# CHAPTER 4: MANAGE SOIL AND WATER RESOURCES/ MANAGING SOIL AND WATER RESOURCES

## 4.1 Introduction

The unit specifies competencies required to manage soil and water resources. It involves aspects like assessment of area topography, conserve soil fertility, farm water conservation, design soil and water conservation structures, lay out soil and water structures, carry out farm irrigation, carry out farm drainage, farm water harvesting, waste water disposal, manage water supply and prepare soil and water resources management. The knowledge and skills gained on soil and water resources management will be critical in conservation of scarce water and soil resources.

The critical aspects of competency to be covered include; ability to test soil fertility, ability to design and construct farm water structures. Demonstrate understanding of soil nutrients, ability to asses area topography, ability to calculate fertilizer requirements, ability to manage waste water disposal, ability to prepare soil and water resources management report, demonstrate understanding of drainage systems, ability to harvest farm water, ability to irrigate farm and ability to manage water supply. Basic resources required include; Topography mapping tools, measuring tape, notebooks, levelling board, shovels, jembes, panga, water tanks, gutters, rope, soil auger, soil sample packaging bag and soil science laboratory and equipment.



The unit of competency covers eleven learning outcomes. Each of the learning outcome presents; learning activities that covers performance criteria statements, thus creating trainee's an opportunity to demonstrate knowledge and skills in the occupational standards and content in curriculum. Information sheet provides; definition of key terms, content and illustration to guide in training. The competency may be assessed through written test, demonstration, practical assignment, interview/oral questioning and case study. Self-assessment is provided at the end of each learning outcome. Holistic assessment with other units relevant to the industry sector workplace and job role is recommended.

## 4.2 Performance Standard

Manage soil and water resources as per; soil and water conservation manual, environmental management plan, waste water management manual, soil laboratory manual, soil and water conservation handbook and water supply and maintenance manual.

### 4.3 Learning Outcomes

#### 4.3.1 List of learning outcome

a) Assess area topography
b) Conserve soil fertility
c) Conserve farm water
d) Design soil and water conservation structures
e) Lay out soil and water structures
f) Carry out farm irrigation
g) Carry out farm water drainage
h) Harvest farm water
i) Manage waste water disposal
j) Manage water supply
k) Prepare soil and water resources management report

### 4.3.2 Learning Outcome No 1: Asses area topography

#### 4.3.2.1 Learning Activities

| **Learning Outcome No 1: Asses area topography** | |
|---|---|
| **Learning Activities** | **Special Instructions** |
| 1.1 Map area topography according to guidelines stipulated in soil and water conservation manual.<br>1.2 Asses area topography according to soil and water conservation manual<br>1.3 Document area topography as per soil and water conservation manual<br>1.4 Asses area topography for land use viability according to soil and water conservation manual | Demonstrate one soil and water conservation method using A- Frame |

#### 4.3.2.2 Information Sheet No4/LO1: Assess area topography



**Introduction**

This learning outcome covers; area topography, area topography mapping, assessment methods, land survey, land use systems and agro-ecological zones.

**Definition of key terms**

**Topography:** This refers to the arrangement of the natural and physical features of an area.

**Land survey:** It is the technique, profession, art and science of determining the terrestrial or 3 dimensional positions of points and the distance and angles between them.

**Content/procedures/methods/illustrations**

**1.1Area topography to be assessed is mapped out according to guidelines stipulated in soil and water conservation manual**

Mapping out area topography: The method for topography mapping involves:

- Using aerial photographs to determine distances, elevations and areas
- The distance, elevation and location measurement are taken in the field
- Record the measurements obtained in a field book
- Plot on paper in the office

The procedure for carrying out mapping or topographical survey includes the following steps:

- Determining enough horizontal location and elevation called side shots of grounds which will provide enough data for plotting during map preparation.
- Locating natural and man-made features that may be required for purposes of survey.

Topography mapping tools include: 3D surface view. Convert vector topographic maps, Raster DEMs and DEM extraction.

## 1.2 Area topography is assessed in accordance to soil and water conservation manual

Area topography assessment refers to mathematical measuring elevations and stream flow. It is also involves defining various geologic and geographical variables to describe a region. A topography assessment involves two steps;

- Measuring the elevations of the mountain peaks or raised services on the area under consideration. This is done as follows:

Using tools like transits with which the angle between measuring vantage and the sighted summit is taken at two points.

Construct a triangle with those two angles as corners and geometrically calculate the mountain heights.

- Taking measurements of streams.

Streams measurements include aspects such as width, depth, discharge volume and speed.

**Methods of area topography assessment**

It involves modern day remote sensing and satellite imagery analysis. An older survey is however used in on-the ground survey.



## 1.3 Assessed area topography is documented as per soil and water conservation manual.

**Topography documentation involves the following procedure**

i) Interpreting the colored lines, areas and other symbols, e.g. blue shading or coloring on maps usually represents water bodies while green shadings or shaded regions usually represent forested regions.
ii) Show features as points, lines or areas depending on their size and extent e.g. individual houses may be shown as black squares. Clusters of such small squares may be therefore representative of several houses.
iii) For large buildings, actual shapes are mapped as opposed to black squares.

**Methods of documenting area topography**

The following methods are used when documenting area topography: mapping, pictorial representations of topography. In mapping method, a key is provided which explains the symbols and features used in the map.

**1.4 Area topography is assessed for land use viability according to soil and water conservation manual**

Land use planning or Land use viability consists of a logical decision-making process in which the available resources are evaluated in the context of objectives and potentials are then identified which can be implemented by the user. Resource evaluation is carried out by a set of systematic technical procedure which will guide choice of sustainable options that will satisfy objectives of the land user. Procedure for assessing land use viability involves the following steps which aid in decision making:

i. Identifying stakeholders, their goals, needs and stake
ii. Establishment of multidisciplinary task force
iii. Collecting date and information
iv. Preliminary identification and screening of option
v. Negotiating and deciding upon options-Set up the plan
vi. Monitoring and evaluation of options.

Methods of land use viability: It involves 3 methods;

i. **National land use policy:** Refers to long term development objective formulated for allocation of the natural resources in the whole country
ii. **District land use plan:** It is based at district levels and has objectives which aim at development in the district level. It conforms to national land use policy.
iii. **Community land use plan:** People formulate objectives relevant to their community. The objectives should consider short- and long-term aspects and be focused on sustainable development of the community and its land resource

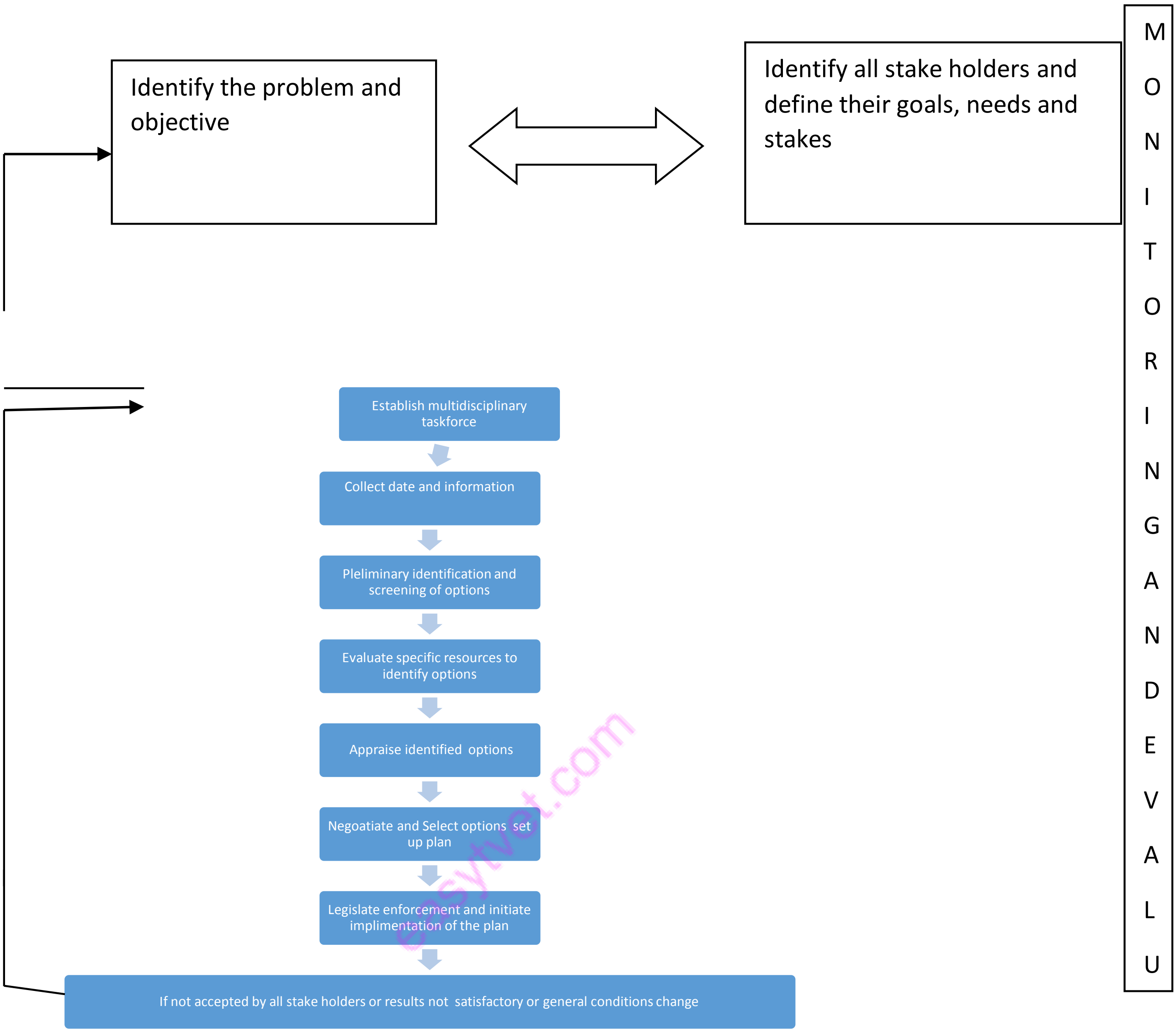



Figure 8: Planning Method

## Conclusion

This learning outcome covered; area topography mapping, area topography assessment methods, land survey, land use systems, and agro ecological zones.

## Further Reading


1. Journal of topography and land survey volume 8. Land surveying simplified. Paul L. Gay 2016

### 4.3.2.3 Self-Assessment

**Written assessment**

1. The following are area topography mapping tools except.
    a) 3D surface view
    b) Convert vector topography maps
    c) Topography instrumentation auger
2. The following aspects are focused about in land use viability except?
    a) Decision making process
    b) Soil degradation
    c) Resources evaluation
3. The following are agro ecological zones in Kenya except.
    a) Semi-arid
    b) Hot and wet regions
    c) Medium potential
4. The following aspects are assessed in measuring area topography except?
    a) Elevation of mountain peaks
    b) Flood water control
    c) Taking measurement of river's depth, height and discharge
5. The following are steps involved in topographical survey procedure except
    a) Locating natural and man-made features
    b) Determining ground side shots
    c) Developing topographical map key
6. What is land survey?
7. Give two methods of land use viability
8. What is topography?
9. What do you understand by the term land use viability?
10. Give two steps in topography documentation.

**Oral Assessment**

1. How are symbols and features explained in a topographical map.
2. Give two steps involved in logical decision-making process

**Practical Assessment**

1. Carry out a topographical survey/mapping of an identified area.

#### 4.3.2.4 Tools, Equipment, Supplies and Materials

- Topography mapping tools
- Measuring tapes
- Notebook
- Jembes
- Shovels
- Pangas
- Soil Auger
- Soil sample packaging bags
- Soil science laboratory and equipment
- Shovels

#### 4.3.2.5 References


Edward G.Taylor( 2002). GPS for Land Surveyors. Edinburg. Freetowns PRINTERS.

KLA (2000).Land use in Kenya. The case for a national land use policy.Nairobi. Kenya Land Alliance

Muchena. F.N. ( 2008). Indicators for Sustainable Land management in kenya context. Nairobi. Government printers.

Jia, N. F., Duan, J. N., & Qiao, Z. M. (2007). Analysis method of spatial distribution of land use in relation to topography. Economic Geography, 27(2), 310-312.

Delgado, J. A., & Berry, J. K. (2008). Advances in precision conservation. Advances in agronomy, 98, 1-44.

### 4.3.3 Learning Outcome No 2: Conserve soil fertility

#### 4.3.3.1 Learning Activities

| **Learning Outcome No 2: Conserve Soil fertility** | |
|---|---|
| **Learning Activities** | **Special Instructions** |
| 2.1. Sample Soil for fertility test following the procedures as per soil conservation handbook.<br>2.2 Test soil for nutrients elements as per soil laboratory manual<br>2.3 Record soil test results as per soil laboratory manual<br>2.4. Improve soil fertility through organic farming as per organic farming manual<br>2.5 Recommend soil fertility improvements given as per soil laboratory manual**.** | Demonstrate how to carry out soil fertility test in the farm |

#### 4.3.3.2 Information Sheet No4/LO2: Conserve soil fertility



**Introduction**

This learning outcome covers; basic soil science, soil nutrition, soil fertility management and improvement, fertilizer requirements and soil conservation systems.

**Definition of key terms**

**Soil science:** This is the scientific study of the soil including; soil formation, physical, chemical and biological properties of soil, classification and mapping of soils and these properties in relation to use and management of soils.

**Soil nutrition:** This is the prevention of soil loss from erosion or prevention of reduced fertility caused by over usage, acidification, salinization or other chemical soil contamination.

**Content/procedures/methods/illustrations**

**2.1 Soil is sampled for fertility testing following procedures as per soil conservation handbook.**

Soil sampling; this refers to the process of taking a small quantity of soil from the field to act as a representative sample of the soil in that particular field.

**Significance of soil sampling**

Analysis of the sample gives the farmer information about fertility status of the soil in order to:

- Optimize crop production
- Aid in diagnosis of plant culture problems
- Improve nutritional balance of the soil
- Protect the soil from contamination by leaching of excess fertilizers
- Saves money and conserve energy thus protecting the environment

**Factors to consider in soil sampling**

- Size of the land. The larger the size of the land, the higher the land, the higher the number of samples to be collected.
- Cropping systems. For most soil tests, the sampling depth is the tillage depth (6 inches).

For the deep rooted non legumes such as wheat, sorghum and cotton, a separate sample representative of the subsoil should be taken in addition to the tillage depth sample.

i. **Past management:** Fields used for production of cultivated crops may be sampled any time after harvest or before planting.

Non cultivated fields should be sampled during dormant season.

In either case, do not sample immediately after lime, fertilizer or manure applications.



ii. **Sampling tools:** They include:

- Soil auger, panga or spade
- Clean plastic bucket for collecting soil sample
- Sampling bags- for packaging of soil samples for submission to the testing Laboratories.

iii. **Unusual areas during soil sampling:** The following unusual areas should be avoided: dead furrows, terrace stands, old fence lines and manure heaps, swampy areas, near trees and boundaries and between slopes and bottom lands. These areas may not be representative of the field as they may give misleading information.

iv. **Procedure for soil sampling**

i. Divide the field into different homogenous units based on visual observation and farmer's experience.
ii. Remove surface litter at the sampling spot.
iii. Drive the auger to a plough depth of 15cm and draw the soil auger.
iv. Collect at least 10 to 15 samples from each sampling unit and place in a bucket or tray.
v. If the auger is not available, make a V-shaped cut to a depth of 15cm in the sampling spot using spade.
vi. Remove thick slices of soil from top to bottom of exposed face of the V-shaped cut and place in a clean container.

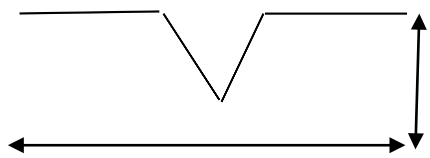


*Figure 9: Sampling spot*

vii. Mix the collected samples thoroughly and remove foreign materials like stone, pebbles and gravel.

viii. Reduce the bulk to about half a kg to one kg by quartering or compartmentalization. Quartering is done by dividing their ugly mixed sample into 4 equal parts. The two opposite quarters are discarded and the remaining two remixed.

The process is repeated until the desired sample size is obtained. Compartmentalization is done by uniformly spreading the soil over a clean hard surface and dividing into smaller compartments by drawing lines along and across the length and breadth. From each compartment, a pinch of soil is collected.

ix. To both samples obtained after quartering and compartmentalization, collect in a clean cloth or polythene bag.

x. Label the bag with information like: name of famer, location of the farm, survey number, previous crop grown, present crop grown, crop to be grown in the next season, date of collection and name of supplier.

The above procedure applies to shallow and deep-rooted crop.
For tree crops, soil sampling is done from a soil profile.



**Procedure of soil sampling from a profile.**

i. After the profile has been exposed, clean on efface of the pit carefully with a spade and note the succession depth of each horizon.

ii. Prick the surface with a knife or edge of the spade to show up structure, color and compactness.

iii. Collect samples starting from the bottom most horizon by holding a large basin at the bottom limit of the soil while the soil above is loosened by a khurei.

iv. Mix the soil sample and transfer to a polythene bag.

v. Label the polythene bag with information same as the one provided in sampling for shallow and deep-rooted crops.

**Methods of soil sampling**

There are two methods of soil sampling. These are:

i. Traverse method
ii. Zigzag method

i. **Traverse method**

In traverse method, four corners of the field are determined and sampling is done diagonally as illustrated below

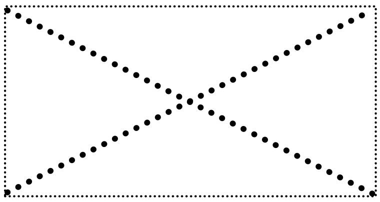

Figure 10: Illustration on traverse method

ii. **Zigzag method**

In the zigzag method, locations are arranged in such a way that they are in zigzag form. It is also referred to as random sampling method

The zigzag method is as illustrated below

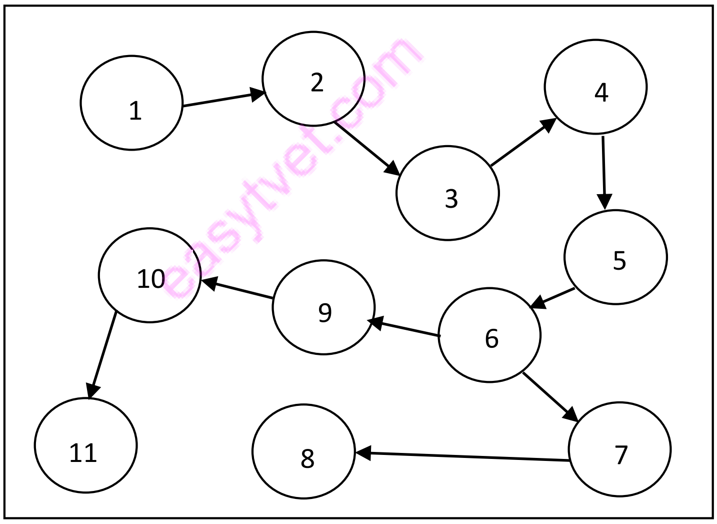


Figure 11:Zigzag Method

**2.2 Test soil for nutrients elements as per soil laboratory manual.**

Soil test: This refers to the analysis of a soil sample to determine nutrient content, composition and other characteristics such as the acidity and basicity.

In testing for soil nutrients elements, the soil test focuses on macro elements i.e. nitrogen, phosphorus and potassium.

**Importance of soil nutrient testing**

It may be carried for various purposes. Its main use includes:

- Monitoring of soil fertility levels
- Providing guidelines as to the type and amount of fertilizers to be applied for optimum plant growth on that particular field.

- As a diagnostic tool to help identify reasons for poor plant performance.
- Identifying and quantifying soil constraints. In order to obtain meaningful results, the following basic steps must be taken:
    a) Take a representative sample of soil for analysis.
    b) Analyze the soil using the accepted procedures that have been calibrated against fertilizer experiments in that particular field.
    c) Interpret the results using criteria derived from this calibration experiments.

Each of these steps may be under the control of a different person or entity e.g. soil samples may be taken by a farm manager or by a consultant agronomist then sent to an analytical laboratory for interpretation by an agronomist.

