NEW HOLLAND AGRICULTURE

Irrigation

GUIDELINES

CROP HANDBOOK

Irrigation

CROP HANDBOOK

Conversion Factors

1mm water column (mm)	=	1l/m^2 = 10m^3/Ha
1 hectare (ha)	=	10,000 square meter (m^2)
1 cubic meter (m^3)	=	1000 liters (l)
1 atmosphere (atm)	=	10.33m water colum
1 atmosphere (atm)	=	1.013bar
1bar	=	10.197m water column
1bar	=	0.9869 atmosphere (atm)
1 kilopascal (kPa)	=	0.10197m head = 0.01bar
1 horse power (hp)	=	0.736kw
1 kilowat (kW)	=	1.36hp
mg.l-1	=	parts per million (ppm)
1meq.l-1	=	(mg.l-1)/equivalent weight
1mhos	=	1000mmhos/cm
1mmhos/cm at 25 ^{o}C	=	1000micromhos/cm
1Siemen/meter in SI units	=	10mmhos/cm
1mmho/cm at 25 ^{o}C	=	1deciSiemen/meter in SI units
1milliSiemen/cm	=	1mmhos/cm
1microSiemen/cm	=	1micromhos/cm

Foreword

Areas requiring irrigation are very extensive and encompass portions of every continent of the world. APAC and EMEA Regions are no exception. The arid belt is spread on over half of Africa, sizable portions of Central Asia as well as most of Australia.
Over 500 million of the earth's people live in these regions, many of them barely able to support existence with difficulty and effort, from the limited resources of land and water available to them. Under such conditions, even a slight improvement of the water use efficiency, may spell the difference between marginal subsistence and profitable production.
In recent years, revolutionary developments have taken place in the science and art of irrigation.
A more comprehensive understanding has evolved of interactive relationships governing the soil-water-plant regime as affected by climate and irrigation methods. These scientific developments have been paralleled by a series of technical innovations in the technology of water control, which have made it possible to establish and maintain nearly optimal soil moisture conditions practically continuously.

- This document is intended for presenting basic facts about irrigation practices on different crops.
- Basic irrigation parameters are treated.
- It is widely recognized that good water management at the farm level is of crucial importance to crop production in irrigated agriculture, to increase the effectiveness of fertilizers, plant protection measures and related inputs.

A SYSTEM BASED ON AGRONOMY

Irrigation is a costly operation.
You can control how much water is given by irrigation, and hopefully some rainfall will help: once the drop hits the soil surface, **you are now in charge!**

- Will it runoff?
- Will it cause erosion?
- Will it be absorbed?
- Will it soak down into the subsoil?
- Will it be available to the plants?

That depends on how you've prepared the soil.

To maximize the effectiveness of:

- Primary tillage
- Soil productivity
- Utilization of rainfall
- Utilization of irrigation water
- Fertilizer

All these factors impacts yield.

Tillage systems impact field capacity and ET.

Evapotranspiration (ET)

ET is the measurement of partial water losses in the soil. Water is lost basically through evaporation from soil and transpiration through vegetal tissues (leaves, roots, stalks and the such).
The sum of these losses is ET. Thus, ET is also a measurement of quantity of water needed by crops, and it depends basically on soil texture, crop and climatic conditions. ET is measured in millimeters (mm) or cube meters per hectare (mc/ha).

A direct assessment of ET for a given place is easily possible using **evaporimeters**. On this basis, ET_{crop} can be estimated using specific formulas.

E.g.:

