NATURAL RESOURCES CONSERVATION AND DEVELOPMENT

Level-II

Learning Guide-61

Unit of Competence: Identify Different Water Sources and Irrigation Methods

Module Title: Identifying Different Water Sources and Irrigation Methods

LG Code: AGR NRC2 M14 L61 L01-LG-61

TTLM Code: AGR NRC2 M14 TTLM 0919v1

LO1: Identify potential irrigation Water sources and Irrigation Methods

Instruction Sheet	Learning Guide #61

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

- Identifying potential areas of irrigation water sources and Irrigation Methods
- Identifying water contributors
- Identifying and interpreting Climatic variables
- Identifying Seasonal water ways
- Checking Soil moisture status & level of ground water
- Identifying appropriate practices to recharge underground water table
- Planning best trees species for afforestation purpose on degraded land

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

- Identify potential areas of irrigation water sources
- Identify water contributors
- Identify and interpreting Climatic variables
- Identify Seasonal water ways
- Check Soil moisture status & level of ground water
- Identify appropriate practices to recharge underground water table
- Plan best trees species for afforestation purpose on degraded land to improve water absorption and permeability characteristics of the soil.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 and 4.
3. Read the information written in the information “Sheet 1, Sheet 2, Sheet 3 Sheet 4, Sheet 5, Sheet 6 and Sheet 7”.
4. Accomplish the “Self-check 1, Self-check 2, Self-check 3, Self-check 4, Self-check 5, Self-check 6 and Self-check 7” **in page -12, 14, 18, 24, 37, 47 and 49** respectively.

Information Sheet-1	Identifying potential areas of irrigation water sources

1.1. Identifying Irrigation water sources and Irrigation Methods

1.1.1 Identifying Irrigation water sources

Sources of irrigation water can be groundwater extracted from springs or by using wells(shallow and deep), surface water with drawn from rivers, lakes, spring, river, stream, lakes or reservoirs or non-conventional sources like treated wastewater, desalinated water or drainage water. Rainwater harvesting is the collection of runoff water from roofs or unused land and the concentration of this.

Potential areas where available water resources include:

- **Rivers/streams flow**
  - ✓ The amount of water flowing along the river varies through time and space.
  - ✓ Variation with time occurs because during and immediately flowing a storm, runoff generated by overland flow causes the discharge to increase.
  - ✓ Spatial variation occurs because, as the river flows downstream, its discharge increases, as it collects water from more and more of its tributary streams.
- **Ground water**
  - ✓ Ground water exists in pores b/n sedimentary particles and in the fissures (cracks) of more solid rocks.
  - ✓ Ground water is often preferable because it tends to be less contaminated by wastes and organisms.
  - ✓ Ground water may appear at the surface in the form of springs or it may be wells.
  - ✓ The rate of movement of ground water depends on the of subsurface rock materials in a given area.
  - ✓ Saturated permeable layers capable of providing a usable supply of water are known as aquifers. Typically, they consist of sands, gravels, and lime stones.
  - ✓ Layers that tend to slow down ground water flow, such as clays, shale's, and silts, are called aquitards (of tardy penne able layer).
  - ✓ Impermeable rocks are known as aquifuges, or basement rocks.
  - ✓ In permeable zones, the upper surface of the zone of water saturation is called the water table.

- **Flood**
  - ✓ A flood can be defined as an excess flowing or over flowing of water especially over land which is not normally submerged.
  - ✓ Flood occurs when soil and vegetation cannot absorb all the water; water then runs off the land in quantities that cannot be carried in river channels or retained in natural ponds and constructed reservoirs held behind dams.
  - ✓ Floods not only damage property and endanger the lives of humans and animals, but have other effects as well. Rapid runoff causes soil erosion as well as sediment deposition problems of downstream

- **Water well**

Water well is an excavation or structure created in the ground by digging, driving, boring or drilling to access groundwater in underground aquifers. The well water is drawn by an electric submersible pump, a trash pump, a vertical turbine pump, a hand pump or a mechanical pump (e.g. from a water-pumping windmill). It can also be drawn up using containers, such as buckets that are raised mechanically or by hand. Wells can vary greatly in depth, water volume and water quality. Well water typically contains more minerals in solution than surface water and may require treatment to soften the water by removing minerals such as arsenic, iron and manganese.

