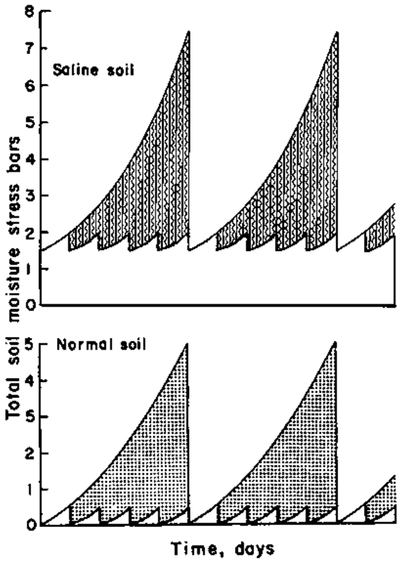


Figure 7: Salinity levels as a consequence of irrigation intervals timing in normal and saline soil (adopted from the FAO website)

Salt accumulation in the soil occurs with relatively low salinity water sources, but where there is shortage in available fresh water to support the population and agriculture needs, saline water, at salinity levels of up to 4 dS/m, is used for irrigation. Moreover, degradation in soil fertility and the shortage of new available cropping area leads to the usage of marginal soils that are relatively saline. In saline water or saline soils, salinity effect on crops is reduced by keeping high moisture level in the soil as constantly as possible.

With furrow irrigation, keeping high moisture levels can be done only if irrigation is applied every day, which could mean high water and energy investment that is often not available.

With drip irrigation, daily application is common practice, and in some locations, irrigation is repeated several times per day, in light of coarse soils and dry areas. Furthermore, low flow rate of down to 0.7 l/h emitters can be used, so that a daily irrigation event can keep a soil constantly wet for several hours. Therefore, irrigation with drip systems can reduce the salinity effect by keeping high moisture level in the soil and can be used in saline soils or saline water irrigation.

6.8 Soil and land conservation

Soil erosion is part of land degradation occurring worldwide, see 4.6. Some of it is natural, caused by storms and heavy rain, but some of it is man made in cropland as illustrated in Figure 8.

Figure 8: soil erosion by water in a furrow irrigated corn field

Figure 8 is an illustration of soil erosion by water runoff in a furrow irrigated corn field. High energy of water flow collects soil particles that settle where the water energy is lower. Thus, over years of surface irrigation practice, considerable quantities of soil are translocated away from the fields. Together with the soil particles translocation, chemicals and fertilizers leave the field to the environment.

Soil erosion is less common in sprinkler irrigation although it may occur in excessively irrigated steep sloped fields. When using drip irrigation, soil erosion is prevented due to low emitting rate of drippers. Water emitted from the dripper infiltrates the soil and free water flow on the soil surface is prevented.

6.9 Energy saving

Surface irrigation is considered a low energy consumer that was practiced before any pump was invented. This method is applicable in near river fields where a river channel can be dug and directed toward a field, and dams can be opened and closed according to need, with no energy investment required.

Nowadays, fields are located far from water sources. In most cases, the water source is ground water that needs to be pumped out from the ground. The large amount of water required for surface irrigation causes large consumption of energy needed to lift large quantities of water from the ground to field level.

Sprinkler irrigation requires less water from surface irrigation and therefore consumes less energy. However, sprinklers and center pivots use high pressure in order to disperse the water far from the sprinkler. The desired high pressure requires the use of high energy consuming pumps which increases costs for farmers.

In drip irrigation, less water is used: for the irrigation of a given area, drip irrigation will need a smaller pump than other, more water consuming methods. Drip irrigation also requires low pressure for operation, thus smaller pumps can be used, see Table 3.

Drip irrigation low energy consumption allows it to be operated by solar power solely. Some drip manufactures offer a small family drip system (FDS): kits adapted for developing countries farmers for self-consumption crops. The FDS kit consists of a small solar panel and an electric pump capable of pumping water from a small creek of even a barrel and irrigating a 250 square meter field. Irrigation control is not required, as the pump is self-triggered by sunlight.

Table 3: Irrigation methods required pressure

irrigation method	typical pump pressure (bar)
Sprinklers	6-9
Center pivot (low pressure)	3-6
Center pivot (med. pressure)	5-8
Hose pulled traveler	3-14
Drip	0.3-3

6.10 Treated wastewater irrigation

Current water scarcity challenges policy makers to seek alternative water sources for domestic and agricultural uses. Increasing numbers of desalination plants are built worldwide to mitigate fresh water demand for domestic uses, which is enabled by improved technology and reduced costs. For irrigation, desalinated water is too expensive, and thus alternatives must be considered.

One alternative that has been long used in many countries is agriculture and domestic use of treated wastewater for irrigation. About half the water consumed by domestic consumers is flushed away as wastewater. Wastewater contains substantial content of organic matter, salts and nutrients. Following a proper treatment to remove most of the organic matter, salts and nutrients, treated wastewater can then be used for agriculture irrigation.

Some of the advantages of treated wastewater irrigation are:

- treated wastewater is a reliable source of water all year round;

- treated wastewater contains some nutrients such as N and P needed for plants;
- sludge produced in wastewater treatment process can be used as organic matter additive for soil application.

However, treated wastewater contains additional salts that can accumulate in the soil or leach to ground water. In such case, drip irrigation can be practiced under salinity conditions and salty water irrigation in order to avoid yield losses, see 6.7.