ETM = E x 0.8 x Kc

ETM = Evapotranspiration maximum

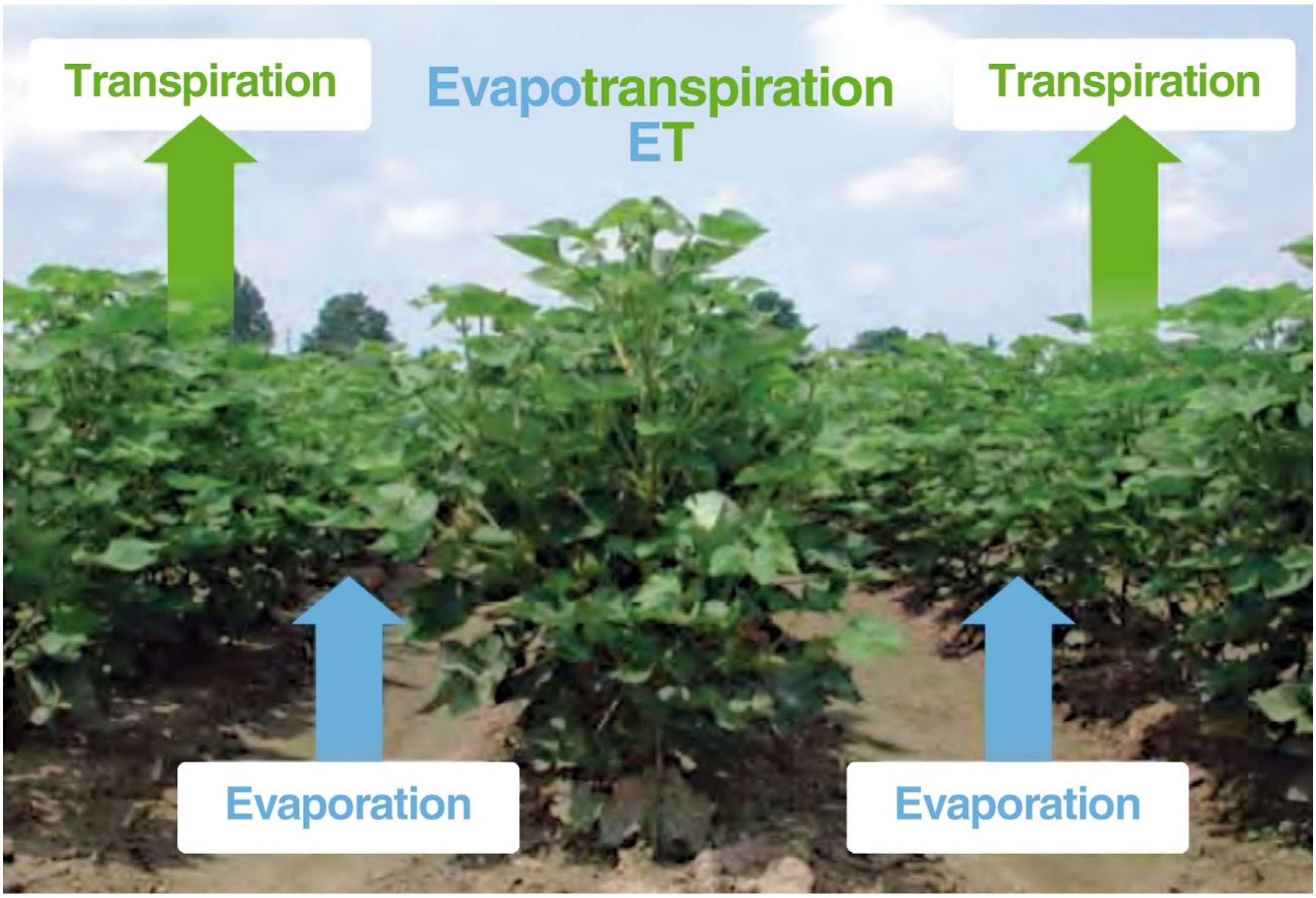
E = Measured transpiration with evaporimeters

0.8 = Fixed coefficient

Kc = Crop coefficient

Monthly and seasonal crop coefficients were developed from experimental determined ET_{crop}(s), which are related to different stages of crop development and different climatic conditions.

Evaporimeter class "A"



ET - WATER LOST FROM SOIL

USA OVERVIEW

	(mm) H_2O (ETM) PER DAY					
	April	**May**	**June**	**July**	**August**	**September**
North						
Cloudy	1.5	1.8	3	3	1.8	1.5
Partially cloudy	2.3	3	4.3	4.3	3	2.3
Sunny	3.3	4.5	5.5	5.5	4.5	3.3
Mid west						
Cloudy	2	2.8	3.5	3.5	2.8	2
Partially cloudy	2.8	3.5	4.3	4.3	3.5	2.8
Sunny	3.5	4.8	5.8	5.8	4.8	3.5
South						
Cloudy	2.3	3.3	3.5	3.5	3.3	2.3
Partially cloudy	3.3	4	4.3	4.3	4	3.3
Sunny	4	5.5	5.8	5.8	5.5	4

SOUTH RUSSIA OVERVIEW

	(mm) H_2O (ETM) PER DAY					
1991	**April**	**May**	**June**	**July**	**August**	**September**
Sunny		3.6	4.5	6	6	
Drought		2.9	4	8	7	

Crop Coefficients (Kc)

CROP COEFFICIENT FOR ESTIMATING EVAPOTRANSPIRATION IN DIFFERENT CROPS AT DIFFERENT STAGES

Four stages of crop development for field crops and vegetables are described as reference for the entirely growing season as below presented:

1. initial stage
germination and early growth when the soil is not or is hardly covered by crop (groundcover < 10%)

2. crop development stage
from end of initial stage to attainment of effective full groundcover (groundcover = 70-80%)

3. mid-season stage
time of start of maturing as indicated by discolour of leaves (beans) or leaves falling (cotton).
For some crops this may extend to very near harvest (e.g. sugar beet) unless irrigation is not applied at late season and reduction in ET_{crop} is induced to increase yield and/or quality (sugarcane, cotton, some grains); normally well past the flowering stage of annual crops.

4. late-season stage
from end of mid-season stage until full maturity or harvest.

