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Understanding and applying drip irrigation for sustainable agriculture

Compréhension et application de l'irrigation goutte à goutte pour l'agriculture durable

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Foreword

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International Workshop Agreement IWA 20 was approved at a workshop hosted by the Swedish Standards Institute (SIS), in association with the Standards Institution of Israel (SII), held in Stockholm, Sweden, in August/September 2016.

Introduction

Dwindling vital natural resources, such as land and water, and rising world population pose a constant threat that could develop into a future food and water crisis. Given the limited availability of water and land resources, the amount of food grown today needs to be increased to meet the demands of tomorrow. Reduction of available water for human consumption needs be addressed. As direct consumption of fresh water by populations cannot be decreased, the amount of water consumed by agricultural uses needs to be reduced and allocated for domestic or industrial use.

Drip irrigation addresses water scarcity and other environmental considerations. Its use can save large amounts of water (over 50 % of water can be saved for certain crop types), and can increase yields.

Drip irrigation not only addresses the need to reduce water consumption and increase yield, but also requires less labour and energy for operation, leading to lower costs to farmers due to reduced usage of labour, fertilizers and other chemicals.

Drip irrigation relates to sustainability agriculture issues, and can be used in dry areas, in saline soil with saline water, and in steep-sloped topographies, 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 system's simplicity makes it easy to install, operate, maintain and repair.

Other than irrigation, the drip irrigation method is used as a delivery system for fertilizers and other agrochemicals. Drip's advantage as a delivery system is its ability to optimize fertilizer usage, and distribute it exactly where needed, in the root zone, while minimizing its release to the environment.

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

The purpose of this document is to review the benefits of the drip irrigation method in relation to other practiced irrigation methods, and to outline a future standardization roadmap.

Understanding and applying drip irrigation for sustainable agriculture

1 Scope

This document reviews drip irrigation in comparison to major irrigation methods available and practiced today by farmers worldwide. This document reviews the benefits of drip irrigation, such as increased yield, reduced water consumption, reduced energy consumption, lower environmental impact, reduced contamination of groundwater and surface water, reduced greenhouse gas emissions and reduced labour.

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

This document does not provide a technical specification for the implementation of drip irrigation.

The qualities of drip irrigation referred to in this document apply to systems manufactured in accordance with ISO 9261 or equivalent standard.

This document is intended to be used by agricultural policymakers, infrastructure providers, water supply regulatory bodies and authorities, and food chain and farmer cooperatives interested in developing agricultural policies to preserve natural resources and funds. This document is also intended to be used by farmers and smallholders interested in applying an economic agricultural method.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
application efficiency
ratio between the amount of water consumed by the plant and the amount of water applied in the field

Note 1 to entry: Application efficiency units are normally presented as the percentage of water consumed by the plant in relation to the amount of water applied.

3.2
chemigation
injection of agrochemicals, such as pesticides, herbicides or other growth-enhancement products, to the irrigation system, together with irrigated water

3.3
drip irrigation
irrigation method whereby drippers are installed along a polyethylene (PE) pipe of between 10 cm and 1 m, from which water is released at a given capacity (e.g. 1 l/h)

3.4
evaporation
type of vaporization of a liquid that occurs at its surface and goes into a gaseous phase that is not saturated with the evaporating substance

3.5
evapotranspiration
combination of the water transpirated through the plant and the water evaporated through the soil surface

3.6
fertigation
injection of soluble fertilizers into the irrigation system together with water

3.7
irrigation efficiency
amount of productivity (yield) in relation to the amount of water applied

Note 1 to entry: Irrigation efficiency units are normally presented as the weight of yield per volume of water applied.

3.8
sprinkler irrigation
method of applying irrigation water that is similar to natural rainfall

Note 1 to entry: In sprinkler irrigation, water is distributed through a system of pipes, usually by pumping, and then sprayed into the air through sprinklers so that it breaks up into small water drops that fall to the ground.

Note 2 to entry: Sprinkler irrigation is also referred to as overhead irrigation.

3.9
surface irrigation
group of application techniques, such as flood irrigation and furrow irrigation, in which water is applied and distributed over the soil surface by gravity

Note 1 to entry: Surface irrigation is the most common form of irrigation throughout the world. It has been practiced in many areas, and has remained virtually unchanged for thousands of years.