Moreover, due to wastewater's domestic source, it may contain some pathogens that may pose a risk to population exposed to the water or to population consuming crops that were irrigated with treated wastewater.

Designed barriers to remove risks and prevent direct contact between wastewater and edible crop are specified in ISO 16075 Part 2.

As drip irrigation is sensitive to clogging, particularly when low quality treated wastewater is used, proper manufacturing, installation, maintenance, adjusted filtering systems and occasional flushing – as specified in ISO Draft Standard Irrigation Equipment Adaptation to Treated Wastewater - Guidelines should substantially extend the durability of drip irrigation systems.

6.11 Labor saving

In agriculture, labor is one of the largest resources invested annualy, regardless of yield or expected profit. Labor is also the only resource that can be minimized without reducing yield by decreasing the number of irrigation workers with use of automation.

While surface irrigation and sprinkler irrigation need constant labor to operate dams and irrigation sets, drip irrigation can be operated with just one person, by remote access, see EN 15099 Part 1.

The operation of a drip irrigated field is scalable: one person can manage several field operations simultaneously. See Table 2 for comparison with other irrigation methods.

7 Drip irrigation limitations

Although drip irrigation is adjusted for various types of crops, soils and climates, it does have few limitations:

- Although investment in drip equipment is quickly returned, and although governments worldwide subsidize installations, its cost is relatively high;
- Although a set drip irrigation system only needs one person for operation, which is labor saving, the first installation of drip irrigation could take a few weeks and requires knowledge and planning;

- Drip irrigation is subjected to emitter clogging mainly in low flow rate emitters, if not protected by proper filtration systems adjusted to any type of water, as specified in ISO 16075 Parts 1-4.

Annex A

Role of governments: National investment as a driver of growth

Government investment can determine whether or not agriculture can create a sustainable livelihood in low-income communities. An agricultural support system implementation can generate positive impacts: for poor farmers whose ability to compete is hindered by lack of advanced drip irrigation equipment and infrastructure, an investment can be the determining factor that leads to poverty alleviation and growing incomes. Government in these economies should support policies that make agriculture in general and drip irrigation in particular a vehicle for poverty alleviation, while protecting environmental resources on which low-income farmers depend. These agencies should focus on specific, targeted goals to achieve an effective subsidy model.

As most effective agricultural advances are led by technology and supported by strong government policy, working in conjunction with the private sector and NGO's, governments have the ability to make meaningful investments that will serve their countries for many years to come.

Governments and policy makers should take the initiative to strengthen agricultural innovation, and cooperate with private funds, banks and industry. The relationship between government and private participants is important to ensure success, in purpose of benefiting local populations, strengthening rural communities and securing future food resources.

A successful drip irrigation project can generate primary benefits for communities, public institutions, as well as governments, and secondary benefits to private industries. The primary objectives are focused on local outcomes, with secondary objectives addressing wider project benefits.

The following steps can be followed:

- create a task force to explore opportunities;
- establish an investment policy;
- initiate cooperation with financial institutions;
- implement transparent project development.

Infrastructure is one of the key challenges facing governments throughout the world, with certain regions in urgent need of investment. However, the benefits of infrastructure investments should be considered. Improved infrastructure creates new growth opportunity throughout a variety of sectors in the economy. New infrastructure drives the growth of agriculture, manufacturing and service sectors. It also reduces barriers to intraregional trade. For most countries, this is a critical component in the transition to higher value production. Without such investment, an increase in productivity and economic diversification will be diminished and may lead to a deceleration in growth rates.

The following conditions should be followed by the public-private partnership to ensure maximum outcomes. For the program to be successful, efforts should be made to raise awareness to the benefits of the project. Stakeholders should fully understand the benefits before providing necessary support to achieve stated goals. Technology should not be deployed in a manner that will adversely affect farmers' interests.

A subsidy model requires the support of focused group of advocates. In order to successfully initiate the subsidy model, it is necessary to have several advocates that will lead the project and promote the benefits of implementation. Advocates should include:

- Government leaders and ministry officials;
- Influential community members;
- Third-parties such as non-government organizations;
- International institutions;
- Private Industry and Bankers.

Farmers are primary stakeholders in such a project. Educating farmers about the benefits of drip irrigation is required. Farmers should also be important community advocates for government investment. They will need initial support from the educational campaign in order to truly understand the potential benefits of the new technology. Once the initial awareness campaign is completed, farmers should also be given agronomic training in order to use the drip irrigation systems properly.

For a long-term viability of the project, all relevant government ministries should understand and support the efforts to modernize agriculture. Some of the key ministries may include: Ministry of Agriculture, Ministry of Finance, Ministry of Economy, Ministry of Environment & Natural Resources, Ministry of Education and all extension services.

Bibliography

[1] T.C. Peterson et al., "State of the Climate in 2008," Special Supplement to the Bulletin of the American Meteorological Society, v. 90, no. 8, August 2009, pp. S17-S18.

[2] I. Allison et al., The Copenhagen Diagnosis: Updating the World on the Latest Climate Science, UNSW Climate Change Research Center, Sydney, Australia, 2009, p. 11.

[3] IPCC Fifth Assessment Report, Summary for Policymakers, 2014.

[4] FAO website.

[5] A. Narayanamoorthy, Deemed University.

[6] University of Nebraska–Lincoln · Lincoln extension.

[7] USDA website.