**Procedure for testing nutrient elements**

The three macro-nutrients i.e. nitrogen, phosphorus and potassium have same procedures for testing. The procedure is referred to as nutrient extraction filtration and is performed for all three analytes (nitrates, phosphates and potassium). Nutrient extraction filtration involves the following steps:

i. Secure one end of the funnel hose onto a vacuum jet.
ii. Secure the other end of the funnel hose onto the vacuum side arm of the flask.
iii. Assemble the funnel by snapping together the cylinder and perforated top disk.
iv. Place 1 clean filter paper on top of the funnel.
v. Turn on the vacuum jet.
vi. Slowly pour soil extract solution into the funnel allowing the extract to drain away from the soil and into the bottom of the funnel.
vii. Pour filtered extract into a new labelled 50 ml beaker. This filtrate will be analyzed as it is.
viii. Remove funnel, discard filter paper and rinse funnel and flask with deionized water. Use air jet to dry funnel and flask

**Methods of testing for soil nutrients**

These methods isolate each nutrient from the soil into a solution that can be analyzed using turbidity and color to determine the concentration of nutrients present in the soil sample. The analytical methods used by the soil test laboratory must be applicable to your region of soil testing to meet your specific needs. To determine available (and total) levels of specific nutrients present, a prescribed amount of extract is added to a fixed amount of soil and shaken for prescribed time before filtering to recover the extract (now dissolved nutrients) for testing.

**2.3 Soil test results are recorded as per soil laboratory manual**

After soil testing has been done, the results need to be documented well and in a precise manner. Accurate recording of results ensures efficient interpretation which then leads to appropriate recommendations about the soil test. The results can be tabled or recorded in chart forms. The table has a result section and an interpretation section box.

**Procedure of recording results**

- At the far left of the result section is a box labelled "sample/ field number" which contains the identifying number or name you attached to the soil sample when you sent e.g. 5.
- To the right of "sample/ field number" is "estimated soil texture." Texture is determined by an experienced lab technician on the basis of how a moist sample feels when it is felt between the thumb and fingers. In this case, soil texture is classified as medium and if you go up to the soil texture code box in the interpretation section you will see this means that your soil sample. "organic matter" is 3.5%, "pH" is 5.5, "buffer index" is n6.2," bray 1 phosphorus" is 10 parts

**2.4 Soil fertility improvements recommendations are given as per soil laboratory manual**

**Soil fertility improvement:** This basically refers to the process, techniques or ways of boosting amount of soil nutrients. Soil fertility depletion and soil degradation presents the most serious problems to African soil hence making them poor. African soil loses an annual average of 48kg/ ha of nutrients, the equivalent of 100kg/ year of fertilizer. To compensate for this loss, they receive a partly 10 kg of mineral fertilizer which cannot adequately cater for the loss. Maintaining or increasing soil fertility therefore is one of the most importance things farmers have to do to increase output. In maintaining and improving soil fertility, farmers have to know the characteristics and constraints of their soils and use sustainable agricultural practices and methods for conserving and making them fertile.



**Causes of low soil fertility**

- Loss of top soil due to erosion
- Uptake of nutrients by plants without replenishing/ adding absorbed nutrients to soil
- Increased acidity or basicity of soil leading to loss of some nutrients e.g. in increased acidity, nutrients e.g. nitrogen, phosphorous and sometimes potassium are low

**Methods of soil fertility improvements**

As a general consideration, the method to be used should be environmentally friendly and sustainable in the long run.

Some of the methods used in soil fertility improvements include:

i. **Use of organic fertilizers: manure, compost and crop residues**

Organic fertilizers are materials derived from plants and animal droppings e.g. weed residues, tree pruning, urine, green manure and crop residues. These are used to fertilize the soil. Plants contain three substances that determine their quality when their residues are used as organic fertilizers; these are:

- Nitrogen: Leguminous plants contain a lot of nitrogen fixing bacteria that fix atmospheric nitrogen into the soil through root nodules. Leguminous plants are therefore preferred for use as organic fertilizers as opposed to non-leguminous crops.
- Phenols: These are substances in the plants that make them rot slowly. Plant residues to be used as organic fertilizers should rot and decompose faster hence plants with less phenols are suitable for use as organic fertilizers.
- Lignin: This is a tough tissue like fiber which make up a plant stem. Plants with a lot of lignin are woodier hence rot slowly compared to herbaceous plants. Herbaceous plants therefore are highly recommended for use as organic fertilizer compared to woody plants since woody plants will rot slowly.

**ii.** **Liming**: This is the application of agricultural lime to soils so as to lower acidity. Acidic pH values of under 4.5 to 5.0 can severely damage the plants by causing nutrient deficiencies e.g. potassium, magnesium and toxicities of aluminum, manganese and iron. To neutralize acidity, lime must therefore be applied in the soil.

**Advantages of Liming**

- Neutralize acidity hence higher yields are obtained
- Prevents molybdenum deficiency
- Ensure water solubility and availability of phosphates to crops
- Improves the structure of heavy soils
- Promotes activities of soil microorganisms hence improving decomposition rotting of residues to release nitrogen, phosphorus, sculpture and other micro elements



**iii.** **Vermiculture/ vermicomposting:** Vermiculture refers to the growth of earthworms in organic wastes while vermicomposting refers to the processing of wastes using earthworms. Earthworms play an important role in improving soil fertility since they feed on dead and decaying materials, digest then excrete nutrients-rich dung.

**iv.** **Use of fertilizer trees e.g. Calliandra and Pygeum cefricana**

**v.** **Intercropping legumes with cereals**: Legumes will aid in improving nitrogen content of the soil since in their root nodules, there are nitrogen fixing bacteria e.g. rhizobium which fix nitrogen into the soil for plant cereals use.

**vi.** **Crop rotation**: This refers to the practice of growing different crops on the same piece of land at different seasons. Crop rotation prevents uptake of one nutrient by same plant species hence preventing loss of such nutrients. Rotating heavy feeder crops with light feeder crops also help in retaining crop nutrients.

**vii.** **Fallowing**: This refers to allowing the soil to rest for some period of time without crop establishments. It helps maintain and improve soil fertility since there is no nutrient uptake by plants during the fallow period.

**viii.** **Controlling soil erosion**: Soil erosion leads to loss of top fertile soil hence lowering fertility hence when soil erosion control measures are put in place, soil fertility is maintained.

ix. **Use of commercial fertilizers**: This refers to the application of artificial fertilizers e.g. calcium ammonium nitrate (CAN) and diammonium phosphate (DAP) to the soil.

However, the use of fertilizers must consider the chemical properties of the local soils, the crops planned and the required output. Farmers must also pay attention to environmental conservation i.e. they should not use ready-made fertilizers that have been designed for other regions. They need mixtures that have been especially formulated to address the deficiencies of that particular soil.

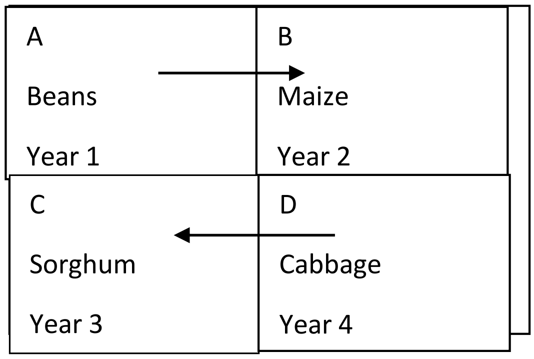


Figure 12: Crop Rotation

The field is divided into section and the crops are grown differently during different years on a rotational basis as shown using the arrows.



**Conclusion**

This learning outcome covered; basic soil science, soil nutrition, soil fertility management and improvement, fertilizer requirements, soil conservation systems.

**Further Reading**

1. Gichuru, M.P, Batiano, a Bekunda, Nyati, P. and Swift, M.J (2003) soil fertility management in Africa; A regional perspective. Academy science publishers, Nairobi, Kenya.

2. Carrow, R.N, Waddington, D.V and Rioke, P.E (2001). Turf grass soil fertility and chemical problems: Assessment and management, Ann Arbor Press, Chelsea

#### 4.3.3.3 Self-Assessment

**Written assessment**

1. All of the following tools are used during soil sampling except
   a) Soil auger
   b) Dagger
   c) Sampling bags
   d) Soil testing kit
2. Which of the following best define soil sampling?
   a) Analysis of a soil sample to determine nutrient availability
   b) The study of soil and its properties
   c) Process of collecting representative samples in a particular
3. The following factors are considered in soil sampling. Except?
   a) Availability of funds
   b) Size of land
   c) Post management
4. The following are soil sampling methods. Except?
   a) Complete randomized block design
   b) Zigzag method
   c) Traverse method
5. The following are importance of soil testing. Except?
   a) Identifying and quantifying soil constraints
   b) As a diagnostic tool to help identify reasons for poor plant growth
   c) To prevent soil erosion
6. What do we mean by the following terms?
   a) Soil science
   b) Soil nutrition
7. Outline three basic steps to be taken during soil test to obtain meaningful results
8. Briefly outline the soil sampling procedure
9. Give 2 importance of liming
10. Mention three nutrients that are tested for in a soil test



**Oral Assessment**

1. What is the use of a sampling bag during soil sampling?
2. Mention any 2 areas to avoid during soil sampling

**Case Study Assessment**

Nduigula, a farmer in Meru while inspecting his farm, discovered his crops were withering despite the fact that he has been watering. He therefore consulted an agro-mist to assess the situation. Briefly explain what could be the probable findings of the agronomical assessment.

**Practical Assessment**

1. On a given piece of land, conduct soil sampling from a profile
2. Construct a vermicomposting bed-technique

#### 4.3.3.4 Tools, Equipment, Supplies and Materials

- Note book
- Jembes
- Soil sample packaging bags
- Soil science laboratory and equipment
- Soil auger
- Topography maps

#### 4.3.3.5 References


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Walker, R. H., & Walters, A. W. (2019). A mechanistic understanding of ecological responses to land-use change in headwater streams. *Ecosphere*, *10*(10), e02907.

### 4.3.4 Learning Outcome No 3: Conserve farm water

#### 4.3.4.1 Learning Activities

| Learning Outcome No 3: Conserve farm water | |
|---|---|
| **Learning Activities** | **Special Instructions** |
| 3.1 Identify farm water sources as per soil and water conservation manual<br>3.2 Identify farm water conservation methods as per soil and water conservation manual<br>3.3 Construct farm water conservation structures as per soil and water conservation manual<br>3.4 Care of conserved farm water to minimize wastage as per soil and water conservation handbook | Discussion<br>Field excursion<br>Constructing farm water conservation structure |

#### 4.3.4.2 Information Sheet No4/LO3: Conserve farm water



**Introduction**

This learning outcome covers; sources of farm water harvesting methods, water conservation systems and water conservation method.

**Definition of key terms**

**Water conservation:** This refers to the preservation, control and development of water resources, both surface and ground and prevention of pollution

**Water harvesting:** This refers to capturing rain water where it falls and capturing the runoff from catchment, streams etc. and collecting the run off for productive purposes.

**Content/Procedures/Methods/Illustrations**

**3.1 Farm water sources are identified as per soil and water conservation manual.**

Sources of water in the farm

There are three typical sources of agricultural water in the farm. These include:

- Surface water: Rivers, streams, irrigation ditches, open canals, impounded water such as ponds, lakes and reservoirs
- Ground water from wells and boreholes
- Rainwater: Locally collected water such as cisterns, rain barrels and water storage tanks

**Factors to consider when choosing or identifying sources of farm water.**

The following guidelines or procedures are followed when settling on a source of water in the farm.

i) **Soil type:** The soil type should support the lay down of structures which will be used when conveying water to the farm. The soil type should also support construction of a particular source for example in ground water sources when drilling of wells.

ii) **Land topography:** The topography of the land is considered especially when choosing surface water e.g. rivers. This is because for the farm, the land should be gently sloping.

iii) **Availability of capital:** Different sources of farm water have different capital requirements e.g. ground water sources require a lot of capital to construct wells and boreholes as opposed to surface water where rivers or streams provide farm water.

iv) **Water quality:** Rainwater has a better quality hence preferred as a source of water.

**Farm water sources**

**Surface water**: This is rain water running off from land surface into rivers, lakes, seas and which can be collected, stored and utilized through rain water harvesting. The runoff is collected by use of ponds and earth dams e.g. charcoal, hillside and valley dams. The method depends on some factors e.g. type of landscape available like;

a) **Charco dams:** Suitable for flat land, preferably with road catchment to supply rain water run off
b) **Hillside dams:** Best option for slightly slopping land in places where rain water flows
c) **Valley dams:** Built on valleys flooded with low floods catchment.



**Charco dams**: Are built in a way which reduces evaporation losses but deepening water reservoirs and minimizing their surface area. Trees, shrubs are grown on the windy side of the dams to function as wind breaks and reduce evaporation

**Site selection for charco dams:** The best sites for construction are in natural depressions where runoff water flows or accumulates during rainy seasons.

**Best soils**

Deep clay soil or black cotton soil. Coarse sand should be avoided as they lead to high seepage loss through permeability. Seeping can also be controlled through plastering clay soils and use of compactors made of tree trunks. The site should be located near a gully or a natural water way that carries water during and after rainfalls as the water can easily be diverted into the dam.

**Size of charcoal dams**

The sizing depends on:

i) Area available for construction
ii) Expected volume of runoff water catchment
iii) Farmers capacity to hire laborers to assist in excavation

**Hill side dams**

Are small earth dams with curved walls. The curved heap becomes dam wall while the excavated pit will be the water reservoir. The size of the dam wall and its reservoir depends on the capacity to remove soil from the reservoir and placing it on the dam wall. The gradient of the sides of the dam should be 2:1 i.e. 2m width for every 1m height.



Figure 13: Hill side dams

https://www.researchgate.net/figure/10-Example-of-a-hillside-dam-in-the-Darwin-catchment-Photo-CSIRO_fig38_329828621

**Valley dams**

An earth dam built in a valley is the cheapest way to create water storage since the excavation work is less than hillside and charco dams. However, the gain in cost per volume can be lost easily due to one heavy thunderstorm or shower. The washout of a dam wall can be very serious and endanger the lives of both livestock and man hence experienced technical help should always be sort to design and construct valley dams.

Figure 14: Valley dams

https://www.elanvalley.org.uk/discover/reservoirs-dams/6-dams



**Ground water**

Ground water is rainwater that has percolated into the ground. There are two main types of ground water namely:

- **Shallow ground water**: This refers to ground water that can be reached by means of hand dug well in areas where rainwater has been trapped in the underground e.g. seasonal water courses, river Sand lakes.
- **Deep ground water:** It is rainwater that has percolated deep into the ground during centuries or thousands of years. Deep ground water can only be reached by drilling deep boreholes from where water is extracted using electric powered submersible pumps. Deep boreholes often suffer from sinking water level and high salinity hence deep ground water is not an efficient farm water source.

**How to identify places with shallow ground water tables**

Water: Indicating vegetation and trees. This involves use of tree species which have their tap roots reaching the water tables.

Table 5: Shallow ground water tables

| Botanical name | Kiswahili/kikamba names |
|---|---|
| *Cyperus rotundus* | Kiindium |
| *Delonix elota* | Muiru kikomoa |
| *Vangueria tomentosa* | mwangi |

In this method of identification; the height of the tree is found by measuring the length of the shadow the tree is casting on the ground and comparing it with the length of a shadow of a stick 100 centimeters long. Both measurements should be taken in the sunshine of early morning or late afternoon when the shadows are longest.
An illustration is shown below

Figure 15: Sticks' Shadow

E.g. if the sticks shadow is 80cm long, the ratio is 100/80 =5/4 of the tree's shadow. If the tree's shadow is 12m long, then the tree is 12m x 5/4=15m high and the tap root and water level is at 15m x ¾=11.25 depth. The tap root of a tree has a depth equal to about ¾ of the height of the tree

**Rainwater harvesting**

Rainwater harvesting running for land surface can be harvested, stored and utilized using a technique called rainwater harvesting instead of being washed in rivers, lakes and seas. Rainwater harvesting consists of 5 methods of rainwater harvesting

i) Catchment areas also called watersheds onto which rainwater falls
ii) Gutters or conveying channels to bring rainwater from a catchment area to storage reservoir
iii) Storage reservoirs can be tanks, ponds, dams
iv) Retrieval water is extracted from reservoirs either by gravity or by pumps and lifts

## 3.2 Farm water conservation methods are identified as per soil and water conservation manual

Farm water conservation is a key component in production of both crops and livestock. Water conservation in the farm entails strategies that ensure efficient utilization of available farm water, preservation and storage of farm water for future use.

**Methods of farm water conservation**

The following techniques or methods can be used in conservation of farm water. These methods not only optimize water usage but also produce healthier crops with less water. They include;

i) **Organic farming:** Organic farming conserves soil moisture, add more groundwater and prevent pesticides from going into streams and other bodies of water. This conserves water bodies by preventing pollution. Application of organic manures instead of artificial fertilizers help in conserving soil moisture since organic manures buffer the soil cushioning it against excess moisture loss.

ii) **Installing better water systems:** Some irrigation methods e.g. basin and furrow irrigation require a lot of water which at times leads to wastage of run off. Such water intensive methods also lead to soil erosion leading to pollution of water sources when silt is deposited in the water sources. Better watering systems e.g. watering through drip irrigation instead of the traditional overhead spray method can decrease evaporation and save up to 80% of water.



**Advantages of drip irrigation as a water conservation method**

- Field levelling is not necessary.
- Fertilizer and nutrients loss are minimized due to localized application and reducing leaching.
- Water is directly applied to the plant roots thereby minimizing water loss when water is applied to other parts of the field where crop is not growing.

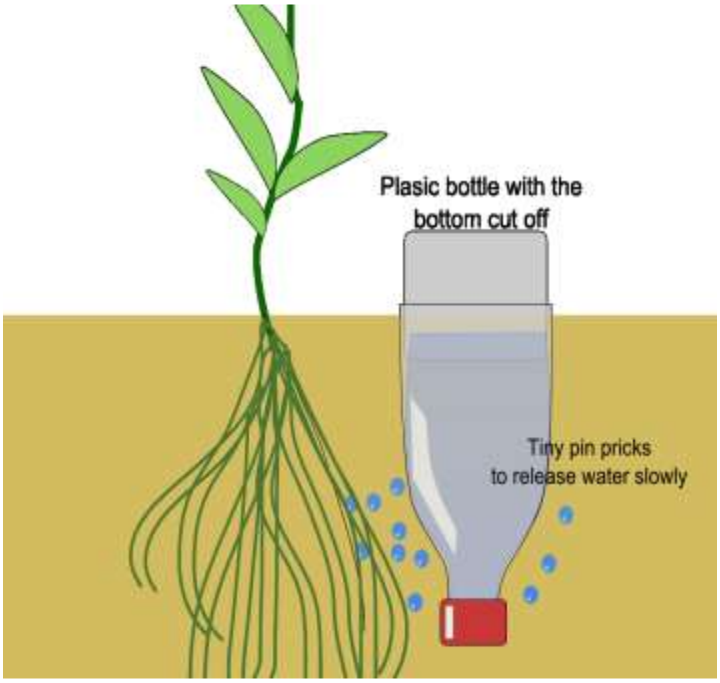

Figure 16: Drip irrigation

https://www.google.com/search?rlz=1C1CHBF_enKE847KE847&sxsrf=ACYBGNQGUjRwKxqjgOLGVo3O9cBw0kY23Q:1572855488013&q=diagram+of+drip+irrigation&tbm=isch&source=univ&sa=X&ved=2ahUKEwi4nZWlj9DlAhUNCxoKHTYmDLcQ7Al6BAgHED8&biw=1366&bih=608



**Choosing more drought tolerant crops**

Different crops have diverse water requirements i.e. some crops require a lot of water for healthy growth while others require little water for growth. In dry regions therefore it is recommended that farmers consider growing crops that are adapted to periods without enough water. This can help cut down on watering. Example of drought tolerant crops to consider include cassava, millet and sorghum instead of growing maize, beans and other horticultural crops.

**Harvesting and storage of rainwater**

Harvesting rainwater not only prevents run off wastage but also help in putting the rainwater into productive use. The harvested rainwater can then be stored and used in future when there is insufficient rainfall.

**Irrigation scheduling**

Smart water management and conservation is not just about how water is delivered but also when, how often and how much water is supplied to crops. To avoid under or overwatering their crops, farmers carefully monitor the weather forecast as well as soil and plant moisture and adopt their irrigation schedule to the current conditions. An example of irrigation scheduling is carrying out flood irrigation in orchards at night to slow down evaporation allowing water to seep down into the soil and replenish the water table.

