Small Scale Irrigation Development

Level III

MODEL TTLM

Learning Guide #10

Unit of Competence: Determine Crop Water Requirement

Module Title: Determining Crop Water Requirement

LG Code: AGR SSI3 M10 LO1-4

TTLM Code: AGR SSI3 TTLM10 1218V_1

Nominal Duration: 70 Hours

Instruction Sheet	Learning Guide #10

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics –

- Collect & collate all required data
- Identify type and characteristics of crops
- Monitor irrigation system process
- Record, Compile & analyze Data

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- ✓ Collect and collated meteorological data
- ✓ Collect soil data
- ✓ Determine available water
- ✓ Analyze data use statistical method
- ✓ Select economically, agro- ecologically and nutritionally beneficial crops
- ✓ (Nutrition, environment & entrepreneur ship)
- ✓ Collect data on crop characteristics ,*crop coefficient*, growth stage, and period and root depth at different growth stages
- ✓ Record frequency of irrigation
- ✓ Measure and record water usage
- ✓ Compute actual and estimated water use
- ✓ Measure water quality
- ✓ Assess crop growth and water use efficiency
- ✓ Measure soil chemical characteristics and assessing soil moisture
- ✓ Measure labor performance
- ✓ Record climate and weather conditions; plant environment data; water orders and usage; irrigation shifts and system process data
- ✓ Analyze soil data for physical properties
- ✓ Check data consistence
- ✓ Choose method for computing crop water requirement based on available data
- ✓ Select appropriate computer software model

Learning Activities

1. **Read the specific objectives of this Learning Guide.**
2. **Read the information written in the "Information Sheet"**
3. **Accomplish the "Self-check".**
4. **If you earned a satisfactory evaluation proceed to the next "Information Sheet". However, if your rating is unsatisfactory, see your facilitator for further instructions or go back to Learning Activity.**
5. **Submit your accomplished Self-check. This will form part of your training portfolio.**
6. **Read and Practice "Operation Sheets".**
7. **If you think you are ready proceed to "Job Sheet".**
8. **Request you facilitator to observe your demonstration of the exercises and give you feedback.**

INFORMATION SHEET#1	Collect & Collate all Required Data

1.1. Understanding Crop Water Requirements

Crop water requirements are defined here as "the depth of water needed to meet the water loss through evapo-transpiration (ETcrop) of a disease-free crop, growing in large fields under no restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment".

Crop water requirement or potential evapo-transpiration is the amount of water required to compensate the evapo-transpiration loss from the cropped field is defined as crop water requirement. Although the values for crop evapo-transpiration and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapo-transpiration.

The irrigation water requirement basically represents the difference between the crop water requirement and effective precipitation. The irrigation water requirement also includes additional water for leaching of salts and to compensate for non-uniformity of water application.

1.2. Identifying Factors influencing Crop Water Requirement (CWR)

1.2.1 Influence of climate

A certain crop grown in a sunny and hot climate needs more water per day than the same crop grown in a cloudy and cooler climate. There are, however, apart from sunshine and temperature, other climatic factors which influence the crop water need. These factors are humidity and wind speed. When it is dry, the crop water needs are higher than when it is humid. In windy climates, the crops will use more water than in calm climates.

The highest crop water needs are thus found in areas which are hot, dry, windy and sunny. The lowest values are found when it is cool, humid and cloudy with little or no wind. From the above, it is clear that the crop grown in different climatic zones will have different water needs. For example, a certain maize variety grown in a cool climate will need less water per day than the same maize variety grown in a hotter climate.

It is therefore useful to take a certain standard crop or reference crop and determine how much water this crop needs per day in the various climatic regions. As a standard crop (or reference crop) grass has been chosen.

For the various field crops it is possible to determine how much water they need compared to the standard grass. A number of crops need less water than grass, a number of crops need more water than grass and other crops need more or less the same amount of water as grass.

1.2.2 Influence of crop type.

The influence of the crop type on the crop water need is important in two ways.

a) The crop type has an influence on the daily water needs of a fully grown crop; i.e. the peak daily water needs of a fully developed maize crop will need more water per day than a fully developed crop of onions.

b) The crop type has an influence on the duration of the total growing season of the crop. There are short duration crops, e.g. peas, with duration of the total growing season of 90-100 days and longer duration crops, e.g. melons, with duration of the total growing season of 120-160 days. There are, of course, also perennial crops that are in the field for many years, such as fruit trees.

   While, for example, the daily water need of melons may be less than the daily water need of beans, the seasonal water need of melons will be higher than that of beans because the duration of the total growing season of melons is much longer.

   Data on the duration of the total growing season of the various crops grown in an area can best be obtained locally. These data may be obtained from, for example, the seed supplier, the Extension Service, the Irrigation Department or Ministry of Agriculture. It is obvious that there is a large variation of values not only between crops, but also within one crop type. In general, it can be assumed that the growing period for a certain crop is longer when the climate is cool and shorter when the climate is warm. Crops differ in their response to moisture deficit. This characteristic is commonly termed "drought resistance". When crop water requirements are not met, crops with high drought sensitivity suffer greater reductions in yields than crops with a low sensitivity.

1.3. Collecting and organizing data of climate and crop types

1.3.1 Climate Data Collection

In order to calculate ETO, the respective climatic data should be collected from the nearest and most representative meteorological station. Several institutes and agencies may keep climatic records such as the Irrigation Department, the Meteorological Service or nearby Agricultural Research Stations and may provide information on climatic stations inside or in the vicinity of our irrigation scheme which should be considered for crop water requirement (CWR) calculations.

In some cases, when the scheme is large, more than one station may be available, but often no suitable stations with sufficient climatic data are located in the scheme.
In such a case a careful selection should be made of the data on:

- Rainfall
- Temperature
- Humidity
- Sunshine
- Wind speed.

1.3.2 Crop and Cropping Pattern Data Collection

A local survey should be carried out in the irrigation scheme to assess the crops grown rain fed as well as under irrigation. Through field observations, interviews with extension agents and farmers and additional information from other agencies, for instance a revenue department, an assessment can be made of the present cropping pattern.

Essential information/data collected from the field should include:

- Crop and crop variety
- First and last planting date
- First and last harvesting date
- Indicative yield level
- Indicative irrigation practices: Such as;
  - Field irrigation methods
  - Irrigation frequencies and interval
  - Irrigation application depths

1.4 Collecting soil data following standard procedures of soil survey:

During soil survey, a large amount of data, of various types and in various formats, is commonly collected or developed. These data include, but are not limited to, field notes, soil profile and landscape descriptions, drawings, laboratory data, photographs, descriptions of soil map units and map unit components, and, of course, the basic soil map.

Before a soil survey project begins, a decision must to be made as to what type of system is going to be used to collect, store, manage, and disseminate the information to be gathered and/or developed. For example, the data and information may be maintained and distributed as hard copy, in electronic form, or by some combination of the two. Deciding how to manage these data can be a daunting task, but it is a very important one.

First, a few questions need to be answered:

- What is the purpose of the soil survey?
- For whom is the information intended?
- Is the information to be publicly available to anyone that wants it, or is it to be kept within the organization that is conducting the soil survey?
- What types of products or output will need to be generated at the end of the project?
- In what format are the products to be made available—electronic or hard copy, or both?
- Do the end users of the information only need the summarized soil survey data, or will they also need access to the various pieces of point data collected at individual points on the landscape?
- Will the data and/or generated information be delivered via the Internet?

- What resources and expertise are available for maintaining and disseminating the data?

The answers to these and other questions will help determine what sort of system is needed. Distinction is needed to be made between “soil data” and a “soil information system.” Soil data refers to the actual data that are collected or generated during the course of a soil survey. A soil information system includes not only the data, but also the various methods and/or systems used to collect, store, and manage the data and resulting interpretations and information and to disseminate them to end users.

Standard methodologies or protocols for data collection are needed to ensure that data collected from different locations, at different times, and by different people can be appropriately combined and summarized or evaluated as needed. For example, slope should be measured in the same way and clay content should be determined using the same procedures throughout the survey area.

Recording Data and Information – Field and Lab

Information gathered during the course of a soil survey is recorded in a variety of formats and content. In addition to the basic soil map, important forms of data include field notes, soil profile descriptions, laboratory analytical results, photographs, and drawings. These forms of information are working together to ensure a quality survey. The data fall into three basics categories: point data, aggregated data, and spatial data.

Point Data

Point data are data that are collected, measured, or observed at a particular geographic location in the field. They generally record a single value for each attribute recorded about the soil map unit as a whole, or an individual soil map unit component, and the landscape in which it occurs. At a specific geographic location at a particular point in time, each attribute only has one value. Attributes may include slope, landform setting, depth to each soil horizon, pH or texture of each horizon, etc. Each piece of point data collected should include a reference to the soil map unit and/or soil map unit component that it represents.

Aggregated Data

Aggregated data capture the ranges of various physical and chemical properties of soil map units as a whole and individual soil map unit components. They include the descriptions of each soil map unit and map unit component; the detailed physical, chemical, and morphological attributes of each soil; and descriptions of the relationship of one soil map unit to another on the landscape. Aggregated soil property data generally are the data used to generate interpretive ratings for each map unit and its components.

Aggregated data are developed by summarizing the various pieces of point data that have been collected during the soil survey and referenced to a particular soil map unit or map unit component. Values for a particular soil property are commonly expressed as a range.

Spatial Data

Spatial data is a major portion of the data collected or developed during a soil survey. It includes the geographic coordinates (e.g., latitude and longitude) that define the boundary of each map unit polygon on the soil map, whether it is in vector or raster format. It also includes the geographic coordinates for each point on the landscape where point data were collected. Boundaries of various political and physiographic areas may also be included as ancillary data layers. Other ancillary data layers, such as vegetative cover, digital elevation model (DEM) data, aerial photography, land use, and geology, are commonly used in a geographic information system (GIS) when conducting a soil survey.