Classification of Water well types.

There are two broad classes of drilled-well types, based on the type of aquifer the well is in:

- ✓ ***Shallow* or *unconfined wells*** are completed in the uppermost saturated aquifer at that location (the upper unconfined aquifer).
- ✓ ***Deep* or *confined wells*** are sunk through an impermeable stratum into an aquifer that is sandwiched between two impermeable strata (aquitards or aquicludes). The majority of deep aquifers are classified as artesian because the hydraulic head in a confined well is higher than the level of the top of the aquifer. If the hydraulic head in a confined well is higher than the land surface it is a "flowing" artesian well (named after Artois in France).

Two additional broad classes of well types may be distinguished, based on the use of the well:

- ✓ **Production or pumping wells**, are large diameter (greater than 15 cm in diameter) cased (metal, plastic, or concrete) water wells, constructed for extracting water from the aquifer by a pump (if the well is not artesian).

- ✓ **Monitoring wells or piezometers** are often smaller diameter wells used to monitor the hydraulic head or sample the groundwater for chemical constituents. Piezometers are monitoring wells completed over a very short section of aquifer. Monitoring wells can also be completed at multiple levels, allowing discrete samples or measurements to be made at different vertical elevations at the same map location.

1.1.2 Irrigation Methods

Principles of appropriate irrigation development

Why it that irrigated farming in some areas is fails to achieve its potential benefits?

The problem is not inherent in the principle of irrigation as such, but in the frequently inappropriate practice of it.

More often than not the fault lies in the unmeasured and generally excessive application of water to land, with little regard either for the real cost of extracting the water from its source and delivering it to the farm, or for the cost of restoring the water resource after it has been depleted or polluted.

More often than not the fault lies in the unmeasured and generally excessive application of water to land, with little regard either for the real cost of extracting the water from its source and delivering it to the farm, or for the cost of restoring the water resource after it has been depleted or polluted.

By deliberately maintaining a low price for water, governments perpetuate the false notion that fresh water is a free good, rather than the scarce and expensive resource that it really is.

It is the universal fallacy of humans to assume that if a little of something is good, then more must be better.

In irrigation (as indeed in many other activities), just enough is best, and by that is meant a controlled quantity of water that is sufficient to meet the requirements of the crop and to prevent accumulation of salts in the soil, no less and certainly no more.

- ➢ The application of too little water is an obvious waste, as it fails to produce the desired benefit.
- ➢ Excessive flooding of the land is, however, likely to be still more harmful, as it tends to saturate the soil for too long, inhibit aeration, leach nutrients, induce greater evaporation and Stalinization, and ultimately raise the water-table to a level that suppresses normal root and microbial activity and that can only be drained and leached at great expense.
- ➢ Apart from wasting water, therefore, excessive irrigation contributes to its own demise by the twin scourges of water-logging and soil Stalinization. Instead of achieving its full

potential to increase and stabilize food production, irrigation in such cases is in danger of becoming unsustainable.

The ultimate economic and environmental consequence of poorly managed irrigation is the destruction of an area's productive base. The cost of rehabilitating the land after it has been degraded may be entirely prohibitive.

The classical method of irrigation consists of flooding the land to some depth with a large volume of water so as to saturate the soil completely, then waiting some days or weeks until the moisture thus stored in the soil is nearly depleted before flooding the land once again. In this low-frequency, high-volume, total-area pattern of irrigation, the typical cycles consist of repeated periods of excess soil moisture alternating with periods of likely insufficiency. Optimal conditions occur only briefly in transition from one extreme condition to the other

In contrast, the newer irrigation methods are designed to apply a small, measured volume of water at frequent intervals to where the roots are concentrated.