**Rotational grazing**

This is the process in which livestock are moved between fields to help promote pasture re-growth. Good grazing management decreases the run off and rotational grazing also conserves water by increasing soil organic matter when animals drop dung. Further it conserves water by improving forage cover hence preventing soil water evaporation and erosion.

**Compost and mulch**

Mulch refers to materials spread on top of the soil to conserve moisture. Mulch can be either organic or inorganic. Organic material e.g. straw or wood chips when used as mulch break down into compost, further increasing the soils ability to retain water. Inorganic mulch e.g. black plastic mulch when used as soil cover suppresses weed and reduces evaporation. Compost or decomposed organic matter used as fertilizer; has been found to improve soil structure, increasing its water holding capacity thereby conserving soil water.

A simple mulching technique is illustrated bellow;

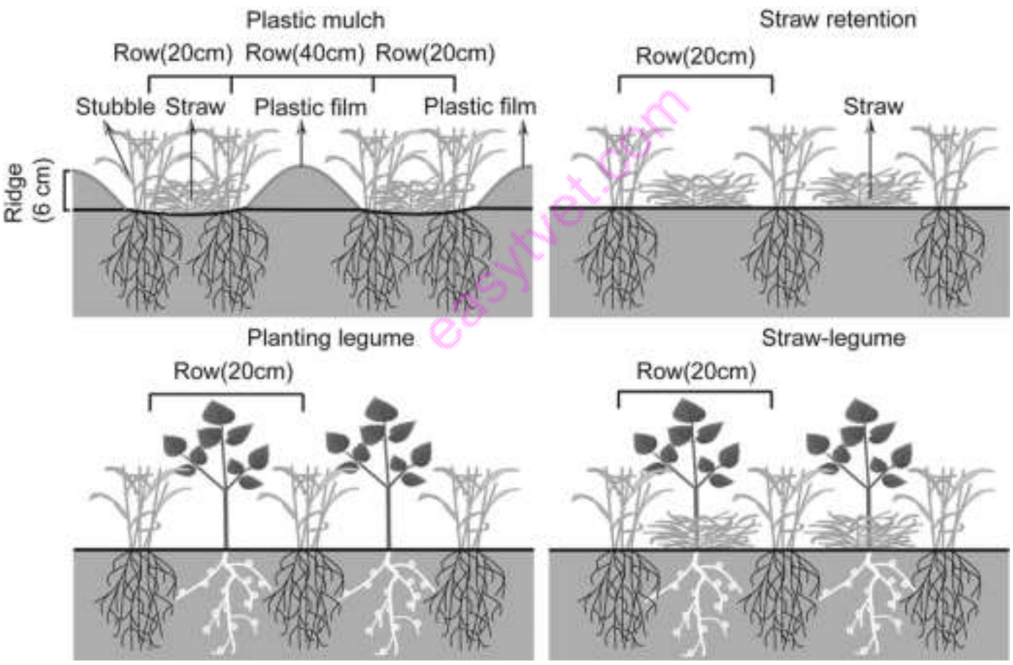


Figure 17: Simple mulching technique

https://www.researchgate.net/figure/Schematic-diagram-showing-the-treatments-of-plastic-mulch-straw-retention-planting_fig1_298724105

**Conservation tillage**

This refers to application of tillage methods that cause least disturbance of soil and causing minimum loss of soil vegetation cover. Cover cropping as an example of conservation tillage technique increases water absorption and reduce evaporation, erosion and compaction

### 3.3 Farm water conservation structures are constructed as per soil and conservation manual

Soil and water structures includes all mechanical or structural measures that control the velocity of surface runoff and thus minimize soil erosion and retain water when it is needed. These structures can be constructed to either conserve or discharge water safely. The suitability of soil and water conservation structure depends on the following guidelines:

i) Climate and the need to retain or discharge run off
ii) Farm sizes
iii) Soil characteristics (textures, drainage and depth)
iv) Availability of an outlet or water way
v) Labour cost and availability
vi) The adequacy of existing agronomic or vegetative conservation measures

**Methods of constructing soil and water conservation structures**

These structures are physical soil conservation structures which are permanent features made of earth stones or masonry to protect the soil from uncontrolled run off and retain waterhence conserve the water when needed. They include:

i. Cut off drains
ii. Retention ditches
iii. Infiltration ditches
iv. Water retaining pits
v. Broad beds and furrows
vi. Terraces- fanya juu, fanya chini, bench and stone terraces



**i) Cut off drains**

They are dug across a slope to intercept surface run off and carry it safely to an outlet such as a canal or stream.

**ii) Retention ditches**

These are dug along the contours to catch and retain incoming runoff and hold it until it seeps into the ground. They are an alternative to cut run off. They are often used to harvest water in semi-arid areas.

**iii) Infiltration ditches**

This is a structure designed to harvest water from roads and other surfaces run off. They consist of 0.7-1.5m deep, dug along the contour up slopes from a crop. Water is blocked at one end after being deviated from the roadside into the ditch. The trapped water seeps into the soil.

**iv) Broad beds and furrows**

In a broad bed and furrow system, runoff water is diverted into the field furrows (30cm deep and wide). The field furrows are blocked at the lower end when water fills up, it overflows into the next compartment.

## v) Terraces

Fanya juu terraces (converse terraces)

Are made by digging a trench along the contour and throwing the soil uphill to form an embankment. The embankment is stabilized with fodder grasses in between cultivated portions. They are useful in semi-arid areas to harvest and conserve water.

An illustration of fanya juu terrace.

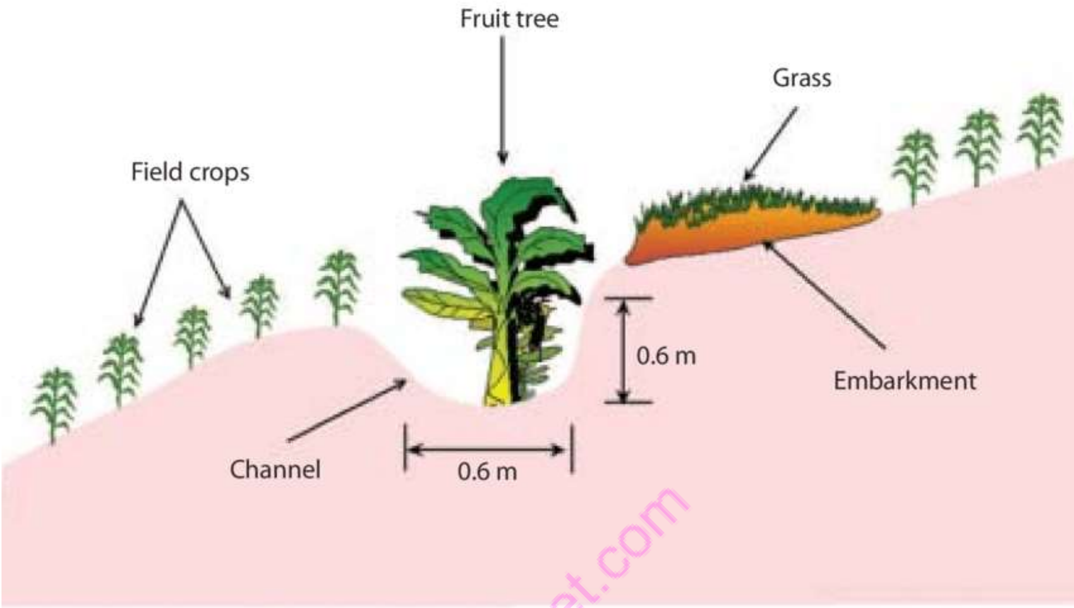




Figure 18:Fanya juu terrace

https://www.researchgate.net/figure/Illustration-of-a-fanya-juu-terrace_fig2_254426136

**Fanya chini terraces**

They are made by digging a trench along the contours and soil is put on the lower side of the contours trench.

**Bench terraces**

These are leveled or nearly leveled steps constructed or formed on the contour and separated by embarkments known as risers. They are formed by excavations or developed from grass strips.

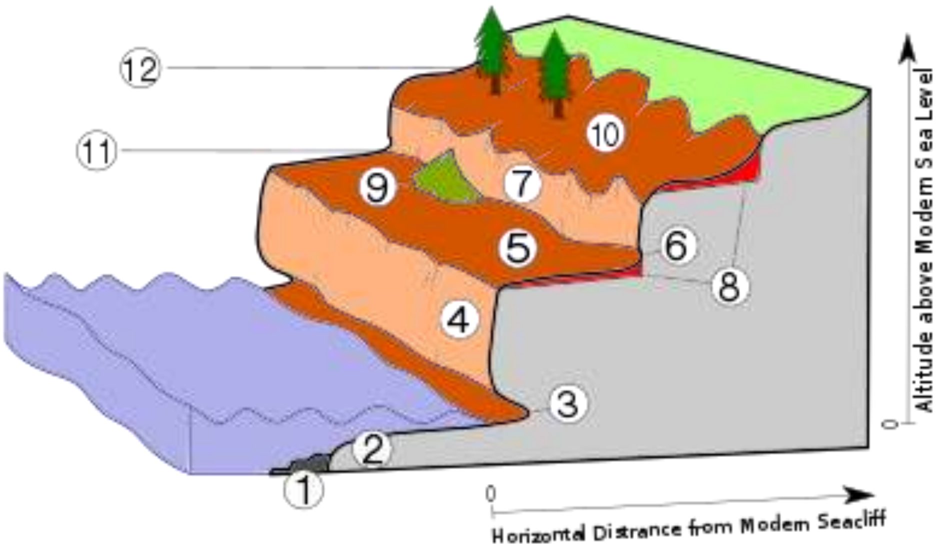


Figure 19: Bench Terraces

https://en.wikipedia.org/wiki/Raised_beach



**3.4 Conserved farm water is taken care of to minimize wastage as per soil and water conservation handbook**

Caring for farm water: This involves strategies and techniques that prevent contamination of conserved water, increase efficiency of water use and reduce water losses which could lead to water wastage.

**Methods of caring for conserved water**

The methods generally include those that;

- Prevent water pollution or contamination
- Prevent water loss
- Ensure maximum utilization of water resources

These methods include:

i. Reducing use of fertilizers and pesticides: Excessive use of fertilizers and pesticides pollute conserved water when these chemicals dissolve in the soil and are washed into conserved water sources polluting them hence leading to wastage. Reduction of use of fertilizers and other agrochemicals therefore prevent wastage.

ii. Efficient storing of water: Conserved water can be stored for future use when there are water shortages. In the farm, water can be stored in the following ways.

- Water tanks

These are usually used in storing harvested rainwater from roof catchment. Water from underground sources e.g. wells can also be pumped for storage in water tanks.

- Dams and reservoirs

These are used to collect excess flood water which could otherwise go to waste, destroying crop farms and human settlement. Dams are constructed along river channels by blocking the river channels and then directing the flood water into a river.

- Soil at moisture

Water stored in form of soil moisture involves carrying out practices that minimize water loss from the soil. Examples of such practices include mulching whereby organic or inorganic mulch is used to cover the soil.

- Use of containers

Containers e.g. jerry cans are used when storing little volumes of conserved water in the farm especially for domestic purposes. The storage containers must be clean and have a means of covering/ concealment to prevent contamination of water by dirt and dust particles.

**Benefits of storing water**

Water storage simultaneously serves multiple purposes such as irrigation, energy generation and flood control.

**Make irrigation efficient**

To reduce amount of water used in agriculture as well as prevent water wastage, irrigation must be made as efficient as possible. Irrigation methods that lead to water wastage e.g. basin irrigation that require high amount of water should be avoided at all costs. Strategies/ methods on how to make irrigation efficient include:

- Irrigation systems can be optimized to water
- Existing irrigation systems must be efficient and free frame leakages contain no leaks that waste water
- Soil moisture can be directly measured to determine the current water needs of individual plants.
- Drip irrigation lines can be used only to water a plant’s roots instead of the surrounding soil.

**Perm culture farming methods**

Many perm culture farming methods such as swales built on contour inherently hold water on the landscape, reduce (or even eliminate) the need for supplemental watering of crops and helps to restore aquifers.

**Conclusion**

This learning outcome covered; sources of farm water, water harvesting methods, water conservation systems and water conservation structures

**Further Reading**

1. Soil erosion site www.soilerosion.net

**4.3.4.3 Self-Assessment**

**Written assessment**

1. The following are typical sources of farm water except?
    a) Local government
    b) Surface water
    c) Underground water
2. Which of the following terms best describes water harvesting?
    a) Collecting water from any source
    b) Collecting rainwater from where it falls and capture the runoff from catchment and collecting it for reproductive purposes
    c) Construction of dams
3. The following are methods of caring conserved farm water except?
    a) Terracing
    b) Storing of water
    c) Reducing agro-chemicals usage
4. The following are soil and water conservation structures except?
    a) Climate
    b) Available farm water
    c) Preservation and storage of farm water for future use
5. What do you understand by water conservation?
6. Outline methods of farm water conservation.
7. Outline the procedure of identifying places with shallow ground water using water indicating vegetation and trees.
8. Outline 3 types of dams.
9. Outline 5 components of rainwater harvesting.

**Oral Assessment**

1. Give any two types of terraces
2. Give any two advantages of drip irrigation

**Case Study Assessment**

A farmer noticed that after a heavy downpour on his sloping farm land, the soil was heavily washed downstream. Describe soil and water conservation structures that he can use to correct this.

**Practical Assessment**

On an identified piece of land, conduct both "fanya juu" and "fanya chini" terraces. Outline the detailed procedure for construction in both cases

#### 4.3.4.4 Tools, Equipment, Supplies and Materials

- Jembes
- Soil auger
- Machetes
- Measuring tape
- Topography mapping tools
- Note books
- Soil sample packaging bags
- Soil science laboratory and equipment

#### 4.3.4.5 References


Constable, Greg, Danny Llewellyn, Lewis Wilson, and Warwick Stiller. "An industry transformed-the impact of GM technology on Australian cotton production." (2011).

Nissen-peterson, E (1992). How to make and install gutters with splash-guard, asalcon Kenya.

Raju, KCB (1983). Subsurface dams and its advantages. Ground water board India.

Soil erosion site www.soilerosion.net

### 4.3.5 Learning Outcome No 4: Design soil and water conservation structures

#### 4.3.5.1 Learning Activities

| Learning Outcome No 4: Design soil and water | |
|---|---|
| Learning Activities | Special Instructions |
| 4.1 Identify soil and water conservation structures as per soil and water manual<br>4.2 Design soil and water conservation structures as specified in soil and water conservation manual | Group discussion<br>Field excursion |

#### 4.3.5.2 Information Sheet No3/LO4; Design soil and water conservation structures

**Introduction**

This learning outcome covers; soil and water conservation designs, soil and water conservation structures.



**Definition of key terms**

**Soil and water conservation:** Are those activities at the local level which maintain or enhance the productive capacity of the land including soil, water vegetation in areas prone to erosion through prevention or reduction of soil erosion of drainage water and maintenance or improvement of soil fertility.

**Content/procedures/methods/illustrations**

**4.1 Soil and water conservation structures are identified as per soil and water manual**

There exists a variety of soil and water conservation structures also referred to as soil and water conservation measures. Procedures for identifying soil and water conservation structures. Soil and water conservation measures are identified and classified based on:

**Purpose and type**

Based on the above two parameters there are three types of soil and conservation structures as listed below:

- Physical measures
- Biological measures
- Agronomical measures

**Methods of identifying soil and water conservation structures**

i. **Physical measures**

For structures built for soil and water conservation, some principles should be considered. They should aim to:

- Increase the time of concentration of runoff, thereby allowing more of it to infiltrate into the soil.
- Divide a long slope into several short ones and thereby reducing amount and reduce the velocity of surface runoff, this is evidenced when terracing is done.
- Protect the environment against damage due to excessive runoff.

The following are physical soil and water conservation measures:

**Stone/ Earth terraces**

**Terraces:** Are earthen embarkment installed at right angles to the steepest slope to intercept the surface runoff. Run off embankment usually consists of two parts.

**An excavated channel:** A bank or ridge on the downhill side of the channel which is formed with the material excavated from the channel.

**NB:** Different types of terraces exist based on the design and shape of the channel and the ridge. The different types of terraces should be selected in accordance with the local conditions and problems.



**Types of earth terraces**

1. **Bench terraces**

This type of terraces is practiced on areas of steep slope.

Building only walls that reduce slope length is not sufficient here to reduce the power of runoff. It is therefore necessary to modify the degree of slope by excavating half way and half- filling a bank. The original ground will be converted into levels step-like fields.

**Functions of bench terraces**

- To control erosion by reducing the degree and length of the slope.
- To increase infiltration of rain water
- Maintain soil fertility
- Allow improved irrigation where necessary

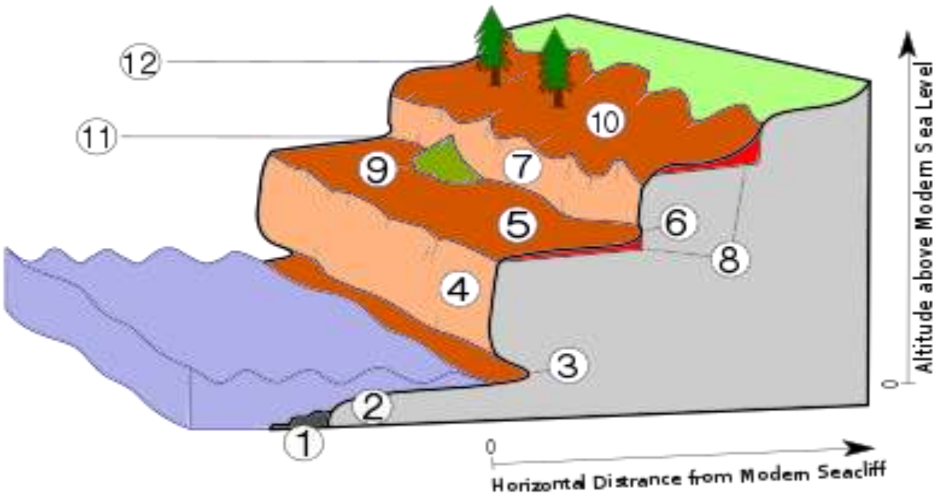


Figure 20: Bench Terraces

https://en.wikipedia.org/wiki/Raised_beach

**Fanya Juu Terraces (converse terraces)**
Are made by digging trenches along the contour and throwing the soil uphill to form an embankment. The embarkment is stabilized with fodder grass in between cultivated portions. They are useful in semi-arid areas to harvest and conserve water. They not only conserve water but rampant in arid and semi-arid areas due to flash floods.



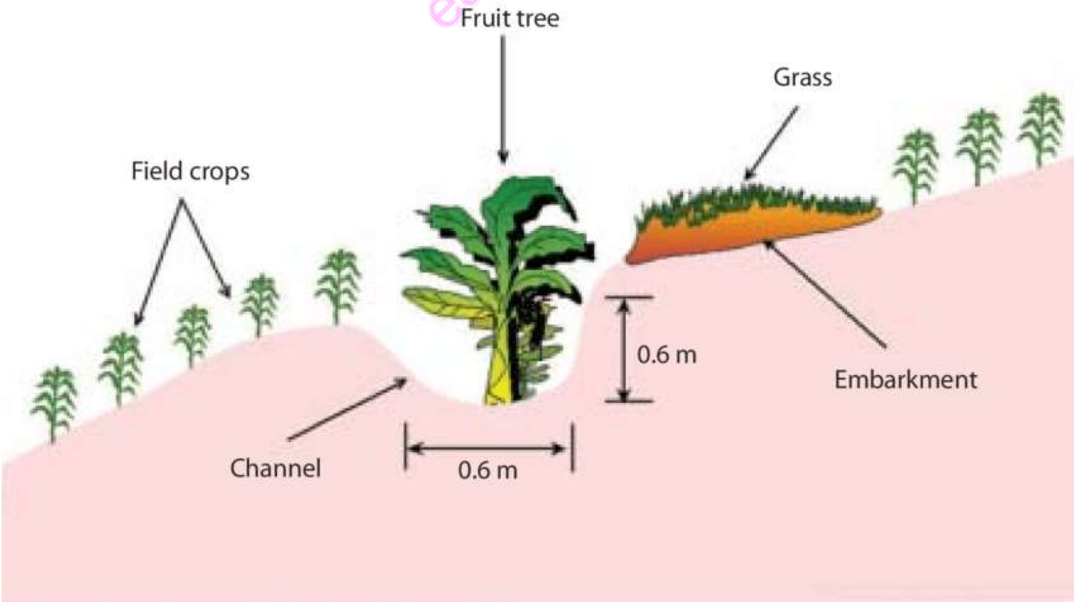


Figure 21: Fanya juu terraces

https://www.researchgate.net/figure/Illustration-of-a-fanya-juu-terrace_fig2_254426136

**2. Grassed water ways**

Are broad shallow and typically sauce water –shaped channels designed to move surface water across farm land without causing soil erosion. The vegetative cover in the water way slows the water flow and protects the channel surface from the eroding forces of runoff water.

