1- Crop and Crop seasons.

One of the primary drivers in irrigation system selection is crop type. For example, vegetable crops cannot be flooded. the crops were divided into four general categories.

Category 1. Row or bedded crops: sugar beets, sugarcane, potatoes, pineapple, cotton, soybeans, corn, sorghum, milo, vegetables, vegetable and flower seed, melons, tomatoes, and strawberries.

Category 2. Close-growing crops (sown, drilled, or sodded): small grain, alfalfa, pasture, and turf.

Category 3. Water flooded crops: rice and taro.

Category 4. Permanent crops: orchards of fruit and nuts, citrus groves, grapes, cane berries, blueberries, cranberries, bananas and papaya plantations, hops, and trees and shrubs for windbreaks, wildlife, landscape, and ornamentals.

1-1 Multiple Cropping

There are two forms of multiple cropping:

(i) intercropping, and (ii) sequential cropping. When two or more crops are grown simultaneously on the same field, it is termed **intercropping**. Crop intensification is in both time and space dimensions. There is, obviously, strong intercrop competition in this form of multiple cropping. On the other hand, when two or more crops are grown in sequence on the same field in a year, it is termed **sequential cropping**. The succeeding crop is planted after the preceding crop has been harvested. Crop intensification is only in the time dimension and there is no intercrop competition in sequential cropping.

2- consumptive use (OR EVAPOTRANSPIRATION)

The combined loss of water from soil and crop by vaporisation is identified as evapotranspiration. Crops need water for transpiration and evaporation. During the growing period of a crop, there is a continuous movement of water from soil into the roots, up the stems and leaves, and out of the leaves to the atmosphere. This movement of water is essential for carrying plant food from the soil to various parts of the plant. Only a very small portion (less than 2 percent)of water absorbed by the roots is retained in the plant and the rest of the absorbed water, after performing its tasks, gets evaporated to the atmosphere mainly through the leaves and stem. This process is called transpiration. In addition, some water gets evaporated to the atmosphere directly from the adjacent soil and water surfaces and from the surfaces of the plant leaves(i.e., the intercepted precipitation on the plant foliage). The water needs of a crop thus consists of transpiration and evaporation and is called evapotranspiration or consumptive use.

Consumptive use refers to the water needs of a crop in a specified time and is the sum of the volume of transpirated and evaporated water. **Consumptive use is defined as the amount of water needed to meet the water loss through evapotranspiration.** It generally applies to a crop but can be extended to a field, farm, project or even a valley. **Consumptive use is generally measured as volume per unit area or simply as the depth of water on the irrigated area.**

Knowledge of consumptive use helps determine irrigation requirement at the farm which should, obviously, be the difference between the consumptive use and the effective precipitation.

Evapotranspiration is dependent on climatic conditions like temperature, daylight hours,humidity, wind movement, type of crop, stage of growth of crop, soil moisture depletion, and other physical and chemical properties of soil. For example, in a sunny and hot climate, crops need more water per day than in a cloudy and cool climate. Similarly, crops like rice or sugarcane need more water than crops like beans and wheat. Also, fully grown crops need more water than crops which have been just planted.

While measuring or calculating **potential evapotranspiration**, it is implicitly assumed that water is freely available for evaporation at the surface. Actual evapotranspiration, in the absence of free availability of water for evaporation will, obviously, be less and is **determined by: (i) the extent to which crop covers the soil surface, (ii) the stage of crop growth which affects the transpiration and soil surface coverage, and (iii) soil water supply.**

Potential evapotranspiration from a cropped surface can be estimated either by correlating potential evapotranspiration with water loss from evaporation devices or by estimations based on various climatic parameters. Correlation of potential evapotranspiration assumes that the climatic conditions affecting crop water loss (Det) and vaporation from a free surface of water (Ep) are the same. Potential evapotranspiration Det can be correlated to the pan evaporation Ep as ,

$$D_{et} = KE_p \ldots 1$$

in which, K is the crop factor for that period. The crop factor K depends on the crop as well as its stage of growth (Table 1). The main limitations of this method are the differences in physical features of evaporation surfaces compared with those of a crop surface.