The aim is to reduce fluctuations in the moisture content of the root zone by maintaining moist but unsaturated conditions continuously, without subjecting the crop either to oxygen stress (from excess moisture) or water stress (from lack of moisture). Moreover, applying the water at spatially discrete locations rather than over the entire area has the effect of keeping much of the soil surface dry, thus helping not only to reduce evaporation but also to suppress proliferation of weeds

This optimization of soil moisture is difficult to achieve with the traditional flood irrigation methods still dominant in many river valleys. As a result, the new approach to irrigation management has not yet been adopted very widely in developing countries. Although it is gaining ground gradually, its progress should be encouraged and accelerated wherever appropriate.

In general, it is difficult to change a pre-existing pattern of human behaviour and institutional norms. An infrastructure designed for one mode of operation cannot readily be converted to another. Habits and traditions, once established, acquire inertia, with vested interests in maintaining the status quo and a resistance to reforming it. That is why it is considered so important to start new irrigation projects appropriately by instituting efficient practices from the outset.

Irrigation methods and their selection criteria

There are three broad classes of irrigation systems: (1) pressurized distribution; (2) gravity flow distribution; and (3) drainage flow distribution. The pressurized system include sprinkler, trickle, and the array of similar systems in which water is conveyed to and distributed over the farmland through pressurized pipe networks. There are many individual system configurations identified by unique features (centre-pivot sprinkler systems). Gravity flow systems convey and distribute water at the field level by a free surface, overland flow regime. These surface irrigation methods are also subdivided according to configuration and operational characteristics. Irrigation by control of the drainage system, sub irrigation, is not common but is interesting conceptually. Relatively large volumes of applied irrigation water percolate through the root zone and become a drainage or groundwater flow. By controlling the flow at critical points, it is possible to raise the level of the groundwater to within reach of the crop roots.

Irrigation systems are often designed to maximize efficiencies and minimize labour and capital requirements. The most effective management practices are dependent on the type of irrigation system and its design. For example, management can be influenced by the use of automation, the control of or the capture and reuse of runoff, field soil and topographical variations and the existence and location of flow measurement and water control structures. Questions that are common to all irrigation systems are when to irrigate, how much to apply, and can the efficiency be improved. A large number of considerations must be taken into account in the selection of an irrigation system. These will vary from location to location, crop to crop, year to year, and farmer to farmer.

In general these considerations will include the compatibility of the system with other farm operations, economic feasibility, topographic and soil properties, crop characteristics, and social constraints (Walker and Skogerboe, 1987).

Compatibility

The irrigation system for a field or a farm must function alongside other farm operations such as land preparation, cultivation, and harvesting. The use of the large mechanized equipment requires longer and wider fields. The irrigation systems must not interfere with these operations and may need to be portable or function primarily outside the crop boundaries (i.e. surface irrigation systems). Smaller equipment or animal-powered cultivating equipment is more suitable for small fields and more permanent irrigation facilities.

Economics

The type of irrigation system selected is an important economic decision. Some types of pressurized systems have high capital and operating costs but may utilize minimal labour and conserve water. Their use tends toward high value cropping patterns. Other systems are relatively less expensive to construct and operate but have high labour requirements. Some systems are limited by the type of soil or the topography found on a field. The costs of maintenance and expected life of the rehabilitation along with an array of annual costs like energy, water, depreciation, land preparation, maintenance, labour and taxes should be included in the selection of an irrigation system.

Topographical characteristics

Topography is a major factor affecting irrigation, particularly surface irrigation. Of general concern are the location and elevation of the water supply relative to the field boundaries, the area and configuration of the fields, and access by roads, utility lines (gas, electricity, water, etc.), and migrating herds whether wild or domestic. Field slope and its uniformity are two of the most important topographical factors. Surface systems, for instance, require uniform grades in the 0-5 percent range.

Soils

The soil's moisture-holding capacity, intake rate and depth are the principal criteria affecting the type of system selected. Sandy soils typically have high intake rates and low soil moisture storage capacities and may require an entirely different irrigation strategy than the deep clay soil with low infiltration rates but high moisture-storage capacities. Sandy soil requires more frequent, smaller applications of water whereas clay soils can be irrigated less frequently and to a larger depth. Other important soil properties influence the type of irrigation system to use. The physical, biological and chemical interactions of soil and water influence the hydraulic characteristics and filth.

The mix of silt in a soil influences crusting and erodibility and should be considered in each design. The soil influences crusting and erodibility and should be considered in each design. The distribution of soils may vary widely over a field and may be an important limitation on some methods of applying irrigation water.