**3. Retention reservoirs**

A retention basin, sometimes called a wet pond, wet detention basin or storm water management pond is an artificial pond with vegetation around the perimeter

**4. Biological measures**

Biological measures for soil and water conservation work by their protective impact on the vegetation cover. A dense vegetation cover conserves soil and water by;

- Preventing splash erosion
- Reduces the velocity of surface runoff
- Facilitate s accumulation of soil particles
- Increases surfaces roughness which reduce run-off and increases infiltration.
- The roots and organic matter stabilize the soil aggregates and increase infiltration.
- Biological measures are an effective method of soil and water conservation especially since they are low in cost.
- In addition, this method can be used with structural and agronomical measures.



Types of biological measures

- Protective bush land
- Reforestation
- Live fences
- Vegetative strips

**Reforestation**

It is used in highly degraded regions for regeneration of the soil and water balances. Factors to consider before carrying out reforestation

- Climatic factors e.g. rainfall
- Biotic factors e.g. human activities
- Soil factors. e.g. soil fertility

**Agronomic soil and water conservation measures**

Agronomic soil and water conservation measures conserve soil and water by:

- Reducing the impact of rain drops through interception and thus reducing soil erosion.
- Increasing infiltration rates and thereby reduces surface runoff and erosion.

Agronomical measures can be applied together with physical or biological soil and water conservation measures. Agronomic conservation measures however are often more difficult to implement compared with structural ones as they require change in familiar practices.

Methods of agronomic soil and water conservation measures

They include;

i. Strip cropping
ii. Mixed cropping
iii. Intercropping
iv. Fallowing
v. Mulching
vi. Contour ploughing
vii. Grazing management
viii. Agroforestry

**Fallowing**

This refers to the practice of allowing the soil to rest for some period of time without crop establishment. During the fallowing period soil surface remains undisturbed encouraging vegetation growth. This vegetation growth provides soil cover hence conserving soil water by preventing evaporation of water from the soil.

**Mulching**

This refers to the practice of spreading material on top of the soil

**Types of mulches**

a. **Organic mulch**: This includes organic materials e.g. straw wood chips, dry grass and plant residue which can be spread on top of the soil.
b. **Inorganic mulch:** This includes inorganic mulching techniques e.g. black plastic polythene sheets which are spread on the soil surface.



**Importance of mulching in soil and water conservation**

- Provide soil cover hence preventing direct sun from hitting the soil surface. This reduces evaporation of water from the soil hence conserving soil moisture.
- Organic mulch decomposes to release organic matter which improves the soil structure hence improving its water holding capacity thereby conserving soil water.
- Mulch reduces the intensity with which raindrops hit the soil. This prevents splash erosion hence conserving soil.
- Mulch reduces runoff velocity hence preventing the soil from being washed away.

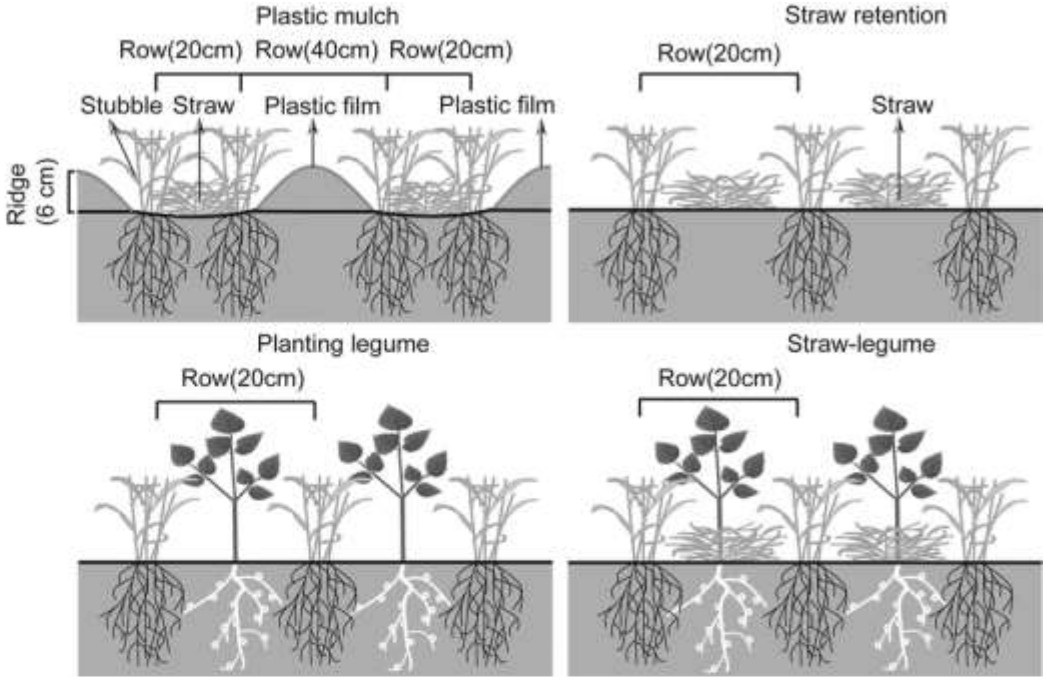

Figure 22: Mulching in Soil

https://www.researchgate.net/figure/Schematic-diagram-showing-the-treatments-of-plastic-mulch-straw-retention-planting_fig1_298724105



**Grazing management**
This refers to adoption of strategies of controlled grazing to prevent either under grazing or overgrazing on pasture lands e.g. rotational grazing

**Rotational grazing**
This is grazing method in which livestock are moved between paddocks in the field on a rotational basis. When properly managed, it conserves water by increasing soil organic matter from animal dropping grazing process. The dung helps in improving soil structure thereby conserving soil as well as its soil moisture content hence conserving soil water. Rotational grazing also allows for pasture regrowth which improves forage cover. This prevents soil water evaporation hence conserving soil water.

**Contour ploughing**
It is widely used agronomic measure and when well established, immensely contributes to soil and water conservation. The soil is ploughed along the contour install of up and downward. This decreases the velocity of runoff and thus soil erosion by concentrating water in the downward furrows.

**Role of contour ploughing in soil and water conservation**
Contour ploughing conserves soil and water by building a barrier against rain water runoff which is collected on the furrows hence conserving runoff water. Increases infiltration rate hence boosting underground water reserves thereby conserving runoff

water. Protects the soil from being washed down slope if the so contour was to be ploughed upward- downward. The effectiveness of contour ploughing decreases with increase in:

- Slope gradient and length
- Rainfall intensity
- Erodibility of the soil

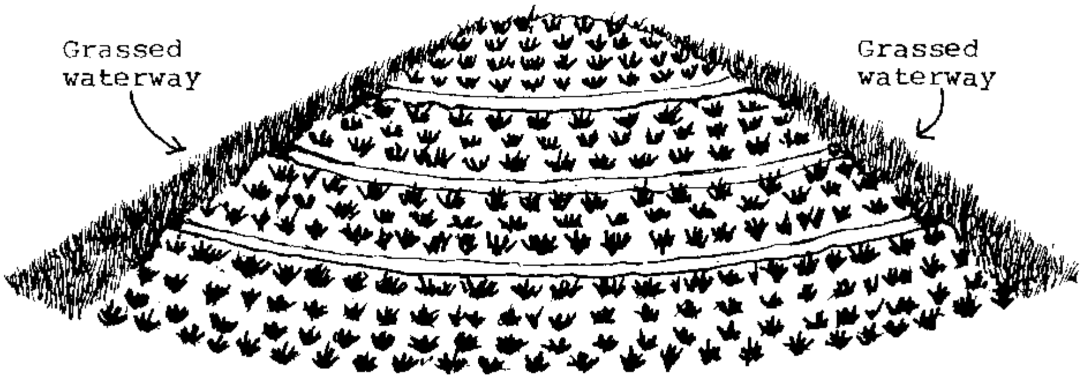


Figure 23: contour ploughing

http://www.nzdl.org/gsdlmod?e=d-00000-00---off-0hdl--00-0----0-10-0---0---0direct-10---4-------0-1l--11-en-50---20-about---00-0-1-00-0--4----0-0-11-10-0utfZz-8-00&cl=CL1.16&d=HASH412cd503b5262205ac14c6.5&gt=1



**Agroforestry**

This refers to the practice of growing trees with crops on the same piece of land. It conserves soil and water by:

Trees act as wind break hence protect the soil from being blown away by wind. The roots of large trees hold soil particles together preventing water erosion. Trees increase the infiltration rate of the water into the soil thereby conserving soil water.

**Intercropping and mixed cropping**

This refers to a type of agricultural technique that involves planting two or more plants simultaneously on the same piece of land, interdigitating the crops so that they grow together.

**Roles of intercropping and mixed cropping in soil and water conservation**

- Prevents soil depletion
- Increase soil fertility
- Reduces soil erosion

**Strip cropping**

This is a method of farming which involves cultivating a field portioned into long-narrow strips which are alternated in a crop rotation system. It conserves soil and moisture by:

- Creating natural dams for water
- Helping to preserve the strength of the soil.

Figure 24: Strip cropping

https://www.youtube.com/watch?v=FhB1pZLK4Gc



**4.2 Soil and water conservation structures are designed as specified in soil and water conservation manual**

Soil and water conservation structures are designed as specific in soil and water conservation manual. Soil and water conservation structures includes all mechanical or structural measures that control the velocity of surface runoff and thus minimize erosion and retain water where it is needed. They consist of physical structures which reduce the effect of the slope length and angle. Soil and water control structures can be designed to either conserve water or safely discharge it away. The suitability of a design for soil and water control structure depends on the following factors:

- Climate and needed to retain or discharge runoff
- Farm sizes
- Soil characteristics (texture, drainage and depth)
- Availability of an outlet or waterway
- Labour availability and cost
- The adequacy of existing agronomic or vegetative conservation measures.

Methods of determining soil and water conservation structures.

**N/B:** The main method involved in designing soil and water conservation structures is to:

- Determining amounts runoff for design of soil and water conservation structures.

- Determining amounts of runoff for design of SWC structure characteristics of surface Runoff.

Surface runoff (runoff) is the portion of precipitation that makes its way towards the stream channels lakes or oceans as subsurface flow. It occurs when precipitation rate exceeds infiltration rate and is the most distractive component of rainfall.

**Factors to consider in determining amounts of run off for designing SWC measures**

These factors include;

- Peak runoff rates
- Runoff volumes
- Temporal distribution of runoff rates and volumes.

**Factors affecting runoff**

These include both catchment factors and rainfall factors.

**Catchment factors**

Runoff is influenced by catchment factors such as;

- Topography
- Vegetation
- Infiltration rates

Soil storage capacity and drainage pattern. The larger a catchment the more runoff it will generate. Slope steepness is particularly important as soil erosion is more prone on steeper slopes.

**Rainfall factors**

Rainfall factors associated with surface runoff and erosion include: rainfall amounts storm duration, intensity and distribution as well as seasonal patterns. e.g. dry areas are more prone to erosion than wet areas because prolonged dry spells destroy vegetation cover and rainstorms tends to be of high intensity and thus erosive. The most significant component of rainfall is the intensity which is a function of the energy raindrops impact on the soil. The intensity duration relationship of rainfall gives an indication of expected runoff as illustrated below.

$1=a(t+b)$

Where 1= rainfall intensity

t= duration of rainfall (in minutes)

b and a are constants

For any given duration the graph or equation will indicate the highest average intensity which is probable for a storm of that duration. This is calculated as:

$1=kT^{x}It^{n}$

Where T= is the return period in years e.g. 10years

k, x and n are all constants.

**Design storm**

This refers to a storm known period and is used as a basis for designing structures e.g. for a 10-year, 1-hour rainfall is the maximum rainfall amount expected in a 1-hour period within a 10-year return period.

**Design runoff rates**

The capacity to be provided in a structure that must carry runoff may be termed as designed to carry runoff that occurs within a specified return period (Tr) e.g. 10 years for vegetative water ways and 100 years for permanent channels.

**Estimation of surface runoff**

It is important to know the quantities of water to be handled. If the objective is to impound water e.g. dams, peak volumes are used while, if the purpose is to convey water e.g. channels/ water ways, peak runoff rates are used. Estimation of runoff is necessary to avoid failure due to overlapping. Estimating runoff depends on two processes:

i. Estimating the rate of rainfall.
ii. Estimating how much of the rainfall becomes runoff. The runoff rate is more crucial and is determined using various methods or equations as described below.

a. **Runoff coefficient**

The simplest method is to use a single coefficient which represents the ratio of rainfall loss. If half of the rainfall is lost by infiltration the other half appears as run off then the coefficient is 0.5

**Example** of runoff coefficients

Woodland on flat sandy loam, C=0.10

Woodland, flat tight clay C= 0.40

Cultivated fully clay soil C=0.60

Urban, rolling, 50% built up, C=0.65

b. **Catchment characteristic or cook's method**

The method consists of summing numbers each of which represents the extent to which runoff from catchment will influence a particular characteristic. The effect of four fruiters is considered in method each of which are.

i. The relief
ii. Water infiltration
iii. Vegetation cover
iv. Soil surface storage

Each of these is considered in turn and the condition of the watershed compared with four descriptions i.e. Extreme, high, normal and low.

An illustration is as shown below:

30=10=15=10=65

c. **Rational formula**

The rational method predicts runoff through this equation

Q=0.028CIA

Where Q = The design peak runoff in $M^3$/s

C =Runoff coefficient (a function of catchment vegetation, slope, surface culture)

A = Area of watershed in hectares

I = Rainfall intensity in mm/hr. for the design return period and for a duration Equal to the time of concentration of the watershed

The rational method is developed on the assumption that.

- The rainfall occurs at uniform intensity for a duration equivalent to the time of concentration.
- Rainfall occurs at a uniform intensity over the entire area of the catchment.

**Conclusion**

This learning outcome covered; soil and water conservation designs and soil and water conservation structures

**Further Reading**

1. www.geo.fu-berlin.de

**4.3.5.3 Self-Assessment**



**Written assessment**

1) The following are soil and water conservation structures except?
    a) Grass strips
    b) Terraces
    c) Cut off drains
2) The following are biological measures of soil and water conservation except?
    a) Irrigation of the land
    b) Reforestation
    c) Protective bushland
    d) Live fences
3) Three of the following are agronomical soil and water conservation measure except?
    a) Fallowing
    b) Agroforestry
    c) Mixed cropping
    d) Crop cultivation
4) The following constitute physical measures of soil and water control except?
    a) Terraces
    b) Grassed water ways
    c) Vegetation cover

5) Strip cropping conserves soil and moisture in the following ways except?
    a) Creating natural dams for water
    b) Helping to preserve strength of the soil
    c) Trapping soil particles
6) The following strategies make up farm water conservation except?
    a) Climate
    b) Available farm water
    c) Preservation of farm water for future use.
7) What do you understand by soil and water conservation?
8) Outline factors to consider in determining runoff for designing soil and water conservation structure.
9) Outline 3 ways in which agroforestry conserve soil and water.
10) Outline 4 importance of soil and water conservation measures.
11) Outline role of intercropping and mixed cropping in soil and water conservation.

**Oral Assessment**

1. Outline methods of estimation of surface run off.
2. State the rational formula?

**Practical Assessment**

On a provided piece of land, construct the following physical soil and water conservation measures.

1. Bench terraces
2. Fanya Juu Terraces

For both cases, clearly outline the procedure and tools required



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**4.3.5.4 Tools, Equipment, Supplies and Materials**

- Soil Auger
- Soil sample packaging bags
- Soil science laboratory and equipment
- Topography mapping tools
- Notebooks

**4.3.5.5 References**


Benson Mochoge (2002). Sustainable soil and water conservation. Government of Kenya. Nairobi

Fao (2001). An integrated Approach to soil and water conservation ABI Publishing Texas.

Rahma, KCB 1983. Design of soil and water conservation structures for small holder Agriculture Asalcon Kenya

### 4.3.6 Learning Outcome No 5: Lay out soil and water conservation structures

#### 4.3.6.1 Learning Activities

| Learning Outcome No 5: Lay out soil and water structures | |
|---|---|
| **Learning Activities** | **Special Instructions** |
| 5.1 Establish area layout as per soil and water conservation manual<br>5.2 Peg established area as per soil and water conservation manual<br>5.3 Measure pegged area as per size and type of structure to be constructed<br>5.4 Excavate area as per structure design<br>5.5 Maintain soil and water structures are maintained as per good agricultural practices | Demonstrate how to construct different types of conservation measures in the farm. |

#### 4.3.6.2 Information Sheet No4/LO5: Lay out soil and water structures



**Introduction**

This learning outcome covers, soil and water conservation designs, layout / construction of soil and water conservation structures, maintenance of soil and water and conservation structures

**Definition of key terms**

**Soil and water conservation designs:** These are activities that maintain on enhance the productivity capacity of land in areas affected by or prune soil erosion.

**Soil and water conservation structures:** These are mechanical or structural measure that control the velocity of surface run off and this minimize soil erosion and retain water where it is needed.

**Content/procedures/methods/illustrations**

**5.1 Area layout is established as per soil and water conservation manual**

**General principles for the design of SWC (Soil and Water Conservation)**

The design of SWC structure considers severity and extent of erosion damage or risks the factors causing erosion as well as the suitability of land to the identified intervention. Soil and water control measure are directed at protecting the soil from raindrop impact and hydraulic force of run-off.

The process involves areas of attentions;

i) Reduction of raindrop impact on soil
ii) Reduction of overland flows
iii) Increase inflation rate
iv) Slowing run off velocities

**Factors considered when laying out SWC**

SWC structures are usually made by hand labour or machinery although some terraces develop naturally from vegetative barriers. They are particularly important on steep slopes where annual crops are grown and in marginal rainfall areas where there is a need to conserve rainfall in situ. They include:

i. Climate and the need to retain or discharge runoff
ii. Farm size and system (large or small-scale, mechanized oR non-mechanized).
iii. Cropping patterns (perennial or annual, with or without rotations) slope steepness
iv. Soil characteristic (erodibility, texture, drainage, debt, stoniness and risk of mass movement)
v. The availability of an outlet or waterway for safely discharging run-off away from crop land.
vi. Labour availability and cost
vii. The availability of material e.g. stone.
viii. The adequacy of existing agro-economic on vegetative conservation measures.



Determine amount of run-off for design for SWC structure surface runoff is the portion of precipitation that makes its way towards the stream channels, lakes or ocean or surface and subsurface flow. Runoff occur when precipitation rate exceeds infiltration rate and is the most destructive components of rainfall.

In the design of SWC structure, the important factors used are:

i) Peak runoff rates
ii) Runoff volumes
iii) Temporal distribution of runoff rates and volumes.

**Factors affecting Runoff**

These include both catchment factors and rainfall factors.

**a) Catchment Factors**

Runoff is influenced by catchment factors such as topography, vegetation, infiltration rate, soil storage capacity and drainage pattern size of the catchment, its shape, orientation, geology and surface culture also affect run-off.

**b) Rainfall Factors**

Rainfall factors that are associated with surface run-off and erosion includes rainfall amount, storm duration, intensity and distribution as well as seasonal pattern. e.g. dry areas are prone to erosion than wet areas because prolonged dry spells destroy vegetation cover, and rain storms tend to be high intensity and this erosive. The intensity duration relationship of rainfall gives an indication of expected run-off.

$I=\frac{a}{t-b}$

I= rainfall intensity
t= duration of rainfall (min)
a and b are constant.
For any given duration, the graph or equation will indicate the highest average intensity which is possible for a storm of that duration. It’s calculated as
$I= KTx/tn$
T = Is the return period in years
k, x and n are all constant

**c) Time of concentration**

The storm duration which correspond with the maximum rate of runoff is known as the time concentration (Tc). It is assumed that during the time of concentrations, all parties of the watershed are contributing simultaneous due to the discharge at the outlet.

