BSE 11042 Principles of Irrigation

Professor M.M.M. Najim

Vice Chancellor
South Eastern University of Sri Lanka

TOTAL HOURS	**Theory**	**25**
	Practical	**10**
EVALUATION AND MARKS	**Continuous Assessment**	**30%**
	End Semester	**70%**

LEARNING OUTCOMES

On completion of the course, students should be able to;

- Explain the soil moisture constants and water requirements by crops.
- Decide on frequency of irrigation, efficiency of irrigation
- Carryout irrigation scheduling for different crops
- Explain the importance of land grading on irrigation
- Describe different types of water application systems

- Soil Moisture constants (1. BSE 11042 Irrigation Practices).
- Water requirement of crops and factors affecting it (1. BSE 11042 Irrigation Practices).
- Intensity and Frequency of Irrigation (1. BSE 11042 Irrigation Practices).
- Irrigation Efficiencies (1. BSE 11042 Irrigation Practices)..
- Approaches of irrigation scheduling (2. Irrigation Scheduling).

- Systems and methods of irrigation (3. Surface Irrigation, 4. Furrow Irrigation, 5. Sub Surface Irrigation, 6. Sprinkler irrigation, 7. Drip Irrigation.)
- Effective rainfall ,
- Leaching requirement ,

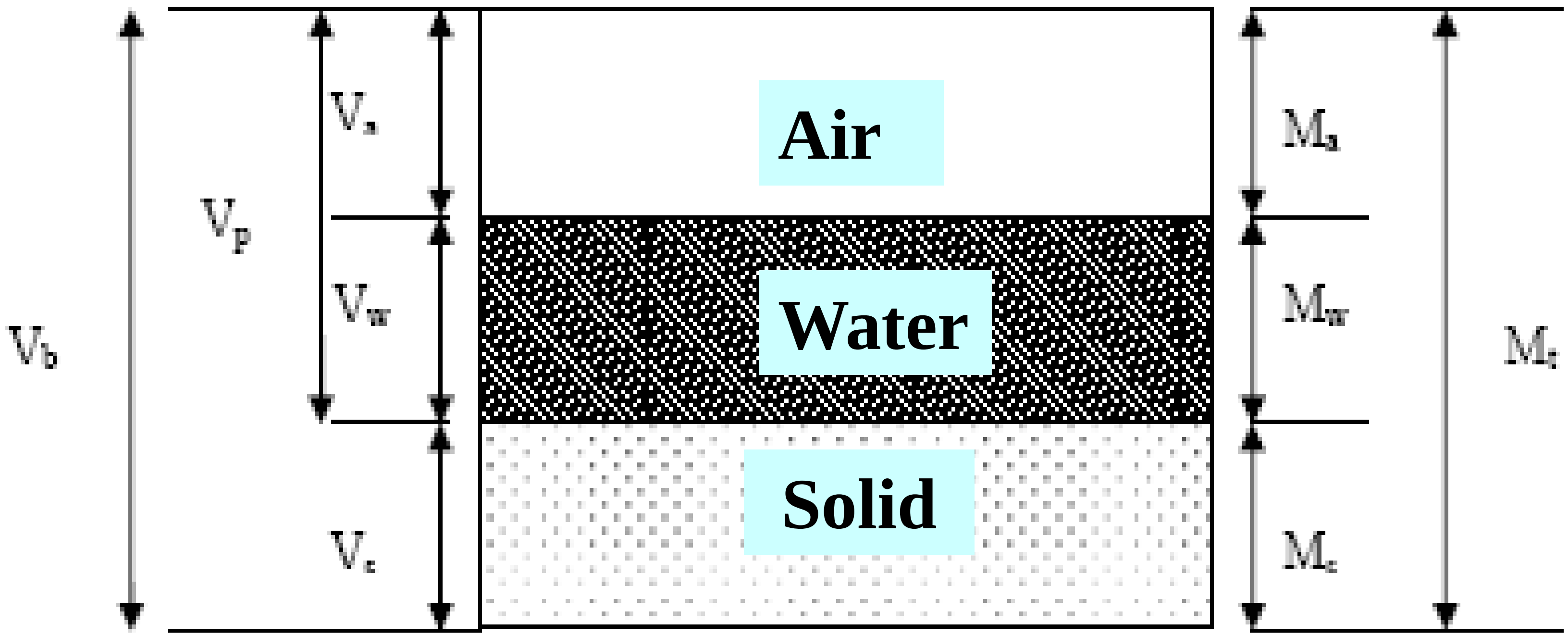
- Quantity and quality of irrigation water.
- Measurement of irrigation water.
- Elementary idea of drainage on farms.
- Land Grading and Drainage for Irrigation.
- On farm conveyance.
- Gravity application Methods.
- Pressurized application systems.

- Pumping techniques, automatics of pumping stations, subsurface irrigation network.
- Visit to irrigation and drainage projects.

- Answers needed during irrigation
  - How much to irrigate?
  - When to irrigate?
  - How to irrigate?

How much to irrigate?

Soil Water

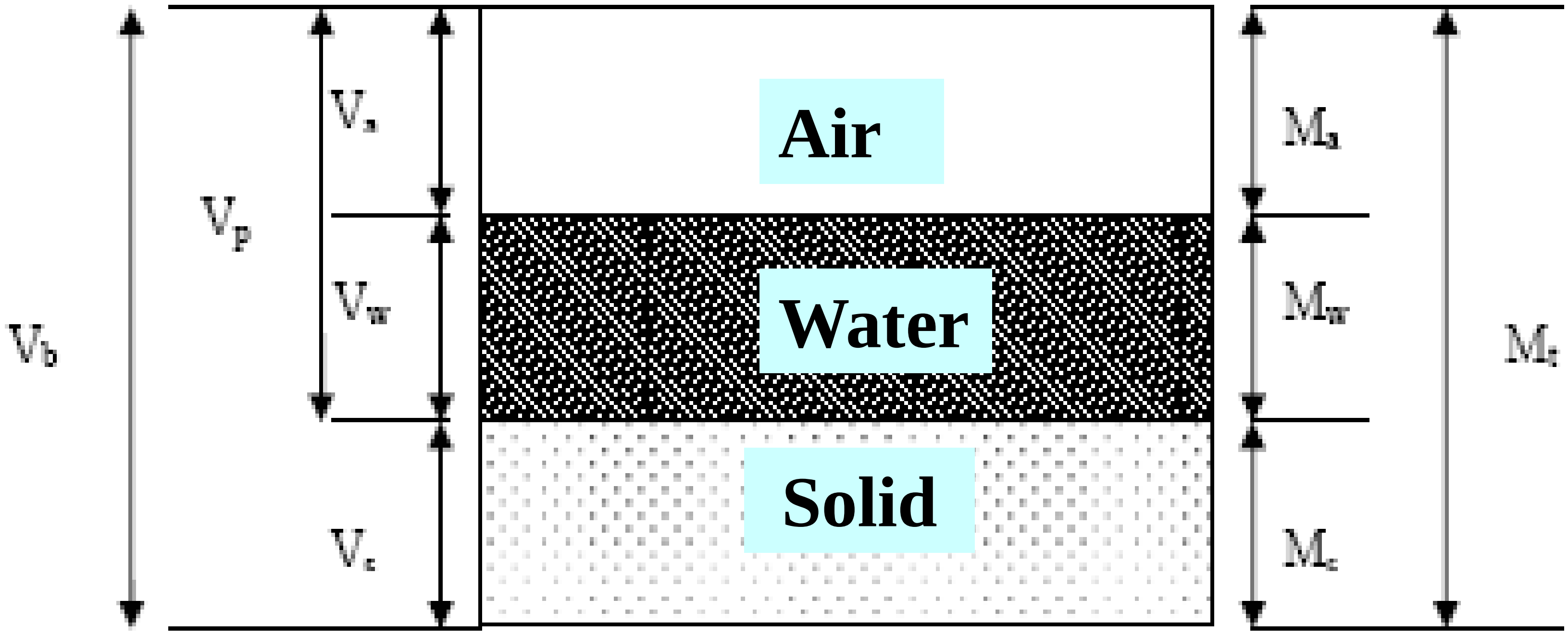


Water Content - Mass Basis

$$\theta_m = \frac{mass\ water}{mass\ dry\ soil} = \frac{M_w}{M_s}$$

= Mass of water / Mass of oven dried soil

Dry soil sample in an oven



Volumetric Water Content

$$\theta_v = \frac{volume\ water}{bulk\ volum\ soil}$$

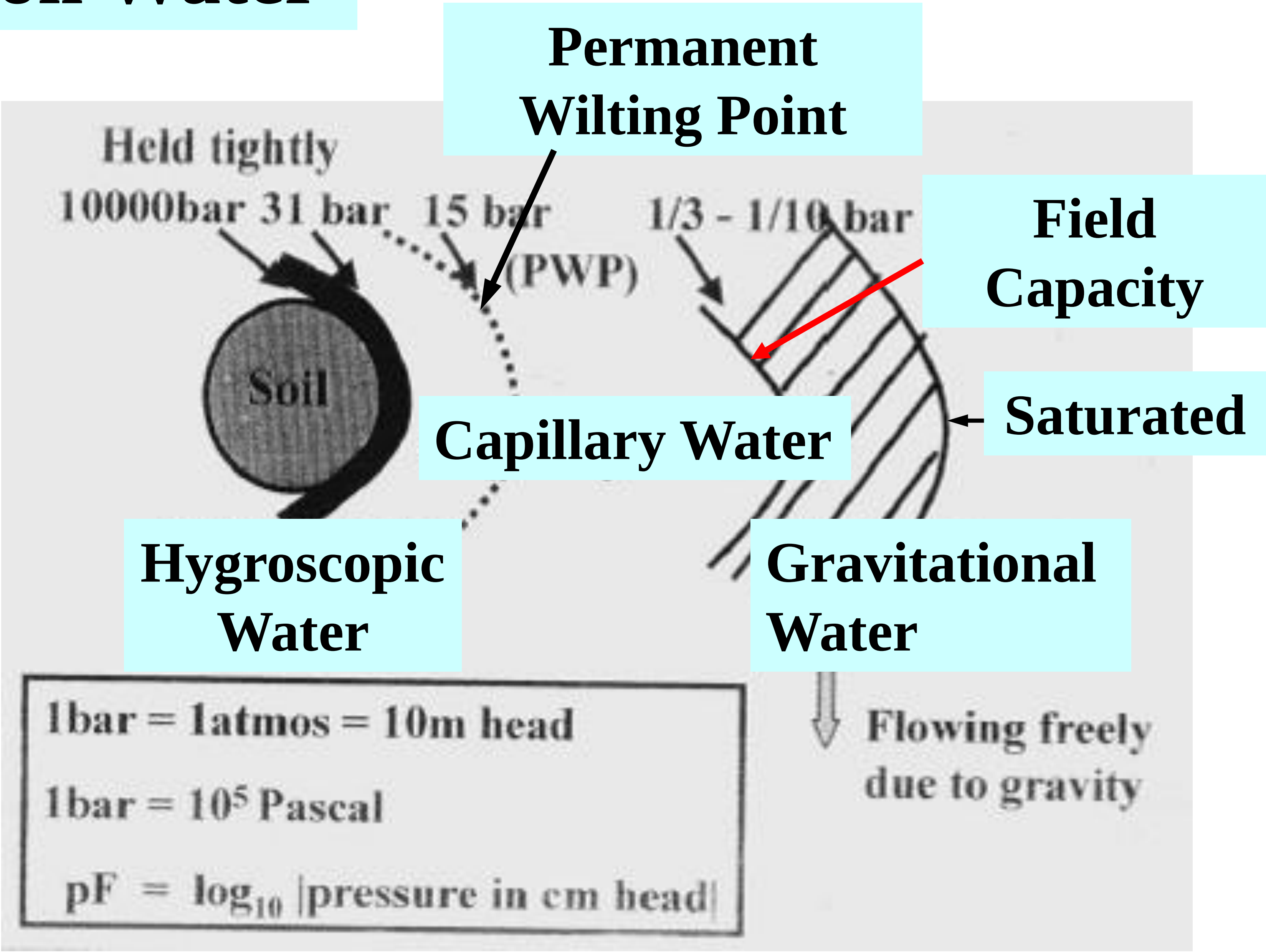
= Volume of Water / Volume of Bulk Soil

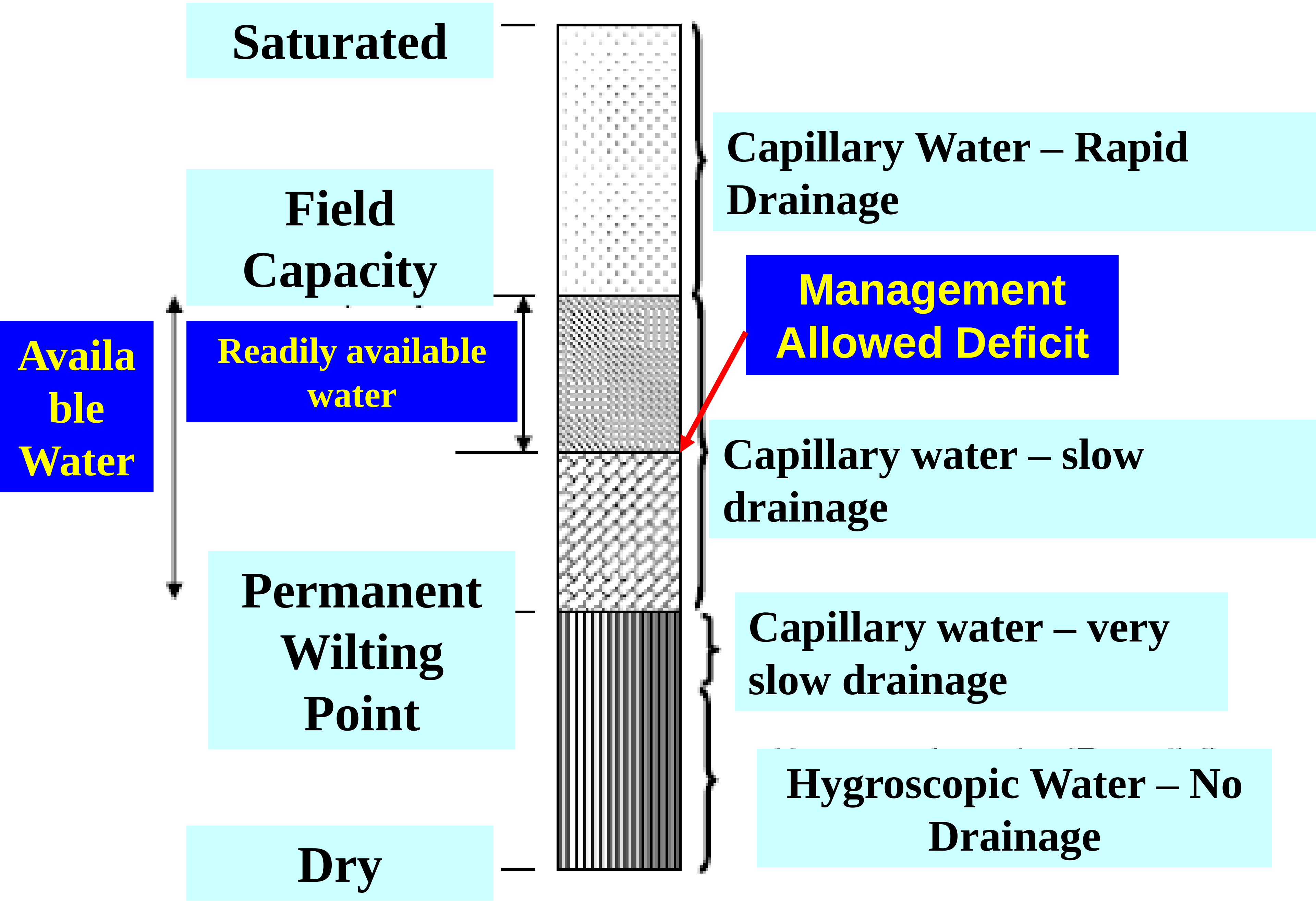
$$\theta_v = \theta_m \frac{\rho_b}{\rho_w}$$

Volumetric Water Content = Water content – Mass Basis x (Soil bulk density / water density)

Volumetric Water Content – express as a height
i.e. 0.28 or 28% means there is 0.28 m (28 cm) of water in 1 m depth of soil

Soil Water


Permanent Wilting Point
Held tightly
10000bar 31 bar 15 bar
(PWP)
1/3 - 1/10 bar
Field Capacity
Soil
Saturated
Capillary Water
Hygroscopic Water
Gravitational Water
1bar = 1atmos = 10m head
1bar = 10^5 Pascal
pF = log10 |pressure in cm head|
Flowing freely due to gravity


Saturated
Field Capacity
Available Water
Readily available water
Permanent Wilting Point
Dry
Capillary Water – Rapid Drainage
Management Allowed Deficit
Capillary water – slow drainage
Capillary water – very slow drainage
Hygroscopic Water – No Drainage