1.5. Estimating Crop water need and knowing available water amount

1.5.1 Introduction

The calculation of crop water requirements by means of the two methods described in this section is relatively simple. The basic formula for the calculation reads as follows:

ETcrop = kc x Eto

Where;

ETcrop =the water requirement of a given crop in mm per unit of time e.g. mm/day, mm/month or mm/season.

kc = the "crop factor"

ETo = the "reference crop evapotranspiration" in mm per unit of time e.g. mm/day,

mm/month or mm/season.

1.5.2 ETo - reference crop evapo-transpiration

The reference crop evapotranspiration ETo (sometimes called potential evapotranspiration, PET) is defined as the rate of evapotranspiration from a large area covered by green grass which grows actively, completely shades the ground and which is not short of water.

The highest value of ETo is found in areas which are hot, dry, windy and sunny whereas the lowest values are observed in areas where it is cool, humid and cloudy with little or no wind.

In many cases it will be possible to obtain estimates of ETo for the area of concern (or an area nearby with similar climatic conditions) from the Meteorological Service. However, where this is not possible, the values for ETo have to be calculated. Two easy methods will be explained below:

a) Pan evaporation method

With this method, ETo can be obtained by using evaporation rates which are directly measured with an evaporation pan. This is a shallow pan, containing water which is exposed to the evaporative influence of the climate. The standard pan is the Class A Pan of the US Weather Bureau (Figure 1). It has a diameter of 1.21 m, a depth of 25 cm and is placed 15 cm above the ground.

Figure_1: Class A evaporation pan.

An evaporation pan is easy to construct and in most situations the material can be found locally. The principle of obtaining evaporation rates from the pan is as follows:

The pan is installed in the field 15 cm above the ground; the pan is filled with water 5 cm below the rim; the water is allowed to evaporate during a certain period of time (usually 24 hours).

For example, each morning at 7.00 hours a measurement is taken. Rainfall, if any, is measured simultaneously; after 24 hours, the water depth is measured again; the amount of water which has evaporated in a given time unit is equal to the difference between the two measured water depths.

This is the pan evaporation rate: Epan (mm/24 hours).

The readings taken from the pan (Epan) however do not give ETo directly, but have to be multiplied by a "Pan Coefficient" (Kpan). thus: ETo = Epan x Kpan

For the Class A evaporation pan, Kpan varies between 0.35 and 0.85, with an average of 0.70. If the precise pan factor is not known, the average value (0.70) can be used as an approximation.

b) The Blaney-Criddle Method

If no measured data on pan evaporation are available, the Blaney-Criddle method can be used to calculate ETo. This method is straightforward and requires only data on mean daily temperatures. However, with this method, only approximations of ETo are obtained which can be inaccurate in extreme conditions.

The Blaney-Criddle formula is: ETo = p (0.46Tmean + 8)

Where:

ETo = reference crop evapotranspiration (mm/day)

Tmean = mean daily temperature (° C)

p = mean daily percentage of annual daytime hours

1.5.3. Crop Factor – Kc

In order to obtain the crop water requirement ETcrop the reference crop evapotranspiration, ETo, must be multiplied by the crop factor, Kc. The crop factor (or "crop coefficient") varies according to the growth stage of the crop.

There are four growth stages to distinguish:

- The initial stage: when the crop uses little water;
- The crop development stage, when the water consumption increases;

- The mid-season stage, when water consumption reaches a peak;
- The late-season stage, when the maturing crop once again requires less water.

However, the length of the different crop stages will vary according to the variety and the climatic conditions where the crop is grown.

1.5.4 Calculation of ETcrop

While conventional irrigation strives to maximize the crop yields it applying the optimal amount of water required by the crops at well determined intervals. As already discussed, the farmer or agro pastoralist has no influence on the occurrence of the rains neither in time nor in the amount of rainfall.

Bearing the above in mind, it is therefore a common practice to only determine the total amount of water which the crop requires over the whole growing season. The crop water requirement for a given crop is calculated according to the formula:

ETcrop = Kc x ETo

Since the values for ETo are normally measured or calculated on a daily basis (mm/day), an average value for the total growing season has to be determined and then multiplied with the average seasonal crop factor Kc as given.

1.5.5 Seasonal scheme water demand

The seasonal water demands of a scheme is the volume of water (in cubic meters (m3)) used over the growing season, taking into account the water losses in the distribution system and in field application.

It can be calculated from:

$$\text{Seasonal scheme water demand } (m^3) = \frac{\text{Crop water requirement } (m^3/ha) \times \text{cropped area } (ha)}{\text{irrigation efficiency}}$$

Self check #1	Knowledge questions

Name: _________________________ Date: _______________

Directions: Answer the following questions in the space provided

1. Describe the four growth stages of crops (8ponts?_ _

2. What is the difference between crop factor and crop evapo-transpiration (4 points)_ _ _

3. Write the three basics categories of data fall in the soil survey (3 points) _ _ _ _ _ _ _ _ _

Note: satisfactory Rating-8 and above points.   Unsatisfactory Rating-below 8 points

You can ask your teacher for the copy of the correct answers

Information Sheet #2	Identify type and characteristics of crop

2.1. Selecting economically, agro- ecologically and nutritionally beneficial crops

The main consideration in selecting the crops that are most suitable for smallholder production is of course the demands of the market - there is no point in producing something unless someone wants to buy it. However, among crops for which there is a sure demand some require agronomic practices or environmental controls which make them particularly suitable, or particularly unsuitable, for smallholder producers.

Factors influencing decisions on the selection of crops & cropping system

Farmers need to answer all the below questions while making decisions for choosing a crop/ cropping pattern. During this decision making process, farmers cross check the suitability of proposed crop/cropping systems with their existing resources and other conditions. Thereby, they justify choosing or rejecting a crop/cropping systems. This process enables the farmers to undertake a SWOT analysis internally which in turn guides them to take an appropriate decision.

1. **Climatic factors** - Is the crop/cropping system suitable for local weather parameters such as temperature, rainfall, sun shine hours, relative humidity, wind velocity, wind direction, seasons and agro-ecological situations?
2. **Soil conditions** - Is the crop/cropping system suitable for local soil type, pH and soil fertility?
3. **Water**
    - Do you have adequate water source like a tanks, wells, dams, etc.?
    - Do you receive adequate rainfall?
    - Is the distribution of rainfall suitable to grow identified crops?
    - Is the water quality suitable?
    - Is electricity available for lifting the water?
    - Do you have pump sets, micro irrigation systems?
4. **Cropping system options**
    - Do you have the opportunity to go for inter-cropping, mixed cropping, multi-storeyed cropping, relay cropping, crop rotation, etc.?
    - Do you have the knowledge on cropping systems management?
5. **Past and present experiences of farmers**
    - What were your previous experiences with regard to the crop/cropping systems that you are planning to choose?
    - What is the opinion of your friends, relatives and neighbours on proposed crop/cropping systems?
6. **Expected profit and risk**
    - How much profit are you expecting from the proposed crop/cropping system?
    - Whether this profit is better than the existing crop/cropping system?
    - What are the risks you are anticipating in the proposed crop/cropping system?

- Do you have the solution?
- Can you manage the risks?
- Is it worth to take the risks for anticipated profits?

7. **Economic conditions of farmers including land holding**
   - Are the proposed crop/cropping systems suitable for your size of land holding?
   - Are your financial resources adequate to manage the proposed crop/cropping system?
   - If not, can you mobilize financial resources through alternative routes?
8. **Labour availability and mechanization potential**
   - Can you manage the proposed crop/cropping system through your family labour?
   - If not, do you have adequate labours to manage the same?
   - Is family/hired labour equipped to handle the proposed crop/cropping system?
   - Are there any mechanization options to substitute the labour?
   - Is machinery available? Affordable? Cost effective?
   - Is family/hired labour equipped to handle the machinery?
9. **Technology availability and suitability**
   - Is the proposed crop/cropping system suitable?
   - Do you have technologies for the proposed crop/cropping system?
   - Do you have extension access to get the technologies?
   - Are technologies economically feasible and technically viable?
   - Are technologies complex or user-friendly?
10. **Market demand and availability of market infrastructure**
    - Are the crops proposed in market demand?
    - Do you have market infrastructure to sell your produce?
    - Do you have organized marketing system to reduce the intermediaries?
    - Do you have answers for questions such as where to sell? When to sell? Whom to sell to? What form to sell in? What price to sell for?
    - Do you get real time market information and market intelligence on proposed crops?
11. **Policies and schemes**
    - Do Government policies favour your crops?
    - Is there any existing scheme which incentivises your crop?
    - Are you eligible to avail those benefits?
12. **Public and private extension influence**
    - Do you have access to Agricultural Technology Management Agency (ATMA)/ Departmental extension functionaries to get advisory?
    - Do you know Kissan Call Center?
    - Do you have access to KVKs, Agricultural Universities and ICAR organizations?
    - Do you subscribe agricultural magazines?
    - Do you read agricultural articles in newspapers?
    - Do you get any support from input dealers, Agribusiness Companies, NGOs, Agriclinics and Agribusiness Centers?
13. **Availability of required agricultural inputs including agricultural credit**

- Do you get adequate agricultural inputs such as seeds, fertilizers, pesticides, and implements in time?
- Do you have access to institutional credit?

14. **Post harvest storage and processing technologies**
    - Do you have your own storage facility?
    - If not, do you have access to such facility?
    - Do you have access to primary processing facility?
    - Do you know technologies for value addition of your crop?
    - Do you have market linkage for value added products?
    - Are you aware about required quality standards of value added products of proposed crops?

