

## Session 2.4: Soil and water management

### Key learning points



- Water sources
- Soil conservation
- Irrigation systems
- Soil drainage

### Main objectives of the session

By the end of the session participants will be better able to:



- Understand the alternative sources of water
- Calculate the water balance and irrigation water requirements for different crops
- Evaluate sprinkler and drip irrigation systems
- Design and construct an automatic irrigation system
- Conserve soil effectively
- Drain soil effectively using surface and sub-surface techniques

### 2.4.1 Water resources

The greatest demand for water comes from agriculture. Across Europe more than two thirds of water taken from rivers and lakes is used for irrigation. Farmers are not only the biggest user of water, but also the least efficient. On average about 60% of the water taken for irrigation is lost, and at the same time many laws require growers to relinquish water for industrial and public use.

Water most readily available is surface water from rivers, streams, and natural or artificial water collection basins, carried to the fields by either open-air channels or piping. In recent years increasing use has been made of groundwater allowing irrigation according to individual needs and with relatively economical pumping costs and that free growers from the set shifts and schedules of cooperative/public water distribution networks.

Within groundwater there may be several water-bearing strata, and normally numbered starting from the surface and going down. The uppermost stratum is known as the water table, and when the impermeable layer supporting it is limited in size, it is called a perched water table. The deeper strata, are termed artesian and are numbered progressively 2, 3, etc. Surface water-bearing strata usually interact with the rivers that intersect them and give up or receive water depending on whether the river water level is above or below that of the surrounding stratum. The river acts more or less as a regulator for the groundwater level. Water-bearing strata are thus subject to a water regime that varies during each season as a function of both the direct intake from precipitation as well as that from the rivers intersecting them.

The drawing of groundwater from wells has been well established for centuries. The earliest wells were dug by hand to obtain water at the water table and often remain from just a few meters to a few dozen meters deep. Wide diameter wells can be seen in the courtyards of old farms and with stone or brick walls. Water was drawn with a bucket for family use, or with a wind or animal-powered bucket conveyor for irrigation use. With improvements in technology, deeper and deeper water-bearing strata are being exploited with the construction of small diameter (100-300 mm) tubular wells.

The quantity of water that can be extracted from a well in a constant and continuative manner is called the well yield. The well water can be drawn:

- With a surface pump if the dynamic level of the water in the well does not fall below 7-8 meters;
- With a submersible electric pump when the dynamic level of the well water goes below 7-8 meters.

For home use and for watering flower and vegetable gardens a pump capable of providing 50-100 l/m of water may be sufficient, whereas for agricultural use the seasonal consumption goes from 1 200 – 1 800 m<sup>3</sup>/ha for low water requirement crops (grapevines and some fruit trees) to 6 000 – 8 000 m<sup>3</sup>/ha for maize. Thus a well for farm irrigation must be able to provide a continuous yield of 40-50 l/min per hectare irrigated.

### 2.4.2 Soil conservation

Modern soil conservation, as we know it today was developed in the 1930s when problems of soil erosion led to the creation of soil conservation services in the United States and, shortly after in other countries. Since then a vast amount of money, time and effort has been expended on many different soil conservation projects and programmes. Soil erosion is the result of many factors, including:

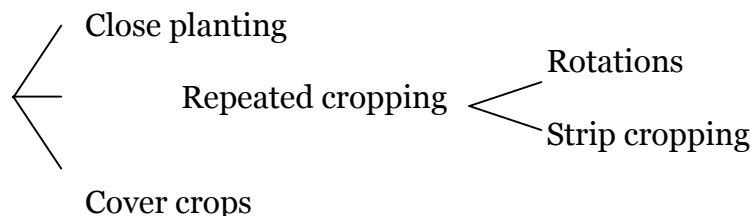
- ❑ Overly deep tilling of hillside terrains
- ❑ Cropping on excessive land gradients
- ❑ Intense rainfall
- ❑ The quantity and quality of the vegetation present.