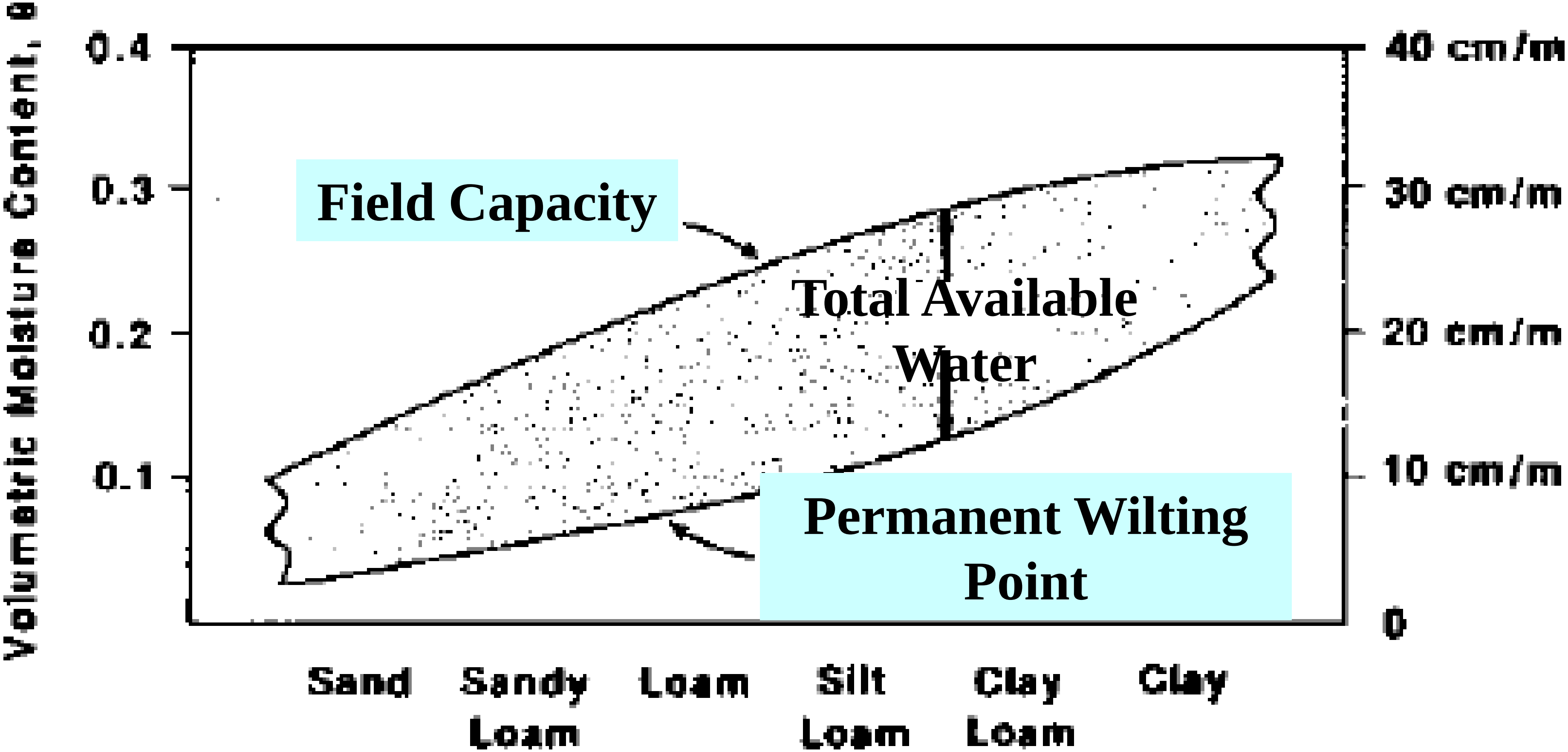
Total available water for plant

=

(Field Capacity_v – Permanent Wilting Point_v) x Root Depth

or

(Field Capacity_m – Permanent Wilting Point_v) x (Soil bulk density / water density) x Root Depth



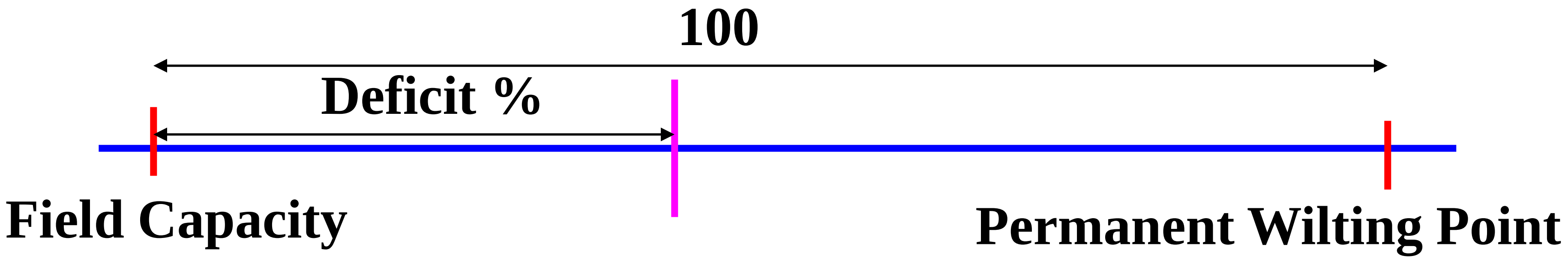
Volumetric Moisture Content, θ
0.4
0.3
0.2
0.1
40 cm/m
30 cm/m
20 cm/m
10 cm/m
0
Field Capacity
Total Available Water
Permanent Wilting Point
Sand
Sandy Loam
Loam
Silt Loam
Clay Loam
Clay

- **But, we cant allow for plants to absorb all this water. Why?**
  - When water in soil decreases
    - Absorption become difficult
    - Water stress
    - Reduces yield
    - Stress during critical stages – yield reduces considerably. i.e. Onion – bulb formation stage, some grains – flower initiation to flowering

Solution:

- When a part of Total Available Water (TAW) decreases irrigate and provide the lost content
- What % of TAW is allowed to decrease (deficit %)
- This Stage is – Management Allowed Deficit
- Net Irrigation Water Requirement =

(Field Capacity$_v$ – Permanent Wilting Point$_v$) x Root Depth x Deficit %



Deficit % Examples

- **Corn – Development Stage 50%**
- **Potato – Yam formation Stage 50%**
- **Grapes 65%**
- **Beans 40%**
- **Fruit trees 50 – 65%**

- Is it enough to supply the Net Irrigation Water Requirement? No –
- Due to water losses during irrigation
  - Seepage and Percolation (In Field and along conveyance canals)
  - Evaporation (field evaporation is included in crop evapotranspiration)
    - From Canals
  - Field Runoff

  - When these losses are considered – we have to irrigate more than the net irrigation requirement

Total (Gross) irrigation water requirement = =

$$\left[(\text{Field Capacity}_v - \text{Permanent Wilting Point}_v) \times \text{Root Depth} \times \text{Deficit } \% \right] / \text{Water Application Efficiency } (E_a)$$

or

$$\left[(\text{Field Capacity}_m - \text{Permanent Wilting Point}_m) \times (\text{Soil bulk density} / \text{water density}) \times \text{Root Depth} \times \text{Deficit } \% \right] / \text{Water Application Efficiency } (E_a)$$

- **Crop Water Requirement**
  - Evapotranspiration
    - Cannot measure easily
    - Calculate/estimate (using weather data)
    - Easiest Method – Using pan evaporation data

Crop water requirement (ETc) = ETo * Kc

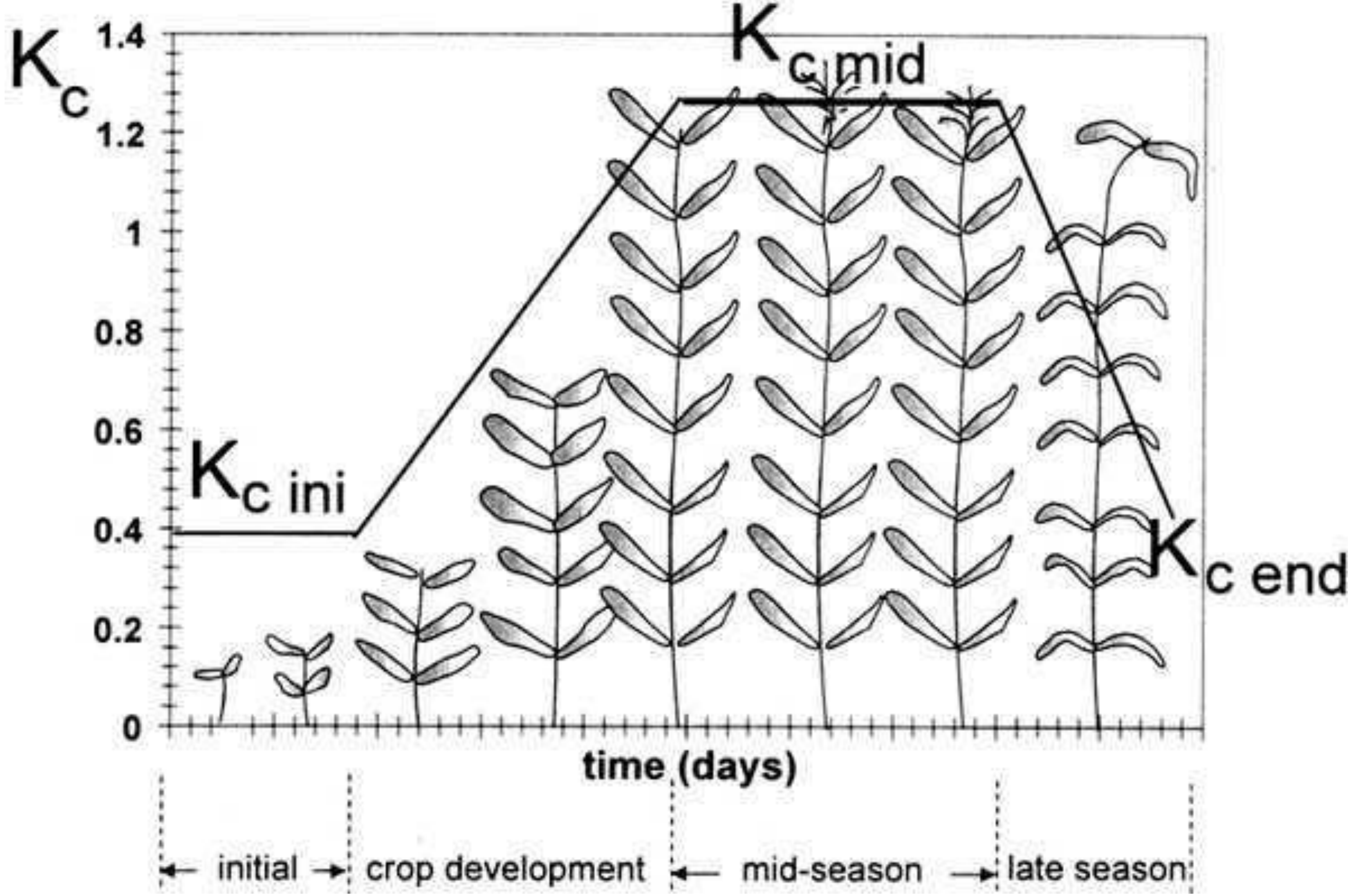
ETo – Reference crop evapotranspiration
(Imaginary/hypothetocal grass cover)

Kc – Crop Coefficient (Under standard conditions)

Need to adjust the Crop Coefficient for field conditions

$ETc_{adj} = ETo * Kc_{adj}$

- Single and dual crop coefficicieint approach


K c
1.4
1.2
1
0.8
0.6
0.4
0.2
0
K c mid
K c ini
K c end
time (days)
initial
crop development
mid-season
late season

- Dual Crop Coefficient Approach
-

Soil evaporation   Crop Transpiration

Need to calculate ETc for each growth stage

In the designing of irrigation systems, maximum water requirement has to be considered