REFERENCE Kc

		RELATIVE HUMIDITY > 70%		RELATIVE HUMIDITY < 20%	
	Wind (m/sec)	0-5	5-8	0-5	5-8
CROP	**STAGE**		**Kc**		
Barley	3	1.05	1.10	1.15	1.20
	4	0.25	0.25	0.20	0.20
Beans (green)	3	0.95	0.95	1	1.05
	4	0.85	0.85	0.90	0.90
Beets (table)	3	1	1	1.05	1.10
	4	0.90	0.90	0.95	1
Corn (maize)	3	1.05	1.10	1.15	1.20
	4	0.55	0.55	0.60	0.60
Cotton	3	1.05	1.15	1.20	1.25
	4	0.65	0.65	0.65	0.70
Cabbage, cauliflower	3	0.95	1	1.05	1.10
FAO 1985	4	0.80	0.85	0.90	0.95

REFERENCE Kc

CROP	STAGE	Kc			
Cucumber	3	0.90	0.90	0.95	1.00
	4	0.70	0.70	0.75	0.80
Egg plant (aubergine)	3	0.95	1.00	1.05	1.10
	4	0.80	0.85	0.85	0.90
Melons	3	0.95	0.95	1.00	1.05
	4	0.65	0.65	0.75	0.75
Onion	3	0.95	0.95	1.05	1.10
	4	0.75	0.75	0.80	0.85
Potatoes	3	1.05	1.10	1.15	1.20
	4	0.70	0.70	0.75	0.75
Sorghum	3	1.00	1.05	1.10	1.15
	4	0.50	0.50	0.55	0.55
Spinach	3	0.95	0.95	1.00	1.05
	4	0.90	0.90	0.95	1.00
Sugar beet (no irrig. last month)	3	1.05	1.10	1.15	1.20
	4	0.90	0.95	1.00	1.00
Sunflower	3	1.05	1.10	1.15	1.20
	4	0.40	0.40	0.35	0.35
Tomato	3	1.05	1.10	1.20	1.25
	4	0.60	0.60	0.65	0.65
Wheat	3	1.05	1.10	1.15	1.20
	4	0.25	0.25	0.20	0.20

Factors affecting the value of the crop coefficient (kc) and the potential evapotranspiration (ET_{crop}) are mainly the **crop characteristics, crop planting or sowing data, rate of crop development, length of growing season and climatic conditions.** Particularly following sowing and during the early growth stage, the frequency of rain or irrigation is important. The crop planting or sowing date will affect the length of the growing season, the rate of crop development to full groundcover and onset of maturity. For instance, depending on climate, sugar beets can be sown in autumn, spring and summer with a total growing season ranging from 160 to 230 days. General climatic conditions, especially wind and humidity, are to be considered; compared with smooth grass cover, wind will affect the rate of transpiration of taller crops more due to air turbulence above the rougher crop surface. This is more pronounced in dry-hot than in humid climates and (kc) values for rougher crop surfaces are therefore greater in dry climates. ET_{crop} is the sum of transpiration (T) by the crop and evaporation from the soil surface (E) and it can be written as (E+T) expressed in mm/day, mm/month. During full groundcover, evaporation is negligible; just following sowing and during the early growing period evaporation from the soil surface (e) may be considerable, particularly when the soil surface is wet for most of the time from irrigation and rain.

Kc OF ROW CROPS DEPENDING ON DEVELOPMENT STAGES

SUGAR BEET

Kc	STAGE
0.3	20% covered soil
0.5	20-40% covered soil
0.7	40-60% cov. soil
1	80% cov. soil
1.1	Until 40 days after Kc 1 stage
1	Until 60 days after Kc 1 stage
0.7-0.3	From 80 to 100 days after Kc 1

SUNFLOWER

Kc	STAGE
0.1	Emergence-4th leaf
0.8	4th leaf- flower button (R1)
1.1	Flower button-seed formation (R1-R4)
0.8	Seed formation- waxy maturity (R4-R6)
0.4	Ripening (>R6)

SOY

Kc	STAGE
0.3	First node
0.8	Vegetative period (until nth node)
1	Full bloom
0.8	Seed filling
0.4	Full maturity

CORN

Kc	STAGE
0.2	Emergence and first leaf
0.5	V3-V7 (jointing-boot)
1	Flowering
0.8	Waxy maturity
0.4	Full maturity

Seasonal Reference ET_{crop} (mm)

HOW MUCH WATER DOES IT TAKE TO GET AN YIELD?

Alfalfa	600 - 1,500
Potatoes	350 - 625
Sugar beet	450 - 850
Sorghum	300 - 650
Soybeans	450 - 825
Cereals	300 - 450
Beans	250 - 500
Vegetables	250 - 500

Cotton	550 - 950
Tobacco	300 - 500
Maize	400 - 750
Tomatoes	300 - 600
Vine yards	450 - 900
Orange	600 - 950
Onions	350 - 600
Bananas	700 - 1,700

Knowledge of soil-water relationship is valuable to all who have the opportunity to improve irrigation practices, including farmers who desire to obtain best use of water available for their farms. The following chapter is devoted to a consideration of the relationship of soil and water, with special reference to their influence on irrigation and drainage practices.