Water supply

The quality and quantity of the source of water can have a significant impact on the irrigation practices. Crop water demands are continuous during the growing season.

The soil moisture reservoir transforms this continuous demand into a periodic one which the irrigation system can service. A water supply with a relatively small discharge is best utilized in an irrigation system which incorporates frequent applications. The depths applied per irrigation would tend to be smaller under these systems than under systems having a large discharge which is available less frequently.

The quality of water affects decisions similarly. Salinity is generally the most significant problem but other elements like boron or selenium can be important. A poor quality water supply must be utilized more frequently and in larger amounts than one of good quality.

Crops

The yields of many crops may be as much affected by how water is applied as the quantity delivered. Irrigation systems create different environmental conditions such as humidity, temperature, and soil aeration. They affect the plant differently by wetting different parts of the plant thereby introducing various undesirable consequences like leaf burn, fruit spotting and deformation, crown rot, etc. Rice, on the other hand, thrives under ponded conditions. Some crops have high economic value and allow the application of more capital-intensive practices. Deep-rooted crops are more amenable to low-frequency, high-application rate systems than shallow-rooted crops.

Social influences

Beyond the confines of the individual field, irrigation is a community enterprise.

Individuals, groups of individuals, and often the state must join together to construct, operate and maintain the irrigation system as a whole. Within a typical irrigation system there are three levels of community organization. There is the individual or small informal group of individuals participating in the system at the field and tertiary level of conveyance and distribution. There are the farmer collectives which form in structures as simple as informal organizations or as complex as irrigation districts.

These assume, in addition to operation and maintenance, responsibility for allocation and conflict resolution. And then there is the state organization responsible for the water distribution and use at the project level.

Irrigation system designers should be aware that perhaps the most important goal of the irrigation community at all levels is the assurance of equity among its members.

Thus the operation, if not always the structure, of the irrigation system will tend to mirror the community view of sharing and allocation.

Irrigation often means a technological intervention in the agricultural system even if irrigation has been practiced locally for generations. New technologies mean new operation and maintenance practices. If the community is not sufficiently adaptable to change, some irrigation systems will not succeed.

External influences

Conditions outside the sphere of agriculture affect and even dictate the type of system selected. For example, national policies regarding foreign exchange, strengthening specific sectors of the local economy, or sufficiency in particular industries may lead to specific irrigation systems being utilized. Key components in the manufacture or importation of system elements may not be available or cannot be efficiently serviced.

Since many irrigation projects are financed by outside donors and lenders, specific system configurations may be precluded because of international policies and attitudes.

- Some types of irrigation systems include:
  - ✓ Surface Irrigation
  - ✓ Sprinkler Irrigation
  - ✓ Drip Irrigation
  - ✓ Centre Pivot Irrigation

Surface irrigation methods

In Surface irrigation methods, Water is distributed over and across land by gravity, no mechanical pump involved.

Basin irrigation

Basin irrigation is the most common form of surface irrigation, particularly in regions with layouts of small fields. If a field is level in all directions, is encompassed by a dyke to prevent runoff, and provides an undirected flow of water onto the field, it is herein called a basin. A basin is typically square in shape but exists in all sorts of irregular and rectangular configurations. It may be furrowed or corrugated, have raised beds for the benefit of certain crops, but as long as the inflow is undirected and uncontrolled into these field modifications, it remains a basin.