$ET_o = E_P * K_P$

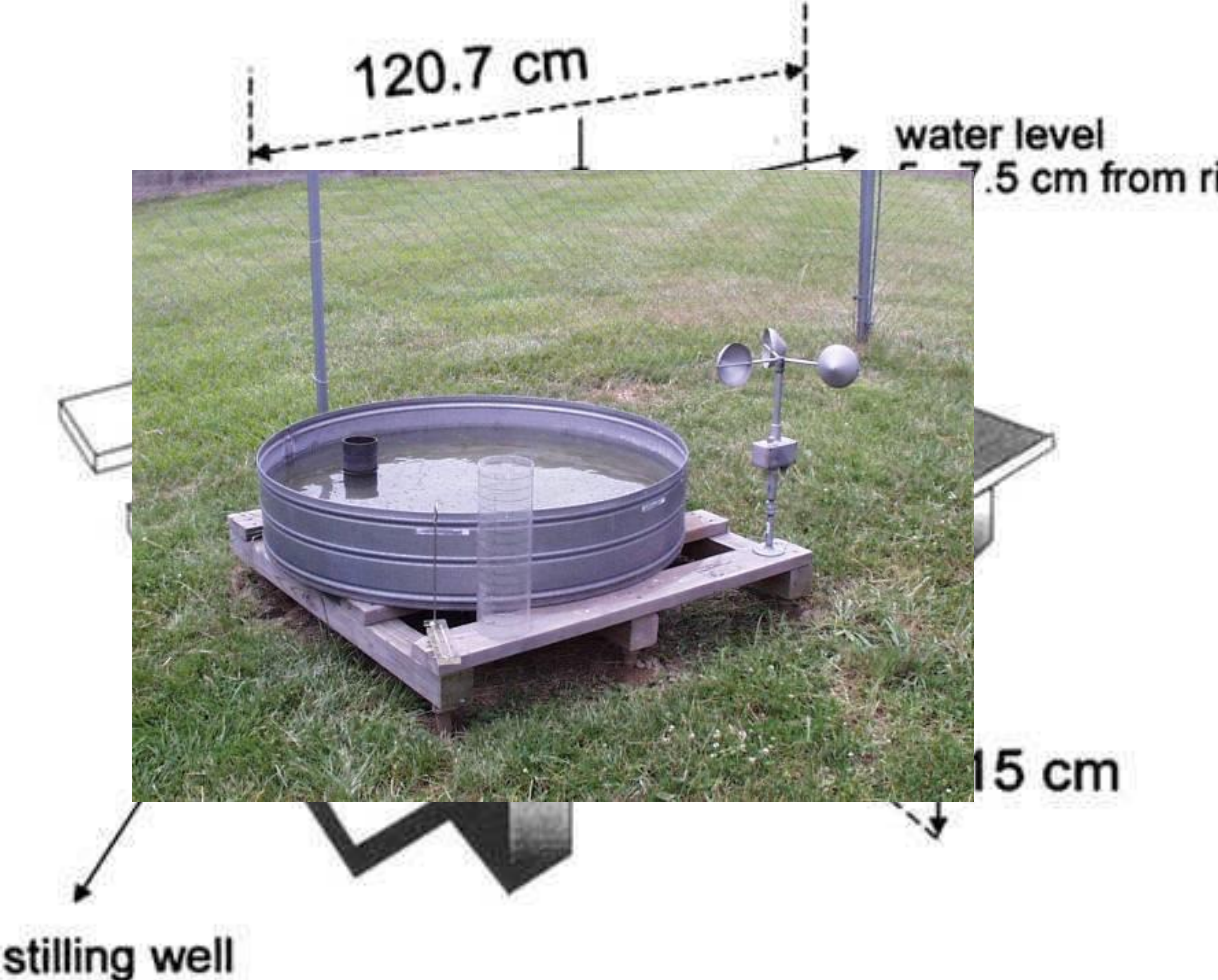
E_P – Pan Evaporation

K_P – Pan Coefficient

or

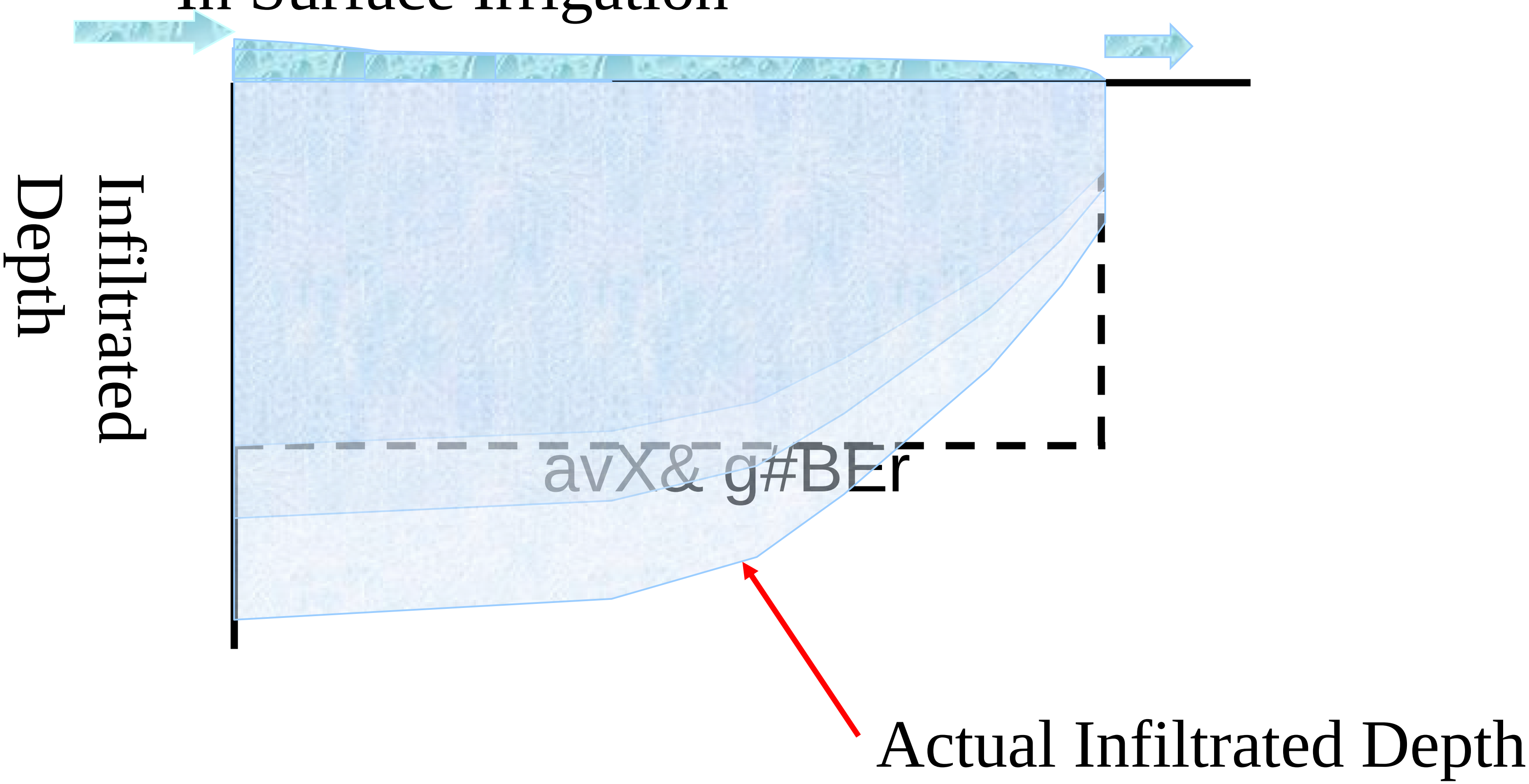
When we have weather data, models like Penman, Penman-Monteith can be used to estimate ET_o

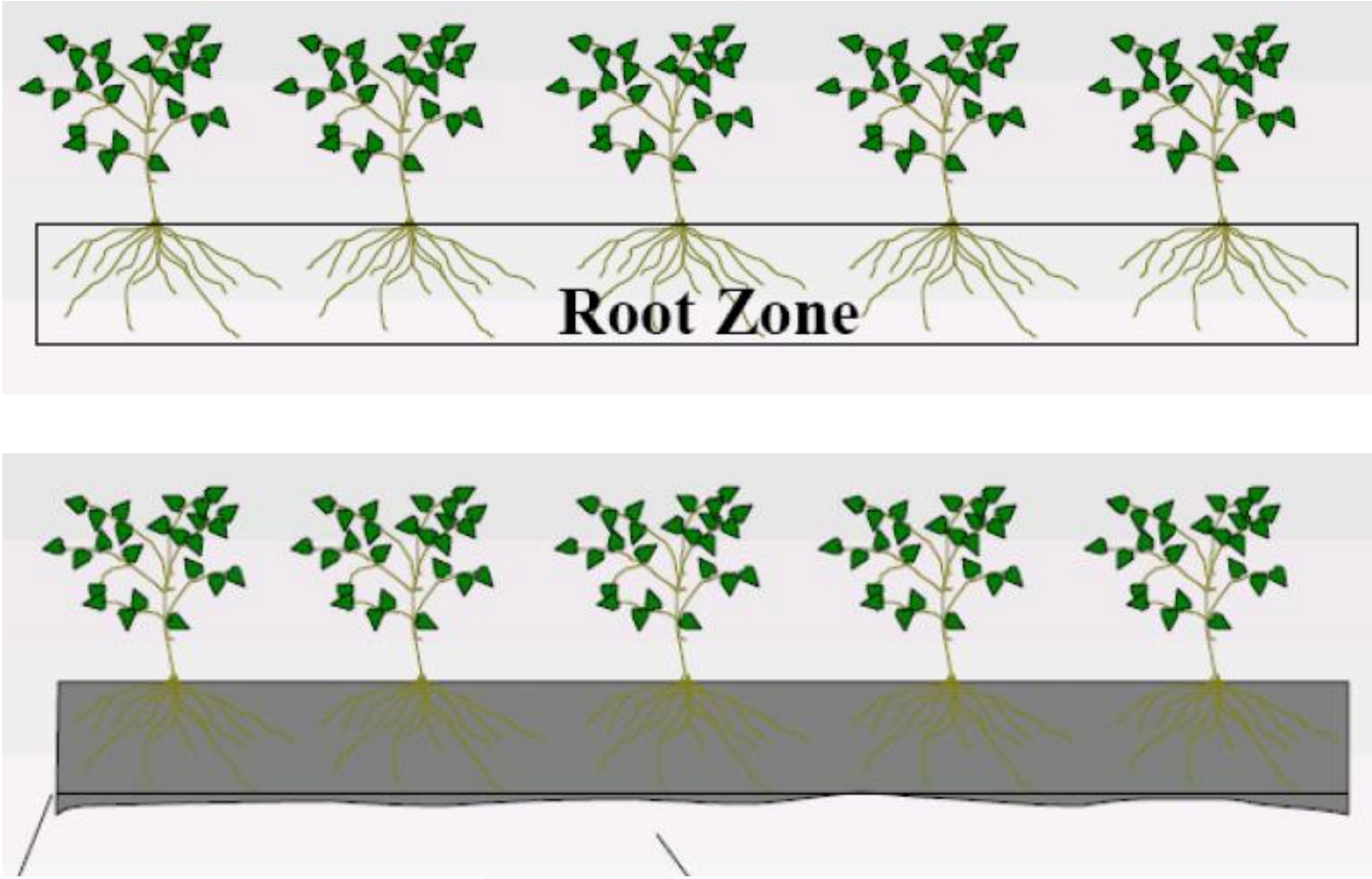
FAO recommends Penman-Monteith


120.7 cm
water level
.5 cm from ri
15 cm
stilling well

Water Loss and Efficiency

- Water application Uniformity:
  - Can measure whether the water is applied uniformly in the field
  - In Surface Irrigation

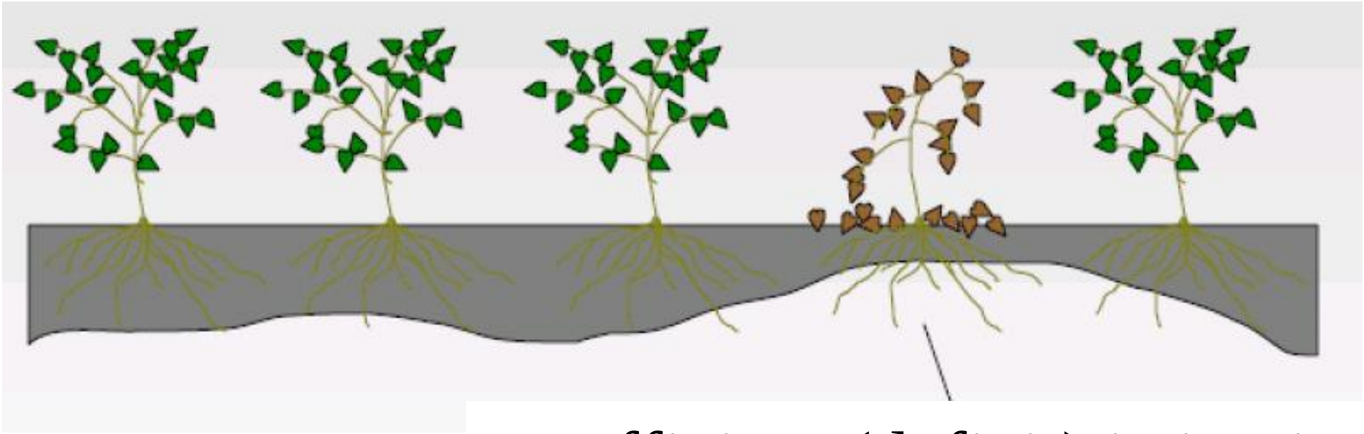




Sufficient Irrigation

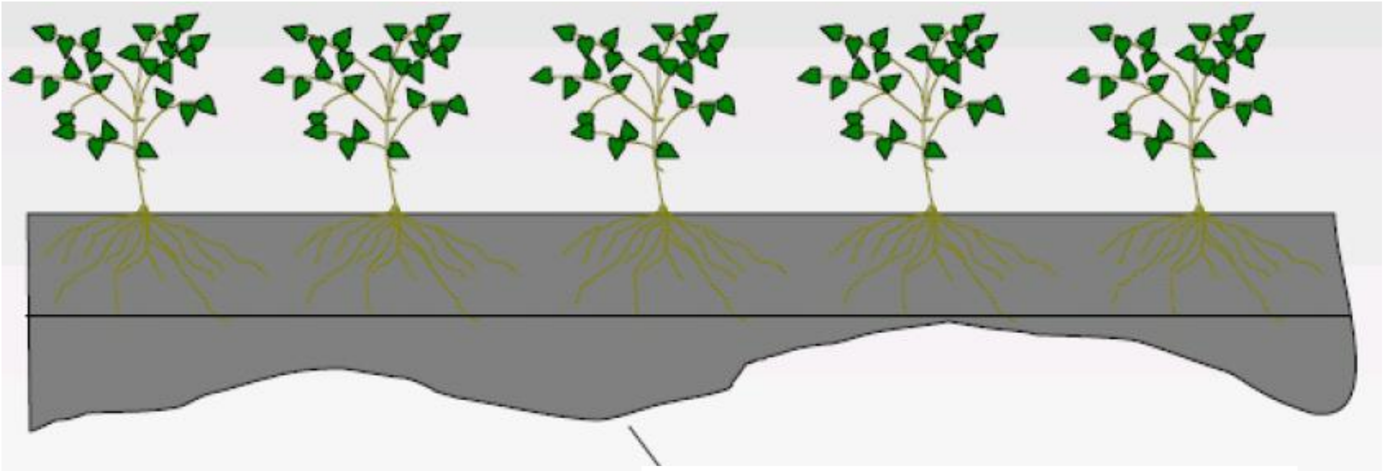
We cannot expect 100% Uniformity

Uniform and efficient water applictaion



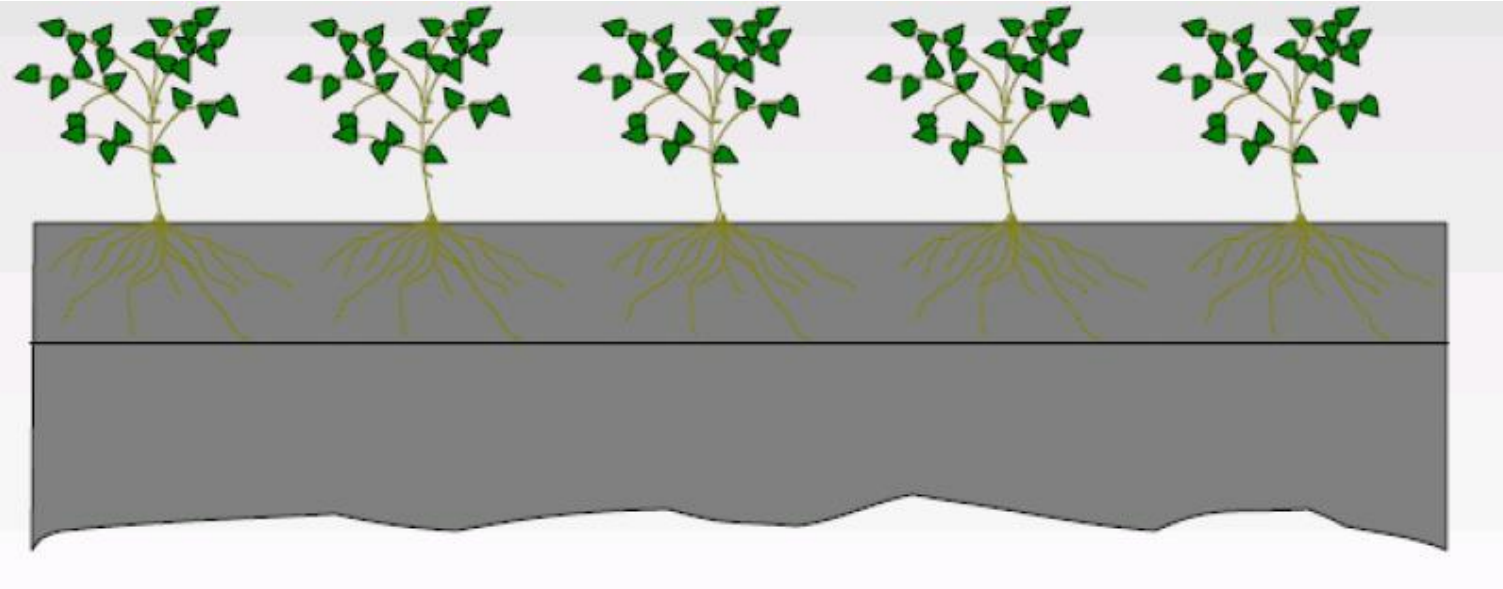
Insufficient (deficit) irrigation

Non-uniform inefficient irrigation



Over irrigation

Non-uniform inefficient irrigation



Non-uniform and inefficient irrigation

- **Distribution Uniformity (U_d):**
  - Percentage of average application amount received in the least watered quarter

$$U_d = \left(\frac{L_q}{X_m} \right) 100$$

L_q –- Depth infiltrated in the lowest quarter (depth caught)

X_m –- Average Depth infiltrated (depth caught)

Gives a clue on distribution

This index do not give any idea on the amount lost or deficit in irrigation requirement

- **Water Distribution Efficiency (Ed)** :
  - percentage of the average application depth delivered to the least-watered part of the field.

$$Ed = \left(1 - \frac{y}{d}\right)100$$

y - Average absolute numerical deviation in depth of water stored from average depth stored during the irrigation

$$\sum \left| x_i - \bar{x} \right| / n$$

d - Average depth of water stored during irrigation

$$\sum x_i / n$$

indicates the degree of uniformity

- **Water Application Efficiency (Ea)**

$$E_a = \frac{Average\ depth\ added\ to\ the\ root\ zone\ storage}{Average\ depth\ applied\ to\ the\ field}$$

- Gives a general idea on the function of an irrigation system
  - possible to have a high Ea but have the irrigation water so poorly distributed
  - possible to have nearly 100 % Ea but have crop failure if the soil profile is not filled sufficiently to meet crop water requirements.
  - does not include
    - losses due to seepage
    - demarcation between tail water runoff and deep percolation