Field Capacity

AN ESTIMATION OF USEFUL WATER IN THE SOIL

- When in a saturated soil, gravity water has been removed, the remaining durable moisture content is called **field capacity**. Field capacity can be measured by determining moisture content of soil after an irrigation, which is sufficiently heavy to insure through wetting of the soil to be tested.
- In practice, field capacity is usually determined two days after an irrigation. Therefore, field capacity defines a specific point on the moisture-content time curve. Precise determinations of field capacity are generally not necessary for field applications. However, soils must be well drained before reliable field determinations can be made in this manner.
- **E.g., for most agricultural, clay-loam or clay soils, a soil moisture tension of 1/3 atmospheres (pF=2.54) corresponds closely to the generally accepted values of field capacity determined by moisture content. Indicative average values for fine textured soils varies between 23 and 28 per cent by dry weight or about 3,250 to 4,000m³/ha, for one meter soil depth.**
- **Knowledge of soil-water relationship is valuable to all who have the opportunity to improve irrigation practices,** including farmers who desire to obtain best use of water available for their farms. The following chapter is devoted to a consideration of the relationship of soil and water, with special reference to their influence on irrigation and drainage practices.

Available Soil Moisture (P_w)

The difference in moisture content of the soil between field capacity and permanent wilting point is termed the **available soil moisture**.
This represents the moisture which can be stored in the soil for subsequent use by plants, and can be calculated by the relation:

$$P_w = F_c - W_p$$

where: P_w = available soil moisture
F_c = field capacity
W_p = permanent wilting point

The field capacity, permanent wilting point and the available soil moisture can be expressed in per cent by weight of dry soil, by volume of dry soil, in millimeter water depth and in cubic meter per hectare. The available soil moisture content (P_w) is known also as the **water-holding capacity.**

In a general sense, the soil water which is bounded by the upper limit, field capacity (F_c), and lower limit wilting point (W_p), is considered available to plants.

E.g., fine texture soils have a good holding capacity between 1,700 and 2,000m³/ha, for one meter soil depth. It means also very low percolation losses and high field application efficiency can be expected (E_a=70 per cent and higher).

Allowable Water Depletion (P_{min})

Soil moisture content near the wilting point is not readily available to the crop. Hence, the term **readily available moisture** is generally used to refer to that portion of the available moisture that is most easily extracted by plants, approximately 75% of the **available moisture.**

Soil water depletion, is defined as the lowest level of soil moisture, between field capacity and wilting point, that can be taken by the crop permitting unrestricted evapotranspiration and crop growth. It can be expressed in percent by weight of dry soil, by volume of dry soil, in millimeter water depth and cubic meter per hectare. For normal irrigation, however, the interval between applications is extended to utilize about half or more of the available soil water.

FINAL INFILTRATION RATES AND ASSOCIATED SOIL TEXTURES

FINAL INFILTRATION RATE	IF (mm/hour)	SOIL TEXTURE
High	30 to 80	sandy loam, sandy clay loam
Moderately high	15 to 30	loam, silt loam
Moderately low	5 to 15	clay loam, clay, silt clay loambacco
Low	2 to 5	clay, adobe clay

Tensiometer

Although no entirely satisfactory, some limits of infiltration rate have been established: this rate can help in determining the **method of irrigation,** or the size of the border strips, or length of the furrow that can be irrigated from one head ditch or tertiary canal.

Water Balance

MEASUREMENT OF SOIL WATER

Measurement of water stored in soils and capacity of soils to store water are important parameters in irrigation operations. Knowledge of the capacity of soils to retain available irrigation water is also essential for efficient irrigation. If the farmer applies more water than the root-zone soil reservoir can retain at a single irrigation, the excess is wasted by **deep percolation or run-off.** If the farmer applies less water than the soil will retain, the crops may wilt from lack of water before the next irrigation, unless water is applied more frequently than otherwise would be necessary. Excessive application of water for the purpose of water storage or uncontrolled leaching may cause the groundwater to rise and become injurious to crops during the early part of the season. Electrical properties of resistance (or conductivity) have been used to indicate soil moisture content. Changes of moisture affect the electrical properties of soil.