2.2. Collecting data on crop characteristics

Crop characteristics which define potential yields include physiological and phenological traits. The physical environment and management can influence these characteristics. However, the response of the crop and thus its potential yield under optimum conditions is genetically determined.

While ET_o represents an index of climatic demand on evaporation, the K_c represents the influence of the specific crop characteristics. Being little influenced by climate, standard values for K_c can be transferred between locations and climates.
Crop water requirements are a function of crop characteristics, management, and environmental demands.

Crop characteristics data can be collected from Ministry of Agriculture, Universities, Research centers, etc

2.2.1. Determining crop coefficient

Crop coefficient K_C and its determination

From the potential evapotranspiration P*ET,* **or** ET_o determined by any of the five methods such as Pennman, Blanney Criddle ,pan evaporation method the evapotranspiration or consumptive use of water for the specific crop may be estimated by the use of a crop coefficient as indicated below.

$$ET_c = k_c ET_0$$

Crop coefficient (Kc) = $ET_c \div ETo$

In which
ET_c =*crop* evapotranspiration or consumptive use of water for the crop; and

K_c = crop coefficient.

Crop coefficients are normally determined under highly controlled conditions of adequate soil moisture, good plant health, and cultural practices

Factors determining the crop coefficient

Many factors affect Kc, namely crop type, changing crop characteristics over the growing season (stages of growth), health of plant, cultural practice and, to a limited extent, the prevailing weather conditions. As evaporation is part of crop evapotranspiration, conditions affecting soil evaporation will also affect Kc.

I. Crop type

The large variation in Kc values between major groups of crops is due to the resistance to transpiration of different crops, such as closed stomata during the day (pineapple) and waxy leaves (citrus). Also, differences in crop height, crop roughness, reflection and groundcover produce different Kc values.

II. Climate

General climatic conditions, especially wind and humidity, affect crop coefficients. Variations in wind change the aerodynamic resistance of the crops and their crop coefficients, especially for those crops that are substantially taller than the grass reference crop. Crop aerodynamic properties also change with climate, in particular relative humidity. Kc for many crops increases as wind speed increases and as relative humidity decreases. More arid climates and conditions of greater wind speed will have higher values for Kc. More humid climates and conditions of lower wind speed will have lower values for Kc.

III. Soil evaporation

Crop evapotranspiration is a combination of transpiration by the crop and evaporation from the soil surface. Differences in soil evaporation and crop transpiration between field crops and the reference surface are integrated within the crop coefficient. The Kc for full cover crops reflects differences in transpiration, as the contribution of soil evaporation is relatively small. After rainfall or irrigation, the contribution of soil evaporation is significant, especially if the crop is small and has small groundcover. For such low cover conditions Kc is largely determined by how frequent the soil is wetted.

IV. Crop growth stages

The Kc for a given crop changes over the growing period as the groundcover, crop height and leaf area changes. Four growth stages are recognized for the selection of Kc: *initial stage*, *crop development stage, mid-season stage and the late season stage*.

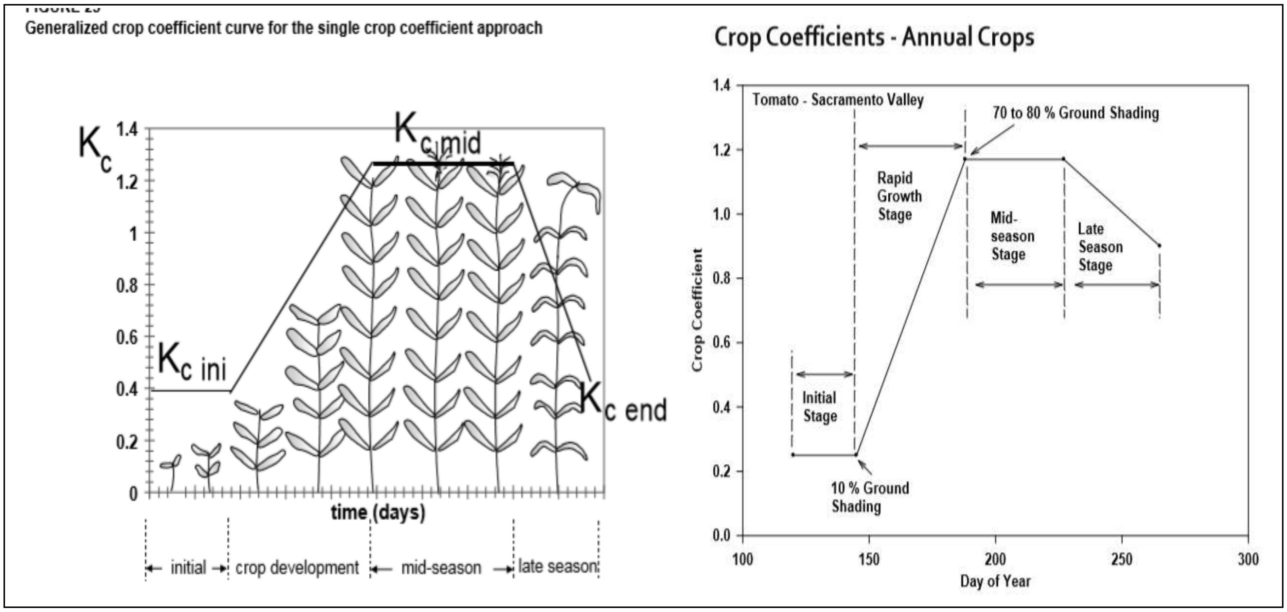

Figure 2. Crop coefficient and crop development stages

Table 1. Values of the crop factor (Kc) for various crops and growth stages

Crop	Initial stage	Crop dev. stage	Mid-season stage	Late season stage
Barley/Oats/Wheat	0.35	0.75	1.15	0.45
Bean, green	0.35	0.70	1.10	0.90
Bean, dry	0.35	0.70	1.10	0.30
Cabbage/Carrot	0.45	0.75	1.05	0.90
Cotton/Flax	0.45	0.75	1.15	0.75
Cucumber/Squash	0.45	0.70	0.90	0.75
Eggplant/Tomato	0.45	0.75	1.15	0.80
Grain/small	0.35	0.75	1.10	0.65
Lentil/Pulses	0.45	0.75	1.10	0.50
Lettuce/Spinach	0.45	0.60	1.00	0.90
Maize, sweet	0.40	0.80	1.15	1.00
Maize, grain	0.40	0.80	1.15	0.70
Melon	0.45	0.75	1.00	0.75
Millet	0.35	0.70	1.10	0.65
Onion, green	0.50	0.70	1.00	1.00
Onion, dry	0.50	0.75	1.05	0.85
Peanut/Groundnut	0.45	0.75	1.05	0.70
Pea, fresh	0.45	0.80	1.15	1.05
Pepper, fresh	0.35	0.70	1.05	0.90
Potato	0.45	0.75	1.15	0.85
Radish	0.45	0.60	0.90	0.90
Sorghum	0.35	0.75	1.10	0.65
Soybean	0.35	0.75	1.10	0.60
Sugarbeet	0.45	0.80	1.15	0.80
Sunflower	0.35	0.75	1.15	0.55
Tobacco	0.35	0.75	1.10	0.90

The table above shows average Kc values for the various crops and growth stages. In fact, the Kc is also dependent on the climate and, in particular, on the relative humidity and the wind speed. The values indicated above should be reduced by 0.05 if the relative humidity is high (RH>80%) and the wind speed is low (V< 2m/sec). e.g. Kc = 1.15 becomes Kc = 1.10. the values should be increased by 0.05 if the relative humidity is low (RH < 50%) and the wind speed is high (V > 5m/sec), e.g. Kc = 1.05 becomes Kc = 1.10.

Since the evapotranspiration or consumptive use of water for a crop varies with the stage of growth of the crop, the values of k_c for different stages of growth are needed to be determined. The growing of a crop is usually divided into four stages viz. Initial stage, development stage, mid-season stage, and late-season stage.

2.2.2. Identifying growth stage

Crop growth periods can be divided into four distinct growth stages; initial, crop development, mid season and late season. The length of each of these stages depends on the climate, latitude, elevation and planting date. Local observations are best for determining the growth stage of the crop and which Kc values to use.

For annual crops, during the crop's germination and establishment, most of the ET_c occurs as evaporation from the soil surface. As the foliage develops evaporation from the soil surface decreases and transpiration increases. For perennial crops a similar pattern may occur as the plant starts to leaf out, grow new shoots and develop fruit. The percentage of canopy cover will determine the rate of evapotranspiration (ETc). Maximum ET occurs when the canopy cover is about 60-70% for tree crops and 70-80% for field and row crops. The maximum canopy cover often coincides with the time of year that sun radiation and air temperature are at their greatest. The maximum ETc therefore occurs during mid season.

During the crop development stage there are no set Kc values. If irrigating during this period choose a Kc value that is between Kc_{ini} and Kc_{mid}. A similar approach should be taken for the time period between Kc_{mid} and Kc_{end}. However this time period may be much shorter and a jump directly from Kc_{mid} to Kc_{end} could be taken.