- **Water Conveyance Efficiency** (Ec):

$$Ec = \left(\frac{Wf}{Ws}\right)100$$

Wf - Water delivered to field

Ws - Water diverted from source

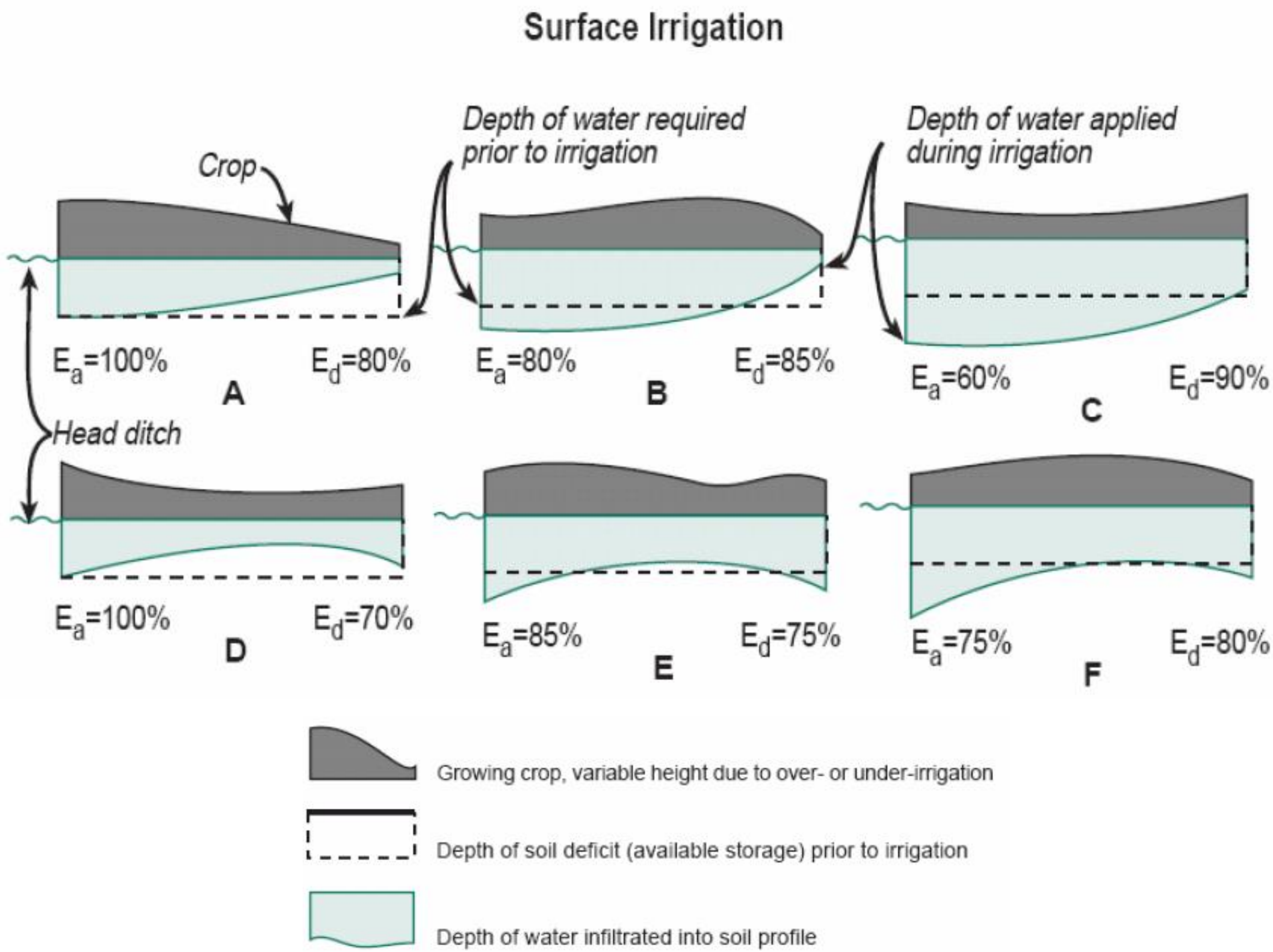
- **Water Use Efficiency** (Eu):

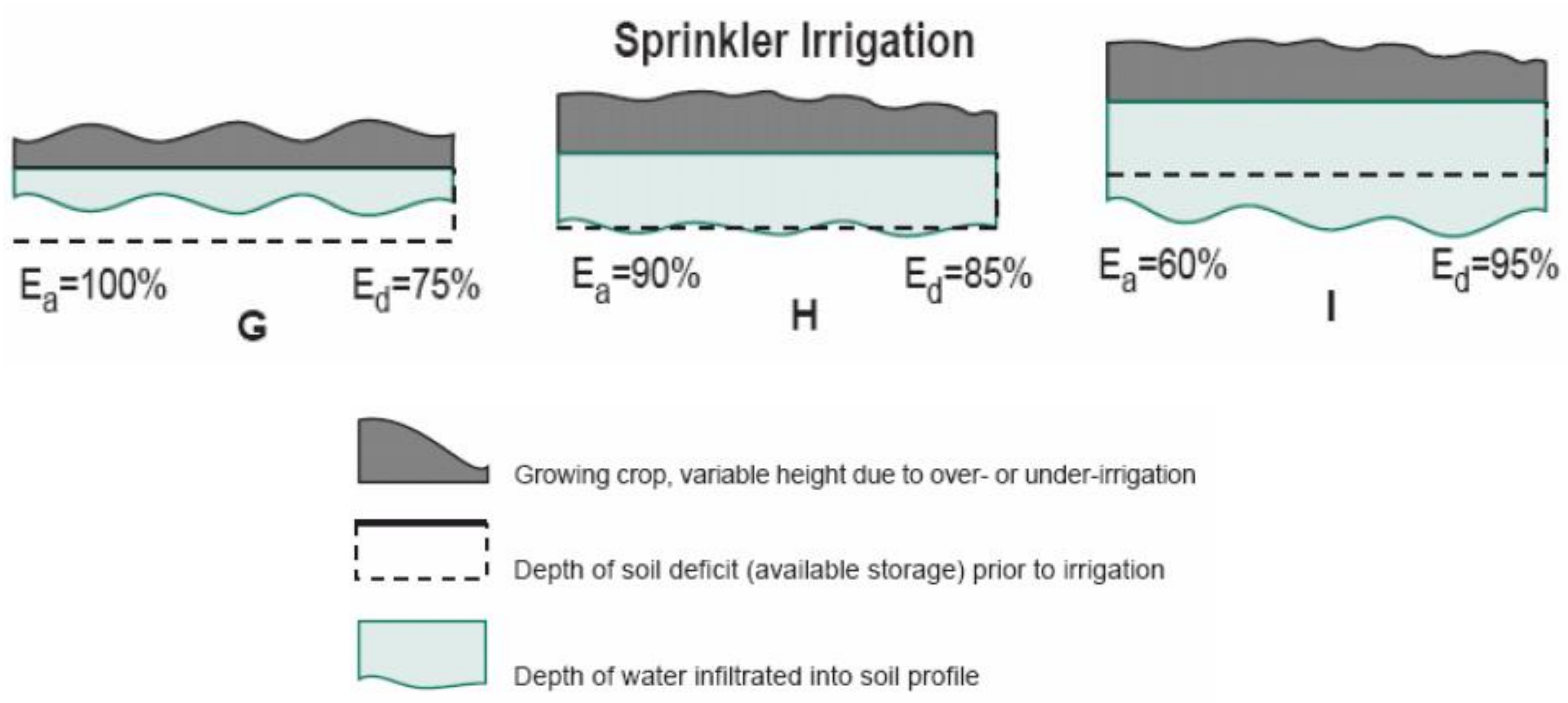
$$Eu = \left(\frac{Wb}{Wf}\right)100$$

Wb- Water used beneficially

Wf - Water delivered to field

Other beneficial uses could include salt leaching, crop cooling, pesticide or fertilizer applications, or frost protection.


Surface Irrigation
Crop
Depth of water required prior to irrigation
Depth of water applied during irrigation
Head ditch
E_a=100%
E_d=80%
A
E_a=80%
E_d=85%
B
E_a=60%
E_d=90%
C
E_a=100%
E_d=70%
D
E_a=85%
E_d=75%
E
E_a=75%
E_d=80%
F
Growing crop, variable height due to over- or under-irrigation
Depth of soil deficit (available storage) prior to irrigation
Depth of water infiltrated into soil profile


Sprinkler Irrigation
Ea=100%
Ed=75%
G
Ea=90%
Ed=85%
H
Ea=60%
Ed=95%
I
Growing crop, variable height due to over- or under-irrigation
Depth of soil deficit (available storage) prior to irrigation
Depth of water infiltrated into soil profile

- **Water requirement efficiency** (E_r):

$$E_r = \frac{\text{Volume of water added to root zone storage}}{\text{Potential soil moisture storage volume}}$$

- indicator of how well the irrigation meets its objective of refilling the root zone.

- **Deep percolation ratio** (DPR):

$$\textbf{DPR} = \frac{\text{Volume of deep percolation}}{\text{Volume of water applied to the field}}$$

- **Tailwater ratio** (TWR):

$$\textbf{TWR} = \frac{\text{Volume of runoff}}{\text{Volume of water applied to the field}}$$

When ?

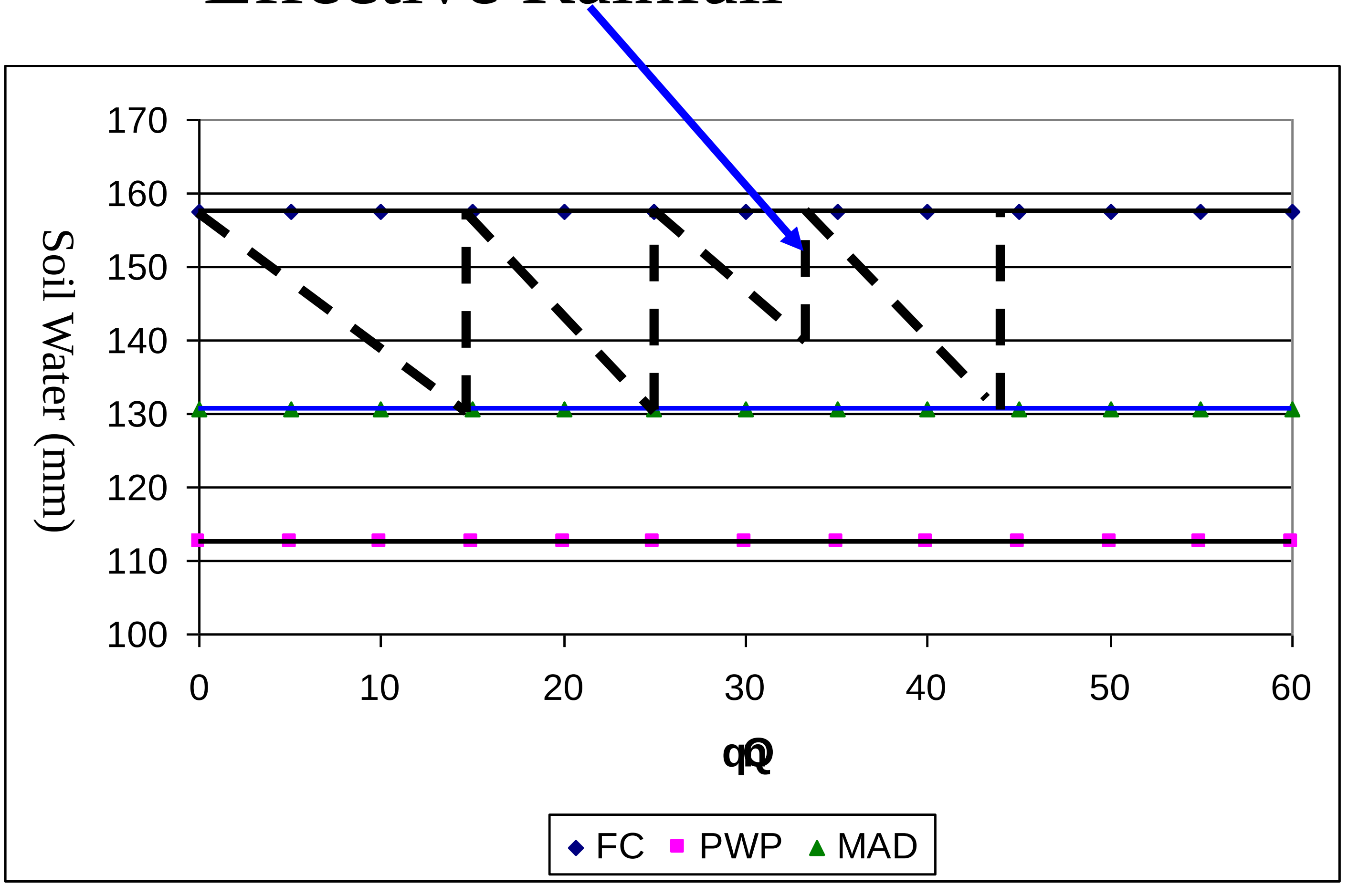
- Irrigation Interval =

  Net Irrigation Requirement / Crop Water Requirement

  Crop Water Requirement:

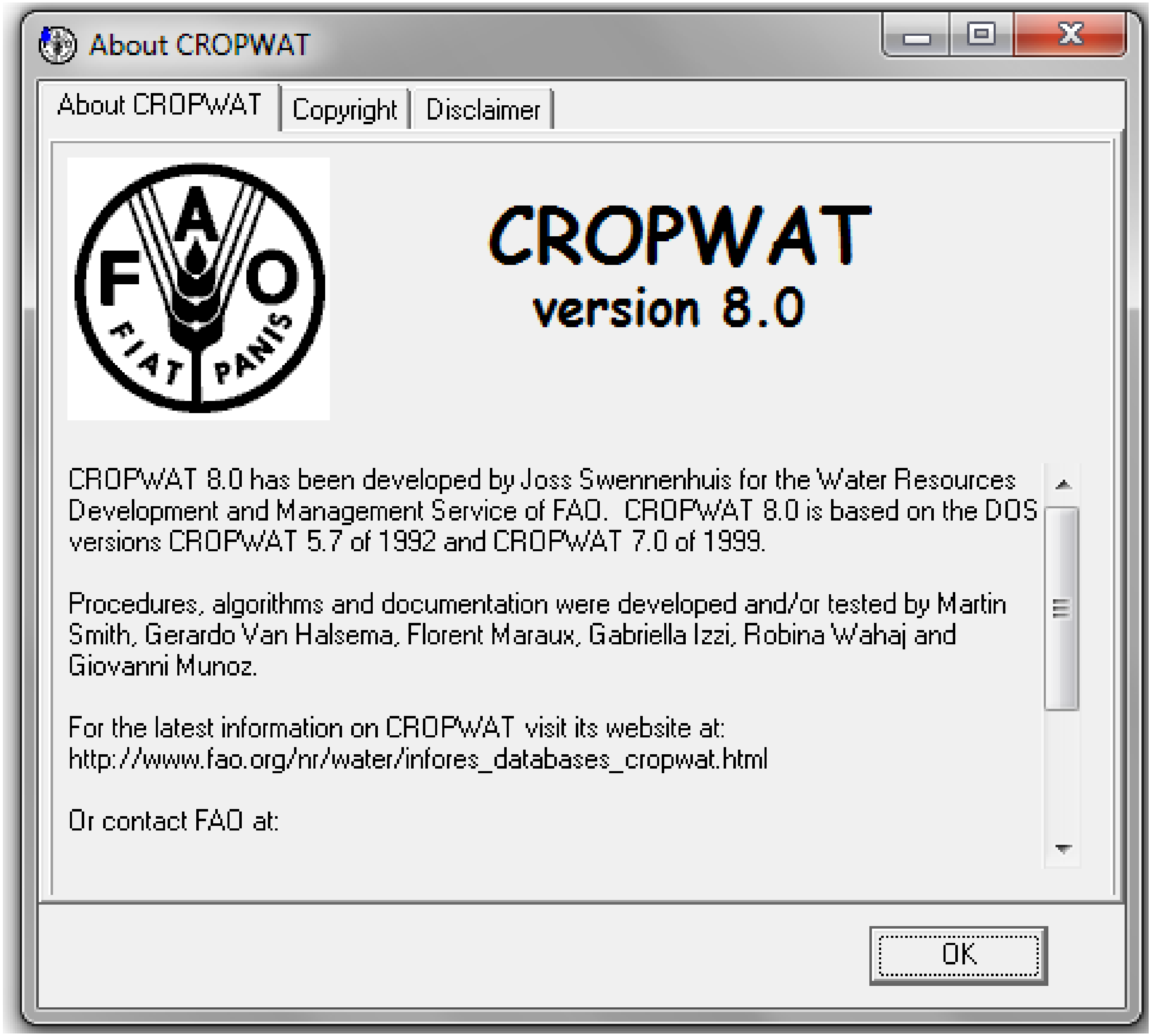
  – Varies according to crop and its growth stage