Table 1 Values of crop factor *K* from some major crops

Percentage of crop growing season since sowing	*Maize, cotton, potatoes, peas and sugarbeets*	*Wheat, barley and other small grains*	*Sugarcane*	*Rice*
0	0.20	0.08	0.50	0.80
10	0.36	0.15	0.60	0.95
25	0.75	0.33	0.75	1.10
50	1.00	0.65	1.00	1.30
75	0.85	0.90	0.85	1.15
100	0.20	0.20	0.50	0.20

In the absence of pan evaporation data, the consumptive use is generally computed as follows:

(i) Compute the seasonal (or monthly) distribution of potential evapotranspiration, which is defined as the evapotranspiration rate of a well-watered reference crop which completely **shades** the soil surface . It is thus an indication of the climatic evaporation demand of a vigorously growing crop. Usually, grass and alfalfa (a plant with leaves like that of clover and purple flowers used as food for horses and cattle) are taken as reference crops.

(ii) Adjust the potential evapotranspiration for the type of crop and the stage of crop growth. Factors such as soil moisture depletion are ignored so that the estimated values of the consumptive use are conservative values to be used for design purposes.
Thus, evapotranspiration of a crop can be estimated by multiplying potential evapotranspiration by a factor known as crop coefficient.

Potential evapotranspiration can be computed by one of the several methods available for the purpose. These methods range in sophistication from simple temperature correlation (such as the Blaney-Criddle formula) to equations (such as Penman's equation) which account for radiation energy as well. Blaney-Criddle formula for the consumptive use has been used extensively and is expressed as

$$u = kf \quad \ldots 2$$

in which, u = consumptive use of crop in mm,
k = empirical crop consumptive use coefficient (Table 2), and
f = consumptive use factor.

The quantities u, k, and f are determined for the same period (annual, irrigation season,growing season or monthly). The consumptive use factor f is expressed as

$$f = \frac{p}{100}(1.8t + 32) \quad \ldots..3$$

in which, t = mean temperature in °C for the chosen period, and
p = percentage of daylight hours of the year occurring during the period.
Table 3 lists the values of p for different months of a year for 0° north latitude. The value of the consumptive use is generally determined on a monthly basis and the irrigation system must be designed for the maximum monthly water needs. It should be noted that Eq.(2) was originally in FPS system with appropriate values of k. Similarly, Eq. (3) too had a different form with t in Fahrenheit.

Table 2 Consumptive use coefficient for some major crops (1)

Crop	Lenght of normal growing season or period	Consumptive use coefficient, k	
		For the growing period*	Monthly (maximum value)**
Corn (maize)	4 months	19.05 to 21.59	20.32 to 30.48
Cotton	7 months	15.24 to 17.78	19.05 to 27.94
Potatoes	3-5 months	16.51 to 19.05	21.59 to 25.40
Rice	3-5 months	25.40 to 27.94	27.94 to 33.02
Small grains	3 months	19.05 to 21.59	21.59 to 25.40
Sugarbeet	6 months	16.51 to 19.05	21.59 to 25.40
Sorghums	4-5 months	17.78 to 20.32	21.59 to 25.40
Orange and lemon	1 year	11.43 to 13.97	16.21 to 19.05

*The lower values are for more humid areas and the higher values are for more arid climates.
** Dependent upon mean monthly temperature and stage of growth of crop.

Table 3 Per cent daylight hours for northern hemispere (0-50° latitude)

