**Lecture 28 Irrigation Efficiency**

The term irrigation efficiency expresses the performance of a complete irrigation system or components of the system. Irrigation efficiency is defined as the ratio between the amount of water used to meet the consumptive use requirement of crop plus that necessary to maintain a favourable salt balance in the crop root zone to the total volume of water diverted, stored or pumped for irrigation. Thus, water applied by the irrigation system and not being made available to be taken up by plant roots is wasted and reduces irrigation efficiency. Fig. 28.1 shows components of water loss from source to point of application.  In addition, losses can also occur during storage in case of pond, tank, or reservoirs. The major causes for reduced irrigation efficiency include storage losses, conveyance losses and field application losses. In India, overall irrigation efficiency of major irrigation projects ranges between 35-40%.  This is one of the reasons for increasing gap between irrigation potential created (102.77 M ha till end of 10th plan 2007) and utilized (87.23 M ha). This gap of about 16%, is same as the irrigation potential created between 1951 and 1970. At the end of eighth plan, Planning commission estimated that with a 10% increase in the present level of water use efficiency in irrigation systems, an additional 14 Mha area can be brought under irrigation from the existing irrigation capacities. In order to meet the growing demands of water for food, environment, urban and industry, it is necessary to improve irrigation efficiency at all levels.



Fig. 28.1.Schematic water flow in irrigation drainage system.

(Source: Bos et al., 2009)

**28.1 Definition of Various Efficiencies**

**28.1.1 Reservoir Storage Efficiency**

It is the efficiency with which water is stored in the reservoir. It is expressed as follows,

         (28.1)

 Where,

Ve = evaporation volume from the reservoir

Vs = seepage volume from the reservoir

Vt = inflow to the reservoir

Vo= volume of out flow from the reservoir

ΔS = change in reservoir storage

**28.1.2 Water Conveyance Efficiency**

The conveyance efficiency is used to measure the efficiency of water conveyance systems associated with the canal network, water courses and field channels. It isdefined as the ratio between the water that reaches a farm or ﬁeld and that diverted from the irrigation water source. Mathematically it is represented as follows:

                                                Ec=100(Vf/Vd)                                   (28.2)

Where,

                      Ec= the conveyance efficiency (%),

                      Vf = the volume of water that reaches the farm or ﬁeld (m3),

                      Vd= the volume of water diverted (m3) from the source.

Ecalso applies to segments of canals or pipelines, where the water losses include canal seepage or leaks in pipelines. The global Eccan be computed as the product of the individual component efficiencies, Eci, where i representthe segment number. Typically, conveyance losses are much lower for closed conduits or pipelines compared with unlined or lined canals. Even theconveyance efficiency of lined canals may decline over time due to material deterioration or poor maintenance.

**28.1.3Application Efficiency**

Application efficiency relates to the actual storage of water in the root zone to meet the crop water needs in relation to the water applied to the field. It might be defined for individual irrigation or parts of irrigations or irrigation sets.Application efficiency includes any application losses to evaporation or seepage from surface water channels or furrows, any leaks from sprinkler or drip pipelines, percolation beneath the root zone, drift from sprinklers, evaporation of droplets in the air, or runoff from the field. In case of surface irrigation evaporation losses are generally small but runoff and deep percolation are substantial.  However, air losses (droplet evaporation and drift) can be very large if the sprinkler design or excessive pressure produces a high percentage of very fine droplets. Application efficiency is deﬁned as:

                                                Ea = 100(Vs/Vf)                                 (28.3)

                      Where,

                             Ea= the application efficiency (%),

                             Vs= the volume of water stored in root zone (m3),

                             Vf = the water delivered to the ﬁeld or farm (m3).

Table 28.1. Typical values of application efficiency for different irrigation systems

(Source: Raghuwanshi, 2013)

**28.1.4Storage Efficiency**

The water storage efficiency evaluates the storage of water in the root zone after the irrigation in relation to the need of water prior to irrigation.

                                                Es= 100 (Vs/Vrz)                                (28.4)

                      Where,

                             Es= the storage efficiency (%)

                             Vrz= the root zone storage capacity (m3).

The root zone depth and the water-holding capacity of the root zone determine Vrz. The storage efficiency has little utility for sprinkler ormicro irrigation because these irrigation methods seldom completely reﬁll the root zone.

**28.1.5Water Distribution Efficiency**

It is the ratio between the mean of numerical deviations from the average depth of water storedduring irrigation (Y) and the average depth stored during irrigation (d). It is mathematically expressed as:

     (28.5)

Where,

Υ= Average numerical deviation in depth of water stored from average depthstored during irrigation

d = Average depth of water stored during irrigation.

It is a measure of water distribution within the field. A low distribution efficiencymeans non-uniformity in the distribution of irrigation water. This may be due to uneven landlevelling. There may beexisting low patcheswhere water will penetrate more and high patches where water cannot reach. This leaves some spots unirrigated unless excess irrigation water is applied. Excess waterapplication lowers irrigation efficiency.It may be noted that water distribution efficiency is identical to Christiansen’s Uniformity Coefficient which is discussed later.