- Irrigation Schedule
    - Effective Rainfall



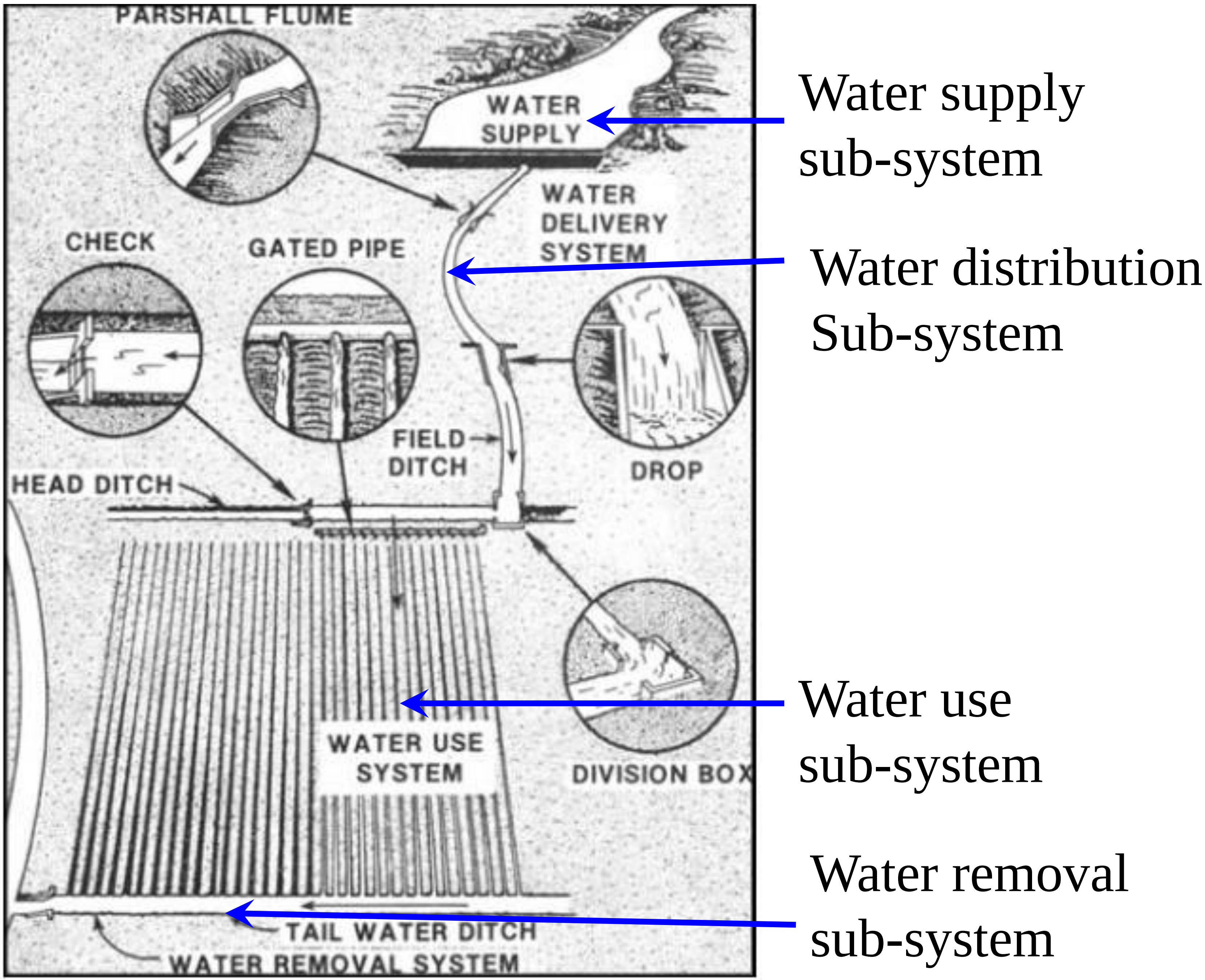
- All the calculations related to irrigation can be done using a computer software

CropWat


About CROPWAT
About CROPWAT
Copyright
Disclaimer
F A O
FIAT PANIS
CROPWAT
version 8.0
CROPWAT 8.0 has been developed by Joss Swennenhuis for the Water Resources Development and Management Service of FAO. CROPWAT 8.0 is based on the DOS versions CROPWAT 5.7 of 1992 and CROPWAT 7.0 of 1999.
Procedures, algorithms and documentation were developed and/or tested by Martin Smith, Gerardo Van Halsema, Florent Maraux, Gabriella Izzi, Robina Wahaj and Giovanni Munoz.
For the latest information on CROPWAT visit its website at: http://www.fao.org/nr/water/infores_databases_cropwat.html
Or contact FAO at:
OK

How?

- Any irrigation system should fulfill the following
  - Supply required amount of water
  - Distribute water uniformly within the root zone
  - Maintain minimum soil erosion and other losses
  - Maximum efficiency during water usage
  - Provide economic benefits

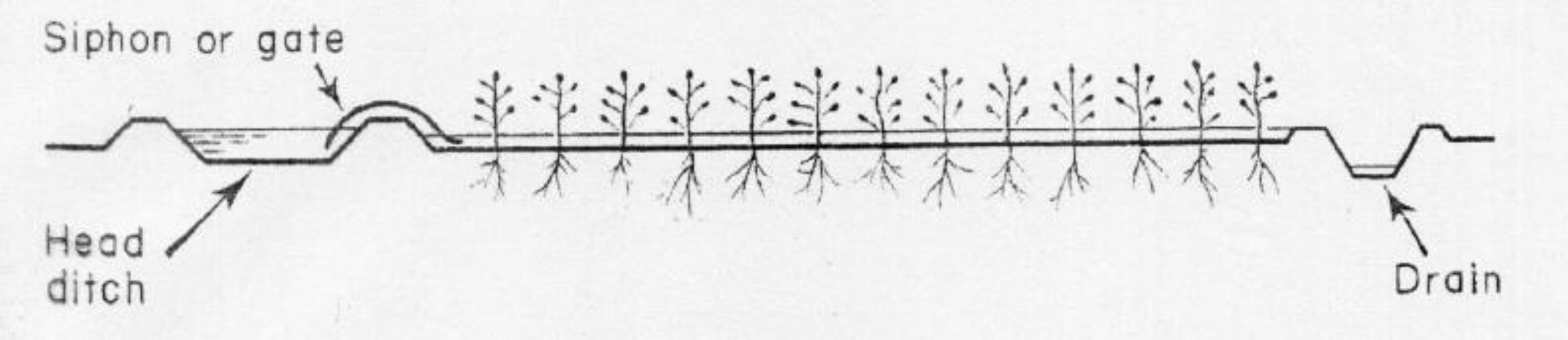

PARSHALL FLUME
WATER SUPPLY
WATER DELIVERY SYSTEM
CHECK
GATED PIPE
FIELD DITCH
DROP
HEAD DITCH
WATER USE SYSTEM
DIVISION BOX
TAIL WATER DITCH
WATER REMOVAL SYSTEM
Water supply sub-system
Water distribution Sub-system
Water use sub-system
Water removal sub-system

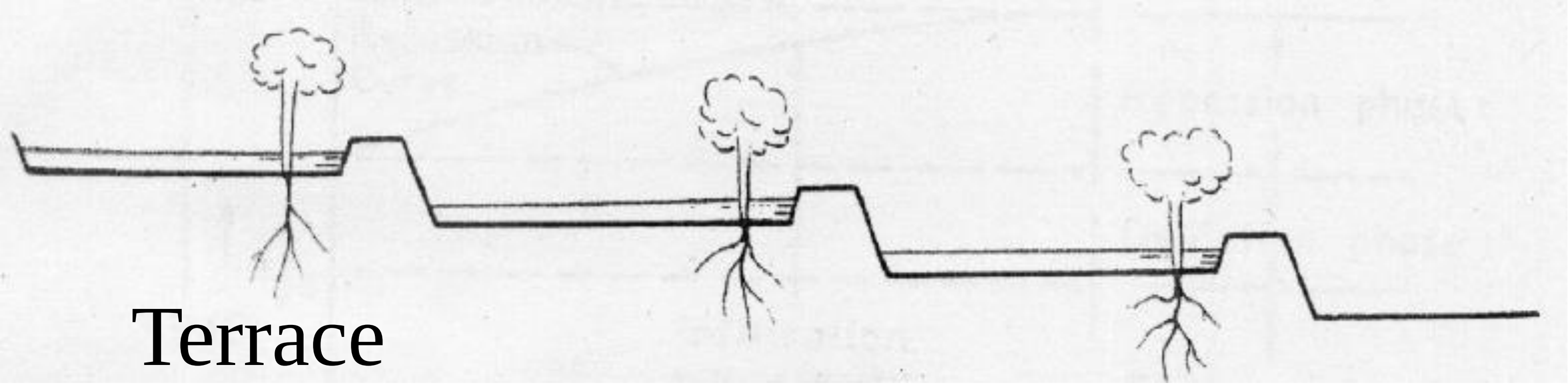
Irrigation methods

- Flood irrigation methods
  - Basin
  - Border
  - Ridge and Furrow
- Sub-surface irrigation
- Sprinkler irrigation
- Drip irrigation