Four crop growth stages

The Kc for a given crop changes over the growing period as the groundcover, crop height and leaf area changes. Four growth stages are recognized for the selection of Kc: initial stage, crop development stage, mid-season stage and the late season stage.

a. Initial stage

The initial stage refers to the germination and early growth stage when the soil surface is not or is hardly covered by the crop (ground cover < 10%). The Kc during this initial stage (Kc_{ini}) is large when the soil is wet from irrigation and rainfall and is low when the soil surface is dry.

b. Crop development stage

The crop development stage is the stage from the end of the initial stage to attainment of effective full groundcover (groundcover 70-80%). As the crop develops and shades more and more of the ground, soil evaporation becomes more restricted and transpiration becomes the dominant process. During the crop development stage, the Kc values correspond to amounts of ground cover and plant development and thus varies. If the soil is dry, Kc_{dev} = 0.5 corresponds to about 20-40% groundcover. A Kc_{dev}= 0.7 often corresponds to about 40-60% groundcover.

c. Mid-season stage

The mid-season stage is the stage from attainment of effective full groundcover to the start of maturity, as indicated for example by discolouring of leaves (as in beans) or falling of leaves (as in cotton). The mid-season stage is the longest stage for perennial crops and for many annual crops, but it may be relatively short for vegetables that are harvested fresh for their green vegetation. At this stage, Kc reaches its maximum value. The value of Kc mid is relatively constant for most growing and cultural conditions.

d. Late season stage

The late season stage runs from the start of maturity to harvest or full senescence. The calculation of Kc and ETo is presumed to end when the crop is harvested, dries out naturally, reaches full senescence, or experiences leaf drop. The Kc value at the end of the late season stage (Kc_{end}) reflects crop and water management practices. The Kc end value is high if the crop is frequently irrigated until harvested fresh. If the crop is allowed to senescence and to dry out in the field before harvest, the Kc end value will be small.

Determination of the growth stages

Once the total growing period is known, the duration (in days) of the various growth stages has to be determined.

The total growing period is divided into 4 growth stages (see Fig. 3.):

1. The initial stage: this is the period from sowing or transplanting until the crop covers about 10% of the ground.
2. The crop development stage: this period starts at the end of the initial stage and lasts until the full ground cover has been reached (ground cover 70-80%); it does not necessarily mean that the crop is at its maximum height.
3. The mid - season stage: this period starts at the end of the crop development stage and lasts until maturity; it includes flowering and grain-setting.
4. The late season stage: this period starts at the end of the mid season stage and lasts until the last day of the harvest; it includes ripening. Table 2, shows the duration of the various growth stages for some of the major field crops.

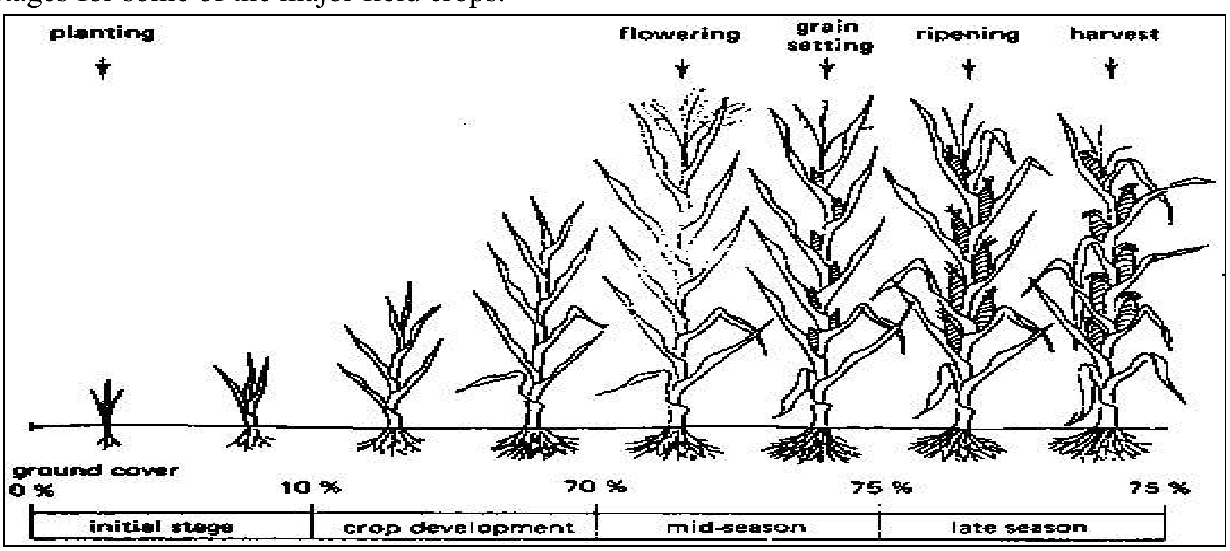

Figure 3. Growth stage of the crop

A crop coefficient graph is thus prepared for the entire growing season of the crop, from which values can be obtained for different periods of the growing season of the crop.

Table 2. Approximate duration of growth stage for various field crops.

	Total	Initial stage	Crop Development stage	Mid season stage	Late season stage
Barley/Oats/Wheat	120	15	25	50	30
	150	15	30	65	40
Bean/green	75	15	25	25	10
	90	20	30	30	10
Bean/dry	95	15	25	35	20
	110	20	30	40	20
Cabbage	120	20	25	60	15
	140	25	30	65	20
Carrot	100	20	30	30	20
	150	25	35	70	20
Cotton/Flax	180	30	50	55	45
	195	30	50	65	50
Cucumber	105	20	30	40	15
	130	25	35	50	20
Eggplant	130	30	40	40	20
	140	30	40	45	25
Grain/small	150	20	30	60	40
	165	25	35	65	40
Lentil	150	20	30	60	40
	170	25	35	70	40
Lettuce	75	20	30	15	10
	140	35	50	45	10
Maize, sweet	80	20	25	25	10
	110	20	30	50	10
Maize, grain	125	20	35	40	30
	180	30	50	60	40

Melon	120	25	35	40	20
	160	30	45	65	20
Millet	105	15	25	40	25
	140	20	30	55	35
Onion/green	70	25	30	10	5
	95	25	40	20	10
Onion/dry	150	15	25	70	40
	210	20	35	110	45
Peanut/Groundnut	130	25	35	45	25
	140	30	40	45	25
Pea	90	15	25	35	15
	100	20	30	35	15
Pepper	120	25	35	40	20
	210	30	40	110	30
Potato	105	25	30	30	20
	145	30	35	50	30
Radish	35	5	10	15	5
	40	10	10	15	5
Sorghum	120	20	30	40	30
	130	20	35	45	30
Soybean	135	20	30	60	25
	150	20	30	70	30
Spinach	60	20	20	15	5
	100	20	30	40	10
Squash	95	20	30	30	15
	120	25	35	35	25
Sugarbeet	160	25	35	60	40
	230	45	65	80	40
Sunflower	125	20	35	45	25
	130	25	35	45	25
Tomato	135	30	40	40	25
	180	35	45	70	30

2.2.3. Identifying length of growing seasons

The length of the growing season in any given region refers to the number of days when plant growth takes place. The growing season often determines which crops can be grown in an area, as some crops require long growing seasons, while others mature rapidly. Growing season length is limited by many different factors. Depending on the region and the climate, the growing season is influenced by air temperatures, frost days, rainfall, or daylight hours.

Changes in the length of the growing season can have both positive and negative effects on the yield and prices of particular crops. Overall, warming is expected to have negative effects on yields of major crops, but crops in some individual locations may benefit. A longer growing season could allow farmers to diversify crops or have multiple harvests from the same plot. However, it could also limit the types of crops grown, encourage invasive species or weed growth, or increase demand for irrigation. A longer growing season could also disrupt the function and structure of a region's ecosystems and could, for example, alter the range and types of animal species in the area.

Data on the duration of the total growing season of the various crops grown in an area can best be obtained locally. These data may be obtained from, for example, the seed supplier, the Extension Service, the Irrigation Department or Ministry of Agriculture.

Table 3. Indicative values of the total following period

Crop	Total growing period (days)	Crop	Total growing period (days)
Alfalfa	100-365	Millet	105-140
Banana	300-365	Onion green	70-95
Barley/Oats. Wheat`	120-150	Onion dry	150-210
Bean, green `	75-90	Peanut/ ground nut	130-140
Dry	95-110	Pea	90-100
Cabbage	120-140	pepper	120-210
Carrot	100-150	Potato	105-145
Citrus	240-365	Radish	35-45
Cotton	180-195	Rice	90-150
Cucumber	105-130	Sorghum	120-130
Eggplant	130-140	Soybean	135-150
Flax	150-220	Spinach	60-100
Grain/small	150-165	Squash	95-120
Lentil	150-170	Sugar beet	160-230
Lettuce	150-140	Sugarcane	270-365
Maize sweet,	80-110	Sunflower	125-130
Grain	125-180	Tobacco	130-160
Melon	120-160	Tomato	135-180

2.2.4. Determining crop root depth

Rooting Depths (water extraction depth)

The effective root zone depth is the depth of soil used by the main body of the plant roots to obtain most of the stored moisture and plant food under proper irrigation. It is not the same as the maximum root zone depth. As a rule of thumb about 70% of the moisture extracted by the

root is obtained in the top half of the root zone; about 20% from the third quarter; and about 10% from the soil in the deepest quarter of the root zone.
Root zone depth will vary according to the effective soil depth, fertility management, and the rooting characteristics of the plant. Each plant has its own root development characteristics, which vary only slightly under adequate soil moisture conditions in a given soil profile.

The root depth of a crop also influences the maximum amount of water which can be stored in the root zone. If the root system of a crop is shallow, little water can be stored in the root zone and frequent - but small - irrigation applications are needed. With deep rooting crops more water can be taken up and more water can be applied, less frequently. Young plants have shallow roots compared to fully grown plants. Thus, just after planting or sowing, the crop needs smaller and more frequent water applications than when it is fully developed.

Different species of plants have different *potential rooting depths*. The potential rooting depth is the maximum rooting depth of a crop when grown in a moist soil with no barriers or restrictions that inhibit root elongation.