**d) Design Strom**

A design storm is a storm of known period. it is used as a basis for designing structures. For example, 1=hour rainfall is the maximum rainfall amount expected in a 1-hour period with a 10-year return period.

**e) Design runoff rates**

The capacity to be provided in a structure that must carry run off maybe termed as the design run-off rate. Within a specified return period (Tr) e.g. 10 years for vegetative waterway and 100 years for permanent channel.



**5.2 Established area is pegged as per soil and water conservation manual**

Established area is marked depending on the types of conservation structure. The main SWC structure measure used on croplands comprises diversion ditches (cut-off drains) retention (inflations) ditches, terraces and waterway. Supportive cultural measures such as grass or vegetative materials for stabilizing the structure are also required for selection of proper species. The design of structure to discharge run off, such as diversion ditches and water ways should not be installed unless there is safe place for disposal of water e.g. a natural or artificial water ways or permanent vegetation. In higher rainfall areas e.g. areas receiving more than 1000 mm of rain per annum, and where crops rarely lack water or where there is risk water. It is necessary to deigns a structure to discharge run-off. However, it would be a mistake to design structures to discharge a run-off if there are no suitable outlets such as natural waterway on artificial water way or grassed slope. In dry areas, it is usually desirable to keep run water in situ and prevent runoff. After putting in considerations of all the above factors right area is pegged awaiting next step.

**5.3 Pegged area is measured as per size and type of structure to be constructed**

**Size of conservation structure**

The design of any structure to be attained on discharge runoff should be based on reasonable estimate of the volume of runoff ($m^3$) to be retained on the peak rate of runoff ($m^3/s$) to be discharged. A retention structure can rarely be made big enough to capture all runoff during exceptionally wet period unless the catchment areas is very small. One alternative role of retention structure is to incorporate a spillway to take the overflow.

Similarly, the design of a structure to discharge runoff can rarely be based on the heaviest storms possible. Usually, it is based on the heaviest storm that can be expected in a given period (e.g. 10 years) with the knowledge that a heavier storm, a magnitude that occur once in a while could take place.

Measurement of the structure will provide precision on how the excavation will be done in order to manage soil and water.

**Reasons for construction conservation structure**

- To increase agriculture productivity
- To conserve potentially productive land
- To reduce nutrients loss from the soil
- To conserve environment to improve catchment hydrology of soil profile
- To facilitate drainage especially in water logged areas
- To protect reservoir from sedimentation



**5.4 Area is excavated as per structure design**

**Suitability of SWC structure depends on**

- Climate
- Farm size
- Soil characteristic (texture, drainage and debt)
- Availability of a waterway
- Availability of labour and cost
- Adequacy of agroeconomic or vegetative conservation measures

**Physical soil conservation measures**

Physical soil conservation are permanent features made of earth, stones or masonry, designed to protect the soil from uncontrolled runoff and erosion and retain water of required. They include the following.

**a) Cut-off drains**

They are excavated across a slope to trap surface runoff and carry it safely to a discharge waterway such as a canal or stream. They divert water from gully hovels.

**b) Retention ditches**

They are dug along the contours to intercept surface run-off and retain as mush water to improve soil hydrology through seepage. They are used as an alternative for cut-off drains where there is no near discharge waterway, they are commonly used in ASALS.

**c) Infiltration ditches**

As the name suggests, they are constructed to harvest surface runoff from roads and retain it. The ditch measures 0.7-1.5 m in depth, they are dug along the contour, upslope from a crops field. Water is then diverted to the ditch from the roadside. It allows water seep or infiltrate into the ground and provide enough soil water.

**d) Water-retaining pits**

They are dug on the ground on the name run-off areas. They allow the water to seep down like the infiltrations ditch. The soil from the pit is heaped to from a bank so that it can accumulate maximum amount of water. Furrows are also constructed to carry excess water from the pits. The size of the pit depends on the amount of run-off. It measures $2m^2$ by 1m deep.

**e) Broad beds and furrows**

Runoff water is diverted into field furrows which measures 30cm wide and 30cm deep. The field furrows are blocked at the end unit they are filled with water which then moves to the next furrow. (crops are planted on a broad bed measuring 190cm wide).

**f) Terraces-Fanya juu, Fanya chini, bench terraces, stone terraces**

**i) Fanya juu (converse) terrace**

They are constructed by digging a trench along the contour. The solid is heaped on the upper side to form embarkment. The embarkments are items reinforced with a strip of grass between the cultivated areas. As time progresses, fanya juu terraces develop into bench terraces. Bench terraces are useful in ASALS to harvest and conserve water. It is applicable to slope below 20%.

**ii) Fanya chini (narrow based channel) terraces**

It is done in opposite way of fanya juu terraces. They are drug along the contour and the solid is heaped on the lower side as the contour trench. It is used to conserve soil and divert water. The embarkment is used to grow fodder and it is applicable on slopes of up to 20%.

**iii) Bench terraces**

They are leveled steps constructed or formed o the contour which are separated by embarkment known as risers. They are excavation or developed from grass strips on fanya Juu terraces. They are suitable on slopes up-to 55%.

**iv) Stone terraces**

They are constructed on steep slope to intercept runoff water with high population density and scarce land. Terraces raises are made up collected stones from the ground. Others include dams, wells and gabions.

**5.5 Soil and water structures are maintained as per good agricultural practices**

SWC structures are maintained to ensure the intended functions has been achieved. They require regular maintenance and repair if they get damaged. Grazing should be controlled and restricted in areas where SWC structures have been established to avoid damage of embarkments. The fodder should not be grazed directly but it should be harvested and fed to the animals. Vegetative material should be replaced and lining of the constructions and channels should be done at least every season.

**Conclusion**

This learning outcome covered: soil and water conservation designs, layout/construction of soil and water conservation structures and maintenance of soil and water conservation structures.

**Further Reading**

1. Design of soil and water conservation structure for small holder agriculture article by Prof. Bancs M. Mater.
2. www.fao.org/3/To32IE/to312e-10.htm
3. Soil and water conservation manual by sustainable agriculture information initiative

**4.3.6.3 Self-Assessment**

**Written assessment**

1. The following are factors used in determining design of SWC structure. Which one is not?
    a) peak runoff
    b) runoff volume
    c) runoff factor
    d) temporal distribution
2. The rainfall factor has the following functions except one. Which one is odd one out?
    a) rainfall intensity
    b) water factor
    c) duration of rainfall
3. The following are types of terraces which one is ideal for slopes of below 20%?
    a) fanya juu terrace
    b) fanya chini terrace
    c) stone terrace
    d) bench terrace
4. Physical SWC structures are used mostly in ASALS. Which one is not suitable in such areas?
    a) cut-off drains
    b) retention ditches
    c) infiltration ditches
    d) water-retaining pits

5. Suitability of SWC structure depends on the following factors except one. Which one?
    a) Run-off rates
    b) climate
    c) farm size
    d) water-retaining pits

6. Rainfall factors are associated with the following conditions except one. Which one?
    a) rainfall amount
    b) storm duration
    c) rainfall reliability
    d) rainfall intensity
7. Catchment factors influence run-off. Which of the following is one of catchment factors?
    a) catchment factor
    b) soil storage capacity
    c) capillarity pattern
    d) contours
8. Define soil and water conservation.
9. Fanya juu terraces are also referred to as?
10. Give one factor considered during laying out SWC structure.
11. Give two factors affecting run-off.
12. Give two reasons for maintain SWC structures.



**Oral Assessment**

1. Name two examples of terraces.
2. Which type of terraces form bench terraces.
3. Give two reasons for construction conservation structure.

**Case Study Assessment**

Visit the nearest farmers within the institution and answer the following questions

1. Does the farmer have established terraces?
2. Name different types of terraces practiced by the farmer.
3. On your understanding has the farmer constructed the correct type of terraces depending on the slope? Explain your answer.
4. Draw types of SWC structure practices by the farmer.
5. How does the farmer maintain their SWC structures?
6. What are the challenges faced by the farmer to carry out SWC measure?

**Practical Assessment**

**4.3.6.4 Tools, Equipment, Supplies and Materials**

- Topography mapping tools
- Measuring tapes
- Note books
- Soil augers
- Soil sample packaging bags
- Soil science laboratory and equipment
- Jembes

**4.3. References**

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Wolosin M (2017). Large-scale forestation for climate mitigation lessons from South Korea, China and India. SSP.

Young A (1990) agroforestry for soil conservation.CAB international Wallingford. 318.P

### 4.3.7 Learning Outcome No 6: Carry out farm irrigation

#### 4.3.7.1 Learning Activities

| Learning Outcome No 6: Carry out farm irrigation | |
|---|---|
| Learning Activities | Special Instructions |
| 6.1 Carry out identified irrigation methods as per soil and water conservation manual.<br>6.1 Identify irrigation methods as per soil and water conservation manual | Group discussion |

#### 4.3.7.2 Information Sheet No4/LO6: Carry out farm irrigation

**Introduction**

This learning outcome covers: Irrigation, Irrigation methods, Installation of irrigation systems and Irrigation water requirements.



**Definition of key terms**

**Irrigation:** This is the artificial application of water to soil in the correct amounts and frequency, for optimal soil infiltration and plant growth.
It is also defined as any process other than natural precipitation which supplies water artificially to the soil to make up for the deficiency of moisture under natural conditions profitable growth of crops, which otherwise would not be assured.

**Benefits of irrigation**

- To replace missing rainfall in periods of drought.
- To protect the plants against frost.

**Content/procedures/methods/illustrations**

**6.1 Irrigation methods are identified as per soil and water conservation manual**

- To identify an irrigation method, one must know the advantages and disadvantages of the various methods.
- Further, testing of the various methods under prevailing local conditions provides the basis for a sound choice of an irrigation method.
- The identification or choosing an irrigation method guided by the following factors.

**Factors that determine the choice of an irrigation method**

- Natural conditions.
- Type of technology.
- Previous experience with irrigation.
- Required labor inputs.
- Cost and benefits

1. **Natural conditions**

The natural conditions such as soil type, scope, climate, water quality and availability have an impact on the choice an irrigation method as explained below.

**Soil type**

Sandy soils have a low water storage and high infiltration rate. They therefore need frequent but small irrigation applications, in particular when the sandy soil is also shallow. Under these circumstances, sprinkler or drip irrigation are more suitable than surface irrigation. Clay and loam soils are suitable for all the 3 methods of irrigation. Clay soil with low infiltration rates is ideally suited to surface irrigation. When a variety of different soil types is found within one irrigation scheme, sprinkler or drip irrigation are recommended as they will ensure a more even water distribution.

**Slope**

Drip irrigation are preferred above surface irrigation on steeper or evenly sloping land as they require little or no land leveling. An exception is rice grown on traces on sloping lands.



**Climate**

Strong wind can disturb spraying of water from sprinklers under very heavy windy conditions, drip or surface methods are preferred. In areas of supplementary irrigation, sprinkler or drip irrigation maybe more suitable than surface because of their flexibility and adaptability to varying irrigation demands on the farm.

**Water availability**

Water application efficiency is generally higher with sprinkler and drip irrigation may be more suitable than surface irrigation and so these methods are preferred when water is in short supply.

**Water quality**

Surface irrigation is preferred if the irrigation water contains much sediment. The sediment may clog the drip or sprinkler irrigation systems. If the irrigation water contains dissolved salts, drip irrigation is particularly suitable, as less water is applied to the soil than with surface methods. Sprinkle systems are more efficient than surface irrigation methods leaching out salts.

**2. Type of crop**

Surface irrigation can be used for all types of crops. Sprinkler and drip irrigation, because of their high capital investment per hectare, are mostly used for high value cash crops such as vegetables and fruit trees which will bring return investment.

Drip irrigation is suited to irrigating individual's plant or trees or row crop such as vegetables and sugarcane. It is therefore not suitable for close growing crops. e.g. rice.

**3. Type of technology**

The type of technology affects choice of irrigation method. Generally, drip and sprinkler irrigation are technically more complicated methods as they require high capital investment per hectare to purchase equipment. Further to maintain them a high level of technological know-how has to be available; a regular supply of fuel and spare parts must also be maintained which together with the purchase of equipment may require foreign currency. Surface irrigation systems- in particular small-scale schemes usually require less sophisticated equipment for both construction and maintenance (unless pumps are used). The equipment needed is often easier to maintain and less dependent on the availability of foreign currency.

**4. Previous experience with irrigation**

The choice of an irrigation method also depends on the irrigation tradition within the region or country. Introducing a previously unknown method may lead to unexpected complications. Since it is not certain that the farmers will accept the new method. In addition, the servicing of the equipment may be problematic and the costs may be high compared to the benefits. Often it will be easier to improve the traditional method than to introduce a totally new method.



**5. Required labour inputs**

Surface irrigation often requires a much higher labour input for construction, operation and maintained than sprinkler or drip irrigation. Surfaces irrigation requires accurate and leveling, regular maintenance and high level of farmer's organization to operate the system. Sprinkler and drip irrigation require little land leveling: system operation and maintenance are less labor intensive.

**6. Costs and benefits**

Before choosing an irrigation method, an estimate must be made of the costs and benefits of the available options. On the cost side, not only the construction and installation, but also the operation and maintenance (per hectare) should be taken into account. These costs should then be compared with the expected benefits (yields) farmers obviously will therefore be only interested in implementing a certain method this economically attractive.

**6.2 Identified irrigation methods are carried out as per soil and water conservation manual**

**Methods of irrigation**

There are 3 common methods or carrying out irrigation, each method having its advantages and disadvantages.

The method of irrigation is determined by the following factors:

- **Water source:** Consider the source of water e.g. lakes, rivers, underground dams etc. and their sustainability, its quality, and quantity and its distance from the fields to be irrigated.
- **Type of crop:** Whether this crop has, good returns to meet the cost of carrying out the particular irrigation method and the crops watering requirements i.e. if the irrigation method will supply the crop with enough quality water.
- **Land topography:** The layout design of irrigation and its drainage and soil erosion vulnerability is considered.

**The following are the methods of irrigation**

i. Surface irrigation system.
ii. Sprinkler or overhead irrigation system.
iii. Drip of trickle irrigation system.

**Surface irrigation system**

This is defined as the group of application techniques where water is applied and distributed over the soil surface by gravity. Water is distributed over and across by gravity hence no mechanical pump is involved.
It includes irrigation methods such as:

i. Basin irrigation.
ii. Border strip irrigation.
iii. Furrow irrigation.



**Basin irrigation**

There are 2 types of basin irrigation: Controlled or check basins and uncontrolled flooding.

**a) Controlled/ check basins**

Basins are also known as check basins, are usually flat areas of land surrounded by low bunds. The bunds prevent the water from flowing to adjacent basins or fields. Basin irrigation is usually used for rice growing and also trees such as fruits, where one tree is normally located in the middle of a small basin.
Basin method is best suited for crops that are unaffected by standing in water for long period.

How to construct basin irrigation

- It is usually constructed on flat lands with a slope of 0.1 or less.
- If the slope is more than 0.1, terraces can be constructed.
- The land is then leveled a little, however the amount of land leveling is considerable.

An illustration is as shown below.

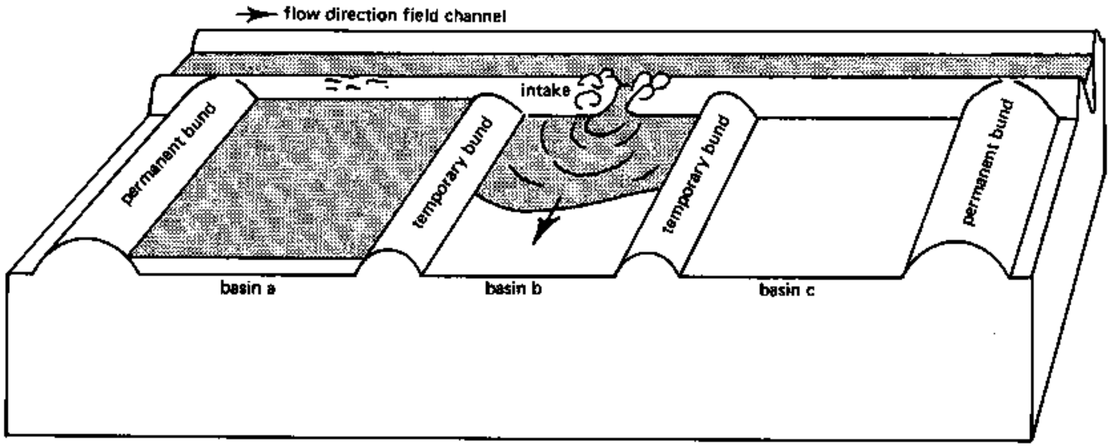


Figure 25:Basin irrigation

http://www.fao.org/3/S8684E/s8684e03.htm

**b) Uncontrolled flooding**

There are many cases where croplands are irrigated without regard to efficiency or uniformity. Uncontrolled flooding is used when the value of the crop is very small or the field is used for grazing recreation purposes.



**Disadvantages of basin irrigation**

- Precision and leveling of basin irrigation
- Crusting of soil in most cases unavoidable
- Perimeters dykes need to be well maintained to eliminate breaching and waste

**Advantage**

- Rapid irrigation is possible
- Low initial cost

**Boarder strip irrigation method**

This can be viewed as an extension of basin irrigation to sloping, long rectangular or contoured field shapes, with free draining at the lower ends.

**How it is carried out.**

Water is applied to individual borders from small hand dug checks from the field head ditch. When water is cut off, it recedes from the upper end to the lower end.

Sloping borders are suitable for nearly any crop that require prolonged pounding.

**Disadvantages**

i. Fair large supply of water is needed
ii. Land must be leveled
iii. Drainage must be provided

**Furrow irrigation**

It is a type of surface irrigation in which trenches a furrow are dug between crops, rows in a field. Water is made to flow down the furrows by gravity and it seeps vertically and horizontally to refill the soil reservoirs. Flow to each furrow is individually controlled. Furrows are small channels having continuous and almost uniform slope in the direction of irrigation. Water infiltrates through the erected perimeters of the furrows and moves vertically the laterally to saturate the soil. Furrows are used to irrigate the crops planted in rows e.g. maize vegetables and trees. However, furrow method is not recommended for very light soils with high infiltration rate as water is wasted on the upper end of the furrow due to deep percolation. Hence it is most suited for soils having infiltration rate of 0.5 to 2.5 cm /hour.

**Advantages of furrow irrigation**

In relation to other surface methods, furrow method;

- Does not need extra-drainage structures because its furrows act as drains.
- Its water use efficiency is higher than that of basin and boarder systems

**Disadvantages of furrow irrigation**

i. Require more labour than any other surface irrigation method.
ii. There is a possibility of an increased erosion



**Sprinkler or overhead irrigation**

Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Water is distributed through a system of pipes usually by pumping. It is the sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. In a uniform patter at a rate less than the infiltration rate of the soil.

**Components of a sprinkler;**

- Pump.
- Filter.
- Control valves injection unit.
- Pipes.
- Nozzles.

Conditions favorable for sprinkler irrigation

- Lands which have steep slopes and easily eroded soil.
- Irrigation channels which are too small to distribute water efficiently by surface irrigation and lands with shallow soils and undulate lands which prevent proper leveling required for surface methods of irrigation.

**Advantages of sprinkler irrigation**

- Crops can be saved from frost damage.
- High yields of crops are maintained.
- No soil erosion since water application is regulated.

**Disadvantages**

- High initial or invest costs that cannot be adopted by ordinary farmers.
- Clogging of filters when water has debris.
- Requires power for running pumping unit.
- Poor application efficiency in windy weather and high temperatures.
- High evaporation losses.
- Maintenance cost is high due to operational and monitoring cost.

**Types of sprinklers**

1. **Centre pivot irrigation**

Water is distributed by a system of sprinklers that move on wheeled towers in a circular pattern.

**2. Lateral move irrigation**

Water is distributed through a series of pipes each with a wheel and a set of sprinklers which are rotated either by hand or with a purpose-built mechanism. The sprinklers move a certain distance across the field and then need to have the water hose reconnected for the next distance. This system tends to be less expensive but requires labor than others.