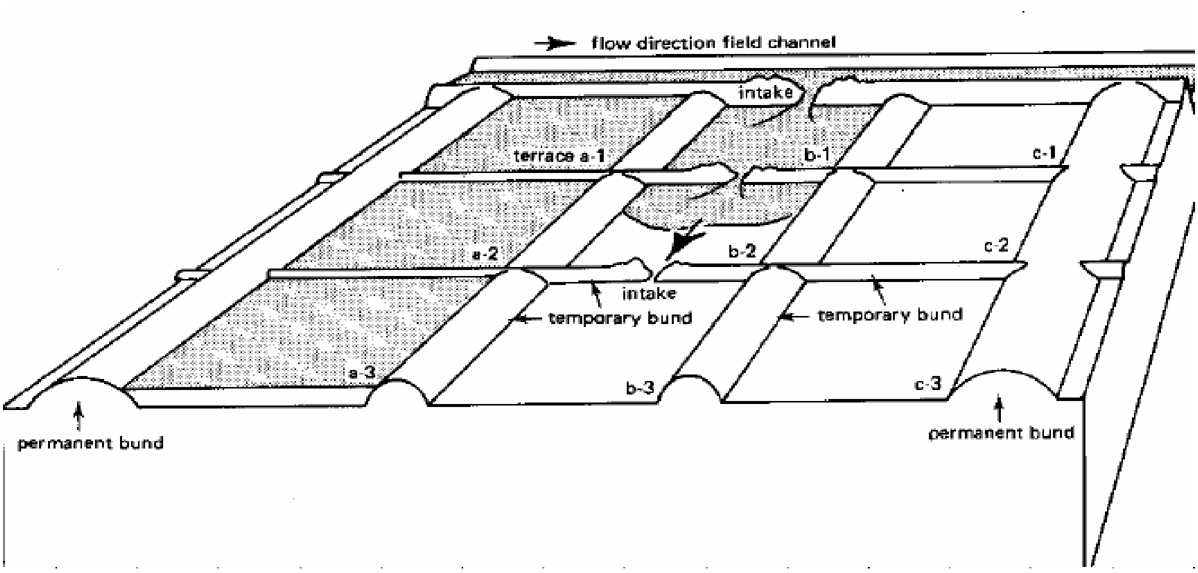


Fig.1. Basin Irrigation (Source: - FAO)

Suitable crop

It is suitable for

- ✓ rice
- ✓ pasture, e.g. alfalfa
- ✓ tree, e.g. citrus
- ✓ Row crop e.g. tobacco

But it is not suitable for crops which cannot stand firm in wet or water logged condition for long period. These are usually root and tuber crops such as potatoes, cassava, carrot which require well drained soil.

Suitable land slope & soil: it is easily constructed on flat land surface. It is suited for soil having moderate to low infiltration rate.

Border irrigation

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

Figure below illustrates a typical border configuration in which a field is divided into sloping borders. Water is applied to individual borders from small hand-dug checks from the field head ditch. When the water is shut off, it recedes from the upper end to the lower end. Sloping borders are suitable for nearly any crop except those that require prolonged ponding.

Border irrigation is generally best suited to the larger mechanized farms as it is designed to produce long uninterrupted field lengths for ease of machine operations. Borders can be up to 800 m or more in length and 3-30 m wide depending on a variety of factors. It is less suited to small-scale farms involving hand labour or animal-powered cultivation methods.

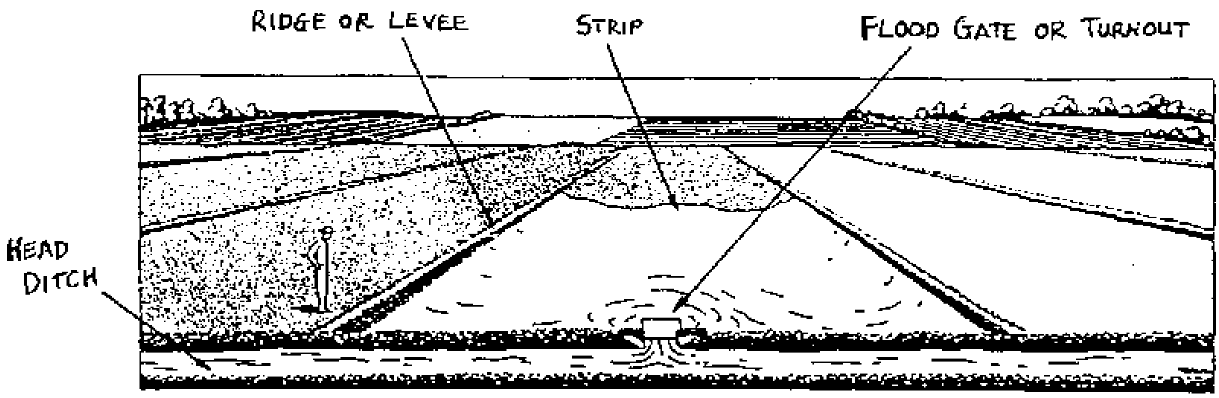


Fig.2. Border Irrigation (Source:- FAO)

Suitable slopes: Border slopes should be uniform, with a minimum slope of 0.05% to provide adequate drainage and a maximum slope of 2% to limit problems of soil erosion.