Water uptake by a specific crop is closely related to its root distribution in the soil. About 70 percent of a plant's roots are found in the upper half of the crop's maximum rooting depth. Deeper roots can extract moisture to keep the plant alive, but they do not extract sufficient water to maintain optimum growth.

Plant Rooting Characteristics

While the soil's texture impacts the amount of stored soil moisture, the plant's rooting characteristics determine how much of the soil moisture can be accessed by the plant. A deep rooted crop has access to a greater amount of soil moisture than does a shallow-rooted crop, usually allowing it to go longer between irrigations. The rooting depths of a number of crops are shown in the table below.

The rooting depth may be affected by the soil depth, constraining soil layers (hardpan, plowpan, etc.), or even abrupt changes in soil texture. When in doubt about the soil profile or rooting depth, use a soil auger or better yet a backhoe, to determine the rooting depth and soil profile textural characteristics.

Table 4. Approximate root depth of the major field crops

Shallow rooting crops (30-60 cm):	Crucifers (cabbage, cauliflower, etc.), celery, lettuce, onions, pineapple, potatoes, spinach, other vegetables except beets, carrots, cucumber.
Medium rooting crops (50-100 cm):	Bananas, beans, beets, carrots, clover, cacao, cucumber, groundnuts, palm trees, peas, pepper, sisal, soybeans, sugarbeet, sunflower, tobacco, tomatoes.
Deep rooting crops (90-150 cm):	Alfalfa, barley, citrus, cotton, dates, deciduous orchards, flax, grapes, maize, melons, oats, olives, safflower, sorghum, sugarcane, sweet potatoes, wheat.

Self-check-2	**Written test**

Name: ___________________________ Date: ________________

1. What is crop coefficient? (1pts)
2. Describe the four stages of growth? (**4pts**)
3. Explain factors affecting crop coefficient. (**4pts**)
4. What is the difference between maximum and active rooting depth? (**1pts**)

Note: Satisfactory rating – 10 points and above Unsatisfactory - below 10points

You can ask you teacher for the copy of the correct answers.

3.1 Recording frequency of irrigation

Irrigation interval or frequency of irrigation is the number of days between irrigation during periods without rain fall. It depends on the consumptive use rate of a crop and on the amount of available moisture in the crop root zone.

$$\text{Irrigation frequency}=\frac{\text{available water to be used by the crop}}{\text{Crop water requirement}}$$

$$II=\frac{(Fc-pwp)\,x\,Rz\,x\,D}{CWR}$$

Where II=Irrigation interval
Rz=depth of root zone (mm)
D=depletion factor /depletion of moisture (%)
Fc=volumetric field capacity
PWP= volumetric permanent wilting point
CWR= crop water requirement (mm/day)

Irrigation period /time of application

Irrigation period is the time that can be allowed for applying one irrigation to a given design area.

$$Ip=\frac{IIxIqxA}{0.36*Qm}$$

Where, Ip=irrigation period in hour
II=irrigation interval in day
Ig=cross irrigation requirement of plant in mm/day
A=Area of irrigated farm in hectare
Qm= manageable discharge in liter /sec

After we have calculated this irrigation frequency, we must follow the schedule and record irrigation frequency, but irrigation frequency should not be greater than irrigation period.

N.B when we record irrigation frequency, we have to look for crop environment and the resulting change as irrigation frequency changed in some moments.

3.2 Measuring and recording water usage

3.2.1. Purpose of Water Measurement

Measuring water in irrigation systems is critical for efficient irrigation water management. Without knowing the amount of water being applied, it is difficult to make decisions on when to stop irrigating or when to irrigate next. A good irrigation manager should know the flow rate of the irrigation water, the total time of the irrigation event and the area irrigated. Irrigation management decisions should be made based on the amount of water applied and how this relates to the consumptive use demands of the plants and the soil water holding capacity. The amount of water applied to a field can be estimated using the following equation:

$$Q \times t = d \times A$$

Q is the flow rate, in cubic meter per second (m3/s); t is the set time or total time of irrigation (hours); d is the depth of water applied (mm) and A is the area irrigated (ha).

3.2.2. Methods/Types of flow measurement

Irrigation water management begins with knowing how much water is available for irrigation. In this module, methods of measuring irrigation flow rate can be grouped into two basic categories:

- direct measurement methods,
- velocity-area methods,

Choice of method to use will be determined by the volume of water to be measured, the degree of accuracy desired and the financial investment required.

3.2.3 Techniques of flow measurement

a) **Direct Measurement Methods**

Measuring the period of time required to fill a container of a known volume can be used to measure small rates of flow such as from individual siphon tubes, sprinkler nozzles, or from individual outlets in gated pipe.

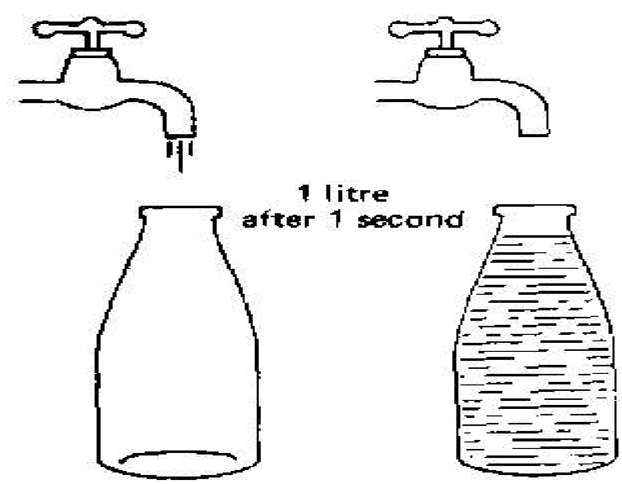

Figure 4: A flow-rate of one liter per second

Question

The water supplied by a pump fills a container of 200 liters in 20 seconds. What is the flow rate of this pump?

The formula used is:

$$Q = \text{flow rate}(l/s) = \frac{\text{volume of water(lt)}}{\text{Time}(s)}$$

$$Q = \frac{\text{volume of water}}{\text{Time}} = \frac{200\ l}{10\ s} = 10\ l/s$$

b) Velocity-area methods

The most practical method of measuring stream discharge is through the velocity-area method. Discharge is determined as the product of the cross-sectional area of the water times velocity. Discharge, or the volume of water flowing in a stream over a set interval of time, can be determined with the equation: $Q = VA$

Where; Q is discharge (volume/unit time (m^3/second), A is the cross-sectional area of the stream (m^2), and V is the average velocity (m/s).

This method comprises measuring the mean velocity V and the flow area 'A' and computing the discharge Q from the continuity equation. The site which satisfies the requirements such as straightness, stability, uniformity of cross-section is chosen for discharge measurement. The discharge measurement site is then marked by aligning the observation cross-section normal to the flow direction. The cross-section is demarcated by means of masonry or concrete pillars on both the banks, two on each side 30 m apart.

Procedures of Water Measurement in an Open Channel

I. Measuring of width or average width of an open channel

In order to measure the width of a channel the following procedures are used:

- ✓ Select straight canal view and stretch a string from one side of the channel to the other side;
- ✓ Put marks on the string to indicate the exact water surface on both sides of the channel;
- ✓ Measure the distance between the two marks and this is the width of the channel. If the field channel does not have equal width along the straight line selected it is better to take measurements at more places and take the average width of the channel.

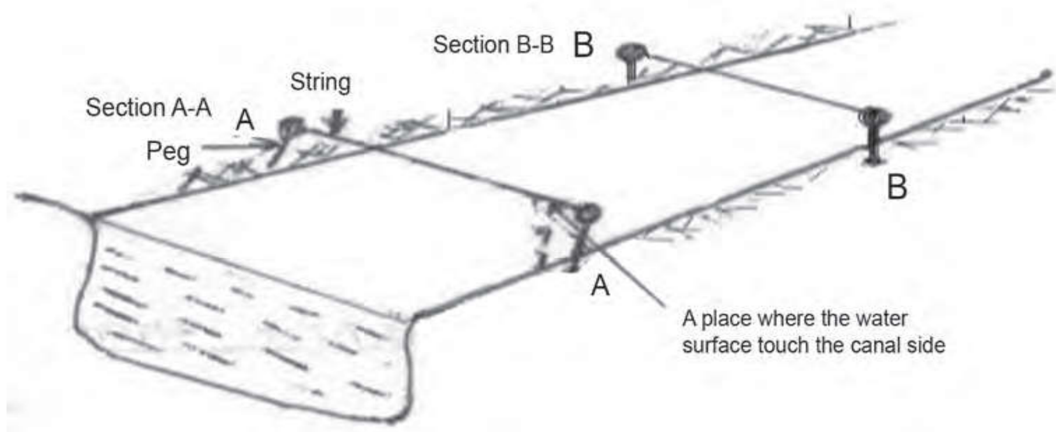

Figure 5: Schematic illustration how to measure width of a canal

II. Measuring the average depth of water

In order to measure the average depth of water it is possible to use bamboo or a piece of wood circular at the base. The wooden piece should have a thickness of 3- 8 cm in order to resist the pressure of the water and delineated on it in meter and centimeter. The height preferably is more than one meter. On the measuring stick numeration should be written starting from 0 following bottom to up approach and zero should be marked at the flat bottom of the stick. The measuring can be done on the same area where the width is measured and measurements are taken at 30 cm interval. The average depth can be determined by dividing the sum of all the measured depths by the number of measurements taken.

Table4: Sample data for measuring depth

# of tests	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**average**
Depth, m	0.30	0.40	0.51	0.52	0.51	0.50	0.35	3.09/7= 0.44

Number of trials for measuring depth are 7 and an average depth of an open channel is therefore, equal to 0.44 m (Total depths measured divided by the number of trials; 3.09/7 = 0.44 m).