**28.1.6 Water Use Efficiency**

The term water use efficiency denotes the production of crops per unit water applied. It is expressed as the weight of crop produce per unit depth of water over a unit area. i.e., kg/cm/ha.

**28.1.6.1 Crop Water Use Efficiency**

It is the ratio of crop yield per amount of water depleted by the crop in the process of evapotranspiration (ET).

Crop water use efficiency = Y/ET              (28.6)

**28.1.6.2 Field Water Use Efficiency**

It is the ratio of crop yield (Y) to the total amount of water used in the field (WR).

Field water use efficiency = Y/WR                          (28.7)

**28.2 Irrigation Uniformity**

Uniformity is a measure to describe evenness ofwater application over the length of the field.It is a statistical measure of the distribution of the applied water, which is affected by various factors suchas the method of irrigation, topography, infiltrationcharacteristics, and hydraulic characteristics(pressure, flow rate, etc.) of the irrigation system.

It is generally expressed using Christiansen’scoefficient of uniformity (CU), distribution uniformity(DU) and emission uniformity (EU) for drip irrigationsystems.Irrigation application distributions are usually based on depths of water (volume per unit area); however, for micro irrigation systems they are usually based on emitter ﬂow volumes because the entire land area is not typically wetted.

**28.2.1 Christiansen’s Uniformity Coefficient**

Christiansenproposed acoefficient intended mainly for sprinkler system based on the catch volumes given as:

                 (28.8)

Where, CU is the Christiansen’s uniformity coefficient in percent, X is the depth (or volume) of water in each of the equally spaced catch containers in mm or ml, and x is the mean depth (volume) of the catch (mm or ml).

**28.2.2 Low-Quarter Distribution Uniformity**

It is defined as the ratio of the average infiltration in the lower quarter to the average infiltration over the entire field

            (28.9)

Where,

DU is the distribution uniformity (%) for the lower quarter of the ﬁeld, Vp is the mean application volume (m3)or depth in the lower quarter, and Vfis the mean application volume (m3)or depth for the whole ﬁeld.

**28.3 Deep Percolation Ratio and Tail Water Ratio**

The Deep Percolation Ratio (DPR) and Tail Water Ratio (TWR) were developed to take into account the losses occurring via deep percolation and runoff in surface irrigation methods.

**28.3.1 Deep Percolation Ratio**

It is the ratio of amount or depth of deep percolation to the amount or depth of applied water and is expressed as:

                  (28.10)

Where,

                             VDP = amount of water lost to deep percolation

                             Vf = amount of water delivered to the field

**28.3.2 Tail Water Ratio**

It is the ratio of amount or depth of runoff to the amount or depth of applied water and is expressed as:

                                  (28.11)

Where,

Vro = amount of runoff from field.

**28.4 Overall Project Efficiency**

It is the ratio between the average depth of water stored in the root zone duringirrigation and water diverted from the reservoir. It is mathematically expressed as:

        (28.12)

Where:

Eo = overall efficiency (%)

Vs= Water stored in the root zone (cm)

Vd= Water diverted from the reservoir (cm)

Or

         (28.13)

**Example 28.1:**

Compute the reservoir storage efficiency for a 24 hr period when 3795 lit/min of water are diverted from reservoir based on the following data,

Reservoir inflow rate = 4425 lit/min and ΔS = 415 m3.

Solution:

                      We know,



                      Where,

                            

                      ΔS = 415m3

                        = 92.27% Ans.

**Example 28.2:**

A stream of 140lps was diverted from a canal and 110 lps were delivered to the field. An area of 1.65 ha was irrigated in eight hours. The effective depth of root zone was 1.85 m. The runoff loss in the field was 435 m3. The depth of water penetration varied linearly from 1.85 m at thehead end of the field to 1.25 m at the tail end. Available moisture holding capacity of the soil is 25 cm/m depth of soil.

Determine the water conveyance efficiency, water applicationefficiency, water storage efficiency and water distribution efficiency,irrigation was started at a moisture extraction level of 50 percent ofthe available moisture.

Solution:

1. Water conveyance efficiency, Ec=100(Vf/Vd) = 100(110/140) =78.5%

2. Water application efficiency, Ea = 100(Vs/Vf)

Water delivered to the field = (110 x 60 x 60 x 8) / 1000 = 3168 m3

Water stored in the root zone = 3168 – 435 = 2733m3

                             = (2733 x 100)/ 3168 = 86.26%

3. Water storage efficiency

We Know, Es= 100 (Vs/Vrz)

Now,             Water holding capacity of the root zone = 20 x 1.85 = 37 cm

                      Moisture required in the root zone = 

                      Or                                 

                                                            = 3052.5 m3

                      Water storage efficiency = 

                                                       = 96.3%

4. Water distribution efficiency

                      We know,    x 100

      

                      Numerical deviation from depth of penetration

                             At upper end = 1.85 – 1.55 = 0.3

                             At lower end = 1.55 – 1.25 = 0.3

                             Average numerical deviation = = 0.3

                             = 80.6%