The following outline summarises the main soil conservation measures for horticultural and horticultural and fruit crops:

#### ***Agronomic practices:***

1) Mulching

2) Crop management



3) Cultivation according to contour lines

4) Minimal tilling or non-tilling

#### ***Mechanical methods:***

1) Terracing

2) Building of retention dams

3) Installation of protection structures

It is difficult to propose a single solution to cover all climatological, agronomic and pedological possibilities. For example, the traditional method of ploughing followed by a rotary cultivator leaves the surface soil with greater porosity and this facilitates infiltration and the dissipation of the energy of surface runoff. But at the same time the formation of a crust at the base of the plough can also hinder water penetration and result in sub-surface runoff and which erodes the tilled layer. Growers need to evolve such practices over time and by adapting experimental and research results to the conditions at their own farms, as well as to use their own experience and guidance from extension agents.

### 2.4.3 Irrigation systems

The purpose of irrigation is to integrate the natural water resources of the soil and so maintain an optimum of moisture level for the crop. The irrigation water need of a certain crop is the difference between the crop water need and that part of the rainfall

that can be used by the crop (the effective rainfall). Effective precipitation is estimated on a monthly basis using measured rainfall data. For each crop grown on an irrigation scheme the crop water need is usually determined on a monthly basis.



Determining how much irrigation water a crop needs is found by calculating the *water balance*. The natural water income ( $A$ ), the losses ( $P$ ) due to surface runoff and percolation, and the consumption due to evapotranspiration ( $ET$ ) are established. It is also important to estimate the land water reserves ( $R$ ), which vary as a function of the season and the type of soil.

The annual irrigation water requirement ( $I$ ) is given by the simple formula:  $I = (ET + P) - (A + R)$ .

For example, in order to determine the volume of irrigation water to be supplied to a hectare of land planted with sugar beet, the following elements must be known:

- Unitary water consumption = 350 l/kg of dry matter (dm)
- Production: roots = 40 tons (25% dm) = 10.0 tons dm  
leaves = 15 tons (16% dm) = ~~2.4 tons dm~~  
12.4 tons dm

□ *Water balance:*

1. Water consumption ( $ET$ )/ha = 12.4 tons x 350 l/kg = 4 340 m<sup>3</sup>
2. Seasonal water income ( $A$ ) = 500 mm = 5 000 m<sup>3</sup>
3. Losses ( $P$ ) = 50% of  $A$  = 2 500 m<sup>3</sup>
4. Reserves ( $R$ ) = 1 000 m<sup>3</sup>
5. Volume of irrigation water ( $I$ ) = (4 340 + 2 500) - (5 000 + 1 000) = 840 m<sup>3</sup>

If losses and consumption are greater than the income, the crop must be irrigated. If in the example above only 70% of the water supplied is used due to losses in the irrigation system, the actual water requirement will increase to:  $840 / 0.7 = 1\,200\text{ m}^3$