TENSIOMETERS

Tensiometers are widely used for measuring soil water tension in the field and laboratory. A tensiometer consists of a porous ceramic cup filled with water and connected through a water-filled tube to reliable vacuum gauge. Water moves into and out of ceramic cup in relation to the soil water tension. The major criticism of the tensiometer is that it functions reliably only in the wet soil range at tensions of about minus 0.85 atmospheres or higher. **Tensiometers are suitable to provide a forecast of when the crops might begin to suffer stress at low depletion levels** (25 to 50 % of available water) and frequent irrigation, i.e., strawberries, flowers and most of vegetables. Trained field agents and routinely skilled farmers commonly use tensiometers. Soil variation requires placement of tensiometers at two to four sites per 65 hectares to obtain representative measurements. At each site a tensiometer is located in the zone of greatest root density (30-50cm) and a second at twice this depth. The first is to schedule irrigation, the second is to detect deep penetration to show when irrigation should be terminated. **Commercial tensiometers are available in various lengths**, allowing the monitoring of soil moisture tension at various depths so as to characterize the root zone as a whole. Electronic devices can be connected to tensiometers and to a computer in order to automatize irrigation operations.

HOW MUCH WATER IS NEEDED

Theoretically, needed volume of irrigation is
I = ETM – N + P

I	=	Irrigation
ETM	=	Evapotranspiration maximum
N	=	precipitations (rain)
P	=	Losses (percolation + runoff)

When ETM + P > Field capacity, irrigation is needed.

Sprinkler irrigation with center pivot

DEPTH OF APPLICATION

The depth of irrigation application presents the **amount of water which is applied to the crop at one watering,** by considering the allowable soil water depletion (P_{min}) and the effective rooting depths (H). The depth of irrigation can be calculated by using the formula:

$$d = \frac{100 * H * Gv\,(F_c - P_{min})}{E_a}$$

where:

d	=	depth of irrigation application (m^3/ha)
H	=	effective rooting depth (m)
Gv	=	apparent specific gravity (bulk density (t/m^3)
F_c	=	field capacity (% by dry weight of soil)
P_{min}	=	allowable soil-water depletion (% by dry weight of soil)
E_a	=	field application efficiency (0.70)

Stage of Growth

Growth of all plants can be divided into five stages with regard to development and irrigation practice as follows:

GROWTH STAGES OF DIFFERENT CROPS

(expressed in days)

CROP	ESTABLISHMENT	VEGETATIVE	FLOWERING	YIELD FORMATION	RIPENING
Cotton	15 - 25	25 - 35	60 - 70	30 - 40	15 - 20
Maize	15 - 25	25 - 40	15 - 20	35 - 45	10 - 15
Potato	15 - 25	15 - 20	-	45 - 55	10 - 15
Sorghum	15 - 20	20 - 30	15 - 20	35 - 40	10 - 15
Sunflower	20	30	30	25	15
Tobacco	40 - 60	50 - 70	-	40 - 70 and ripening	
Tomato	25 - 35	20 - 25	20 - 30	20 - 30	15-20
Wheat	10 - 15	55 - 75	15 - 20	30 - 35	10 - 15

During the vegetative stage water requirements continues to increase. Flowering occurs near and during the peak of water requirements. The yield formation stage is accompanied by a decrease in water requirements until the ET_{crop} essentially ceases during the latter part of the ripening.
The yield formation stage can well be considered in two parts: the wet-fruit stage which follows flowering (in cereals until wax maturity) , and the dry-fruit stage following wet-fruit growth. Dry fruiting is accompanied by a decrease in water use until ET_{crop} ceases and the plant becomes permanently wilted.

Irrigation Planning

WHEN WATER IS NEEDED

Criteria concerning irrigation planning varies depending on situations:

- Where water is scarce, irrigation must be programmed for maximizing the output (yield) from each cube meter of used water
- Where fertile soil is more scarce than water, irrigation must be programmed for maximizing the out put from each hectare.
- When to irrigate: in order to avoid any possible crop damage due to drought, the generally accepted irrigation practices recommend irrigating the crop before the soil reaches the wilting point, i.e., before complete depletion of the total available soil moisture.

IRRIGATION PROGRAM EXAMPLES

CORN USA

APPLICATIONS	YIELD, TONS PER HECTARE	CONSUMMATION H_2O, (mm)	CORN PER mm H_2O, (kg)
No application	4.3	268	16
3 Times before flowering	74	-	-
3 Times: 10 days before flowering, flowering, 10 days after flowering	89	383	23
6 Times during the growing season	94	535	17

SUGAR BEET SOUTH EUROPE / DATES AND DEPTHS

DATE	mm
15-5	25
5-6	25
20-6	30
15-7	30

POTATOES SOUTH EUROPE / DATES AND DEPTHS

DATE	mm
20-5	20
10-6	25
30-6	30
15-7	30

ONIONS SOUTH EUROPE / DATES AND DEPTHS

DATE	mm
1-6	25
20-6	25
10-7	30
30-7	30
15-8	25

DIFFERENT CROPS SOUTH RUSSIA / DATES AND DEPTHS

	DATE / mm								TOTAL (mm)
Corn	8-5	20	20-6	40	5-7	60	1-8	60	180
Soybeans	15-5	20	15-7	30	30-7	60	23-8	60	170
Sugar beet	-	-	20-5	60	20-7	60	-	-	120