III. Measuring the cross- sectional area

The cross- sectional area is calculated by multiplying the width by the average depth of the canal. To do this first it is recommended summing up of all the partitions subdivided to measure the depths at certain intervals and then multiply the result with the average depth.

$$cross\ sectional\ area, m^2 = average\ width, m \times average\ depth, m$$

$$2.30m \times 0.44m = 1.012m^2$$

IV. Measuring of the water velocity in an open channel

For the float method: measure out some convenient distance along the stream bank (try at least 30 meters). Station one person at the upstream end of your selected reach and one at the downstream end. The person at the upstream end has the stop-watch and the oranges. The person at the top releases an orange and starts the clock when the orange floats over the top boundary of your reach. When the orange passes the bottom boundary of your reach, the person at the bottom signals to the top person to stop the clock. Someone records the time and notes the distance traveled. Do this at least three times.

Calculations: $Surface\ velocity = distance/time$

$$average\ surface\ velocity = sum\ of\ surface\ velocities/number\ \ of\ trials$$

Finally, knowing the cross- sectional area of the channel and the average velocity of the water in the channel, the discharge of the water in the open channel could be calculated by multiplying the cross- sectional area by the velocity of the water.

Table 5: Estimated average velocity from different data set

Test #	Time in second	distance in m	Velocity of water in m/s
1	20	10	0.50
2	21	10	0.48
3	22	10	0.45
average	21	10	0.48

At the end of the test the results should be added and divided by the total number of tests. Therefore, an average velocity is 10/20.6 = 0.48 m/s.

$$Q(l/s) = A \times V = 1.012m^2 \times 0.48m/s = 0.49m^3/s$$

After you measure the water usage you will be Recording the water you use may be further complicated if restrictions occur over the summer period so different sources of water need to be accessed to meet crop requirements and be compliant.

There are a number of ways that you can record and keep track of the water you use, and this factsheet provides three examples that may be helpful:

1. Recording water use from irrigation amount
2. Recording water use from meter readings
3. Recording water use from pumping rates

1. Recording water use from irrigation amounts

Many farmers will record the amount of water that is applied to a crop at each irrigation. This makes it easy for you to calculate the amount of water you have used per irrigation and record it against your crop and water source. If your irrigator does not record the output, then simply using rain gauges strategically placed across your crop to catch irrigation water will give you an estimate of the amount used. This will also identify any issues you may have with inconsistent application of water.

A sample table could be used to record crop irrigations by date, amount and water source:

crop	date	Amount (mm/ha)	Area(ha)	Total(ML)	Water source

Table: 6 Irrigation Water Used Record

Including both the crop and the water source will assist you in not only knowing if you have complied with your water allocations, but also in knowing how much water you have applied to each crop. This information may be useful in future planning or benchmarking activities.

2. Recording water use from meter readings

If you have meters installed, then it is possible to record your water use by reading the meters at particular intervals. Generally, you should read your meter:

• At the start of the season;
• Each time you change your water source;
• At the beginning and end of each restriction period;
• At the end of the season

The table below provides an example of how meter readings could be recorded and the data that may be useful. There should be a separate record sheet for each meter.

Meter name /number	Pump house station				
crop	date	Meter reading	Reason	Amount (ML)	Water source

Tebel: 7 Meter Reading Record

Other situations that meters may be read and recorded include:

- Tracking of any unlicensed water that may go through the meter (eg Stock and Domestic);
- Recording of internal movements of water passing through the same meter to ensure that the same water is not accounted for twice;
- Anything else that may be used to explain how water was used.

3. Recording water use from pumping rates

To use this method, you will need to know the capacity of your pump, be operating a fixed irrigation system and regularly check your flow rate. Even then, there are generally inconsistencies in flow rates in many systems that make this system difficult.

This method would require readings to be taken at every irrigation with each pump having its own record sheet. The table below provides an example that may be useful to the recording of water usage.

Meter name /number						
crop	date	Start time	Finish time	Pumping time(hours)	Amount (ML)	Water source

Table: 8 Pumping Hours Record

3.3 Computing actual and estimated water use

When we design any irrigation project we may not get the accurate information about the factors that affect our assumptions and measured values. Alteration of these factors, irrigation efficiency and the manner that different bodies' coordination in the project to deliver irrigation requirements will result in variation of estimated water use and actual water use.
The factors which are responsible for such variation can be;

1. **Change in weather condition**;
   - ✓ An usual rain fall
   - ✓ Rise in temperature
   - ✓ Increase in wind speed and intensity
2. **Irrigation efficiency**: - irrigation efficiency is the major factor that governs the better use of irrigation water. If our irrigation efficiency increases the water that we actually use will be less than the estimated one and vise verse. :. Therefore in order to check the difference, we have to measure or calculate the actual use by recording the water volume that we have used in a given season.

3.4 Measuring water quality

3.4.1 Water quality for irrigation

There are several ways water quality at a basic level can be measured. This is primarily done at the closest possible point to the water source, an 'in the field' form of testing. The quality of water here is determined by making measurements or by taking samples of water and testing them for acidity (PH), color, dissolved oxygen and turbidity (a measure of the suspended particles in the water). Such tests give a water utility operator a basic, general interpretation of the conditions of a water source.

Good quality irrigation water is essential to maintain the soil crop productivity at a high level. The essential prerequisite for quality irrigation water is that it should be safe for use to crops and should not damage soils. Poor quality water damages soils usually by making them saline or alkaline with salt accumulation that injures crops and causes a reduction in yield. Irrigated area is increasing every year and simultaneously lands damaged by salinity and alkalinities are also increasing. It is, therefore, necessary to judge the quality of water before its use and follow certain precautions in irrigating lands with saline water when there is a compelling situation for its use.

Irrigation waters drawn from different sources, surface or underground contains variable quantities of salts, silts and/or other materials. The quality and the quantity salts and silts present in the water depend on the nature of water sources, and the soils and underground strata over which the water flows. River and tank waters carry silts in suspension and salts in solution, whereas well water contains only dissolved salts. Pumped out underground water contains salts in solution and may sometimes contain silts in suspension. The silt content in running water, as in rivers, is usually higher and coarser in texture than in still water of tanks and reservoirs.

3.4.2 Water quality criteria

There have been calls to establish standards as a guide for judging the suitability of water for irrigation. Any classification should be based on the total concentration and the composition of salts. However, the suitability of water for irrigation also depends on other associated factors, such as the crop, soil, climate and management practices. The classification adopted by FAO in 1985 (after Maas), and proposed as an initial guide (Table2), has proved most practical and useful in assessing water quality for on-farm water use. The principal parameters for water classification (crop response to salinity, sodium hazard and toxicity) are quite clear and understood by both the extension engineers and the farmers themselves for proper irrigation management and follow-up purposes.

With the FAO assessment method, the parameters taken into consideration are the four presented below.

Table 9: Water classification by salinity

Salinity classification	EC ds/m	TDS mg/litre
Non-saline water	< 0.7	< 500
Saline water	0.7-42	500- 30000
Slightly saline	0.7-3.0	500- 200
Medium saline	3.0- 6.0	2000- 4000
Highly saline	> 6.0	>4000
Very saline	>14.0	>9000
Brine	>42.0	>30000

- **Electrical conductivity (EC)**

Water that contains salt is able to conduct electricity. The more salt there is in a solution, the easier it is for and electric current to flow. The potential of a solution to pass an electric current is called electrical conductivity (EC) and it is usually measured in micro Siemens per centimeter (µS/cm). This is often expressed simply as an 'EC Unit'.

As the concentration of salt in a solution increases, so does the EC reading. An EC meter can also be used to measure the amount of salt in soil by mixing a soil sample with water and then testing the EC of the solution. The most commonly used units of EC measurement is 'EC Units' or 'µS/cm'. Other units for measuring salinity are:

- Deci Siemens per meter (dS/m)
- milli Siemens per centimeter (mS/cm)
- millimho per centimeter (mmhos/cm)
- Parts per million in water (mg/litre)

❖ **Converting units of measurement**

One unit of measurement can be converted to another by using the following information:

Eg.1000 EC (µS/cm) = 1dS/m = 1mS/cm = 1mmho/cm = 640 ppm.

Table 10: Converting units of measurement

To convert from this …..	To this ….	Do this
EC (µS/cm)	ds/m	Divide by 1000
ds/m	EC ((µS/cm)	Multiply by 1000
ds/m	ppm	Multiply by 640

3.5 Assessing crop growth and water use efficiency

The basic objective of any irrigation project or work is to increase the productivity or yield of a crop. In order to get such yield it is necessary to monitor the crop environment from germination to ripening, (for a given growing period) because some crops require water for germination, some for harvesting and others for most of growing periods. When we assess crop growth in irrigation field we should have some references, since there is no common principle to assess the crop growth for all types of crops and the method will depend on the type of plant, the method of sowing, planting pattern and so, on. Beside this we have to consider critical growth periods (at which crops are sensitive to water stress), root development periods and growing stages.

If the type of crop is broad band type we have to consider the growth seasons and corresponding soil cover. If it is raw crop it is possible to count the plant that survives and so on. After assessing plant growth at each stage and comparing the value with the recommended values we have to recommend our monitoring and irrigation activities.

Irrigation efficiency is the ratio of the average depth of irrigation water beneficially used (consumptive use plus leaching requirement) to the average depth applied, expressed as a percentage.Improved water-conveyance systems are an important potential source of farm-level water savings.System upgrades include ditch lining, ditch reorganization, and pipeline installation and precision field-levelling, shortened water runs, alternate furrow irrigation, and tail water reuse are some of the tools used to improve irrigation efficiencies.