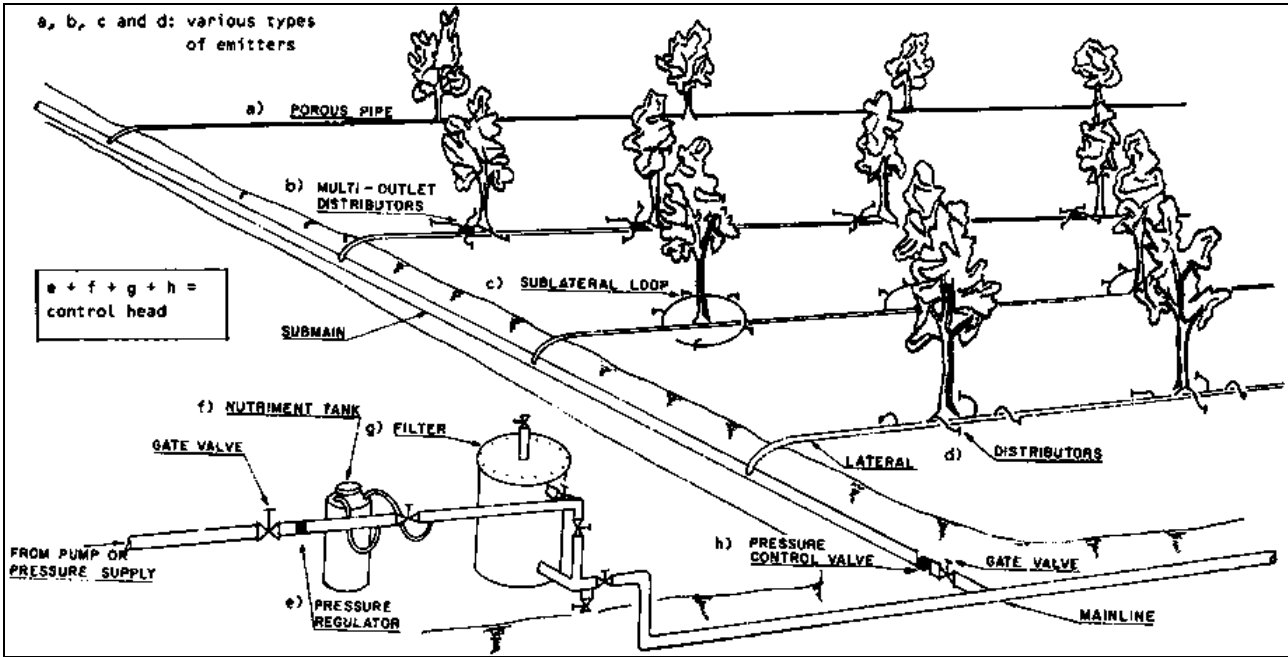
The automatic irrigation systems most commonly used today for horticultural and fruit crops are the *sprinkler (or spray)* and the *drip (or trickler)* type systems.

Sprinkler systems create an artificial rain over the crop and comprise of a motor-pump, piping under pressure, and sprinkler devices. The most commonly used types are, portable pipelines systems, self-propelled coil systems and pivot systems. Low-pressure micro irrigation sprinkler systems are very practical especially for crops that require large amounts of water and frequent irrigating (such as celery, lettuce and fennel.).

Another automatic sprinkler system is the large reel or trolley. The sprinkler is set on a wheeled trolley that is moved by a hydraulic motor powered by the pressure of the irrigation water. These systems have a range of 80 meters and cover an area of 2 ha at a speed between 12 and 120 meters/hour.

Trickler or drip systems provide water continuously in small amounts by means of tricklers attached to plastic pipes. They are suitable for areas where little water is available and make it possible to irrigate even under windy conditions. Many automatic systems are available for trickler or drip irrigation, such as the drip pipe that can have a seasonal or multi-seasonal duration. These save from 1/3 to 1/2 the amount of water used with sprinkler irrigation systems and are composed of a primary network fed by a motor-pump unit, which then branches off into the network of lateral header tubing in rubber or plastic. The primary network can be applied below the surface or simply laid on the ground. The header tubing can also be laid on the ground or suspended 1 to 1.5 meters above the ground. The average working pressures vary between 0.5 and 4 bars, and the flow rates for each emitter are from 1 to 15 litres/hour. A typical drip irrigation system is shown in the following diagram:

**Example: Drip Irrigation Scheme**



(Source: Guidelines for designing and evaluating surface irrigation systems, FAO, 1989)