Latitude North (in degr-ees)	Jan.	Fab.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
0	8.50	7.66	8.49	8.21	8.50	8.22	8.50	8.49	8.21	8.50	8.22	8.50
5	8.32	7.57	8.47	8.29	8.65	8.41	8.67	8.60	8.23	8.42	8.07	8.30
10	8.13	7.47	8.45	8.37	8.81	8.60	8.86	8.71	8.25	8.34	7.91	8.10
15	7.94	7.36	8.43	8.44	8.98	8.80	9.05	8.83	8.28	8.26	7.75	7.88
20	7.74	7.25	8.41	8.52	9.15	9.00	9.25	8.96	8.30	8.18	7.58	7.66
25	7.53	7.14	8.39	8.61	9.33	9.23	9.45	9.09	8.32	8.09	7.40	7.42
30	7.30	7.03	8.38	8.72	9.53	9.49	9.67	9.22	8.33	7.99	7.19	7.15
32	7.20	6.97	8.37	8.76	9.62	9.59	9.77	9.27	8.34	7.95	7.11	7.05
34	7.10	6.91	8.36	8.80	9.72	9.70	9.88	9.33	8.36	7.90	7.02	6.92
36	6.99	6.85	8.35	8.85	9.82	9.82	9.99	9.40	8.37	7.85	6.92	6.79
38	6.87	6.79	8.34	8.90	9.92	9.95	10.10	9.47	8.38	7.80	6.82	6.66
40	6.76	6.72	8.33	8.95	10.02	10.08	10.22	9.54	8.39	7.75	6.72	6.52
42	6.63	6.65	8.31	9.00	10.14	10.22	10.35	9.62	8.40	7.69	6.62	6.37
44	6.49	6.58	8.30	9.06	10.26	10.38	10.49	9.70	8.41	7.63	6.49	6.21
46	6.34	6.50	8.29	9.12	10.39	10.54	10.64	9.79	8.42	7.57	6.36	6.04
48	6.17	6.41	8.27	9.18	10.53	10.71	10.80	9.89	8.44	7.51	6.23	5.86
50	5.98	6.30	8.24	9.24	10.68	10.91	10.99	10.00	8.46	7.45	6.10	5.65

Table 4 gives typical values of the water needs of some major crops for the total growing period of some of the crops . This table also indicates the sensitivity of the crop to water shortages or drought. High sensitivity to drought means that the crop cannot withstand water shortages, and that such shortages should be avoided.

Table 4 Indicative values of crop water needs and sensitivity to drought

Crop	*Crop water need (mm / total growing period)*	*Sensitivity of drought*
Alfalfa	800 - 1600	low - medium
Banana	1200 - 2200	high
Barley/oats/wheat	450 - 650	low - medium
Bean	300 - 500	medium - high
Cabbage	350 - 500	medium - high
Citrus	900 - 1200	low - medium
Cotton	700 - 1300	low
Maize	500 - 800	medium - high
Melon	400 - 600	medium - high
Onion	350 - 550	medium - high
Peanut	500 - 700	low - medium
Pea	350 - 500	medium - high
Pepper	600 - 900	medium - high
Potato	500 - 700	high
Rice (paddy)	450 - 700	high
Sorghum/millet	450 - 650	low
Soybean	450 - 700	low - medium
Sugarbeet	550 - 750	low - medium
Sugarcane	1500 - 2500	high
Sunflower	600 - 1000	low - medium
Tomato	400 - 800	medium - high

Example 1: Using the Blaney-Criddle formula, **estimate the yearly consumptive use** of water for sugarcane for the data given in the first four columns of Table 5.

Solution:

According to Eqs 2 & 3

$$u = k\frac{p}{100}(1.8\,t + 32)$$

Values of monthly consumptive use calculated from the above formula have been tabulated in the last column of Table 5. Thus, yearly consumptive use = Σu = 1.75 m.

Table 5 Data and solution for Example 1

Month	*Mean monthly temperature, t°C*	*Monthly crop coefficient, k*	*Per cent sunshine hours, p*	*Monthly consumptive use, u (mm)*
January	13.10	19.05	7.38	78.14
February	15.70	20.32	7.02	85.96
March	20.70	21.59	8.39	125.46
April	27.00	21.59	8.69	151.22
May	31.10	22.86	9.48	190.66
June	33.50	24.13	9.41	209.58
July	30.60	25.40	9.60	212.34
August	29.00	25.40	9.60	205.31
September	28.20	24.13	8.33	166.35
October	24.70	22.86	8.01	140.01
November	18.80	21.59	7.25	103.06
December	13.70	19.05	7.24	78.15