Corn yield: under irrigation 9tons/ha; no irrigation 6.6tons/ha
Soybeans yield: under irrigation 3tons/ha; no irrigation 2tons/ha
Sugar beet yield: under irrigation 60tons/ha: no irrigation 51tons/ha

Irrigation Methods

The aim of modern irrigation is to make the best economic and technical use of water in conjunction with all other essential farm inputs (i.e., power, fuel, machinery, labour, fertilizers, chemicals) so as to intensify and sustain crop production. The selection of an appropriate technology for any given combination of physical and socioeconomic conditions involves numerous complex, and often conflicting, considerations. Where water shortage is acute, the obvious overriding need is to raise the water use efficiency. Where capital is short, the major requirement might be for an irrigation method with minimal dependence on expensive equipment.

There are, in principle, three main ways to apply water to plants:

1 **SURFACE IRRIGATION** - run the water over the surface of the soil and allow it to infiltrate;

2 **SPRINKLER IRRIGATION** - spray the water into the air and allow it to fall onto plants and soil as simulated rainfall;

3 **TRICKLE IRRIGATION** - apply the water directly or near the root zone.

Drip irrigation

SURFACE IRRIGATION

Surface irrigation is the most ancient of irrigation methods. It has been estimated that this method still serves more than 80-90 per cent of the irrigated land worldwide, and it has little changed over the years. Surface irrigation is generally more labor intensive than sprinkler or trickle irrigation.
The most important advantage of surface irrigation is its simplicity and easy adapt to small land holdings. It requires little in the way of machinery or sophisticated equipment. Such devices as gated pipes and siphons are easy to operate and maintain, and requires little prior training or spare parts.
The main disadvantage of surface irrigation remains its generally low application efficiency, waste of water, and the attendant dangers of raising groundwater-table waterlogging and salinity. It is suggested that surface irrigation to be practiced on medium to fine textured soils, well drained and having groundwater table below 4 meter depth.
In border strips system, the fields are divided into a number of strips, preferable not over 5 to 15 meter wide and 50 to 300 meter in length, separated by low border ridges. Typically the length of border-strips is ranging 10 to 30 times the width. The land should slope gently (at no more than 0.5 per cent) in the flow direction. The required flow rates vary between 10 and 50 cubic meters per hour, per meter width of plot. This system is suitable for close growing row crops, particularly cereals, fodder crops, alfalfa and orchards. The smallest depth of irrigation application is of the order of 1,000 cubic meter per hectare, and larger quantities are often applied in practice. Border-strip irrigation requires very high water volumes and high investment in land shaping and grading, but it offers low maintenance and operation costs. Indicative figures are suggested for size of borders and flows for different soils and land slopes, in the table below presented.

SUGGESTED SIZE OF BORDERS AND FLOWSFOR DIFFERENT SOILS AND LAND SLOPES[1] (DEEP ROOTED CROPS)

SOIL TYPE	SLOPE %	BORDER WIDTH (m)	BORDER LENGTH (m)	FLOW (liter /second)
Sand	0.2-0.4	13-30	60-90	10-15
	0.4-0.6	9-12	60-90	8-10
	0.6-1.0	6-9	75	5-8
Loamy sand	0.2-0.4	12-30	75-150	7-10
	0.4-0.6	9-12	75-150	5-8
	0.6-1.0	6-9	75	3-6
Sandy loam	0.2-0.4	12-30	90-250	5-7
	0.4-0.6	6-12	90-180	4-6
	0.6-1.0	6	90	2-4
Clay loam	0.2-0.4	12-30	180-300	3-4
	0.4-0.6	6-12	90-180	2-3
	0.6-1.0	6	90	1-2
Clay	0.2-0.3	12-30	350	2-4

1) Under conditions of perfect land grading.

FURROW IRRIGATION

Furrow irrigation is most suited for row cultivated crops such as potatoes, maize, cotton, sugar beet, orchards, grapes and vegetables. Water is applied in the furrows, which are generally opened by mechanical cultivation (hilling, earthing up) between plant rows. Slopes for furrows may range from 0.2 to 2.0 per cent, but on occasion may be as high a 5 per cent. The size of flow in furrows is related to infiltration rate, slope, length and shape of furrow, water depth to be applied and erosion hazard. On some soils, furrows having slopes of 10 to 15 per cent are successfully used by allowing only very small flow rates to enter the furrows and by careful inspection to control erosion. Slopes of 0.5 to 3 per cent are preferable, but many different types of soil are satisfactorily irrigated with furrow slope from 3 to 6 per cent. The length of furrows varies from 30 meter or less for gardens to as much as 500 meter for field crops. Furrow lengths of 90 to 200 meter are more common. Excessive deep percolation losses and soil erosion near the upper end of the field result from use of very long furrows. However, reduction of waste land for tertiary and quaternary ditches, and turning of machinery favor longer furrows. Indicative figures for furrow length are given below.