The following table compares typical sprinkler with drip irrigation systems

**Table: Sprinkler and Drip Irrigation Systems Compared**

Parameter	Unit of measurement	Sprinkler system	Drip system
Seasonal water consumption .....	M <sup>3</sup> /ha	4 300	1 350
Seasonal operations.....	no.	10	30
Duration of the operation .....	h	8	6
Seasonal duration of irrigation .....	h	80	180
System operating pressure .....	bar	5	4
Operating pressure at emitter .....	bar	3.5	1.5
Flow of each irrigator .....	l/s	0.6	0.0011
Power installed .....	kW	15	5.6
Energy consumed for each operation .....	kWh/ha	120	33.6
Energy consumed during the season .....	kWh/ha	1 200	1 008

### Case study

#### Tomato crop water needs

Suppose a tomato crop grown in a certain area has a total growing season of 150 days and the following monthly crop water needs:

	Feb	Mar	Apr	May	June	Total
Crop water need (mm/month)	69	123	180	234	180	786

This means that in February the tomatoes need 69 mm of water, in March 123 mm of water, etc. The water need of tomatoes over the total growing season (February-June: 150 days) is 786 mm.

Suppose the following rainfall data for the area where the tomatoes are grown have been obtained from the Meteorological Service or Ministry of Agriculture.

	Feb	Mar	Apr	May	June	Total
Rainfall: P (mm/month)	20	38	40	80	16	194

This means that the average rainfall for February is 20 mm, for March 38 mm, etc. The rainfall over the total growing season of tomatoes (February-June: 150 days) is 194 mm. Only part of this rainfall is effective, and the effective rainfall is estimated.

	Feb	Mar	Apr	May	June	Total
Rainfall: P (mm/month)	20	38	40	80	16	194
Effective rainfall: Pe (mm/month)	2	13	14	39	0	68

This means that the effective rainfall during February is only 2 mm, during April 13 mm, etc. The effective rainfall during the total growing season of tomatoes (February-June: 150 days) is 68 mm. Now the irrigation water need for the tomatoes can be calculated on a monthly basis, as follows:

	Feb	Mar	Apr	May	June	Total
Crop water need (mm/month)	69	123	180	234	180	786
Effective rainfall: Pe (mm/month)	2	13	14	39	0	68
Irrigation water need (mm/month)	67	110	166	195	180	718

Looking at the example for the month March, it can be seen that tomatoes need 123 mm during March. Of this 123 mm, 13 mm is supplied by rainfall. The remaining (123 - 13 =) 110 mm have to be supplied by irrigation. The total water need of tomatoes over the entire growing season is 786 mm of which 68 mm is supplied by rainfall. The remaining quantity (786 - 68 = 718 mm) has to be supplied by irrigation.

When looking at the calculations above, it is obvious that the month May is the month of peak irrigation water need (195 mm irrigation water in May). If the tomatoes would be the only crop grown on the irrigation scheme, the canals would have to be designed in such a way that they allow a flow large enough to supply a net water layer of 195 mm to the whole area covered by tomatoes during the month May. In other words, for designing an irrigation scheme, the month of peak water supply is the critical month.

**Exercise: Calculating the water balance**

Use of the electronic sheet attached to calculate the water balance

**Table: Calculating the water balance**

DATE	PHASE	TEMPERATURE		OUTPUT				INPUT				DEFICIT		WATER VOLUME Mc/Ha		
		T min	T max	Evap. Tank mm	ETP mm	Kc	ETE mm	RAINFALL		IRRIGATIONS		Totals useful mm	Daily progression mm		TOTAL mm	
								Real mm	Utile mm	Real mm	Utile mm					
01-Jun	2	10.1	26.1	5.0	4.0	0.6	2.4							-2.4	-2.4	24
02-Jun	2	9.0	24.0	5.0	4.0	0.6	2.4							-2.4	-4.8	48
03-Jun	2	10.9	22.5	2.5	2.0	0.6	1.2							-1.2	-6.0	60
04-Jun	2	6.4	21.1	7.4	5.9	0.7	4.1							-4.1	-10.1	101
05-Jun	2	3.5	23.3	2.8	2.2	0.7	1.5							-1.5	-11.6	116