**3. Drip or trickle irrigation**

Drip irrigation is a method of watering plants with single drops of water at a time.
Components of drip irrigation system. The system comprises main line, sub mains, laterals valves (to control flow) drippers or emitter (to supply water to the plant), pressure gauges, water meters, filters (to remove all debris) e.g. sand, clay to reduce clogging of the emitters) pumps, fertilizer tanks, vacuum breakers and pressure regulators. The drippers are designed to supply water at the desired rate of 1 to 10 l per hour directly to the soil. Low pressure heads at the emitters are considered adequate as the soil capillary causes the emitted water to spread laterally and vertically.
Flow is controlled manually or set to automatically either:

i. Deliver desired amount of water for a predetermined time.
ii. Supply water whenever soil moisture decreases to a predetermined amount.

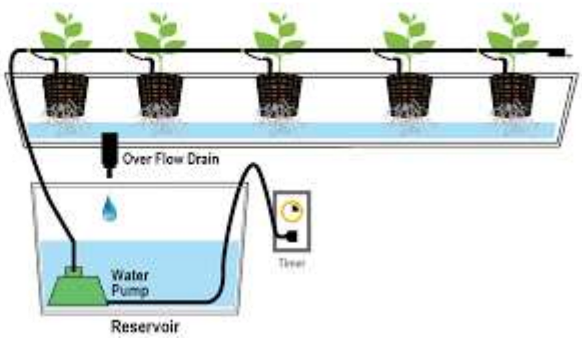


Figure 26: Drip irrigation Source

https://thestempedia.com/project/drip-irrigation-sytem/

**Advantages of drip irrigation**

- Low water and hence saves time
- No fustigation is possible
- No soil erosion

**Disadvantages**

- High installation and cost of maintenance
- Not suitable for closely planted crops
- Replacement of emitters regularly due to spacing required by different crops

**Conclusion**

This learning outcome covered; irrigation, irrigation methods, installation of irrigation systems and irrigation water requirements

**Further Reading**

1. Panuska, J.S.Sanford and A. Newhouse,2015. Methods to monitor soil moisture, university of Wisconsin.

**4.3.7.3 Self-Assessment**



1. The following are natural conditions that determine the choice of an irrigation method except?
    a) Soil type
    b) Slope
    c) Type of crop
2. The following factors determine the choice of an irrigation method except?
    a) Cost and befits.
    b) Required labor input.
    c) Topography.
3. The following are advantages of drip irrigation except.
    a) Requires a lot of water.
    b) Fertigation can be applied.
    c) Controls soil erosion.
4. The following are benefits of irrigation except.
    a) Earn farmers income.
    b) Protect crops against first damage.
    c) Ensure crop production even during dry seasons.

5. The following are components of a sprinkler filter system except.
    a) Pump
    b) Filter
    c) Pressure gauges
6. What do you understand by the term irrigation?
7. Outline any 3 components of a drip irrigation system.
8. Outline factors to consider before carrying out an irrigation system
9. Briefly describe how to construct basin irrigation.
10. Outline 3 methods of surface irrigation

**Oral Assessment**

Describe the maintenance of drip irrigation system.

**Case Study Assessment**

You have been employed by an irrigation system installing company. Formulate guidelines that will help you know the type of system to be installed for your client.

**Practical Assessment**

Demonstrate drip irrigation using locally available materials.eg. Bottles.

**4.3.7.4 Tools, Equipment, Supplies and Materials**

- soil auger
- Soil sample packaging bags
- Soil science laboratory and equipment
- Measuring tape
- Topography mapping tools



**4.3.7.5 References**

Dauka S.J.M Knowles, (2011). Drip and micro irrigation design and management. University of carlifornia, state publishers carlfonia.

Ksiksi, T. S., Trueman, R., Abdelfattah, M., Mousa, M. T., Almarzouqi, A. Y., & Barahim, S. A. (2019). Above and belowground carbon pools are affected by dominant floral species in hyper-arid environments. F1000Research, 8(1043), 1043.

Lamont,W.J, M.D.Orzolic (2012). Drip irrigation for vegetable production, Pennsylvania state University Park.

### 4.3.8 Learning Outcome No 7: Carry out farm water drainage

#### 4.3.8.1 Learning Activities

| Learning Outcome No 7: Carry out farm water drainage | |
|---|---|
| Learning Activities | Special Instructions |
| 7.1 Identify farm drainage systems as per farm plan<br>7.2 Construct water drainage systems as per farm plan<br>7.3 Maintain water drainage systems as per environmental management plan | Demonstrate construction of farm drainage systems |

#### 4.3.8.2 Information Sheet No4/LO7: Carry out farm irrigation

**Introduction**

This learning outcome covers; Water drainage, Farm water drainage systems, Types of drainage systems, Maintenance of drainage systems, Tools and equipment and Operational standards.



**Definition of key terms**

**Drainage:** This is the natural or artificial removal of excess water from the surface or sub surface of an area.

**Aims of drainage:** To remove the unwanted water in order that soil structure and aeration are maintained and that access to the field for cultivation and harvesting is assured.

**Importance of farm water drainage**

- Reduces soil and nutrient loss from ran off
- Prevents soil erosion
- Drainage on hill slopes helps to reduce the risk of soil slippage
- Farm water drainage facilitates early ploughing and planting of wetland fields.
- Lengthens crop growing season
- Leaches excessive salts from the soils in order to limit salinization and sonification process.
- Ensures favorable soil temperatures
- Provides more available soil moisture and plant feed by increasing the depth of root-zone soil.
- Favors growth of soil microorganisms such as bacteria, fungi and others which are important for microbial activities in soil such as decomposition of organic matter, mineralization process like nitrogen fixation etc.

**Drainage system:** An agricultural drainage system refers to a system by which water is discharged or in the soil to enhance agricultural production of crops. It may involve combination of storm water control, erosion control and water table control.

**Content/procedures/methods/illustrations**

**7.1 Farm drainage systems are identified as per farm plan**

**Types of drainage systems**

While there are more than two types of drainage systems employed in agriculture, there are two main types:

- Surface drainage
- Sub surface drainage

**Surface drainage**

The regular surface drainage systems which start functioning as soon as there is an excess of rainfall or irrigation applied operate entirely by gravity. They consist of reshaped or reformed land surfaces and can be divided into:

- Bedded systems which are used in flat lands for crops other than rice.
- Graded systems which are used in sloping land for crops other than rice.

The bedded and graded systems may have ridges and furrows. The checked surface drainage systems consist of check gates placed in the embarkments surrounding flat basins such as those used for rice fields in flat lands. These fields are usually submerged and only need to be drained on certain occasions e.g. at harvest time. Checked surface drainage systems are also found in terraced lands used for rice.

In literature, not much information can be found on the relations between the various regular systems i.e. bedded and graded systems, the reduction in the degree of water logging, and the agriculture or environmental effects. It is therefore difficult to develop sound agricultural criteria for the regular surface field drainage systems. Most of the known criteria for those systems concern the offering of the techniques of land leveling and earth moving. Similarly, agricultural criteria for checking surface drainage systems are not well known.



**Sub surface drainage**

Like the surface field drainage systems, the sub surface field drainage systems can also be differentiated in;

- Regular systems and,
- Checked (controlled) systems

When the drain discharge takes place entirely by gravity, both types of sub-surface systems have much in common except that the checked systems have control gates that can be opened and closed according to the need. Checked drainage systems save more irrigation water and also reduce the discharge, through the main drainage system thereby reducing construction costs.

When the discharge takes place by pumping, the drainage can be checked by simply not pumping or reduces the quantity of irrigation water needed and does not lead to undue salinization.

Sub surface field drainage systems consist of horizontal or slightly sloping channels made in the soil; they can be open ditches, trenches, field with brushwood and a soil cap filled with stones and a soil cap, buried pipe drains, tile drains, or mole drains but they can also consist of a series of wells.

Modern buried pipe drains often consist of corrugated, flexible and perforated plastic (PE) Or PVC pipe lines wrapped with an envelope or filter material to improve permeability around the pipes and to prevent the entry of soil particles which is especially important in fine sandy and silty soils. The surrounding may consist of synthetic fiber. The field drains (or laterals) discharge their water into the collector or main system either by gravity or by pumping.

The wells (which may be open dug wells or tube wells) are normally to be pumped but sometimes they are connected to drains for discharge by gravity. Sub surface drainage by wells often referred to as vertical drainage and drainage by channels as horizontal drainage but it is clearer to speak of 'field drainage by wells' and 'field drainage by ditches or pipes' respectively.

In some instances, sub surface drainage can be achieved simply by breaking up slowly permeable soil layers by deep ploughing (sub-soiling), provided that the underground has sufficient natural drainage. In other instances, a combination of sub-soiling and sub-surface drains may solve the problem.

**Factors to consider in identifying or choosing a farm drainage system**

- **Soil properties**



Detailed information about specific soil properties e.g. soil depth, soil type and existence of any soil layers that restrict water movement must be known to properly design and manage a drainage system e.g. Clay soils generally conduct water much more slowly than sand thus to adequately drain water from a clay soil, a surface system could be needed and tile drains will have to be more spaced closely. This will make installation more expensive for sandy soils which are more permeable, both surface ditches and tile drains can be spaced further apart.

Soil depth is another important consideration; there must be adequate soil depth. 3 to 5 feet is generally recommended to install a tile drainage system. In shallow soils, surface systems can be used and tile drains must be closely installed more closely together or close to the soil surface to adequately lower the water table.

The shallow restricting layer reduces the amount of water that a drain can intercept because it cuts off the deeper flow paths that water can flow to the drain. This makes installation more expensive. Sub surface drains should also be deep enough to provide protection against tillage operations, equipment loading and frosts hence all subsurface drains in mineral soils should have at least 2 feet of soil cover over the drain to protect them against overloading from heavy machinery. Organic soils should have at least 2 feet.

- **System outlet**

The location of the drainage system is an important consideration and should generally be located 3 to 5 feet below the soil surface, where gravity is not available, pumping can be considered. Installing and maintaining a pump adds considerable expenses to any drainage system.

- **Topography assessment**

Topography influences water movement and drainage within a field. Steeper field slopes allow excess water to move laterally down slope in the soil, draining more rapidly than flatter fields. Fields with steep slopes tend to require less drainage than flatter fields. Topography also influences where the outlet can be located. An outlet should be hydraulically down gradient of the system it drains, otherwise pumping will be required.

- **Economic analysis**

Before carrying out a drainage system, a cost benefit analysis should be done to determine if the drainage system will be economically viable. Sub surface tile systems are generally more expensive to install than surface ditches due to specialized equipment needed for installation but they can be more economical because a subsurface file system does not remove land from production like a surface ditch system does.

- **Cropping strategies**

Cropping strategies are important to consider because they can change the economic payback period of any drainage system: Higher yielding or higher value crops will benefit more from drainage than lower yielding, lower value crops. Crops that may be intolerant of saturated conditions might require greater drainage intensity than crops that can tolerate wet conditions for longer periods. Deep rooted crops could require drains to be installed at a greater depth that shallow rooted crops.

- **Maintenance needs**

Like any other systems require maintenance for them to perform correctly. The maintenance required depends on the drainage system type. Tile and ditch systems have different needs. Developing a drainage system management plan is a good first step to ensuring that a drainage system continues to function properly. Any drainage system management plan should include good documentation maps of the location of the ditches, outlets and buried tile and should begin with periodic inspection of the systems. Ditch systems should be inspected regularly for any obstructions or impedance to flow in the ditch, bad erosion bank failures. Obstructions should be removed as they are encountered, and any of bad erosions or bank failures should be removed as encountered.

- **Environmental considerations**

While drainage has clear benefits to crop production, there are also negative environmental consequences of drainage. Since conventional drainage management emphasizes the export of water rather than prudent management of local water tables, generally resulting in excessive drainage. There is the possibility of excessive nutrient export from tile drained fields.

In addition, routine ditch management practices including scrapping and vegetation management can minimize the internal cycling of nutrients in ditch vegetation and destabilize ditch walls, resulting in erosion and water quality concerns. The chosen drainage system therefore should help in environmental conservation.

## 7.2 Water drainage systems are constructed as per farm plan

1. **Construction of subsurface drainage system**

There are three types of sub surfaces systems i.e. open and pipe drains, tube well drainage and mole drainage, each of which has its own construction method. In construction of sub surface drainage system, the following two procedures are involved:

- **Design of sub surface drainage systems**

Depth and spacing of field drains. The depth and spacing of field drains are usually calculated with the help off drainage equations. The data needed for those calculations include the agricultural requirements (depth of water table and root depth). The soil characteristics (hydraulic conductivity and depth to the impermeable layer) and hydraulic factors.

Calculated drain spacing normally show considerable variations due to the variations in input data. If so, the area should be divided into sub-areas of 'blocks' of convenient size e.g. the area served by one collector.

For each of the sub-area or block, a uniform and representative drain spacing can be achieved. An example is as illustrated below:

As an example, suppose that the calculated spacing in a project area vary between 18 and 85m, practical sets of standard spacing could then be:20-25-30-40-50-60-80m or 20-30-45-60-80m. It makes little sense to make the increments too small in view of the many inaccuracies and uncertainties in the entire process of calculating the spacing.



- **Pipes**

The materials used in the manufacture of drain pipes are clay, concrete and corrugated plastics. Important criteria for pipe quality and selecting the most sustainable type of pipe. Availability of raw material. The resistance to mechanical and chemical damage. Longevity and costs. The costs are the total cost for purchase, transport handling and installation.

- **Envelopes in pipe designing**

Sometimes, pipe drains are installed with an envelope. An envelope is the material placed around the pipe to perform one or more of the following functions:

a. Filter function: To prevent or restrict soil particles from entering the pipe where they may settle and eventually clog the pipe.
b. Bedding function: To provide all-round support to the pipe in order to prevent damage due to soil load. Large-diameter plastic pipes are embedded in gravel especially for this purpose.

A wide variety of materials are used as envelopes for drain pipes, ranging from organic and mineral materials and mineral fibers. Organic material is mostly fibrous and includes peanut coconut, heather and sawdust. Mineral materials are mostly used in granular form: they may be gravel, slag of various kinds (industrial waste products) or fired clay granules. Synthetic materials may be in a granular form e.g. (nylon, acryl and polypropylene). Glass fiber, glass wool and rock wool which all are mineral fibers are also used.

**Methods of applying envelopes on pipes**

There are various ways of applying envelope materials. They can be applied in bulk as thin sheets or as more voluminous 'mats". Bulk application is common for gravel, peat, litter, various slags and granules. It is recommended to place pipes in such a way that it is completely surrounded by the envelope material. In this way, the envelope material will fulfill its filter, hydraulic and bedding function. Thin sheets and mats are commonly used with plastic pipes as pre-wrapped envelope.

2. **Construction of pipe drainage systems**

**Construction methods**

Pipe drainage systems are generally constructed by specialized contractors. They are solicited after tenders have been called for, usually from a list of contractors drawn up by the authorities in a prequalification process. This type of construction is very complex hence not ideal for farm pipe drainage systems.

The classical method of pipe installation consists of marking the alignments and levels, excavating the trenches by manual labour, placing the pipes, envelop material and back filling the trenches. Nowadays, field drains are installed by drainage machines either trenchers or trenchless machines. Concrete collectors are often installed by excavators. In addition to the mechanics of installation, other important matters are the work planning, the working conditions, supervision and inspection.

**Alignment and levels**

To make alignments and levels, stakes are placed in the soil at both ends of a drain line with the top of the stakes at a fixed height above the future trench bed. The slope of the drain line is thereby indicated. A row of boning rods is then placed in line (both vertically and horizontally) between the stakes, with an extension at the upstream end of the drain line where the run of the drainage machine ends. The boning lines thus are in a line parallel to the trench bed. The driver of the machine achieves grade control through sighting. The same principle can be applied when drains are installed manually.



Steps in the construction of a sub-surface drainage system include:

- Setting out levels
- Clearing the site
- Installation of pipes
- Backfilling the trench

**Machinery used in construction**

They fell into two categories:

**Trenches and trenchless machines**. Trenchers excavate a trench in which the pipe is laid while trenchless machines merely lift the soil while pipe is being laid.

3. **Construction of surface drainage systems**

Open surface drains can be constructed manually or mechanically. Care should be taken that the soil from the drains do not block the inflow or runoff, but is deposited on the correct side of the ditch or is spread evenly on the adjacent fields. Collector drains are usually constructed with different machinery than that used for field drains. (i.e. excavating instead of land planes). The soil is placed near the sides of the drain. Scrappers are needed when excavated soil is to be transported some distance away.

### 7.3 Water drainage system is maintained as per environmental manage plan

1. **Maintenance of sub surface drainage system**

The maintenance of sub surface drainage system. Three procedural steps:

- Initial inspection and maintenance
- Ongoing inspection and maintenance
- In the field

**Initial inspection and maintenance**

During the initial period following the installation of the new sub surface drainage system, the soil around and above the drains will still be loose and should be left alone to settle naturally with time and rain. Do not use equipment to pack down the soil over the drain as any pressure on the loose soil could damage or collapse the pipes. Minimize traffic on the field as long as possible, and straddle the laterals and mains with equipment or work across (not parallel to) the drains when working the field in the first year after installation.

Confirm that all surface inlets are filled with a proper guard or grate to keep debris, trash and rodents out of the sub surface drainage system.

**Ongoing inspection and maintenance**

The sub surface drainage system should be inspected for developing problems and prompt repair of any noted issues to increase its life span.

**In the field**

Check for any signs of erosion of the drain pipe trench following rain events. If the drainage system is blocked with tree roots

- Reroute the drainage pipe away from the tree(s)
- Remove and replace the section of the blocked drains and remove tree(s) causing the problem.
- Replace the drain using continuous non perforated pipes for a distance of 15m on either side of the tree.

**Maintenance of surface drainage systems**

Remove any trash, debris or plant material that has accumulated around the inlet to make sure that it functions properly. Look for any signs of reddish-orange slim coming from the outfall. This may indicate the presence of iron ochre which can plug the drainage system.

**Conclusion**

This learning outcome covered; water drainage, farm water drainage systems, types of drainage systems, maintenance of drainage systems, tools and equipment and operational standards

**Further Reading**

1. Journals: Agricultural water management- international journal. ISSN 03783774

#### 4.3.8.3 Self-Assessment

**Written assessment**

1. The following are steps involved in construction of a sub-surface drainage system except?
    a) Setting out levels
    b) Clearing site
    c) Planning the site
2. All of the following are factors to consider in choosing a farm drainage system except?
    a) Soil properties
    b) Environmental conservation
    c) Irrigation method
3. The following activities are involved in farm water drainage systems except?
    a) Water control
    b) Erosion control
    c) Vegetation destruction control
4. The following are types of sub surface drainage. Except?
    a) Open and pipe drains
    b) Mole drains
    c) Crulley control drains
5. Maintenance of sub surface drainage system involve the following procedural steps except?
    a) Construction of discharge ways
    b) Ongoing inspection and maintenance
    c) In the field
6. What do you understand by the term;
    a) Drainage
    b) Drainage systems
7. Outline the maintenance of surface drainage system
8. What do you understand by the term ‘envelope’ as used in pipe installation?
9. Outline three ways in which blockage of a drainage system by tree roots can be corrected
10. Outline 2 methods of applying envelopes on pipe

**Oral Assessment**

1. Outline importance of drainage
2. Outlines types of drainage systems

**Case Study Assessment**

1. Visit a water treatment plant; identify the drainage systems carried out

#### 4.3.8.4 Tools, Equipment, Supplies and material

- Soil auger
- Measuring tapes
- Topography mapping tools
- Measuring tools
- Soil science laboratory and equipment
- Jembe
- Shovel
- Note books

#### 4.3.8.5 References

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### 4.3.9 Learning Outcome No 8: Harvest farm water

#### 4.3.9.1 Learning Activities

| **Learning Outcome No 8: Harvest farm water** | |
|---|---|
| **Learning Activities** | **Special Instructions** |
| 8.1 Identify farm water harvesting methods as per soil and water conservation manual<br>8.2 Construct farm water harvesting structures as per soil and water conservation manual<br>8.3 Water harvesting structures are maintained as per environmental management plan | Field excursion |

#### 4.3.9.2 Information Sheet No4/LO8: Harvest farm water

**Introduction**

This unit covers; Roof catchment Surface runoff Ground water Rock catchment



**Definition of key terms**

**Water harvesting**: This is the gathering of water from an area termed as catchment area and channeling it to the cropping area or wherever required.