Flood irrigation methods

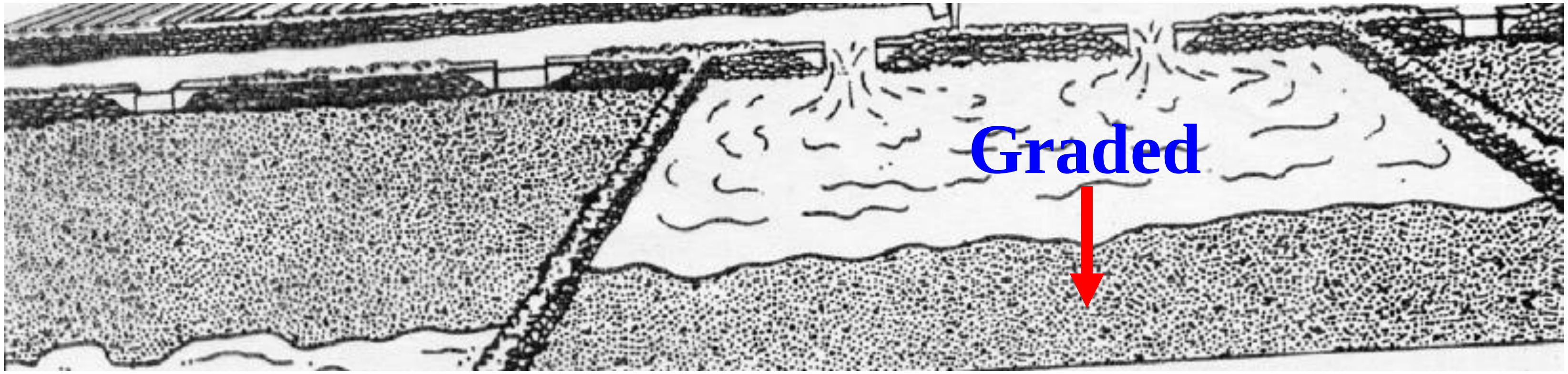
Basin

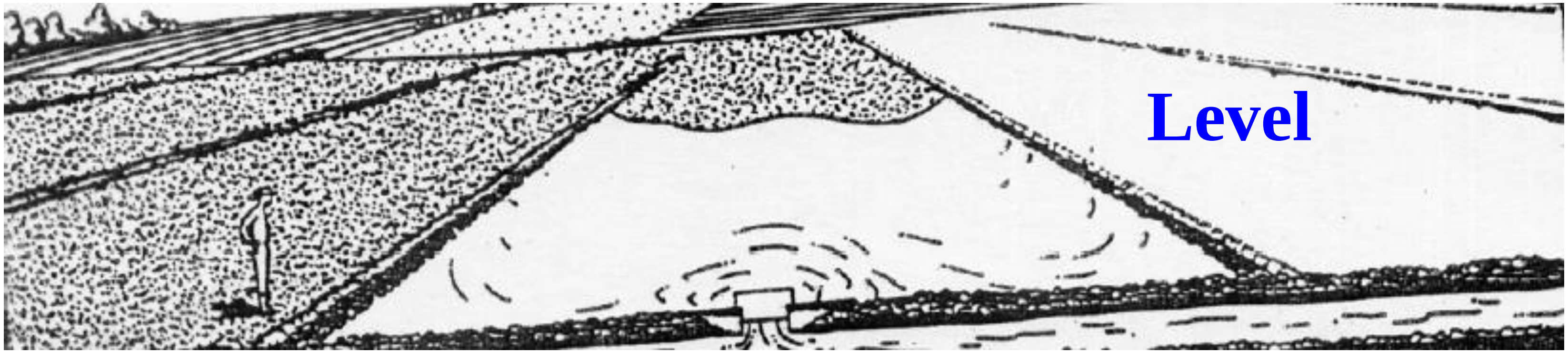


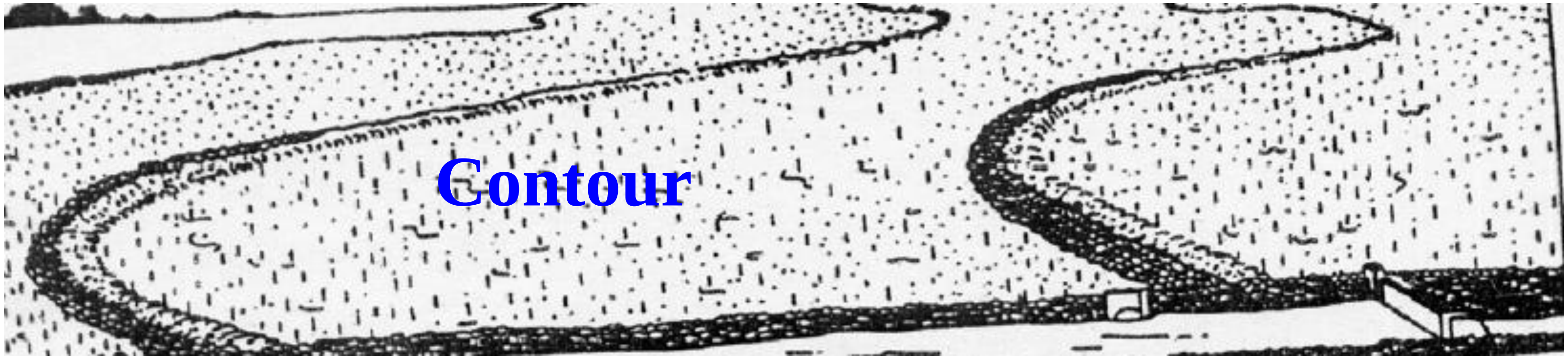


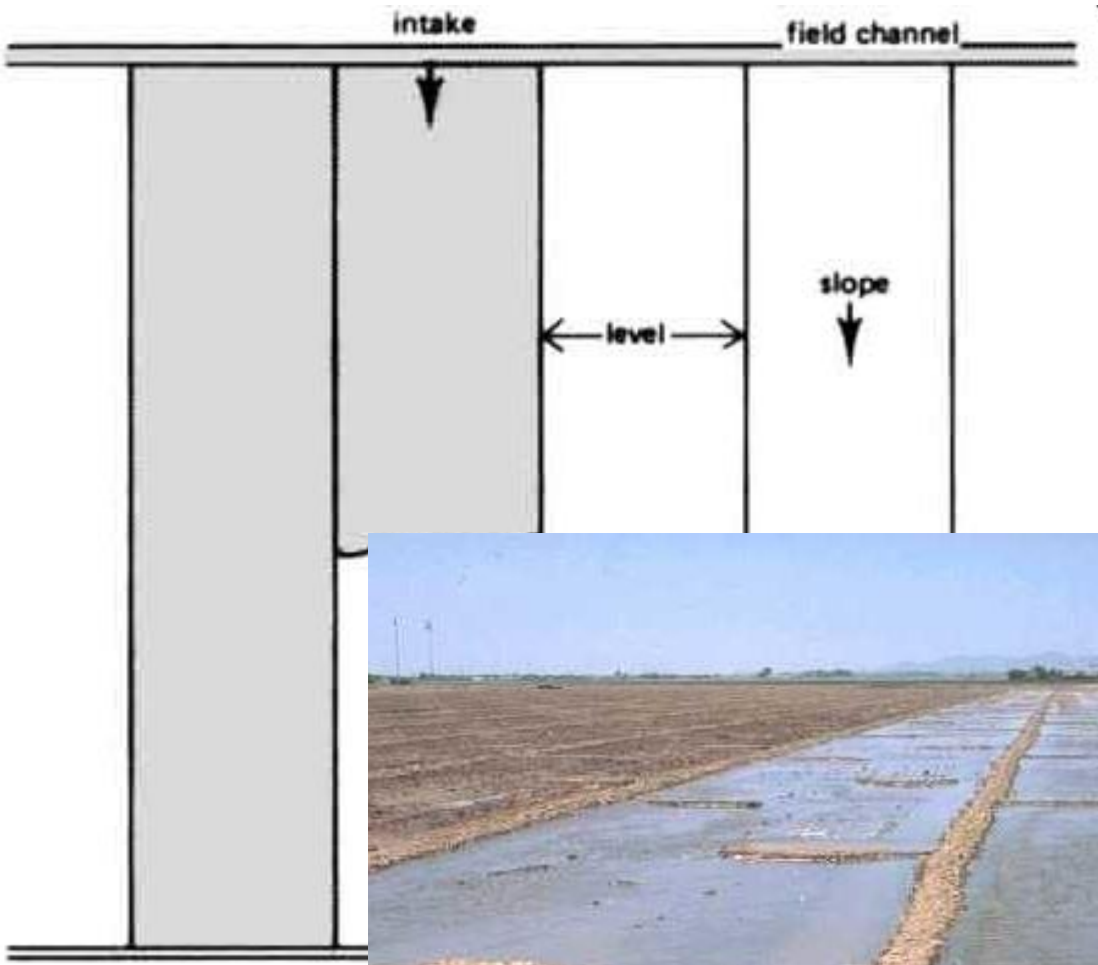
Terrace

Border



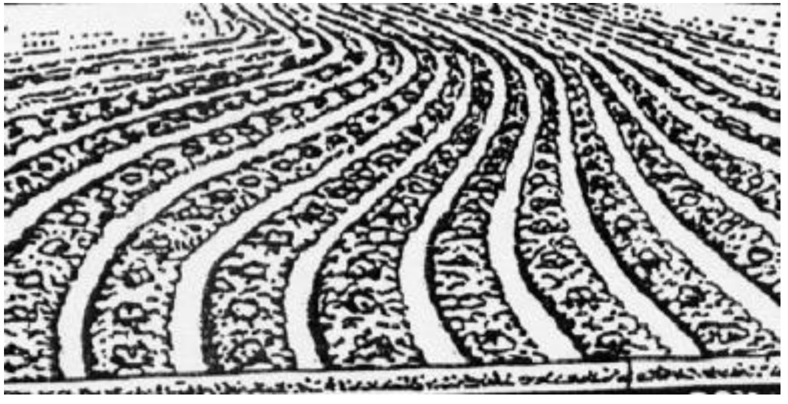




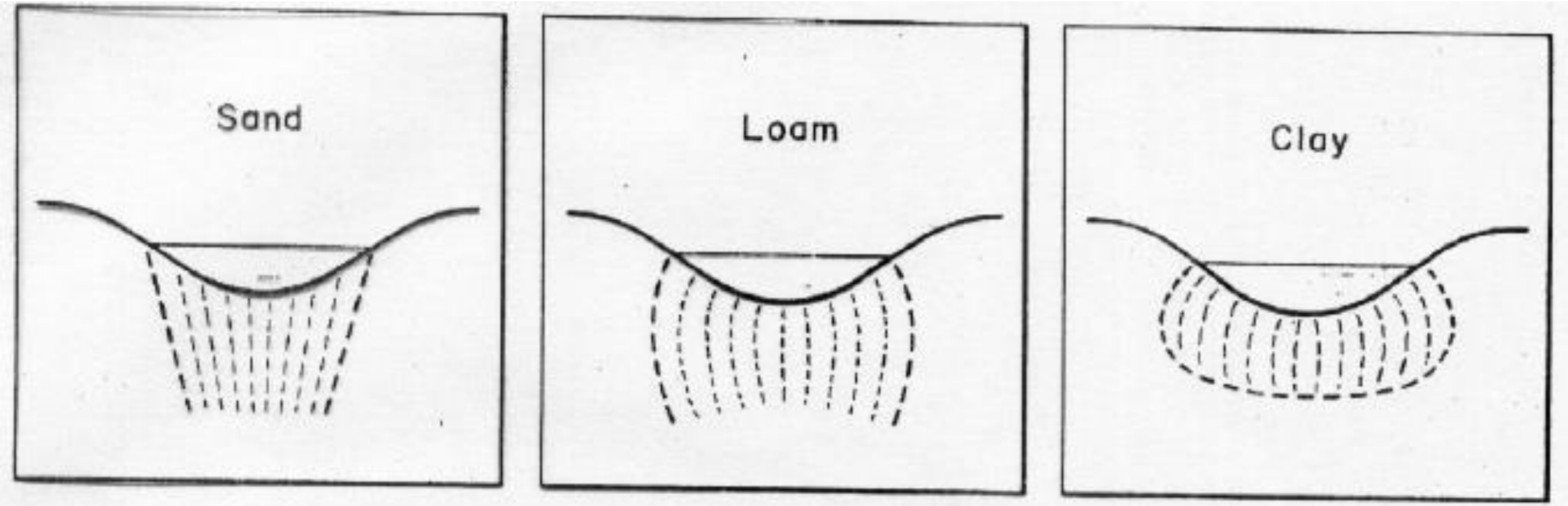

intake
field channel
level
slope


Ridge and Furrow

Level and Graded



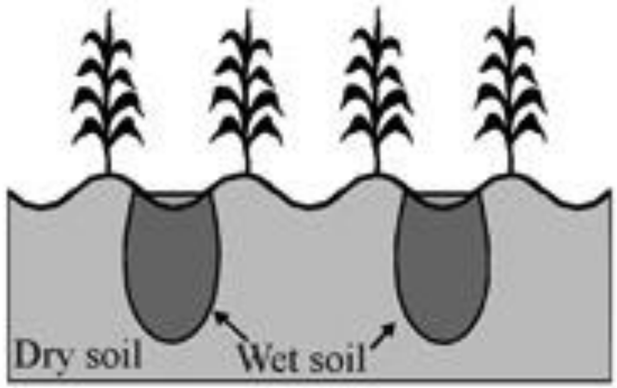
Contour



- Wetting pattern varies with the texture. Accordingly the width and the length has to be decided

Soil A

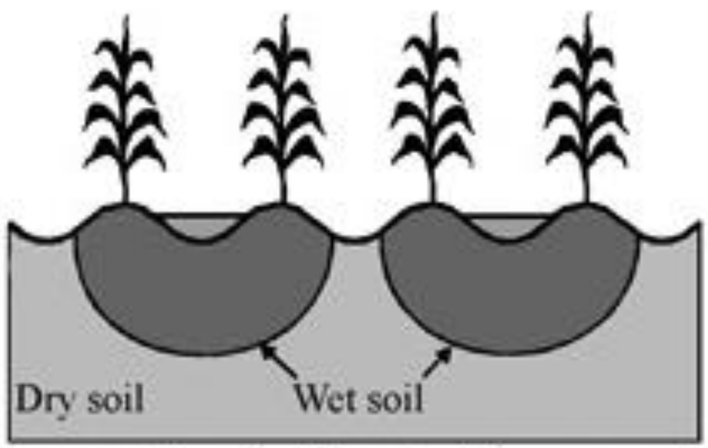
Coarse textured soil



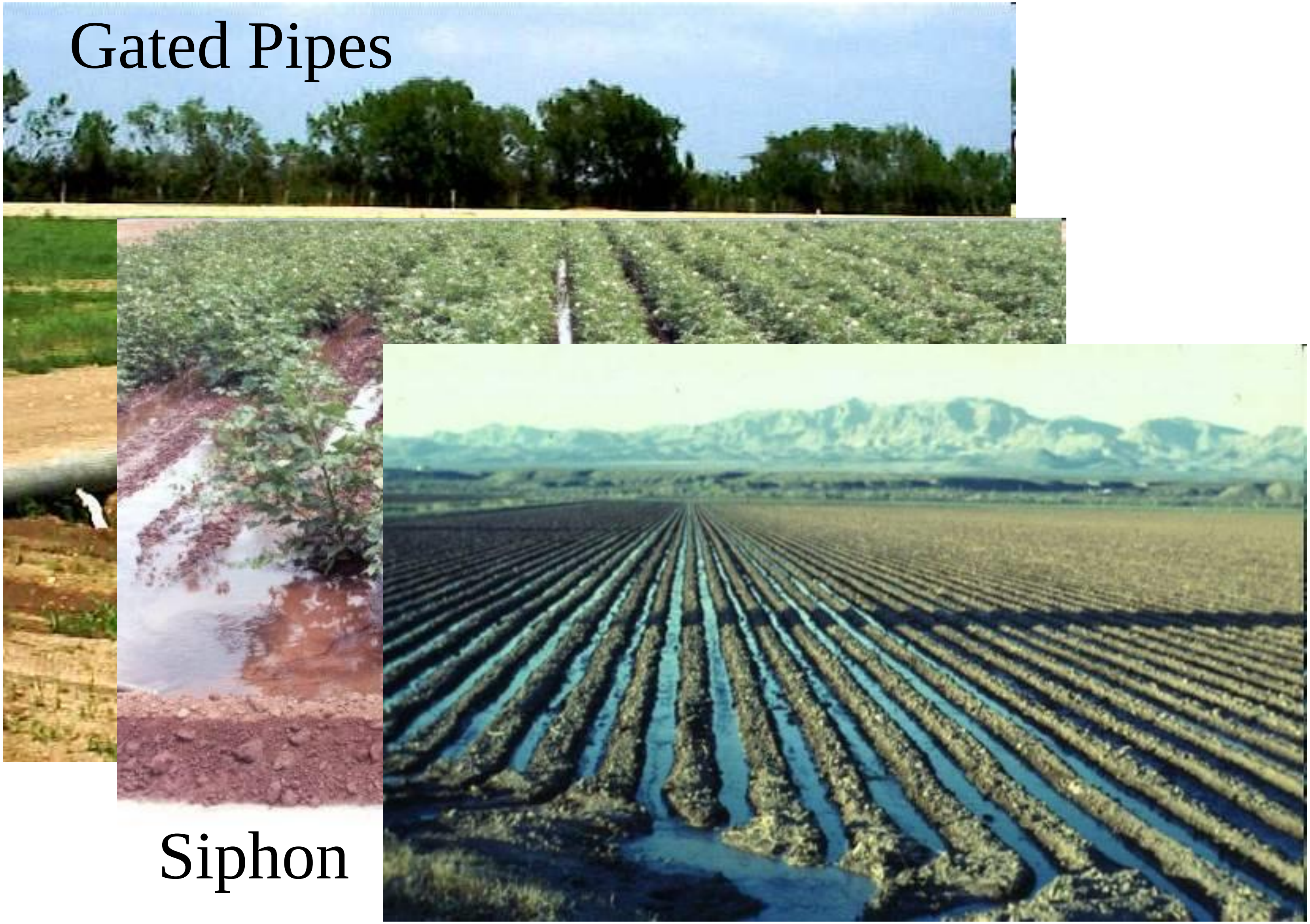
This soil does not provide enough lateral movement for this wetted furrow spacing.

Soil B

Fine textured soil



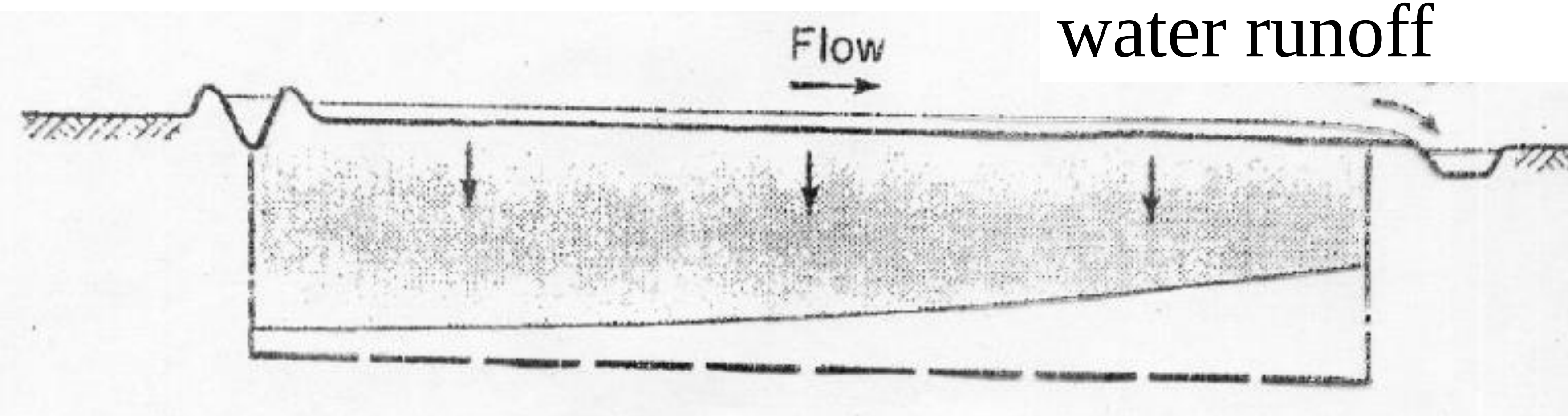
Lateral movement okay for this wetted furrow spacing and soil.