LENGTH OF FURROWS AND FLOW FOR DIFFERENT SOIL TYPE, LAND SLOPE AND DEPTH OF IRRIGATION APPLICATION*)

SLOPE %	LENGTH OF FURROWS METER												AVERAGE FLOW liter / second
	Heavy texture				Medium texture				Light texture				
0.05	300	400	400	400	120	270	400	400	60	90	150	190	12
0.1	340	440	470	500	180	340	440	470	90	120	190	220	6
0.2	370	470	530	620	220	370	470	530	120	190	250	300	3
0.3	400	500	620	800	280	400	500	600	150	220	280	400	2
0.5	400	500	560	750	280	370	470	530	120	190	250	300	1.25
1.0	280	400	500	600	250	300	370	470	90	150	220	250	0.6
1.5	250	340	430	500	220	280	340	400	80	120	190	220	0.4
2.0	220	270	340	400	180	250	300	340	60	90	150	190	0.3
Depth, mm	75	150	225	300	50	100	150	200	50	75	100	125	

*) Under conditions of perfect land grading.

SPACING AND DEPTH OF FURROWS

Spacing of furrows for irrigation of maize (corn), cotton, potatoes, sugar beets, and other row crops **is determined by proper spacing of the plant rows, one furrow being provided for each row.** In orchard irrigation, furrows are usually circular shaped placed around the body of the tree. Furrows from 20 to 30 centimeter deep facilitate control and penetration of water into soils of low permeability. They are well suited to orchards and to some furrow crops. Other furrow crops, such as sugar beets, are best irrigated with furrows from 10 to 15 centimeter deep. Plant spacing for cotton and maize, normally, varies between 0.8 to 1 meter between rows and 0.2 to 0.3 meter between plants on the row.

Sprinkler Irrigation

- Sprinkler irrigation, also called overhead irrigation, is the application and distribution of water over the field in the form of a spray, or a jet which breaks into drops or droplets, created by expelling water under pressure from an orifice (or nozzle). In contrast to surface irrigation, sprinkler systems are designed to deliver water to the field without depending on the soil surface for water conveyance or distribution.

- Sprinkler intensity rate is important in order to prevent pond and surface runoff. Sprinklers are designed and arranged in a pattern (square, rectangular or triangular) to apply water at an intensity (mm/hour) that does not exceed the soil infiltration rate. Indicative figures sprinkler intensity rate with clay loam and fine-textured clay soils are given below:

SOIL TYPE	SPRINKLER INTENSITY (mm/hour)
Coarse sand	20 to 25
Fine sand	12 to 20
Loamy sand	12
Loam and silt loam	10
Clay loam	8
Clay	5


Coarse sand


Loamy sand


Clay loam

SUITABILITY OF SPRINKLERS FOR TO IRRIGATE DIFFERENT CROPS

SPRAY QUALITY	RAIN CLASSIFICATION	CROPS WHICH CAN BE IRRIGATED
F > 0.5	Coarse rain	Light soils, fodder and perennial crops
F = 0.3 - 0.5	Moderate rain	Medium soils and heavy soils, all field crops
F < 0.3	Fine rain	All type odd-soils, all crops, including sensible crops: flowers, vegetables, tobacco

PIVOT SYSTEMS

- Volume from 180 to 360mc per hour.
  Working pressure about 3 bars.

- Water application depth is usually 9mm per day,
  but it can be varied.

- Length from 400 to 1500 meters.
  Covered acreage from 50 to 600ha.