Carefully managed deficit irrigation on crops would provide the greatest potential for substantially reducing agricultural water use because of long season growing period and the larger land areas that are involved. High-value crops may also produce some water savings through various deficit irrigation strategies, but their impact will be much lower because they generally occupy less than 10% of irrigated area (location specific). However, deficit irrigation strategies still must be developed for most crops.

1. **Water Conveyance efficiency (Ec)**

This term is used to measure the efficiency of water conveyance system associated with the canal network, water courses and field channels. It is also applicable where the water is conveyed in channels from the well to the individual fields. It is expressed as follows:

$$Ec = \frac{W_f}{W_d} * 100$$

Where Ec = water conveyance efficiency , %

Wf = Water delivered to the irrigated plot (At the field supply channel)

Wd = Water diverted from the source.

2. **Water application Efficiency (Ea)**

After the water reaches the field supply Channel , it is important to apply the water as efficiently as possible. A measure of how efficiently this is done is the water application efficiency.

$$Ea = \frac{W_s}{W_f} * 100$$

Where Ea = application efficiency , %

Ws = water stored in the rot zone of the plants.

Wf = Water delivered to the irrigated plot (At the field supply channel)

Water application efficiency below 100 percent are due to seepage looses from the field distribution channels, deep percolation below the crop root zone and runoff loses from the tail end of borders and furrows (in very long fields).

3. Water storage efficiency (Es)

Small irrigation may lead to high water application efficiencies, yet the irrigation practice may be poor. The concept of water storage efficiency is useful in evaluating this problem. This concept relates how completely the water needed prior to irrigation has been stored in the root zone during irrigation.

$$E_s = \frac{W_s}{W_n} * 100$$

where Es = Water storage efficiency , %

Ws= water stored in the rot zone of the plants.

Wn = Water needed in the root zone prior to irrigation

Water storage efficiency becomes important when water supplies are limited or when excessive time is required to secure adequate penetration of water in to the soil. Also, when salt problems exist, the water storage efficiency should be kept high to maintain favorable salt balance.

4. Field Canal Efficiency (E_b)

This ratio between water received at the field inlet and that received at the inlet of the block of fields.

$$E_b = \frac{W_p}{W_f} * 100$$

where E_f = Field canal efficiency

W_p = water received at the field inlet

W_f = water delivered to the field channel

5. Water Distribution Efficiency (E_d)

This shows how uniformly water is applied to the field along the irrigation run. In sandy soils there is generally over irrigation at upper reaches of the run when as in clayey soils, there is over- irrigation at the lower reaches of the run.

$$E_d = \left(1 - \frac{\bar{y}}{d}\right) x100$$

Where E_d = water distribution efficiency , %

d = average depth of water penetration.

$\bar{y}$ = average deviation from d.

6. **Water Use Efficiency**

This shows the yield of the crop per unit volume of water used. It may be expressed in Kg/ha.cm or q/ha.cm

A. **Crop Water Use Efficiency**: is the ratio of the crop yield (Y) to the amount of water consumptively used by the crop.

$$E_w = \frac{Y}{CU}$$

B. **Field Water Use Efficiency**: is the ratio of the crop yield (y) to the total water requirement of crops including Cu losses and other needs.

$$E_t = \frac{Y}{WR}$$

7. **Project Efficiency (Ep)**

This shows how efficiently the water source used in crop production. It shows the percentage of the total water that is stored in the soil and available for consumptive requirements of the crop. It indicates the overall efficiency of the systems from the head work to the final use by plants for Cu. The Overall project efficiency must be considered in order to fix the amount of water required at the Diversion head work.

3.6 Measuring soil chemical characteristics and assessing soil moisture

Soil moisture is always being subjected to pressure gradients and vapor pressure differences that cause water to move. Thus it cannot be constant at any pressure. But for particularly significance in agriculture, same soil moisture constants are used. These are;

- saturation capacity

- Moisture equivalent
- Available water
- field capacity
- permanent writing point

Saturation capacity: - when all the pores in the soil are filled with water. The tension of water at this Level is almost zero and it is equal to free water surface.

Field capacity:-soil moisture content after draining excess water and it is relatively stable. The soil moisture tension at field capacity varies from soil to soil, but ranges from 1/10 to 1/3 atmospheres.

Moisture equivalent: the amount of water retained by a sample of initially saturated soil material after being subjected to a center fugal force of 1000times that of gravity for a definite period of time, usually hour in hour.

Permanent wilting percentage /pwp: - soil moisture content at which plant cannot longer obtain

Enough moisture to meet transpiration requirement, and remain wilted unless water is added to the soil. The moisture tension here ranges from 7 to 32 atmospheres.

Available water: - soil moisture between Fc and pwp. It is moisture available for plant use. In general, fine texture soil has a wide range of water b/n Fc and pwp than course textured soil.

Kinds of soil water

a. **Hygroscopic water**: - is water held tightly to the surface of soil particles by adsorption forces.
b. **Capillary water**: - is water held by forces of surface tension and continuous films around soil particles and in the capillary spaces.
c. **Gravitational water**: - is water that moves freely in response to gravity and drains out of the soil.

N.B from the above three water forms, only capillary water is available to the plants.

Measurement of soil moisture

Soil moisture Measurements are important in the suitable scheduling of irrigation and estimating the amount of water to be applied in each irrigation and to estimate evapotranspiration. There are also many experimental situations where careful measurement and control of soil moisture is necessary if the results of investigation on soil –plant-water relationships are to be interpreted properly.

The principal methods of expressing soil moisture are:-

I. By the amount of water in a given amount of soil and,
II. The stress or tension under which the water held by the soil.

<u>Methods of measuring soil moisture</u>.

1. By feel and touch: - this is by far the easiest method. Assessment by feel is good for experienced people who have sort of calibrated their hands.

2. Gravimetric method

- Known volume of soil samples are taken from the field, weighed, and then dried in an oven for 24 hours at an average temperature of 105^0 c
- After dried, the samples will be taken out from the oven and weighed again. The d/ce in weight before and after drying is the amount of moisture present in the soil.

- The amount of moisture that is held by a certain mass or volume of soil can be expressed as *weight percent or volume percent*. Soil moisture on weight basis is based on the dry weight of sample.

Soil moisture content percent by weight

$$\text{SM (\%)} = \frac{(\text{weight of moisture sample} - \text{weight of oven dry sample}) \times 100}{\text{Weight of oven dry sample}}$$

N.B expression of soil moisture content as % age of dry weight may not indicate the amount of water, available to plant, unless the soil moisture cxs carve or the Fc and pwp are known but it is useful to convert moisture content per units of weight into moisture content per units of volume.

Moisture content (% by volume) = moisture content (% by weight) x balk density.

Bulck density is the ratio of the mass of dried particle to total volume of soil (including particles and pores)

Gravimetric method is an accurate method but time consuming and the method is not practical for form use, as the oven cannot orderly be owned by farmers. But it is a standard against w/c other methods of moisture determination are compared.

3. Neutron probe

- ✓ It is indirect way of determining soil moisture content.
- ✓ It uses radioactive sources like beryllium and the sure emits fast neurons, some of which are slowed down when they collide with water molecules (hydrogen molecule)
- ✓ A cloud of slow neutrons (thermal neutrons) build up near the probe and are registered by the rate mater or rate scalar w/c measures the number of slowed down neutrons and it is necessary to have a graph of standardized calibrated curve of counts vs. moisture content of soil and used for wide range of soil moisture content but not suitable for small samples.
- ✓ It is dangerous since it is radioactive and must be used with care.

4. Tesiometer:-

- ✓ It provides a direct measurement of the tenancy with w/c water is held by soils and used to estimate the soil moisture content.
- ✓ It consists of porous ceramic cup filled with water which is buried in soil at any desired depth and connected to a water filled tube to a manometer or vacuum gauge which measure the tension, the reading is then taken and correlated to moisture content using a calibration carve.

Soil Chemical characteristics include salts, (total concentration of soluble salts and residual sodium carbonate), hardness, PH, fluoride, chloride, metals nutrients, organics.
Salts in irrigation water originate primarily through weathering of bedrocks, rocks and minerals. In humid climates, these salts usually get drained out to rivers and seas, while in semi-arid and arid climates; they accumulate in soil profile at lower levels or drain out to lower areas. When the soil water from upper soil layers evaporates, salts come up and accumulate in upper layers and on the soil surface. Accumulation of salt is more serious in low laying areas. Ground water has a higher salt content than the surface water.

Salinity is a common problem facing farmers who irrigate in arid climates. This is because all irrigation waters contain soluble salts. Whether derived from springs, diverted from streams, or pumped from wells, the waters contain appreciable quantities of chemical substances in solution, dissolved from the geological strata through and over which the waters have flowed. Waters with a high salt content may have moved from a saline water table. In areas with intensive agriculture, fertilization is a major cause of aquifer salinization.

The composition of salts in water varies according to the source and properties of the constituent chemical compounds. These salts include substances such as gypsum (calcium sulphate, $CaSO_4.2H_2O$), table salt (sodium chloride NaCl) and baking soda (sodium bicarbonate $NaHCO_3$). When dissolved in water, salts separate into ions; e.g. sodium chloride breaks down into sodium and chloride ions. Thus, it is customary to refer to ions rather than salts. The principle ions in irrigation water and their characteristics are listed in Table 11.

Table 11: Principle ions present in irrigation water

Ions	**Chemical symbol**	**Equivalent weight**

Anions (acidic ions)		
Chloride	Cl^-	35.5
Sulphate	SO_4^{--}	48
Carbonate	CO_3^{--}	30
Bicarbonate	HCO_3^-	61
Nitrate	NO_3^-	62
Cations (basic ions)		
Sodium	Na^+	23
Potassium	K^+	39.1
Calcium	Ca^{++}	20
Magnesium	Mg^{++}	12.2

All ions are expressed in the form of milligrams per litre (mg/litre or ppm) and mill equivalents per litre (meq/litre). The latter unit is preferable because water quality criteria involve mill equivalents per litre calculations.