Suitable soils: Deep homogenous loam or clay soils with medium infiltration rates are preferred. Heavy, clay soils can be difficult to irrigate with border irrigation because of the time needed to infiltrate sufficient water into the soil. Basin irrigation is preferable in such circumstances.

Suitable crops: Close growing crops such as pasture or alfalfa are preferred.

Furrow irrigation

Furrow irrigation avoids flooding the entire field surface by channeling the flow along the primary direction of the field using 'furrows,' 'creases,' or 'corrugations'. Water infiltrates through the wetted perimeter and spreads vertically and horizontally to refill the soil reservoir. Furrows are often employed in basins and borders to reduce the effects of topographical variation and crusting. Furrows provide better on-farm water management flexibility under many surface irrigation conditions. The discharge per unit width of the field is substantially reduced and topographical variations can be more severe. A smaller wetted area reduces evaporation losses. Furrows provide the irrigator more opportunity to manage irrigations toward higher efficiencies as field conditions change for each irrigation throughout a season. This is not to say, however, that furrow irrigation enjoys higher application efficiencies than borders and basins.

Fig.3. Border Irrigation

Sprinkler Irrigation

- Sprinkler irrigation is another popular method, which pipes a set amount of water to the fields, and then sprays this directly over the crops with high pressure sprinklers.
- The amount of water can be closely controlled, which is a huge benefit.

Drip or trickle irrigation is one of the latest methods of irrigation.

- ✓ It is suitable for water scarcity and salt affected soils.
- ✓ Water is applied in the root zone of the crop

Standard water quality test needed for design and operation of drip irrigation system.

Fig.4. **Sprinkler** Irrigation (Source: - FAO)

Drip Irrigation

- Drip irrigation, also known as trickle irrigation, functions as its name suggests. Water is delivered at or near the root zone of plants, drop by drop. This method can be the most water-efficient method of irrigation, if managed properly, since evaporation and runoff are minimized. In modern agriculture, drip irrigation is often combined with plastic mulch, further reducing evaporation, and is also a means of delivery of fertilizer. The process is known as fertigation.

Fig.5. **Drip** Irrigation (Source: - FAO)

Centre-Pivot Irrigation

Centre-pivot irrigation involves a self-propelled system in which a single pipeline supported by a row of mobile towers is suspended 2 to 4 meters above ground. Water is pumped into the central pipe and as the towers rotate slowly around the pivot point, a large circular area is irrigated. Sprinkler nozzles mounted on or suspended from the pipeline distribute water under pressure as the pipeline rotates. The nozzles are graduated small to large so that the faster moving outer circle receives the same amount of water as the slower moving ones on the inside.

Fig.6. Centre-Pivot Irrigation (Source: - FAO)

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. List down Irrigation water sources(5pts)
2. Elaborate *Irrigation methods and their selection criteria(15pts)*
3. *Why it that irrigated farming in some areas is fails to achieve its potential benefits? (5pts.)*