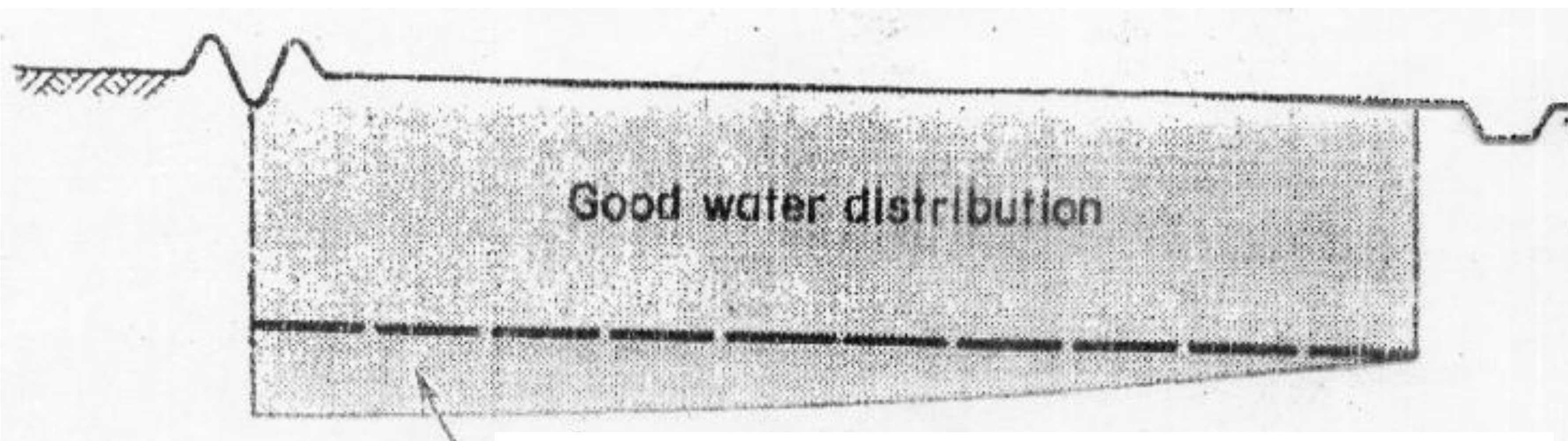


Siphon

Opening the canal bund

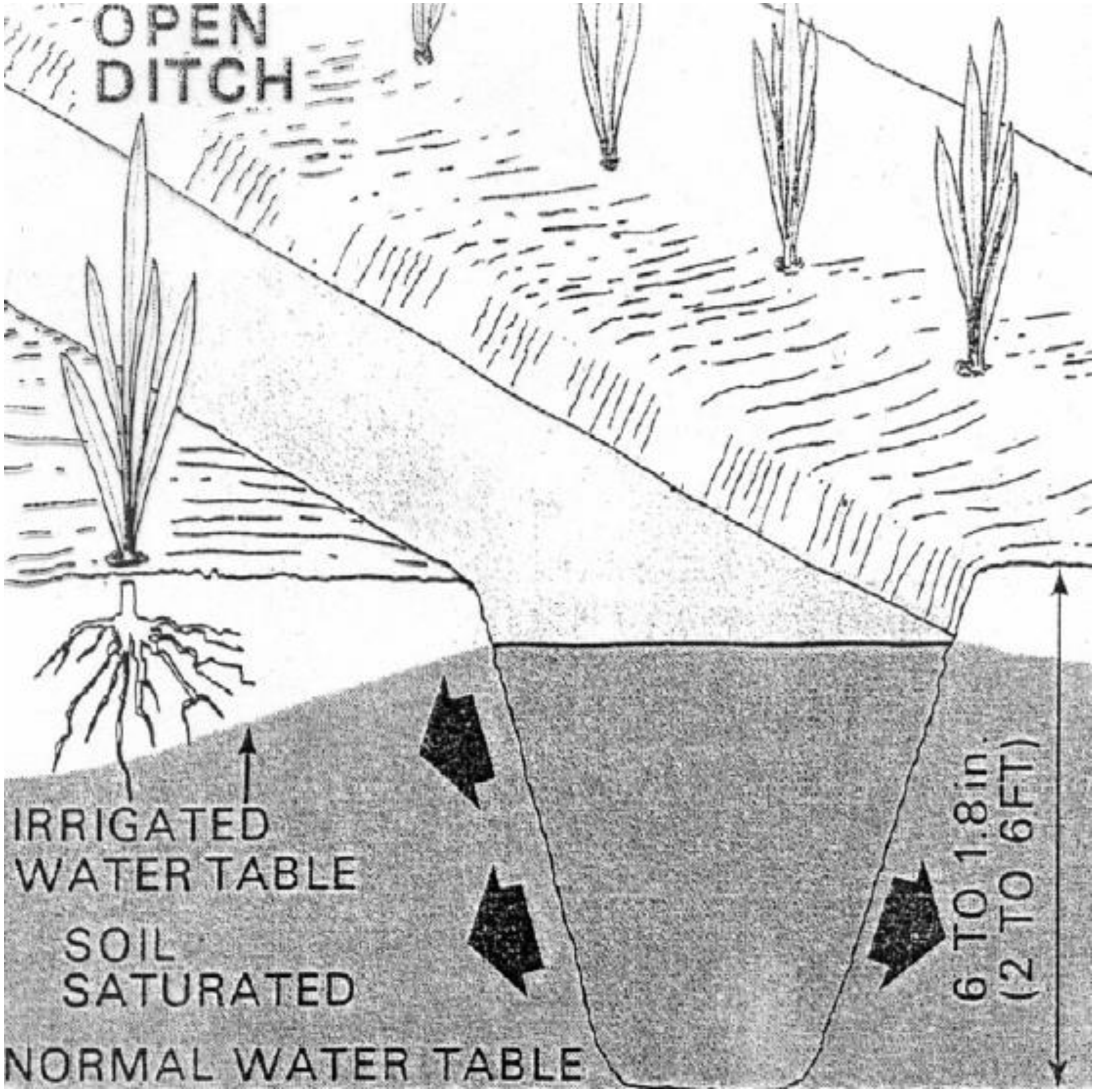
Has to minimize tail water runoff





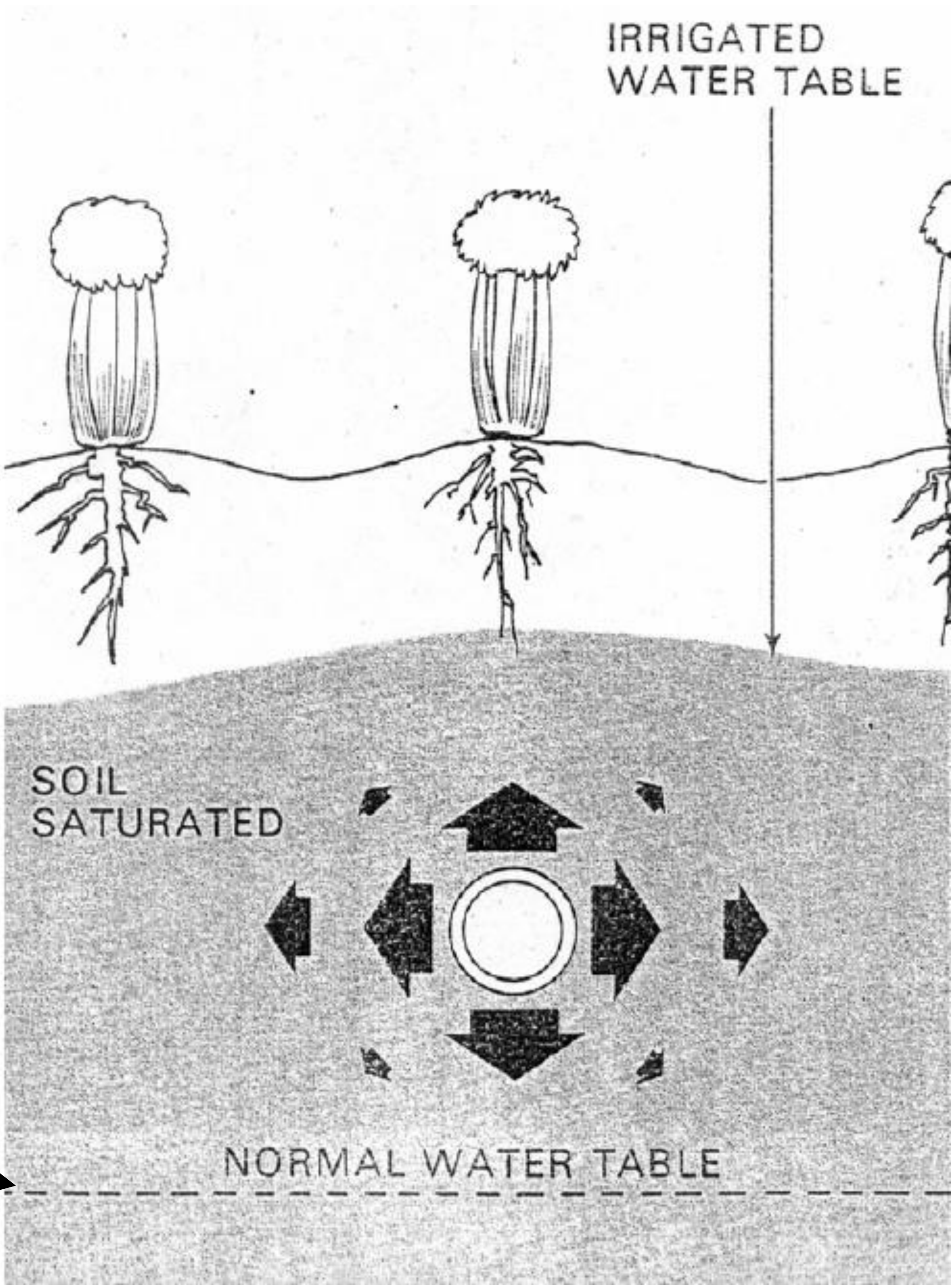
Has to minimize deep percolation

Sub-Surface Irrigation



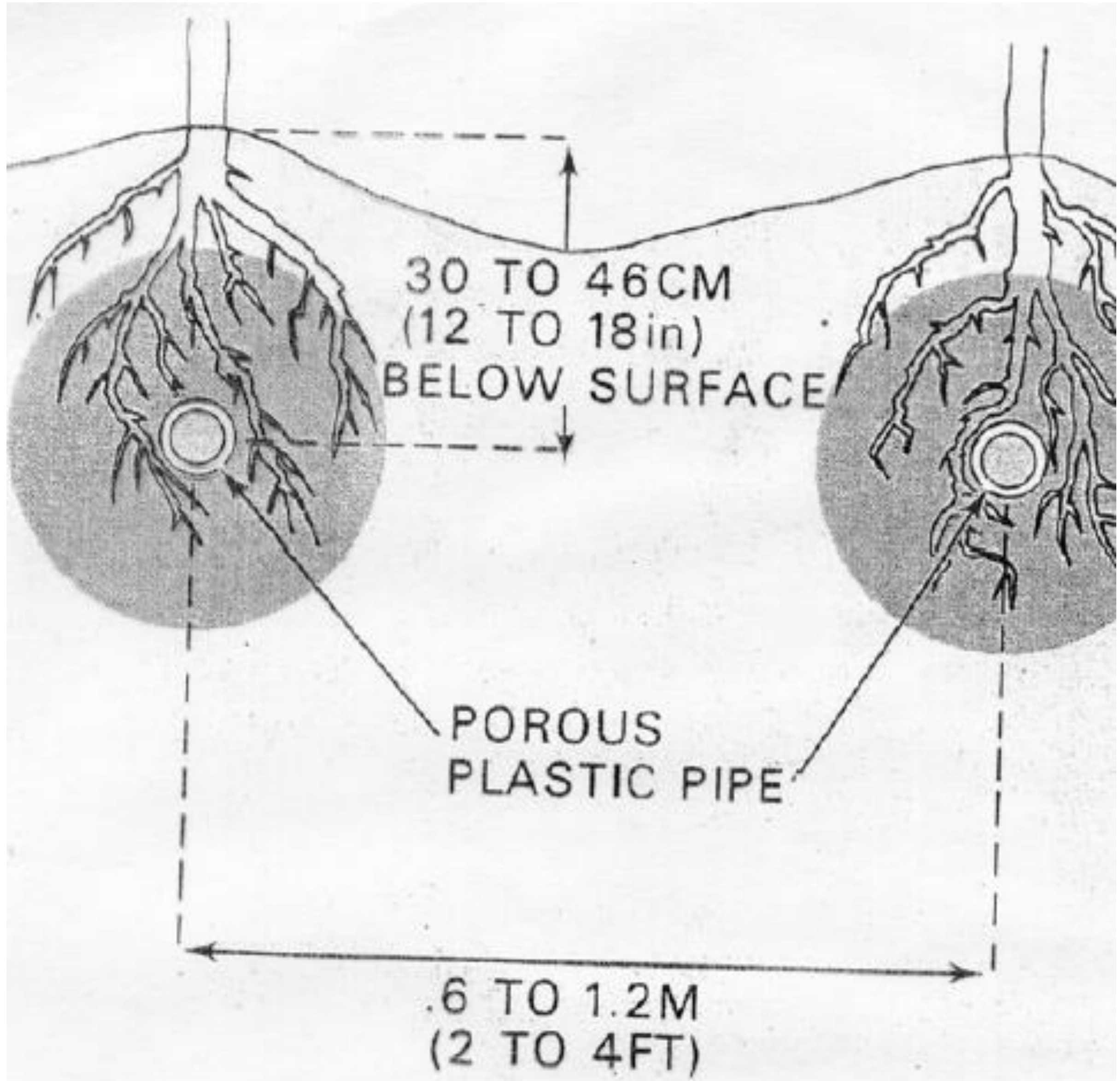
Using open ditches or canal to raise the water table to root zone

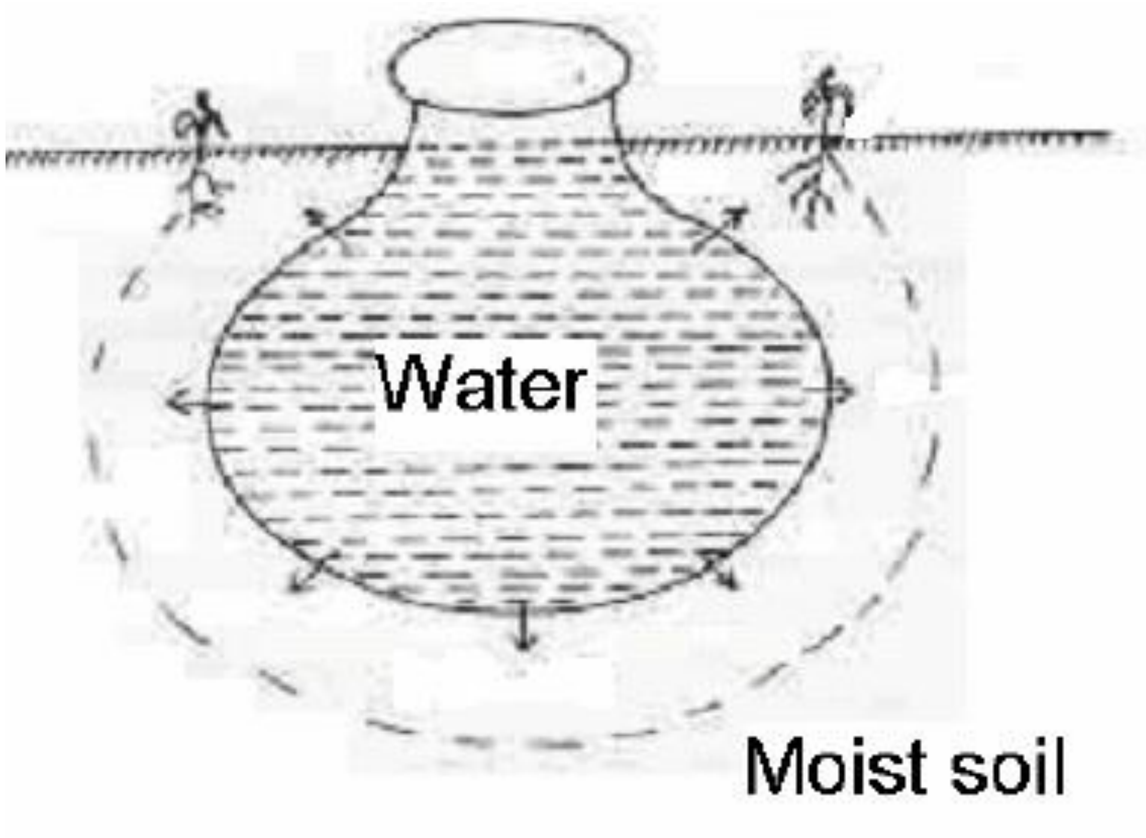
Use of perforated pipe to elevate the groundwater level



Normal Water Table

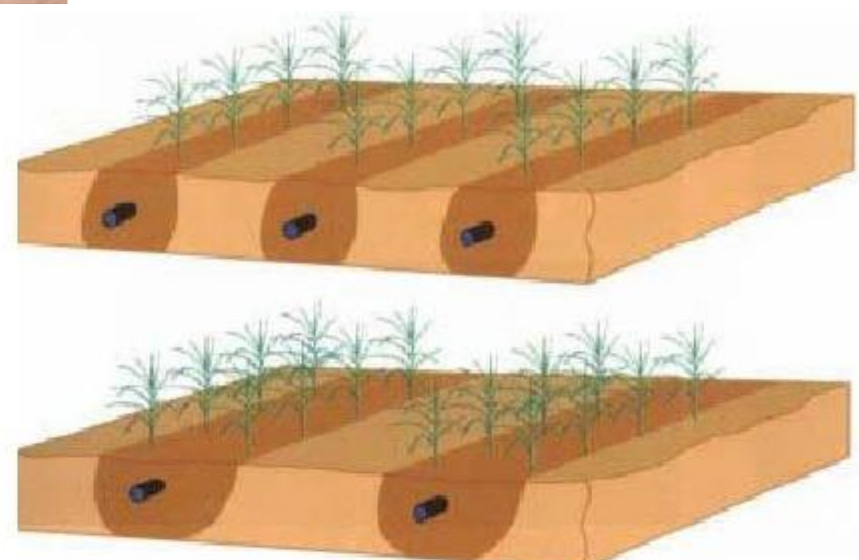
Wetting the root zone by perforated pipes