3.10
transpiration
process of water movement through a plant and its *evaporation* (3.4) from aerial parts such as leaves, stems and flowers

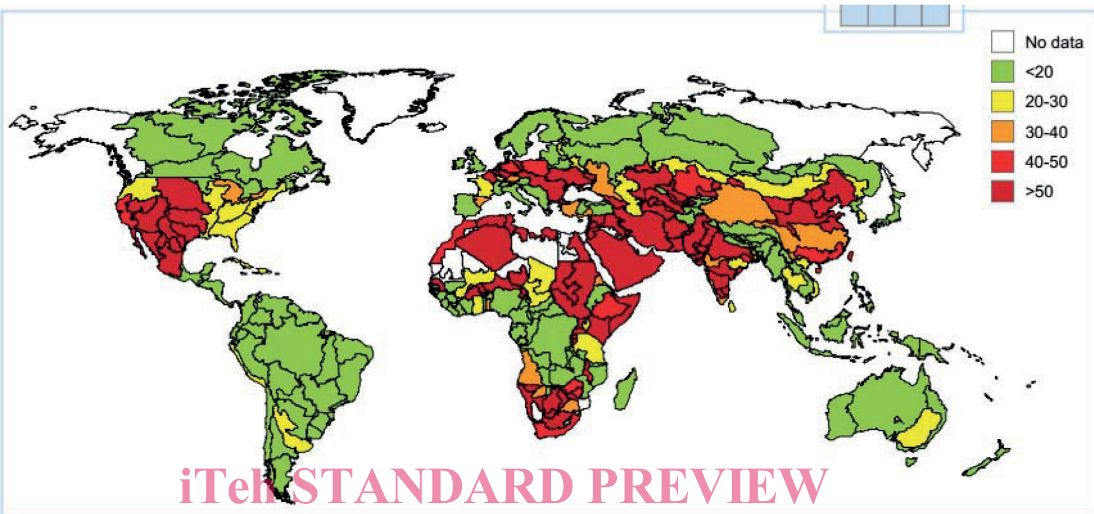
Note 1 to entry: In transpiration, water is necessary for plants, but only a small amount of water is taken up by the roots used for growth and metabolism.

4 Global environmental changes

4.1 Water scarcity

Climate changes on a global scale over the past years have led to extreme conditions such as strong storms with heavy precipitation on the one hand and long and dry periods of elevated temperatures on the other. One major consequence of these changes is the constant reduction of available fresh water worldwide. Water scarcity already affects every continent around the world. Approximately 1,2 billion people, almost one-fifth of the world's population, live in areas with physical water scarcity, and 500 million people are approaching this situation. Another 1,6 billion people, almost one quarter of the world's population, face economic water shortages (where countries lack the necessary infrastructure to take water from rivers and aquifers). Water scarcity is among the main problems that many societies and the world will be facing throughout this century. Water use has been growing at more than twice the rate of the population 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 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 or unsustainably managed. While 1,6 billion people are currently subjected to severe water scarcity, it is projected that that this figure will reach 2,4 billion by 2030. Figure 1 shows the projected water scarcity worldwide in 2030. According to this, most of Europe and Asia, as well as the US, will suffer severe water stress.

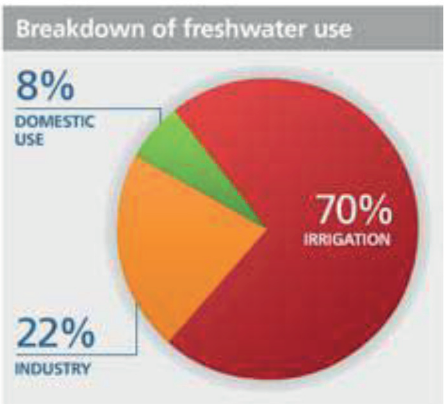


NOTE 1 The different colours stand for water stress, percent of total renewable water withdrawn.

NOTE 2 Source: IFPRI and VEOLIA water project[18].

Figure 1 — Projected water scarcity in 2030

As illustrated in Figure 2, most available water is consumed by agriculture. For this reason, the most significant moves to save water should be carried out in this sector. A more efficient irrigation system can have a positive impact on global water availability. In developing countries where there is water scarcity, such as in Africa, more than 80 % of the freshwater is used for agriculture to provide basic food for the population. An efficient use of water in agriculture can drastically increase freshwater availability for domestic use in these countries.