**Water harvesting structures**: These are structures that are used in conserving water for future use or for daily use.

**Content/procedures/methods/illustrations**

**8.1Farm water harvesting methods are identified as per soil and water conservation manual**

There are different types of water harvesting methods but the two broad ways are:

- Rooftop water harvesting
- Surface runoff water harvesting

**Rainwater harvesting**

It is the collection and connection and storage of rainwater for reuse on site rather than allowing it to runoff. The stored water is used for various purposes e.g. gardening and irrigation

**Rooftop water harvesting**

It is a system of catching rain water where it falls in the rooftop. The roof becomes the catchment and the rainwater is collected and stored in a tank or diverted to artificial recharge system.

**The rooftop rainwater harvesting system components**

- **Catchments:** This is the surface that receives rainwater directly e.g. roof, paths, terraces
- **Transportation:** Rainwater from the roof top should be carried through down to take water pipes or drains
- **First flush:** This is a device used to flush off the water received in first shower of rain to avoid contaminating fresh water
- **Filters:** These are materials put on a water storage to filter away microorganisms, dead animals etc.

Example of filters; sand gravel filter, charcoal filter, sponge filter.

**Method of rooftop rainwater harvesting**

i. Collection of water from roof of the building and diverting to a storage tank that should have a filter for filtration
ii. Recharging ground aquifer. It can be recharged by various kinds of structure to ensure percolation of rainwater in the ground, instead of draining away from the surface runoff

Examples of the structure are

- Recharging of bore wells
- Recharging of pits
- Recharging trenches
- Soak away
- Percolation tanks



**Surface runoff harvesting**

This is where water which flows away can be caught and reused for recharging aquifers

Examples of construction that reduce surface runoff water for harvesting are:

**i. Contour farming**

This refers to field activities such as ploughing and furrowing that are carried out along contours rather than up and down slopes. They conserve water by reducing surface runoff and encouraging infiltration of water into the crop areas. A number of waters harvesting techniques or methods are based along contours. They include; contour ploughing, contour ridges, store lines, grass strips and terraces. Techniques used depend on the steepness of the slope, soil type, crop grown and availability of labour.

**ii. Contour ploughing**

Any ploughing on a slope should be carried out along the contours. This is to reduce run off and soil erosion and increase moisture content. It can be practiced on any slope with gradient less than 10%. On steep slopes it should be combined with other measures e.g. terracing, bunds or strip cropping. It is an important factor in determining the direction of ploughing. It is also important to layout contours properly or they may channel the water and increase run off.


Figure 27: Contour ploughing

**iii. Bench terraces**

Terraces are made by creating ridges and furrows along contours on a slope. The ridges hold back water, soil and runoff. Terraces can be used on steeper slopes than contours. They are firmed by digging a ditch along a contour.

Figure 28: Bench terraces

Other examples of construction that reduce surface runoff water for harvesting include: Grass strips planted along contours. It reduces soil erosion and runoff, store lines and retention ditches

**Advantages of contour farming**

- Reduces soil erosion
- Improves soil moisture content
- Induces natural process of terracing e.g. store lines
- Planting pits

These are the simplest forms of water harvesting. Small holes are dug at spacing of one meter. During rainstorms, planting pits catch runoff and concentrate it around the growing plant; compost manure is also placed in the pits thus improves soil fertility.

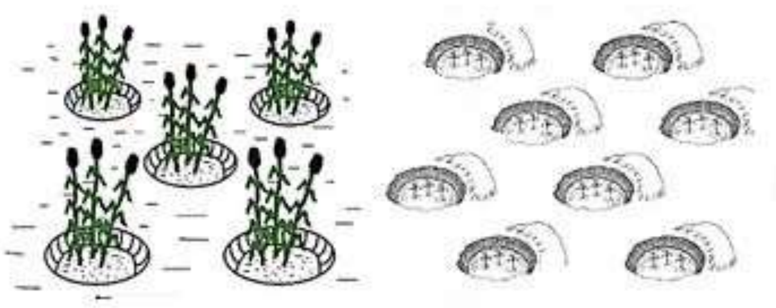

Figure 29:Planting pits

- Semi-circular bunds

These are earth bunds in the shape of a semicircle with the tip of the bunds on the contours. The size of the bunds varies. They are mostly used to harvest water for fruit trees and for seedlings. Large structures are used for rangeland rehabilitation and fodder production. Other planting pits include:

- Mulching
- Cover crops
- Conservation tillage



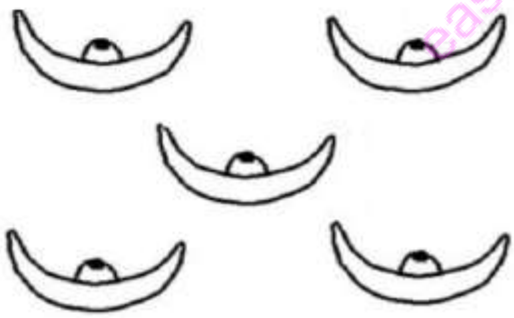

Figure 30: Semi-circular bunds

**8.2 Water harvesting structures are constructed as per soil and water conservation manual**

Water harvesting structures include all mechanical or structural measures that control the velocity of surface runoff and thus minimize soil erosion and retain water where it is needed. These structures consist of engineering works involving physical structures made of earth stones, masonry or other material for construction of earth works. The water harvesting structures can be made to either conserve or harvest water or to safely discharge it away.

Suitability of the water harvesting structure depends on:

- Climate and the need to retain or discharge runoff
- Farm size
- Soil characteristics
- Availability of an outlet
- Labor availability and cost
- The adequacy of existing agronomic or vegetative conservation measures

Amount of surface runoff determines the type of structure of water harvest to be constructed.

**Surface runoff**

Surface runoff is the portion of precipitation that makes its way towards the stream, lakes, rivers. Runoff occurs when precipitation rate exceeds infiltration rate and is the most destructive component of rainfall.

In constructing of water harvest structures, these factors are considered

- Peak runoff rate
- Runoff volume
- Temporal distribution of runoff rates and volumes

**Factors that affect runoff**

- **Catchment factors**

Catchment factors include: topography, vegetation, infiltration rate, soil storage capacity, the size of the catchment, its shape and orientation. The larger the catchment the more the runoff it will generate.

- **Rainfall factors**

Rainfall factors associated with surface runoff and erosion include rainfall amounts, storm duration, intensity and distribution

The most significant component of rainfall is the intensity which is a function of the energy the raindrops impact on the soil

- **Estimation of surface runoff**

It's important to know the quantities of water to be handled if the objective is to impound water e.g. dams peak volumes are used. If the purpose is to convey water e.g. channels, water ways, peak run off rates are used. It is necessary to estimate runoffs or construction of conservation and also conveyance of water to avoid failure due to over topping

Estimate of the rates of surface run off therefore depend on two processes:

i. Estimating the rate of animals
ii. Estimating how much of the rainfall becomes run off

The run off rate is more crucial and is determined using various methods or equations.

**i. The runoff coefficient**

The simplest method to use a single coefficient which represent the ratio of rainfall loss, if half of the rainfall is lost by infiltration, the other half appears as runoff then the coefficient C is 0.5

ii. **Catchment characteristic or cook's method**

The method consists of summing numbers of which represents the extent to which runoff from the catchment will influence a particular characteristic. The effect of four features is considered in cook's method which is the relief
Soil infiltration
Vegetation cover
Soil surface storage

iii. **Runoff curve numbers**

iv. **The rational formula**

The rational method predicts runoff through this equation Q=0.0028 CIA
Q= the design peak runoff rate in $m^3/s$
C=runoff coefficient (a function of catchment vegetation, slope, surface culture)
A=area of the watershed in hectares
I=rainfall intensity in mm/hr. (for the design return period.

**Principles for the design of water harvesting structures**

The construction of structures considers severity and extent of erosion damage or risks of the factors causing erosion. The suitability of land to the identified intervention to be considered. Water harvesting control measures are directed at protecting the soil from raindrop impact and hydraulic forces of runoff.
The process involves three areas of attention

i. Reduction of raindrop impact on the soil
ii. Reduction of overland flow
iii. Increase infiltration rate
iv. Slowing runoff velocities.



**Factors considered in construction of a structure**

The structures are usually made by hand labour or machinery although some terraces develop naturally from vegetative barriers. They are important on steep slopes where annual crops are grown and in marginal rainfall areas where there is a need to conserve rainfall in situation.
The selection and structure to be constructed depend on the factors below:

- Climate and the need to retain and discharge runoff
- Farm size and system
- Cropping pattern
- Soil characteristic
- The availability of outlet for discharging runoff away from cropland
- Labor availability
- Availability of materials

**Types of water harvesting structures**

These structures include diversion ditches (cut off drain) retention ditches, terraces and water ways. Supportive cultural measures e.g. grass or vegetation for stabilizing the structures are recommended. The identification of types of harvesting structures should take into account the need to retain water or drain the excess water. Structures which are intended to discharge runoff should not be installed unless there is a place for disposal of water. In higher rainfall areas. It is good to construct structures to discharge runoff. Discharging water into footpaths, road or existing gully will aggravate the problem of erosion. It is important to dispose water in natural or artificial waterways. In dry areas with low rainfall it is advisable to keep rainwater to prevent runoff.

**Benefits of construction of structures**

- Increase agricultural productivity
- Conservation of potentially productive land
- Reduce nutrients loss from soil
- Environmental conservation by strong more water within the soil profile
- Soil drainage benefit in areas to floods or water logging
- It protects infrastructure e.g. roads from erosion, drainage etc.

**Limitations**

- Small holder farmers cannot plan for construction of the structures
- Constructing can be expensive to in falls
- There is a lot of labour needed

## 8.3 Water harvesting structures are maintained as per environmental management plan



Water harvesting structures require regular maintenance and repairs if they get damaged. Grazing in cultivated lands that have constructed structures should not be allowed as the animals can damage the structures. Replanting vegetative materials and lining out construction and channel should be done at least every season. Regular cleaning catchment, gutters, filters, and tanks should be done to reduce the likelihood of contamination. Water from other sources should not be mixed with that in the tank.

**Conclusion**

This learning outcome covered; roof catchment, surface runoff, how structures are constructed; their limitations and benefits; the different types of methods of how water is harvested in the farm and how the structures are maintained.

**Further Reading**


1. Delmar D.Fangmeier, P.E. Professor Emeritus of agricultural and bio systems engineering. The University of Arizona
2. www.rainfoundation.org

#### 4.3.9.3 Self-Assessment

**Written assessment**

1. Which one is not a rainwater harvesting system component?
    a) Catchments
    b) Tanks
    c) Filters
    d) Flush
2. Which one of the following structures is not an example of recharging ground aquifer?
    a) Recharging boreholes
    b) Recharging pits
    c) Soak away
    d) Rain
3. Which one is not a method of water harvesting?
    a) Contour ploughing
    b) Grass strips
    c) Semi-circular bunds
    d) Catchments
4. Which one does not affect run off?
    a) Catchment factor
    b) The run off coefficient
    c) Rainfall factor
    d) Estimation of surface runoff
5. Which one is not considered in structure selection?
    a) Farm size
    b) Soil characteristic
    c) Labor availability
    d) Footpath



**Short answer question**

1. What is water harvesting.
2. List down 5 benefits of constructing water harvesting structure.
3. List down how maintenance is done in water harvesting structures.
4. Name the methods of farm water harvesting
5. List down types of water harvesting structure.

**Oral Assessment**

1. What do you understand by water harvesting structures?
2. Mention advantages of contour farming

**Case Study Assessment**

Have a trip to one of agricultural institution and have a tour around and view the different types of water harvesting structures. The teacher and the industrial supervisor should guide you.

**Practical Assessment**

1. Having a farm session and construct a bench terraces; cut; off drain
2. In the farm plant grass strips and also make stone lining on a farm of crops in your school

### 4.3.9.4 Tools, Equipment, Supplies and Materials

- Water tanks
- Levelling boards
- Shovels
- Gutters

### 4.3.9.5 References


Anil Kumar, A.K Madhakar August (2019)

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Huffman, R. L. (2009). The Future of the AG PE Exam--Survey results and commentary. *Resource Magazine*, *16*(6), 10-12.

### 4.3.10 Learning Outcome No 9: Manage waste water disposal

#### 4.3.10.1 Learning Activities

| Learning Outcome No 9: Manage waste water disposal | |
|---|---|
| **Learning Activities** | **Special Instructions** |
| 9.1 Identify waste water disposal methods as per water management manual<br>9.2 Identify waste water disposal structures as per wastewater management manual<br>9.3 Construct waste water management structures as per waste water management manual | Arrange to visit a waste treatment plant.<br>Set a lesson to conduct the practical |

#### 4.3.10.2 Information Sheet No4/LO9: Manage waste water disposal

**Introduction**

This learning outcome covers; waste water treatment, waste water recycling, waste water disposal and waste water pollution management



**Definition of terms**

**Waste water disposal:** It is the process of conveying waste water form homes, business and industries to water treatment plant or to a collecting point.

**Waste water:** It is any water that has been affected by anthropogenic use.

**Water treatment:** It is the process of remove contaminants from the water to convert it to reusable water.

**Water pollution:** It is the contamination of water bodies mostly due to human activities.

**Content/procedures/methods/illustrations**

**9.1 Waste water disposal methods are identified as per waste water management manual**

**Water pollution**

**Classification of pollution population**

According to the medium affected that is water pollution, air pollution and soil pollution.

**Sources of water pollution**

- Natural and anthropogenic pollution.
  Natural this is pollution due to presence of gas in the atmosphere that dissolve in the water inform of carbon iv oxide. Also, decomposition of organic materials and lastly suspended materials render it not useful.
- Anthropogenic: This is changing of water activities by human being.

**Activities that cause water pollution**

- Industrial activities
  Some raw materials for the industries contain sediments that make water polluted. The end products such as plastics also cause water pollution.
- Domestic activities
  Waste such food remains, excrement and urban cleaning cause pollution.
- Agricultural activities
  Use of herbicides, fertilizers and manure in farming activities cause water pollution downstream.

**Characteristics /properties of contaminated water**

- The water has a smell
- Water is greyish brown; this colour indicates pollution.
- It has a bad odour. Clean water-clean water should have no odour.
- Water is turbid showing presence of dish water.
- Water contains solid suspension, dissolved solids and colored solids.
- Presence of organic matter such as gravel, dissolved salts and chlorides in the water.



**Waste water disposal methods**

i. **Rain water**

This water is in large volumes but has less load. This water is polluted due to human activities such as industrial emission of waste. Atmospheric pollution also pollutes the water. The water is deposited through precipitation.

ii. **Disposal through domestic water disposal**

Discharge of municipal sanitary system, household, commercial and large facilities such as hospital is discharged to the sewage.

iii. **Industrial waste water**

Industrial effluent from industries is released to the rivers and some of the sewer system. This effluent emission is disposed.

**Urban water**

Water is released from the urban buildings and urban business. The water is conveyed through pipes.

**Onsite effluent disposal**

This is where water is conveyed to be treated on the site of the pollution. These are water stored in a septic tank and leach drains.

**Grey water systems**

The gray water is a system where waste from laundries, kitchen, and bathroom is conveyed to the garden and lawns. This help to save water.

**Decommissioning of the existing disposal system.**

When a new sewage is established, the existing waste water treatment plants should be replaced and contents emptied to the sewage system.

**Factors to consider in choosing a disposal system.**

- Chemical contamination level
- Detection limits of the system
- Quantity of the water required
- Number of analysis to be performed
- The level of analysis of water
- The source of effluent
- The previous treatment of the waste



**9.2 Waste water disposal structures are identified as per waste water management manual**

**Factors to consider when choosing a waste treatment plant**

- Plant location

Location of drinking water sources, surface water intake and ground water is considered because it should be close. It should be isolated from the residential land and its use environs.

- Prevailing wind directions
  The direction of the wind is considered to avoid disrupting the treatment process.
- Susceptibility of the site to flooding.
  The site should not be prone to floods, i.e. it should be gently sloping
- Provision of future expansion
  The site should allow for expansion. The site should have enough space for expansion
- Suitability of the place to receive treated sewage
  The site should be n capacity to receive waste water.
- Accessibility of the area. Areas off site
  The site selected should be in a position where treated water can be conveyed ease to the area of use.
- Design capacity
  The amount of waste water to be treated is considered in designing the capacity.

**Construction of a water treatment Plants**

i. Preliminary treated section

ii. Bar screens are established here. the screens are made of series of sieves. This is the first section of the plant.

iii. Pump and blower house

This section is made of pumps where waste water is received. Pumps provides pressure for water flow.

iv. Piping

PVC pipes are used to convey water from one section to the next

v. Tanks

A series of tanks where water is stored are constructed. At the reception water is received at a tank. Another tank is constructed to receive contents after the water has been sieved.

vi. Concrete section

The various compartments are of concrete to hold water while awaiting the next stage

**Construction of a septic tank**

**What is a septic tank?**

It is a tank constructed underground for sewage or waste water collection.

**Process of construction**

A septic tank should have at least two chambers. The first chamber should be around half the first chamber.



**Measurement**

The first chamber is 1.2m by 1.0m by 1.6m deep

2nd chamber is 0.6m by 1.0m by 1.6m

The tank is designed to be deep, so that it takes less space.


Figure 31: Septic tank

https://www.shutterstock.com/search/septic+tank

**9.3 Waste water management structures are constructed as per waste water management manual**

**Water treatment and recycling**

**Reasons for water treatment**

- To make it safe for drinking and domestic use
- To remove bad taste and smell
- To remove solid sentiments from water
- To prevent disease outbreaks
- To remove chemical contaminants in water.
- To improve flavors in water
- To reduce cost of acquiring water
- Increase the amount of water available for use.

**Water treatment stages**

**Stage 1: Screening and sieving**

At this stage any coarse objects such as solid is removed.

**Stage 2: Aeration**

Dissolving oxygen in water to remove bad smells and taste, here bacteria growth is reduced.

**Stage 3: Ph. correction**

Chlorine is added to water to correct PH. levels

**Stage 4: Coagulation and sedimentation**

Aluminum sulphate is added to the water. This causes agglomeration and sedimentation of solid particles. This removes the remaining solid particles.

**Stage 5: Chlorination**

Chlorine water is added to water to kill microorganisms. This is it keep water free from micro-organisms.

**Stage 6. Filtration**

This is the last stage of removing solid water particles. The smaller particles are removed using fine sieves.

**Stage 7. Storage**

Treated water is conveyed in the storage tanks waiting for the use.

**Water recycling**

This is the process of reusing water from the industries, domestic activities and irrigation to implement a beneficial function.

**Types of water to be recycled**

- Grey water, water from non-toilet plumbing as basins shower and taps
- Black water, water from toilet.
- **Recycling grey water**
  To be reused in flushing the toilets
- **Black water recycling**
  It can be used to mix concrete for construction.

**Water pollution management/ Prevention of water pollution**

- Washing a car or other implements should be done away from water resources
- Don't throw trash, chemicals or solvent in the sewer drain
- Septic tank should be checked after every 3years
- Avoid using pesticides and fertilizers that can run off to the water system
- Waterways should be swept to avoid driving dust to water ways
- Paint brushes should not be washed in the sink to avoid driving chemicals to the water.
- Avoid use of pesticides along river bank
- Industrial effluents should not be drained into rivers.
- Legislation should be established to control waste water disposal and uses.

**Conclusion**

This learning outcome covered; waste water treatment, waste water recycling, waste water disposal and water pollution management.

**Further Reading**

1. Estimation of domestic waste water characteristics in a developing country by campos,H. and von sperling
2. The world commission on environment and development. Ny WCED.
3. Water and waste water technology by Hamma and Hammer.



**4.3.10.3 Self-Assessment**

**Written assessment**

1. The following are classification of pollution according to the medium affected. Which one is not?
   a) Water pollution
   b) Land pollution
   c) Air pollution
   d) Soil pollution
2. Which statement describes best waste water disposal?
   a) The process of conveying waste water from home and business buildings to the treatment plants
   b) The process of carrying water to the farm
   c) The process of removing chemicals from water
   d) None of the above

3. Which of the following is not a waste water method?
    a) Domestic water disposal
    b) Onsite effluent water disposal
    c) Rainwater
    d) All of the above
    e) None of the above
4. Which of the following factors are considered when choosing a water treatment plant?
    a) Plant location
    b) Prevailing wind direction
    c) Provision of future expansion
    d) Design method
5. Choose one method of water treatment?
    a) Recycling
    b) Plant treatment
    c) Water conveyance
    d) Construction of a dam
6. Which best describes water recycling?
    a) Re-use of the water other the first use
    b) Use of water for another reason other than the intended
    c) Re-use of the water after the first time for a beneficial purpose
    d) None of the above
7. Which factors affect water content?
    a) Chemical
    b) Solid particles
    c) Agricultural practices
    d) None of the above
8. What do you understand by water recycling?
9. What do you understand by the term water disposal?
10. State factors considered in selection of a treatment pant
11. What is water treatment



**Oral Assessment**

1. What is the importance of water recycling?
2. What do you understand by land pollution?
3. Explain the factors to consider in sitting a day house.