Pitcher Irrigation

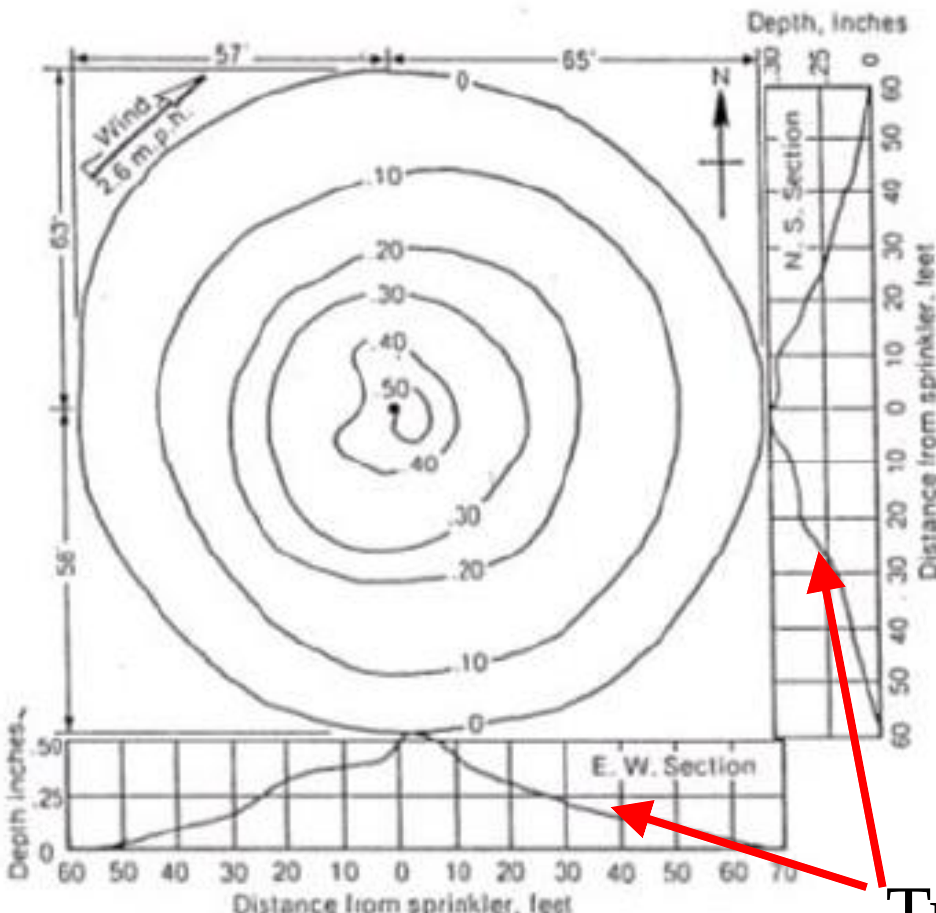
- up p^;~TWy dYQp~ jl sm|p`qny

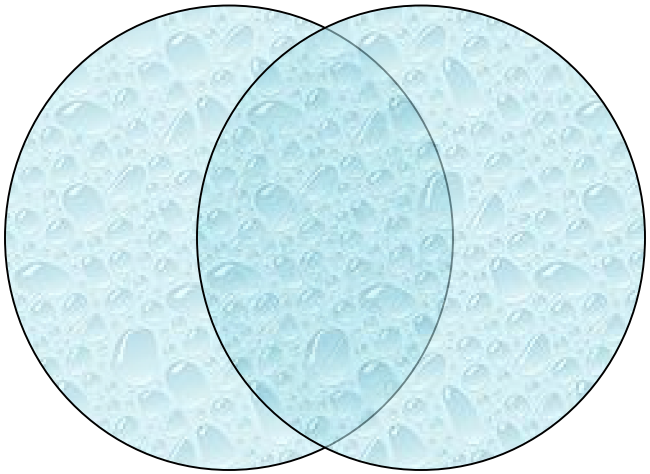


Sprinkler Irrigation

High efficeincy – 50 – 95%

Sprinkler Irrigation





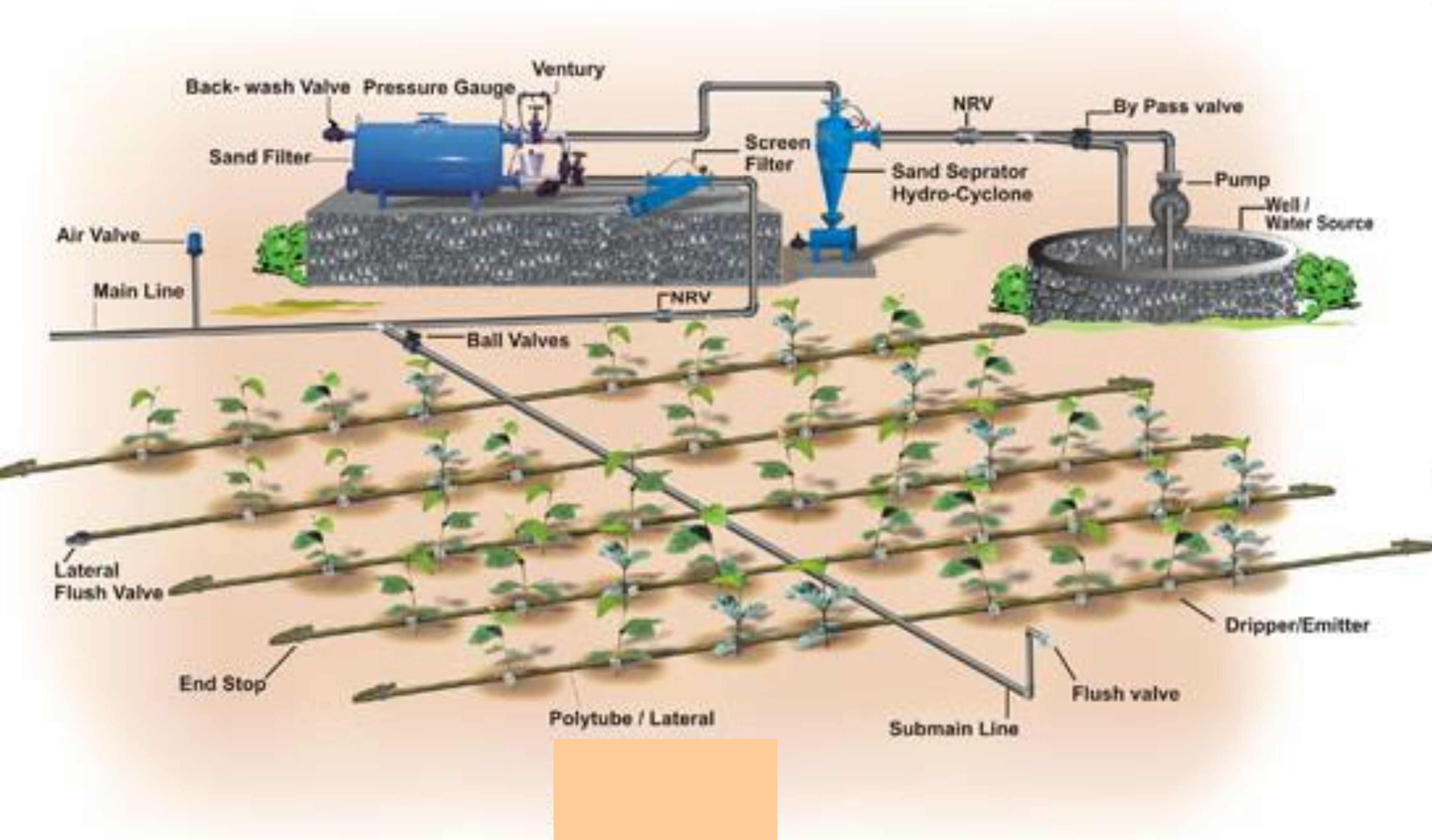
To have uniform wetting
Wetting patterns need to be overlapped

Triangular wetting pattern
(When no wind)

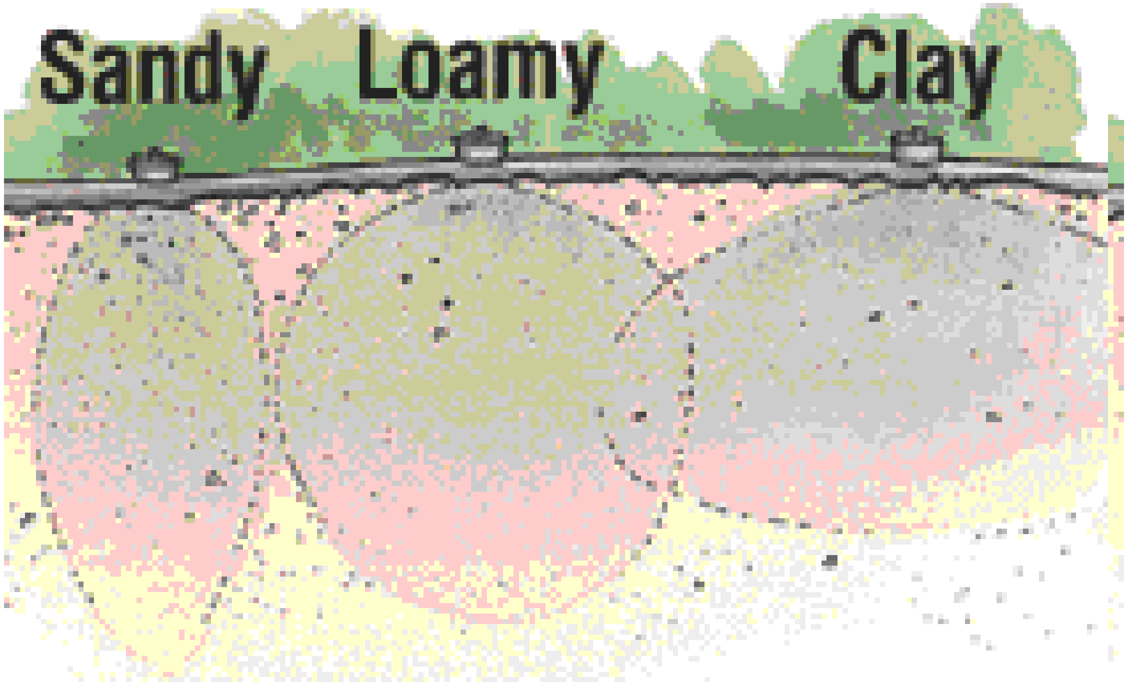
Drip Irrigation

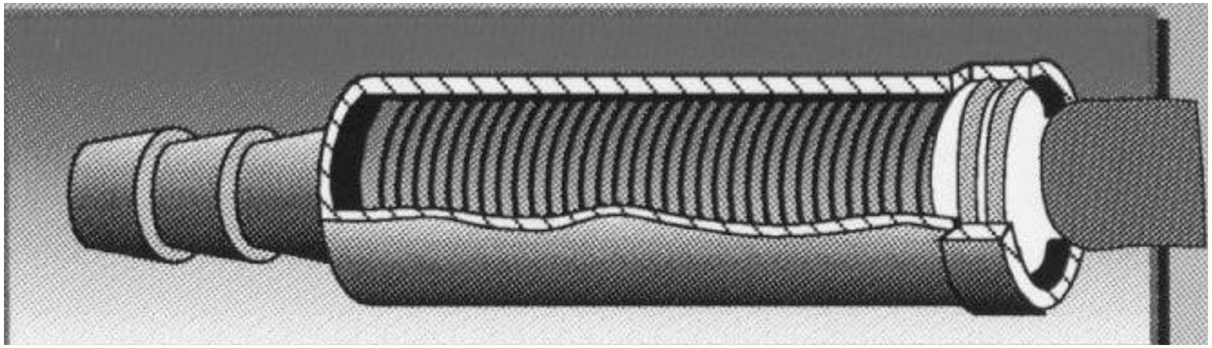
- High efficiency – 75 – 95%
- Suitable for any soil and slopy land
- Can fertigate
- Minimize weed growth
- Can maintain water at optimum level

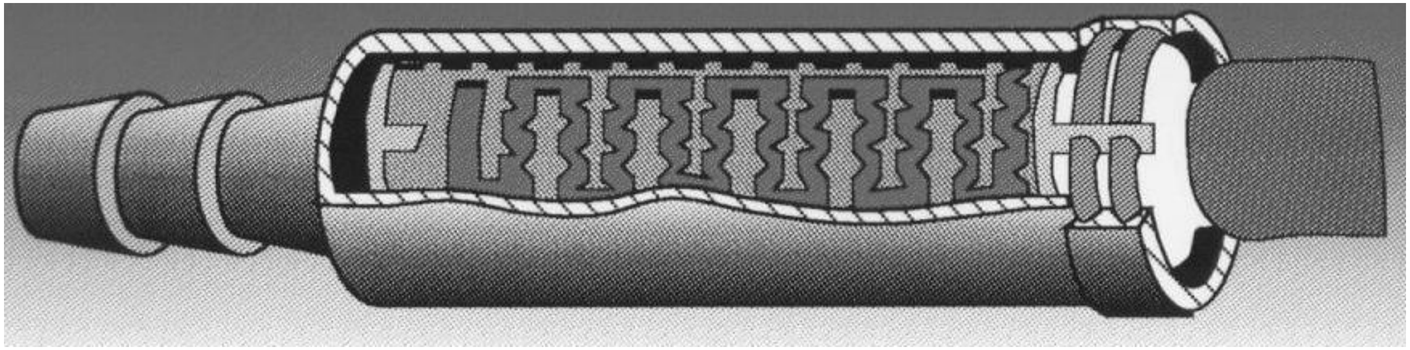
- Disadvantages
  - Clogging when hard water is used
  - High capital requirement

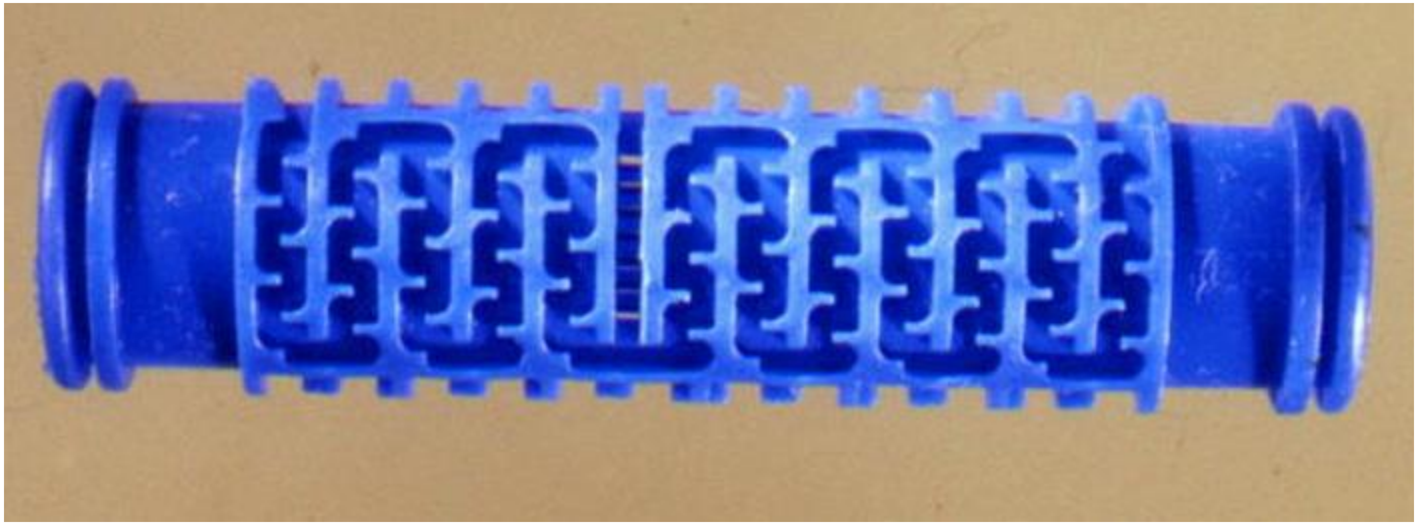

Ventury
Back- wash Valve
Pressure Gauge
NRV
By Pass valve
Screen Filter
Sand Filter
Sand Seprator Hydro-Cyclone
Pump
Well / Water Source
Air Valve
Main Line
NRV
Ball Valves
Lateral Flush Valve
Dripper/Emitter
End Stop
Flush valve
Polytube / Lateral
Submain Line



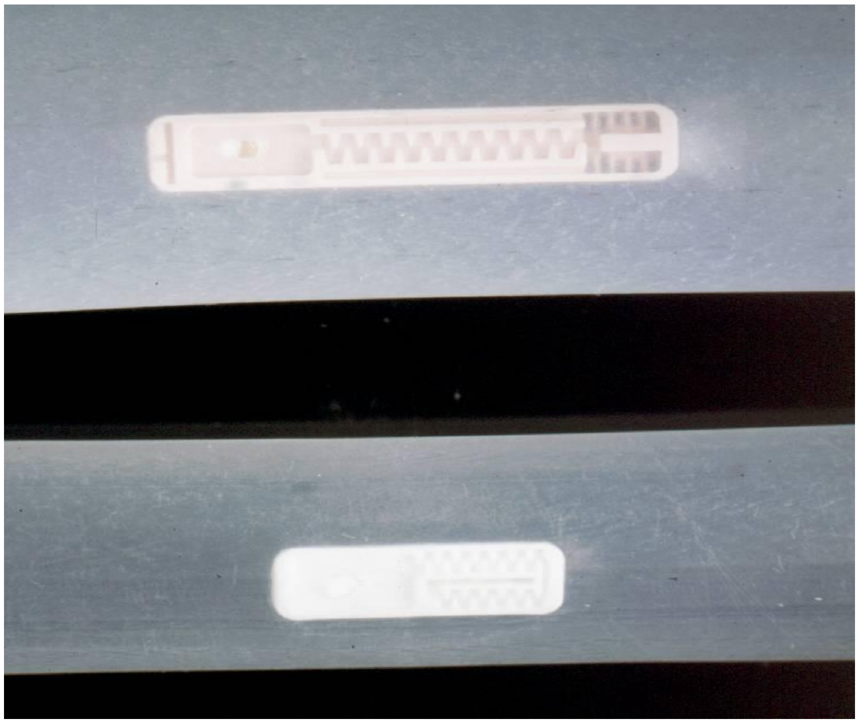

Sandy
Loamy
Clay

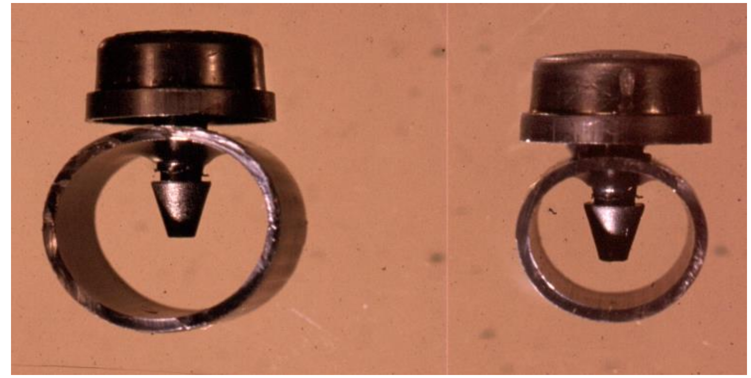


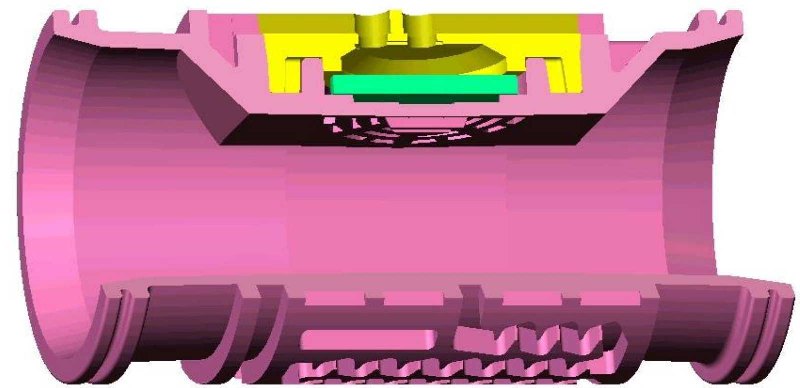




pWdn h`nQpRrN @n







pWdn h`nQpRrN dYQp

Thank you

Potential Evapotranspiration

- Evapotranspiration from a uniformly high green short crop that covers the surface completely and without any water shortage is called the potential evapotranspiration or reference evapotranspiration and is denoted as ETo

- Complications
    - Many field crops fit to the definition
    - Which crop to select
    - Evapotranspiration from a short green grass cover is 10 – 30% more than an agricultural crop

Reference Crop Evapotranspiration

The evapotranspiration rate from a reference surface (a hypothetical grass reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m-1 and an albedo of 0.23) not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ETo.

- Albedo – how much solar radiation is reflected from a surface