The conversion formula is:

$$meq/litre = \frac{mg}{litre\ equivalentweight}$$

Boron is also present in irrigation waters as un-ionized boric acid expressed as boron element (B) in milligrams per litre. The salt concentration in most irrigation waters ranges from **200 to 4 000 mg**/litre total dissolved solids (TDS). The pH of the water is also an indicator of its quality and it normally ranges from 6.5 to 8.4.

The common method for evaluating the total salts content in water is by measuring the electrical conductivity of water (ECw) at 25°C. Electrical conductivities is expressed in Deci Siemens per meter. There is a relation between the electrical conductivity and the concentration of salts in mill equivalents per litre and in milligrams per litre when the ECw is in the range of 1–5 dS/m. Thus, every 10 meq/litre of salts (cation concentration) create 1 dS/m ECw. The relationship between electrical conductivity and total dissolved salts (TDS) is:

$$ECw(ds/m) \times 640 = TDS(mg/litre)$$

The sum of cations should equal the sum of anions. The accuracy of the chemical water analyses should be checked on the basis of the above relationships.

3.7 Measuring labor performance

Labor performance can be a function of many features, including the worker's effort, education, age, or tenure, and the firm's characteristics, such as work environment, wages, or incentives. An observed change in a worker's performance might be due to several reasons, including factors outside of the worker's control. The two most common reasons are changes in the worker's skills, e.g. due to training programs or from learning on-the-job, and changes in effort provided by the worker, e.g. due to different incentives set by the management.

A performance measure's usefulness for assessing workers' behavior crucially depends on the degree to which the worker has influence on the measure. Measures will be unreliable predictors of workers' productivity if they are largely driven by factors that are outside of a worker's control, such as variation in customer demand, or weather and climate conditions in agriculture

Measures of workers' productivity represent a relatively new tool for Monitor irrigation system process. Even if there is no universal definition of workers' productivity, studies using these measures have made important contributions to a wide range of fields. These contributions are not limited to low-skilled routine jobs where performance measurement might be easier. Rather, measures of workers' productivity are available for a wide range of jobs, including low- and high-skilled jobs in both the private and public sectors.

Working hours and performance

Another example of how direct measures of workers' productivity can inform policy involves working hours. The length of the standard workweek varies both between and within countries. Little is known about what an optimal number of weekly working hours would be from an efficiency perspective. Direct measures of workers' productivity allow one to estimate how the number of working hours or shifts in working hours affects performance; this might be crucial with respect to health and safety. Long working hours, for example, might result in increased fatigue, which is particularly dangerous in medical occupations. This type of result can also provide direct advice about whether working hours should be expanded or reduced.

3.8 Recording climate and weather conditions

Weather is the state of the atmosphere at any given time and place. Most of the weather that affects people, agriculture, and ecosystems takes place in the lower layer of the atmosphere. Familiar aspects of weather include temperature, precipitation, clouds, and wind that people experience throughout the course of a day. Severe weather conditions include hurricanes, tornadoes, blizzards, and droughts.

Climate is the long-term average of the weather in a given place. While the weather can change in minutes or hours, a change in climate is something that develops over longer periods of decades to centuries. Climate is defined not only by average temperature and precipitation but also by the type, frequency, duration, and intensity of weather events such as heat waves, cold spells, storms, floods, and droughts.

Therefore we can understand the difference between climate and weather conditions they can be recorded separately to determine the crop water requirements of the irrigated crop.

Self-Check -3	**Written Test**

Name: ___________________________ **Date:** ______________

Directions: **Answer all the questions listed below. Illustrations may be necessary to aid some explanations/answers.**

1. What is irrigation frequency means and how can you determine irrigation frequency?(3pt)
2. What are generally accepted criterions for judging the quality of water?(4pt)
3. Explain the purpose of measuring and recording water usage?(3pt)
4. List and explain methods/types of water flow measurements?(3pt)
5. Which soil components are responsible for chemical properties of soil?(3pt)
6. Write the factors which affect the variation of estimated water use and actual water use?(3pt)
7. What is irrigation efficiency means? How can you estimate irrigation efficiency?(5pt)
8. Write the advantage of measuring labor performance in Monitor irrigation system process?(3pt)
9. Write the advantage of recording climate and weather conditions in Monitor irrigation system process?(3pt)

Note: **Satisfactory rating – 25 points and above Unsatisfactory - below 25points**

You can ask your teacher for the copy of the correct answers

INFORMATION SHEET#4	Record, Compile & analyze Data

4.1: Recording crop environment data

Every information which is relevant to irrigation should be recorded. These can be;

- Crop environment data,
- Water orders and usage,
- Irrigation shifts and
- System process data like, irrigation interval, irrigation frequency and so on.

4.1.1 Water supply – irrigation:

Detail the actual water usage (ML) and associated type and area (ha) of crops irrigated per irrigator/month. Record all water taken against each irrigator' irrigation right (a spread sheet and graph may assist in showing this).

Record total water allocation against actual delivery, link to restriction % (a graph may assist in showing this).

Show how total water taken for irrigation purposes was consistent with the allocations on the water entity and water license.

4.1.2 Environmental Conditions

Measurement of meteorological variables is necessary to understand weather conditions in the field. Daily records of maximum, minimum and mean temperature (air and soil), total precipitation, mean wind speed, potential evapotranspiration, relative humidity and sunshine intensity should be recorded. When irrigation is used to supplement rainfall, timing and amounts of irrigation water should also be reported.

Historical climatologically data should be obtained to help evaluate site data with respect to long-term regional variation, and the source and location of the historical data should be specified. Historical climatic information should include monthly average rainfall, average monthly minimum and maximum temperatures, and the dates and the number of days in the average annual frost-free period.

4.1.3 Soil conditions.

These can be soil moisture, aeration characteristics and soil temperature and so on. All the above data can be presented by; text, graph, table and computer programs.

4.2 Analyzing soil data for physical properties

Soil data is analyzed for physical properties following standard laboratory procedure.

4.3 Checking data consistency using standard statistical package

Basic statistics packages/tools used to check data consistency

Mean

The average of a set of *n* data x_i:

$$\bar{x} = \frac{\sum x_i}{n}$$

Standard deviation

This is the most commonly used measure of the spread or dispersion of data around the mean. The standard deviation is defined as the square root of the *variance (V).* The variance is defined as the sum of the squared deviations from the mean, divided by *n*-1. Operationally, there are several ways of calculation:

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

Relative standard deviation, Coefficient of variation

Although the standard deviation of analytical data may not vary much over limited ranges of such data, it usually depends on the magnitude of such data: the larger the figures, the larger *s*. Therefore, for comparison of variations (e.g. precision) it is often more convenient to use the *relative standard deviation (RSD)* than the standard deviation itself. The *RSD* is expressed as a *fraction,* but more usually as a *percentage* and is then called *coefficient of variation (CV).* Often, however, these terms are confused.

$$RSD = \frac{s}{\bar{x}} \quad CV = \frac{s}{\bar{x}} \times 100\%$$

Confidence limits of a measurement

The more an analysis or measurement is replicated, the closer the mean x of the results will approach the "true" value m, of the analyte content (assuming absence of bias).

A single analysis of a test sample can be regarded as literally sampling the imaginary set of a multitude of results obtained for that test sample. The uncertainty of such subsampling is expressed by

$$\mu = \bar{x} \pm t\frac{s}{\sqrt{n}}$$

Where

m = "true" value (mean of large set of replicates)
$\bar{x}$ = mean of subsamples
t = a statistical value which depends on the number of data and the required confidence (usually 95%).
s = standard deviation of mean of subsamples
n = number of subsamples

(The term $s/\sqrt{n}$ is also known as the *standard error of the mean.)*

4.4 Choosing method for computing crop water requirement devices and models

Method for computing crop water requirement is chosen based on data preference and performance. In order to compute and determine the quantities we can use

- Computers,
- Scientific calculators and
- Powerful mobile.

Selecting appropriate computer software model

For computing crop water requirement and irrigation scheduling various computer software models have been developed some of these common models may include;

- Irrigation scheduler mobile
- FAO Crop-WAT

- Agricultural Production Systems Simulator (APSIM) Model
- Crop Simulation Models

Self check #4	Knowledge questions

Name: __________________________ Date: ________________

Directions: Calculate the following questions in the space provided

For the determination of the clay content in the particle-size analysis, a semi-automatic pipette installation is used with a 20 mL pipette. This volume is approximate and the operation involves the opening and closing of taps. Therefore, the pipette has to be calibrated, i.e. both the accuracy (trueness) and precision have to be established.

A tenfold measurement of the volume yielded the following set of data (in mL):

19.941	19.812	19.829	19.828	19.742
19.797	19.937	19.847	19.885	19.804

Determine the mean, Standard deviation, Relative standard deviation, Coefficient of variation and Confidence limits. (15 points)_ _

Note: satisfactory Rating-8 and above points. Unsatisfactory Rating-below 8 points

You can ask your teacher for the copy of the correct answers

REFERENCE

- FAO Irrigation and Drainage Paper No. 56; Crop Evapo-transpiration (guidelines for computing crop water requirements)

- FAO 1989, Irrigation Water Management: Irrigation Scheduling
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- S. L. Bithell and S. Smith (2011); the Method for Estimating Crop Irrigation Volumes for the Tindall Limestone Aquifer, Katherine, Water Allocation Plan, Northern Territory Government,