**Case Study Assessment**

Visit a water treatment plant in the country of your school and study the various structures

**Practical Assessment**

1. Collect contaminated/ polluted water from your school.
2. Construct a simple water treatment plant in your school.
3. Develop a water treatment manual and present it to your tutor

### 4.3.10.4 Tools, Equipment, Supplies and Materials

- Gutters
- Water tanks
- Jembe
- Panga

### 4.3.9.5 References


Biiley, M.a (1998) health and peri-urban natural resource production. Thowbridge cronwell press.

Ferguso, b (1990) on site. Stormwater.management .Georgia. Columbia.

USEPA. (1980).process Design Manual: onsite wastewater. Treatment and disposal system.. Cinannat.ohio.

### 4.3.11 Learning Outcome No 10: Manage water supply

#### 4.3.11.1 Learning Activities

| **Learning Outcome No 10: Manage water supply** | |
|---|---|
| **Learning Activities** | **Special Instructions** |
| 10.1 Identify sources of water as per water supply and maintenance manual<br>10.2 Identify waste water supply methods as per water supply and maintenance manual<br>10.3 Install water supply systems as per water supply and maintenance manual | Demonstrate installation of water supply systems<br><br>Guide on installation of water supply system |

#### 4.3.11.2 Information Sheet No4/L10: Manage water supply

**Introduction**

This learning outcome covers; water supply equipment, water supply survey, water supply layout, water supply system operation and maintenance.

**Definition of terms**

**Water supply:** It is a source, means or process of making water available by public utilities, commercial organization community endeavors or by individuals via a system of pumps and pipes.



**Water supply system:** It is the infrastructure for the collection, transmission, treatment, storage and distribution of water for homes, commercial establishments, industry, irrigation and public needs.

**Content/procedures/methods/illustrations**

**10.1 Sources of water are identified as per water supply and maintenance manual**

**Water source:** Natural resources of water that is potentially useful.

Types of water sources

- Protected or improved- covered with stones or concrete or materials.
- Unprotected or unimproved.

**Characteristics protected water sources**

- The water source is fully enclosed or capped and no surface water can run directly into it.
- People do not step into the water while collecting it.
- Latrines, solid waste pits, animal excrete and other sources of pollution are inaccessible.
- No stagnant water within five meters of the water source.
- The water collection buckets or hand pump at the source are kept.

**Unprotected sources:** These are sources with no barrier or other structure to protect the water from contamination. Examples are like: lakes, rivers and wells.

**Ground Water:** It is water that is found underground within the rocks. Its presence depends primarily on the type of rock.

**Advantages of ground water**

- Likely to be free from pathogenic bacteria.
- Usually free from turbidity and colour.
- Can usually be used without further treatment.
- Can often be found in close vicinity to consumers.
- Economical to obtain and distribute.
- The water bearing soil or rock provides a natural storage point.

**Disadvantages**

- High mineral content e.g. calcium, magnesium. iron.
- Requires pumping for construction.
- May have high level of bicarbonate and chloride.
- Poor in oxygen content.
- Can contain chemical contaminants e.g. arsenic, fluoride and nitrates.
- Difficult to treat in case of pollution.

**Factors influencing contamination of ground water**

- Polluting source e.g. pit latrine
- Depth of the pit and its vertical distance from the water table.



**Well and boreholes**

They are described according to their depth or the way they are constructed.

**Example**

- Shallow wells- Have a depth of less than 30m, although they can be as much as 60m deep in dry areas.
- Deep wells/Boreholes- Sunk with drilling machines designed for constructing water extraction boreholes. The machines penetrate through harder material that cannot be tackled by hand digging and pas through at least one impermeable layer of rocks.

**Springs**

This is the emerged ground water e.g. at the foot of mountains and hills, in lower slopes of valleys and near the river banks.

**Surface waters**

Found on the land surface.

**Factors that determine quality and quantity of surface water**

- Ecology
- Climate
- Surrounding land use

**Rainwater:** It is available where rainfall is abundant and frequent.

**Rainwater harvesting:** It involves collection, harvesting of rainwater as it runs off from hard surfaces and storing it in a tank or cistern.

**Ways of collecting rain water**

1. **Roof catchments:** Rain water is collected from house roofs made of tiles, slate galvanized metal or equivalent. Pipes feed water from the roof and gutters into a collection tank where it can be stored until needed.

**Precautions to avoid contamination**

- The tank must be completely covered and well-maintained.
- The roof and gutters should be cleaned regularly, especially before the start of the wet season.
- Divert the first rainwater away from the tank so that dust and dirt are washed away.
- Put a mesh screen between the guttering and pipe that leads to the tank.

2. **Ground catchments:** Collect and store water falling on the area or ground.

**Factors determining amount collected**

- Topography of the area: Flat/sloping.
- Permeability of the top layer of ground.

3. **Sand dams:** It is a concrete wall (1-5m high) built across a seasonal sandy riverbed. During rainy season, a seasonal river forms and carries sand and silt downstream. The water can be abstracted from the sand dam, via a slotted pipe buried in the sand that either passes through the dam wall or connected to a simple hand pump situated on the river bank.

Water source development: Availability of plentiful water supply.

**Factors considered**

- Volume of water required
- Quality of water
- Season variations
- Distance between sources and users
- Costs
- Environment impact
- Sustainability



**10.2 Water supply methods are identified as per water supply and maintenance manual**

These are means through which water is conveyed to the destruction of use or storage.

Precautions before supply:

- Treatment- process that ensures purity of water and remove or reduce harmful substances. The methods are purification, disinfection through chlorofication, fluoridation and desalination.
- Methods of water supply are pumping, piping and flow by gravity.

**Pumping:** Water is conveyed through devices known as pumps by mechanical action.

**Types of pumps**

- Positive displacement pumps
- Centrifugal pumps
- Axial-flow pumps

**Positive displacement pumps**

They include the rotary pumps are gear, screw, and rotary. The reciprocating pump are hand, piston and plunger pumps. The linear pumps are gravity, steam and valve less pumps.

**Advantages of pumps**

- Economical and simple solutions for providing a collective supply of water in rural and sub-urban areas.
- They eliminate the risk of people and children falling into open wells.
- Improve the conditions of hygiene under which water is drawn off e.g. when using buckets.

**Disadvantages**

- Regular maintenance is required, which is expensive and the spare parts are rarely found.



**Factors to consider before purchasing a pump**

- Price: cost of the pump.
- Economic environment: Possibility of easily finding space parts and the personnel to repair.
- Social environment: Public acceptance
- Ease and cost of maintenance.

**Piping:** Water is conveyed through a network of pipes.

**Types of pipes used**

- **Cast iron pipe:** Widely used for city water distribution systems. Has a long life and is resistant and corrosion.
- **Galvanized iron pipe:** Made of mild steel sheath.
- **Wrought iron pipe:** Prepared by welding wrought iron sheets.
- **Steel pipe:** Made from steel.
- **Copper pipe:** Made from copper. They are durable since they are resistant to rusting.
- **Plastics pipes:** They include rubber and P.V.C pipes.
- **Asbestos cement:** Made from asbestos, silica and cement converted under pressure to a dense homogenous material possessing considerable strength.
- **Concrete pipe:** Made from concrete.

**Advantages of PVC pipes**

- They are safe, durable and sustainable
- Cost efficient
- Environmentally friendly
- Recyclable

**Limitations**

- Can burst under high pressure.
- Can become brittle on exposure to the sun
- Can be gnawed by rodents.
- Can be damaged easily during land preparation.

**Flow by gravity**

Water is let to flow into reservoirs by the force of gravity. The reservoirs are constructed depending on the flow of water.

**Installation of water supply systems**

Water supply system is the infrastructure for the collection, transmission, treatment and storage of water.

**Types of water supply systems**

- Public water system
- Private water system

**Public water systems**

a) **Community water system:** Supplies water to the same population year-round. They serve at least 25people or 15 residences that are primary residence e.g. municipalities mobile home park, sub- divisions.

b) **Non-community water system**: They are composed of transient and non-transient water systems.

- **Transient non-community water system (TNCWS)**

Provide water to 25 or more people for at least 60days or year, but not to the same people and not on a regular basis. E.g. camp grounds and gas stations.

- **Non-transient non-community water systems (NTNCWS)**

Regularly supply water to at least 25 of the people at least six months per year, but not year-round e.g. schools, factories, office building and hospitals. The places normally have their own water systems.

**10.3 Water supply systems are installed as per water supply and maintenance manual**

**Factors to consider before purchasing and installing water purifiers**

- Cost of the purifiers
- Daily water intake
- Annual maintenance cost
- Electric or non- electric
- Contaminants found in the available water

**Conclusion**

This learning outcome covered; water supply equipment, water supply survey, water supply system layout and water supply system operation and maintenance.

**Further Reading**

1. Impact: A performance Review of kenya's water services sector 2013-2014
2. Joint monitoring programme (JMP) for water supply and sanitation.
3. Ministry of water and irrigation: Annual water services sector review 2009

**4.3.11.3 Self-Assessment**

**Written assessment**

1. Which one of the following is not considered as an unprotected source of water?
    a) Rivers
    b) Rainwater
    c) Lakes
    d) Wells
2. Which one of the following is an example of ground source of water?
    a) Lakes
    b) Oceans
    c) Rivers
    d) Springs
3. Which one of the following is not a natural source of water?
    a) Boreholes
    b) Oceans
    c) Lakes
    d) Permanent
4. The following are not safe sources of drinking water. Except one, Which one?
    a) Well
    b) Rivers
    c) Lakes
    d) Taps
5. Which one of the following is an example of water pollutant?
    a) Silt
    b) Soil
    c) Stones
    d) Chemicals

6. Which one of the following is not an example of water supply system?
    a) Water tanks
    b) Pipes
    c) Pumps
    d) Spring
7. What do you understand by the term water source?
8. Give an example of a protected source of water.
9. Name one pollutant that contributes to pollution of water sources.
10. What do you understand by the term water supply system?
11. State an example of ground water source.

**Oral Assessment**

1. Differentiate between water supply and water supply system.
2. Give any two characteristics of the protected water sources.

**Case Study Assessment**

Visit a water and sewerage company near you and carry out the following activities.

a) Identify the main source of water found.
b) Identify any form of treatment carried out.
c) Observe the water supply methods practiced.
d) What is the common water system present in the area?



**4.3.11.4 Tools, Equipment, Supplies and Materials**

- Water tanks
- Gutters
- Levelling boards
- Measuring tapes
- Topography mapping tools

**4.3.11.5 References**

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R,Gakubia,U.pokorski and p.Onyango. upscaling Access to sustainable sanitation. Kenya, January 2010 slide7, Retrieved 16 March 2010.

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### 4.3.12 Learning Outcome No 11: Prepare soil and water management report

#### 4.3.12.1 Learning Activities

| Learning Outcome No 11: Prepare soil and water management report | |
|---|---|
| **Learning Activities** | **Special Instructions** |
| 11.1 Collect data on soil and water resources as per user needs<br>11.2 Analyze data on soil and water resources as per standard data analysis tools<br>11.3 Record data analysis results | Assign each group a supervisor for the project. |

#### 4.3.12.2 Information Sheet No4/L11: Prepare soil and water management report

**Introduction**

This learning outcome covers; collection of data, data analysis, documentation and report writing

**Definition of terms**

**Data:** These are the facts and statistic collected processed and analyzed to generate useful information.



**Data collection:** This is the process of gathering and measuring data of interest using standardized methods to achieve a particular objective.

**Data analysis:** The process of standardizing, transforming and modeling data to discover useful information

**Content/procedures/methods/illustrations**

**11.1 Data on soil and Water resources is collected as per user needs**

**Types of research**

i. Explorative research: Conducted when few or previous study exists. The learner should use case study and observation of soil and water resources
ii. Descriptive research: This is used to classify the elements and characteristics of a study subject.
iii. Analytical research: This tries to explain the how and why aspects of a subject
iv. Productive research: This attempt to speculate possible outcome basing on the analysis of available evidence

**Research approaches**

**Quantitative and qualitative research**

**Qualitative research**: It is focused on collecting and analyzing numerical data using scale, range and frequency.

**Quantitative research:** This is subjective research. It involves examining and reflecting the less tangible aspects of the research, using value, attitudes and perception.

**Basic and applied research**

Basic approach aims to improve knowledge without any particular applied purpose. Applied research is designed to find outcomes to apply to a particular situation. For instance, improve soil fertility.

**Deductive and inductive research**

Deductive approach is focused on moving from general to specific ideas. Inductive approach is focused on ideas.

**Data collection methods**

**Survey**

This involves selecting a representative sample from a population one wishes to study. the sample is asked questions using face-to-face, interviews or using questionnaire to derive data. It is both descriptive survey, which involves identifying, and counting the frequency from a group

It could be also analytical which tries to get the relationship between various elements. For instance, between high production and level of education.



**Experimental studies**

This is the study done in a controlled environment to enable causal relationship of a phenomenon to be studied. It allows for manipulation. For instance, studies of water infiltration on soil, done in the laboratory, data is collected and recorded.

**Longitudinal studies**

Study done over a long period to observe the effect that time has on the situation under observation. Primary data is collected here. For instance, studies of the effects of rainfall on soil composition after three years.

**Cross-sectional studies**

This is the study of different organizations to look at similarities and differences between subjects. For example, study of the types of the types of soil in different regions of a county.

**Case study**

This is the study of a particular subject such as soil and water conservation policy and analysis its information.

**Action research**

This study is intended to bring intervention by a researcher to influence a change in a given situation or subject. For instance, to improve soil and water management practices. The research explores ways of achieving improvement. After the research, he/she introduces new techniques and monitors the results.

**Ethnography observation**

In this research, the researcher makes a working member of the group or subject to be observed, with the 0bjective of understanding from inside. They are either covert-where the subjects are not aware of the study or overt where the subjects are aware of what is going on.

**Participative enquiry**

The researcher involves the subjects in the process of research. The whole group of subjects may be involved in the process. The researcher can work with the subject, where he or she is already known.

**The process of data collection**

**Step 1.** Establish a general field of interest.

The researcher decides on the research decides on the research problem. The learner should consider the school requirements for the project.

**Step 2.** Background and predatory reading

The researcher acquits himself/herself, with the work or the research that has been done on the topic area. This is to identify research possibilities and avoid repetition. Limitations and weakness of the previous research studies and identify previous findings

**Step 3.** Writing research proposal.

At this stage, the ideas are narrowed down and put together. A title is given to the research problem. Methods of data collection are chosen here. For instance, use of questionnaires observation or review

**Step 4.** Preparing information gathering tools.

After selection of the methods, the data collection tools are gathered and assembled

**Step 5.** Conducting research

The data is collected using the methods chosen and approaches selected are used.

**Types of data collected depending on the source**

- Primary data- data collected first hand
- Secondary data-data sourced from a primary source

**Depending on the source collected**

- Discrete data -data that can take only certain specific values rather than a range of values
- Continuous data-values that can take values between a certain, range for instance ratios

**Ethical considerations in research**

- Individual's privacy should be considered
- Individuals should participate in the research voluntarily
- The consent and possible deception of the participants should be avoided
- Confidentiality of data provided should by the individuals should be kept
- Effect of the research on the participants should be made aware
- If the research is funded the information should only be given to the funder

### 11.2 Data on soil and water resources is analyzed as per standard analysis tools

**Data analysis**

What is the purpose of data analysis? It answers the research questions and helps determine the trends and relationships among variables?

**Types of data analysis**

**Descriptive analysis.** This is description of data from a particular sample, this can be:

i) Frequency distribution - this is the arrangement of numerical value from the highest to the lowest.

ii) Measure of central tendency-this calculation of mean, mode and median

iii) Calculating measures of variability-this is the measure of the degree to which scores in distribution are different or similar to one another

iv) Standard deviation- The most commonly used measure of variability which indicates the average to which the scores deviate from the mean

**Inferential statistics:** Numerical values that enable the researcher to draw conclusion about a population based on the characteristics of the population

**Presentations of findings:** Findings are presented in different forms such as;

**Narrative or textual form:** This is composed of the summary of the findings by considering the objectives of the study. This is where the objectives are checked if they were met. Direct quotations are also used and implications of the study are noted down.

**Tabular form:** Tables provide clear data and presentations, so that is they used it is easy to analysis data.



**Sample table**

| | Dependent variables | |
|---|---|---|
| | | |
| | | |
| Independent Variables | | |
| | | |
| | | |

Table 6: Sample table

**Interpretation of data**

When analysis has been done and the appropriate statistical procedures completed this process of data presentation is done. Area covered in data presentation

i) **Summary of the findings**: The portion summarizes the results of data analysis from the analysis from the analysis from the analysis section. Here, the stated problems of the research are reviewed and linked to the results of data analysis

ii) **Conclusions:** A conclusion is drawn from the findings. it focuses on the answers provided for the hypothesis.

iii) **Recommendations:** This is based on the results of the conclusion, this is aimed at improvements.

### 11.3 Data analysis results are recorded

**The format of report writing**

**Tile page**

This statement describes the research study. It should not be too narrow nor should it be too wide, to allow proper study process

**Acknowledgement page**

Acknowledgement begins on a separate page. It is a section where the researcher expresses his gratitude for those who contributed and participated in the research process.

**Declaration page**

This is the page where a researcher pledges that he conducted the study.

**Table of contents**

It contains the parts of the documents showing all the pages for easy referencing

**List of tables**

After the tables of contents, the tables in the research paper are indicated in this section

**List of figures.** This is composed of the diagrams, graphs and chart

**The main body:** This section is comprised of:

i) **Chapter 1:** Introduction to the

This is what the study is about and what makes the researcher interested in doing the study. It introduces the reader to the subject matter

ii) **Chapter 2:** Review of related literature

iii) **Chapter 3:** Research design and methodology

This is where the method of data collection and the process of collecting data is stated and described

iv) **Chapter 4:** Analysis and interpretation of data

v) **Chapter 5:** Summary, conclusion and recommendations

vi) Bibliography and appendices are listed here



**Conclusion**

This learning outcome covered; collection of data, data analysis, documentation and report writing.

**Further Reading**

1. Research metholody by Ebraim
2. Yusuf Zuber-skerrt(1991)action research and development
3. Shufgnessy,J.EB9(1985).research methods in psychology

### 4.3.12.3 Self-Assessment

**Written assessment**

1. Choose one statement that best describes the definition of data
    a) This are the internet subscription necessities
    b) Data is the information collected processed and analyzed
    c) Data are the facts and statistics, processes and analyzed
2. Which one of the following if the odd one out?
    a) Explorative
    b) Description
    c) Innovation
3. Quantitative data is aimed at collecting numerical data.
    a) True
    b) False
4. Which one of the following is not a method of data collection?
    a) Survey
    b) Longitudinal
    c) Cross-sectional studies
5. Choose two types of data analysis
    a) Descriptive analysis and descriptive data
    b) Frequency distribution and measure of central tendency
    c) Descriptive analysis and inferential analysis
    d) None of the above
6. What do you understand by the term data analysis?
7. What do you understand by the term two types of data analysis?
8. What are cross-sectional studies?
9. Outline the process of data collection.
10. State four methods of data collection.

**Oral Assessment**

1. Discuss the process of data collection.
2. What do you understand by the process of data interpretation and recording?

**Case Study Assessment**

1. In groups of four, find one project that has been published and review it to produce your own version of the project.

**Practical Assessment**

1. Collect data using at least two methods of on the uses of water in your school
2. Design a data analysis manual foe manual for your data in 1 above
3. Analyze your data in 2 above and write a report

### 4.3.12.4 Tools, Equipment, Supplies and Materials

- Notebook
- Measuring tape
- Quick set

### 4.3.9.5 References


Cresswell,J (1994).Reasearch design ,qualitative and quantitavia approaches.Sage.Thiusand oaks

Tuckman .B.W (1988) Conducting educational research 3rd .ed. San Diego. Herecort,Brace.

Howell.D.P(1987) Statistical methods for psycholody. 2nd ed.PWS