Note: **Satisfactory rating 25 points** **Unsatisfactory - below 25 points**

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

Answer Sheet

Score = ____________

Rating: ______________

Name: ___________________________ Date: ________________

Information Sheet-2	Identifying water contributors

2.1 Water contributors

The kinds of water contributors and their peculiarities are as follows

- The total amount of water of the world is about $13.86*10^9$ billion m3,it can be divided in to main kinds as below:-
  - ✓ **Sea water** occupy 97.5% amount of earth water but it is salt. Mankind can use it indirectly (such as distillation) so that it isn't water resources.
  - ✓ **Snow Mountains:** most of them distributed in the Arctic and Atlantic areas, occupy 2% of the amount of earth water. Mankind can't use it directly.
  - ✓ **Rainfall:** about $1.19*10^5$ billion m^3 water is as rainfall (precipitation) to the ground annually, most of them change into run off and supply the underground water and soil water. Very little of it is used by plants or mankind. But mankind can directly use the rain fall is the water resources.
  - ✓ **Runoff**: about 70% of rainfall change into runoff, they are concentrated into rivers, lakes, and fall down into sea again. Only $9*10^3$ billion m^3 of them can be used because of non-proportioned of rainfall on the districts.
  - ✓ **Under ground water**: it's very precious part of water resources. The amount of underground water is dependent on the climate, hydrology, geology, forestry, soil sectors etc... Because of its high quality; it's used for domestic usually.
  - ✓ Surface water is including reservoir waters, lake water, pond water, and the river water (runoff).

Self-Check - 2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What are the water contributors(5pts)

Note: **Satisfactory rating 5 points** **Unsatisfactory - below 5 points**

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

Answer Sheet

Score = ____________

Rating: ______________

Name: ___________________________ Date: ________________

Information Sheet-3	Identifying and interpreting Climatic variables

3.1 Identifying Climatic variables

Climate (from Ancient Greek *klima*, meaning *inclination*) is commonly defined as the weather averaged over a long period. The standard averaging period is 30 years, but other periods may be used depending on the purpose. Climate also includes statistics other than the average, such as the magnitudes of day-to-day or year-to-year variations. The Intergovernmental Panel on Climate Change (IPCC) 2001 glossary definition is as follows:

Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

The World Meteorological Organization (WMO) describes climate "normals" as "reference points used by climatologists to compare current climatological trends to that of the past or what is considered 'normal'. A Normal is defined as the arithmetic average of a climate element (e.g. temperature) over a 30-year period. A 30 year period is used, as it is long enough to filter out any inter-annual variation or anomalies, but also short enough to be able to show longer climatic trends.

Climatic data encompasses information on the quantities and seasonality of rainfall, temperature and evaporation, relative humidity, solar radiation and wind. These factors help determine how much extra water will be needed for irrigation throughout the year, as well as the most suitable crops, and how to sequence them. Generally, an analysis of climatic data with respect to crop production is needed before a cropping programme can be prepared. Accurate estimates of crop water requirements also rely heavily on the availability of accurate meteorological data. For instance, errors of only 20% in crop water requirement estimates can significantly affect the economics of a project, since irrigation development costs tend to be high.

Different crops have different climatic requirements. Other than water availability, crops also respond to solar radiation which supplies the heat energy necessary for photosynthesis. Temperature affects the rate of plant growth, while soil temperature regulates the availability of essential nutrients. Other climatic factors that affect crop performance are relative humidity, wind and the day length. Relative humidity influences the rate of vapour discharge from the stomata and the soil surface in the molecular diffusion process, and wind accelerates water-vapour evaporation. Day length has a positive effect on evaporation by influencing the number of hours of radiation. The more closely the climate matches a crop's basic growth requirements, which are a function of its genotype, the better the production. Thus, climatic data, particularly long-term records are needed for irrigation planning.On Earth, interactions between the five parts of the climate system that produce daily weather and long-term averages of weather are called "climate". Some of the meteorological variables that are commonly measured are temperature, humidity, atmospheric pressure, wind, and precipitation. The climate of a location is affected by its latitude, terrain, and altitude, as well as nearby water bodies and their currents. In a broader sense, the "climate" of a region is the general state of the climate system at that location at the current time.

Climates can be classified according to the average and the typical ranges of different variables, most commonly temperature and precipitation**.** The most commonly used classification scheme was the Köppen climate classification. The Thornthwaite system, in use since 1948, incorporates evapotranspiration along with temperature and precipitation information and is used in studying biological diversity and how climate change affects it. The Bergeron and Spatial Synoptic Classification systems focus on the origin of air masses that define the climate of a region.