NOTE Source: UN water (2013)[14].

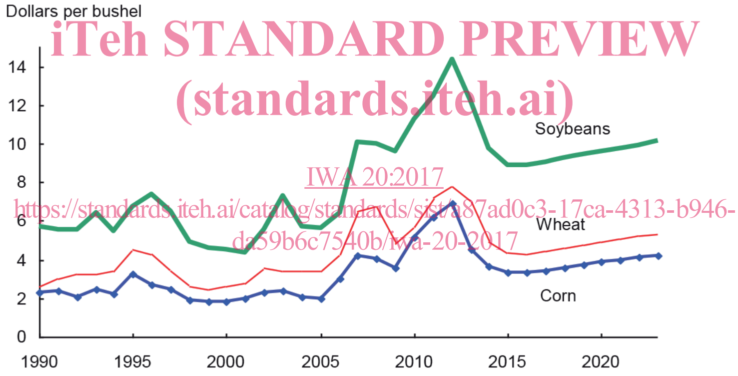
Figure 2 — Global water consumption by sector

4.2 Food scarcity and prices

By the middle of the 21st century, as the world's population reaches around 9 billion, global demand for food, feed and fibre will nearly double while crops may be increasingly used for bioenergy and other industrial purposes. New and traditional demand for agricultural produce will, as a result, put growing pressure on already scarce agricultural resources. While agriculture will be forced to compete for land and water with sprawling urban settlements and increasing industry demands, it will also need to serve across other major fronts: adapting and contributing to climate change mitigation, 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. As such, they will need new technologies to grow more on less land and with less manpower.

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. A report by the International Food Policy Research Institute (IFPRI) has stated that food prices will rise even without climate change, but that global warming will aggravate matters. It concludes that prices are a useful single indicator of the effect of climate change on agriculture.

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



NOTE Source: USDA website[13].

Figure 3 — US farm level prices of corn, wheat and soybean

4.3 Land degradation

Land degradation is the result of 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, particularly in sensitive and vulnerable areas 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 man-made or natural processes with human inputs as an accelerator. Due to recent climate changes, the world has experienced longer drought periods and stronger rain and storm events. These cause a 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, mining activities, and soil salinity are examples of man-made causes of soil degradation that reduce available cropland for food production. Currently, 18 % of the degraded land is cropland, 25 % central forests, and 17 % north forests.

A paper published by the Food and Agriculture Organization of the United Nations (FAO) in 2014[19] recommends several methods to achieve sustainable agriculture, while increasing food quality and quantity and reducing water consumption. One key element suggested is to use water more efficiently in order to grow more food with fewer resources.

5 Irrigation

5.1 General

Fresh water and fresh healthy food are basic human resources that should be provided everywhere, at all times, for everyone. In today's world, large dry regions suffer from water shortages, others suffer from food scarcity, and others suffer from both. Food and water scarcity are two of the main concerns for developed and developing countries and global organizations, as well as for many individuals experiencing drought and hunger.

Agriculture is the clear connection between water and food supply. Food production requires crops, crop production requires water, and water is related to increased crop production. The relationship between water supply and crop production, however, is not one-dimensional. A given crop production can be achieved through less irrigated water; that is, higher yields can be achieved with the same amount of water applied (i.e. water use efficiency). Increased water use efficiency can be achieved by simple, efficient irrigation practices.

For all irrigation methods, water applied in the field is not 100 % transferred into plant biomass. Some of it spreads into the soil by deep percolation or runoff. Some of it evaporates from the soil surface or wetted leaves, while the remaining water captured in the root zone ("effective water", as illustrated in Figure 4) is used by the plant for biomass production. 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.