06-Jun	2	5.5	23.3	5.3	4.2	0.7	3.0							-3.0	-14.6	146
07-Jun	2	5.8	24.3	1.6	1.3	0.7	0.9	2.0	1.5			1.5		0.6	14.0	140
08-Jun	2	7.8	25.6	5.4	4.3	0.8	3.4	5.0	3.8			3.8		0.4	-13.6	136
09-Jun	2	7.1	27.9	7.7	6.2	0.8	5.0							-5.0	18.6	186
10-Jun	2	9.5	29.2	6.0	4.8	0.8	3.8							-3.8	22.4	224
11-Jun	2	13.1	26.1	5.0	4.0	0.0	3.2							-3.2	25.6	256
12-Jun	2	11.5	26.5	5.0	4.0	0.8	3.2							-3.2	28.8	288
13-Jun	2	12.0	26.5	7.0	5.6	0.8	4.5							-4.5	33.3	333
14-Jun	2	9.7	22.9	6.0	4.8	0.8	3.8		47.0	35.0	35.0			3.8	5.5	55
15-Jun	2	6.1	26.1	6.0	4.8	0.8	3.8							-3.8	9.3	93

**Exercise: Construction of an automatic irrigation system**

Calculate the water balance for cauliflower from the following information:

- Average production: 12 tons/ha
- Production of dry matter: 8 tons/ha
- Unitary water consumption: 700 litres/kg d.m.
- Water requirement (ET): 8 x 700 5 600 m<sup>3</sup>/ha
- Seasonal water income (A): 350 mm 3 500 m<sup>3</sup>/ha
- Losses (P) = 30% of A 1 050 m<sup>3</sup>/ha
- Reserves (R) 300 m<sup>3</sup>/ha

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Answer: irrigation water requirement (I) = (ET + P) – (A + R) 2850 m<sup>3</sup>/ha

**2.4.4 Soil drainage**

Many soil structural problems are due to poor soil drainage. Ploughing or cultivating soil when it is too wet will cause a rapid deterioration in its structure. An excess of water in the soil may be due to a high water table or to poor permeability in the soil itself. This has many negative effects on the plants, including:

- Insufficient aeration of the root system
- Reduced absorption of nutrients from both washing out and from poor root absorption
- Slowing down of favourable microbial activity, such as humification or nitrification
- Lower soil temperatures
- Loss of soil structure

For these reasons excess water must be removed by surface or subsurface drainage network. *Subsurface drainage* is carried out by means of a network of covered channels placed at a suitable depth and that collects percolation water or groundwater and conducts it to a drainage receptacle. The maximum drainage levels possible is estimated at 2 l/sec/ha, equal to about 170 m<sup>3</sup>/ha per day. Where rainfall can be very heavy, this capacity is too low, and in these cases are often not the sole means of removing excess water and other techniques, such as surface drainage, are used.

Subsurface drainage can be achieved by using different materials, including stone, tree branches, earthenware or plastic piping. Today the most commonly used material is PVC, in 6-meter rigid pipes or in flexible piping tens or hundreds of meters long. These have lengthwise or crosswise slots to allow the water to enter. The best depth for drains varies with greater depths being used for very permeable soils, and lesser depths for more compact soils. It is difficult to calculate at what distance drains should be placed. As a general rule, the greater the number of fine particles in the soil the shallower the drains are placed and the shorter should be the distance. Generally the maximum depth is 15-20 meters in the most permeable soils and a minimum depth of 5 meters in more compact soils.

*Surface drainage* is carried out by creating open trapezoidal ditches that collect rainwater and groundwater and discharge it into outlet ditches or channels. The technical elements of surface drainage are, storage volume, distance, slope, and section. The storage volume is calculated according to the amount of rain that falls and to the amount of water that must be collected (stored) before being drained. Flow coefficients are considered to be 0.4-0.6. As regards rainfall, those considered heavy and frequent are also taken into consideration.