PIVOT PROJECT EXAMPLE

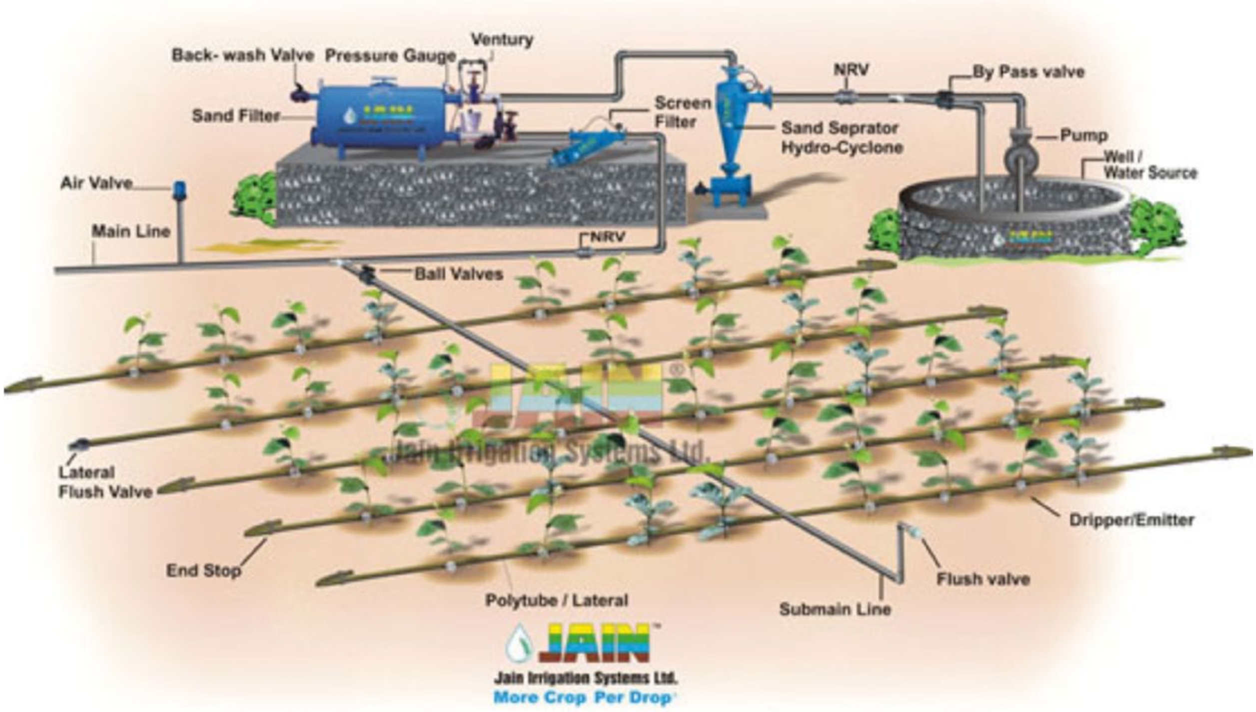
Trickle Irrigation (Drip irrigation)

With trickle irrigation water is delivered to the plants, drop by drop, via a set of plastic lateral tubes laid on the ground or buried at a depth of 15-30cm, which are supplied from a head unit through a field main pipeline. The laterals are commonly 15-25mm in diameter, and are either provided with emitters designed to drip water onto the soil. By drip irrigation daily to twice-weekly, soil water in the root zone is kept about field capacity (soil moisture tension of 0.3 to 0.5bar). Under these conditions, the emitter rate approaches closely the actual crop evapotranspiration (ET_{crop}). The rate of emitters is generally in the range of 1 to 10 liter/hour, (industrial crop about 1 to 3, orchards 3 to 10) and it do not exceed the basic infiltration rate. The operation pressure is usually in the of 1 to 3 atmospheres.

Under trickle irrigation, the wetted portion of the soil is reduced, i.e., the active rooting volume is usually confined to a fraction (often less than 50 percent) of what would be the normal root zone of an uniformly wetted soil. Consequently the water need for irrigation is reduced by 50 percent or more compared to the above described irrigation methods.
With trickle irrigation, it is possible to use salty water (concentration about 1,000mg/liter salt).

Under optimal management conditions, yield increases from 20 to 50% are realistic, as well as high product value of 40 per cent or more per unit volume of water.

DRIP IRRIGATION GENERAL SCHEME



Machinery

IMPLEMENTING YOUR GROWTH PROJECTS

Crop producers know that their soil is the most precious natural resource, and better soil conditions mean higher crop yields. New Holland knows that every individual plant counts towards your bottom line and that's why we design our equipment specifically to help you maximize yield potential.

PRECISION DISK DRILL

New Holland P2080 and P2085 Precision Disk™ Single-Disk Air Drills deliver best-in-class seed placement accuracy for an array of crops grown in diverse conditions and geographies. They are the right tool when it comes down to minimize losses of moisture during the drilling of cereals and other crops. The drills are engineered to help New Holland customers in achieving more even emergence and improved plant stand establishment while sparing moisture.

GUARDIAN™ FRONT BOOM SPRAYERS

Any irrigation is a costly practice and we do not want to water weeds. Irrigation management requires proper weeds control both pre-emergence and post emergence. An efficient sprayer is one of the most important factors to be considered when considering minimizing losses of valuable moisture from soils. The cab-forward, rear-engine design, front boom of New Holland Guardian Sprayers provides equal weight distribution across the machine to get operators into fields earlier for more timely application with less rutting and soil compaction.

POWER UNITS

Power Units from FPT are available for powering any irrigation system, from small volumes trickle systems to pivot machinery. Power range is very wide, from 31 to 490kW, and engines have a very low level of emissions (Tier 4B).

NEW HOLLAND ST 830

When it comes down to spare water for crops, everything helps: an alternative for primary tillage is the New Holland heavy cultivator ST 830. This implement delivers a suitable seed bed without lifting and revolving soil layers, thus avoiding important moisture losses from soil due to evaporation. Economy in irrigation water is sensible during the firs stages of crop growth.

AT YOUR OWN DEALER

APAC

Visit our website: **www.newholland.com**
Send us an e-mail: **international@newholland.com**

New Holland prefers AMBRA lubricants

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