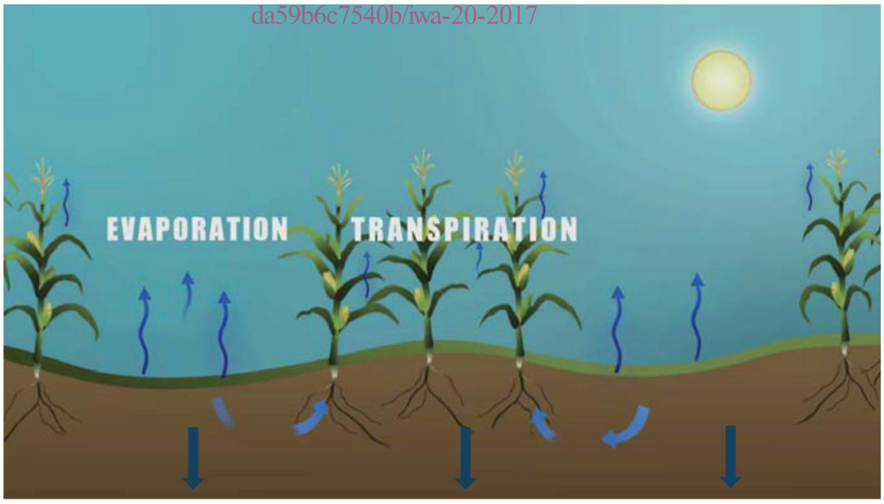


Figure 4 — Water evaporation and transpiration in the field

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 all cultivated land) and accounts for 40 % of global food production. This shows the relative importance of irrigation in the worldwide global food balance. Current irrigation methods are surface irrigation, sprinkler irrigation (which includes irrigation machines and centre pivots), and micro-irrigation methods such as drip irrigation.

Crop irrigation goes back thousands of years. 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 remains the most popular irrigation method in developed and developing countries today. The major improvement for this method was the invention of pumps that could deliver water further and higher than the water source. Much research was conducted in surface irrigation (i.e. flood irrigation, furrow irrigation) since the beginning of the industrial revolution and in agro science to improve efficient use of water. Formulae to calculate irrigation periods, field slopes and furrow structure were developed to design and plan furrow irrigated fields. Surface irrigation offers advantages of simplicity, visibility (i.e. the farmer can see water along the field), and easy control, and when excluding pumping costs, it can be a low-cost irrigation system.

The next step in irrigated farmlands was the development of sprinklers and similar products such as rain guns and pivots. In these methods, the water is delivered via buried or surface pipes at high pressure and high flow rates. Sprinkler irrigation can be easily installed, used and then relocated at the next field. Sprinkler irrigation not only maintains uniform water distribution on the soil surface, which can be advantageous for some crops, but also irrigates bare soil not containing plants (i.e. in row crops), which reduces efficient use of water.

Drip irrigation was invented in the mid-1960 by an Israeli water engineer who developed a method for delivering a small amount of water directly to where it is needed, i.e. the root zone. In drip irrigation, only a small portion of the soil that is needed for the plant's water supply is wetted while the rest of the soil remains dry. Major progress was made in drip irrigation products and know-how, including the introduction of better raw materials and new solutions for all crop types. The emitter discharge rate in drip irrigation systems has dropped over the years. While the first emitters had a flow rate of 8 l/h or more, today, agricultural irrigation emitters produced according to ISO 9261 specifications have flow rates of less than 1 l/h with a low probability of clogging. Flow rate reduction leads to less required energy for system operation, which means that a larger area can be irrigated simultaneously. The flow rate should be adjusted to the plant's needs, power availability, water availability, and other local conditions.

6 Advantages of drip irrigation

6.1 Crop production

Drip irrigation used at optimal scheduling in a given field can increase yields by tens to hundreds of percent compared to other irrigation methods. Reports show that drip irrigation has led to an increase in sugar cane yield of 133 % in India with a 50 % reduction in water usage compared to flooded plots. They also show an increase of 16 % in potato yield in China with a 33 % reduction in water usage compared to sprinkler irrigation. Results like these are due to improved water management by supplying the exact quantity of water at the right time and at the right place.

Drip irrigation enables not only water delivery to the plant's roots, but also fertilizer and other supportive nutrient delivery (see 6.5). To achieve high yields, the right amount of water and nutrients need to be applied to the plant at the right time and at the right place, according to 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 (i.e. days to weeks).

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

In sprinkler irrigation, yields can be relatively high, since water can be applied in much shorter intervals, depending on the farmer's ability to reinstall sprinklers in the field or the centre pivots. With sprinkler irrigation methods, time intervals are a matter of days, which enables effective irrigation scheduling.

Drip irrigation scheduling enables 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. Irrigating in short intervals enables maintaining relatively constant water content at the root zone, and preventing over-