Paleoclimatology is the study of ancient climates. Since direct observations of climate are not available before the 19th century, paleoclimates are inferred from proxy variables that include non-biotic evidence such as sediments found in lake beds and ice cores, and biotic evidence such as tree rings and coral. Climate models are mathematical models of past, present and future climates. Climate change may occur over long and short timescales from a variety of factors; recent warming is discussed in global warming. Global warming results in re-distributions. For example, "a 3°C change in mean annual temperature corresponds to a shift in isotherms of approximately 300–400 km in latitude (in the temperate zone) or 500 m in elevation. Therefore, species are expected to move upwards in elevation or towards the poles in latitude in response to shifting climate zones". mospheric pressure, wind, and precipitation.

Rainfall Characteristics

The amount of water that can be harvested depends on the rainfall amounts, seasonal patterns and intensities. Thus rainwater can be harvested in both wet and dry zones, and actually, it should be more cost-effective in the wet areas where structures can be made smaller. In the arid, semi-arid or sub-humid zones rainfall is characterized by low amounts of up to 700mm per annum. Further, it is erratic with periodic droughts and unreliable patterns. Inter-annual rainfall varies from 50- 100% in the arid zones with averages of up to 350 mm. In the semi-arid zones, inter-annual rainfall varies from 20-50% with averages of up to 700 mm. Thus it is necessary to gather rainfall data and its characteristics.

Rainfall data

In order to determine the potential rainwater supply for a given catchment, reliable rainfall data are required preferably for a given period of at least 10 years. Ideally if accurate local historic rainfall data for the past few decades are available a 20 or 30-year rainfall series is preferable especially in drought prone climates.

3.2 Interpreting Climatic variables

3.2.1 Climate data and their interpretation

No conclusive cause-effect relationship can be derived from the scarce climate data at hand. Although it is possible to correlate global temperature evolution with carbon dioxide concentration, well fitted regression formula can also be obtained when ignoring this parameter. Faced with such findings, prudence requires refraining from using any singularly preferred phenomena to explain and quantify climate mechanisms, while others may be as significant, if not more.

Direct physical climate observations are scarce:

- ✓ Various time series of temperature anomalies are available from various sources, either from stations (land, sea buoys, balloons), or from remote satellite measurement, however only since 1979;
- ✓ Solar input changes, due to astronomical configuration with long time cycles (Milan kovitch), or to shorter ones in line with solar spots. Not only the overall energy is changing, but also the “solar wind” is varying, made of high energy particles that interact with the atmosphere. For the latter, no historic data is available;
- ✓ Earth configuration: sea level change and declination angle of the magnetic field;
- ✓ Perturbations: multi-decadal oceanic temperature oscillations, volcanic events.

Human activities have also changed the composition of the atmosphere since the beginning of the industrial era; records of emission data and atmospheric carbon dioxide (CO_2) concentrations are available. Some other gases are also involved, but recorded only over a too recent time, as compared with century long climatic limping.

Obtaining reliable records is already a challenge because data massaging cannot be avoided. The time span over which they are available is at best 2 centuries. The rest is second hand reconstruction using proxies; in this case, uncertainties are not only in the exactness and precision of the physical values themselves, but also in the time scale estimates of the data points. In addition, entire domains are void of quantitative information, e.g. precipitation distribution over the globe and during past climatic events, soil composition, humidity and biomass accumulation, or solar activity, and many unknown etcetera.

Self-Check -3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Write down some of the meteorological variables that are commonly measured. (5 pts.)

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

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

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-4	Identifying Seasonal water ways

4.1 Seasonal water ways

The **waterway key** is used to describe rivers, streams and boat-yards with a flow of water from one place to another.

By definition, a waterway is assumed to have a *direction of flow*. The direction of the way should be downstream (from the waterway's source to its mouth).

For small waterways, a way indicating a direction of flow and its path is sufficient. When a waterway becomes wide enough that mapping *the area it flows through* is desired.

If a waterway way is known to not have water flow year round, it should always be tagged with intermittent=yes. (Non-permanent flow can be further described with the seasonal=* tag to describe *when* a flow of water exists, but intermittent=yes should still be present in these cases.)

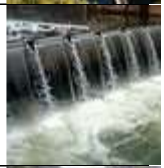
If a waterway is named from its source to its destination, it's strongly suggested that all of its ways be placed in a waterway relation. Doing this allows Nominate to group the ways together and return exactly one named result per named waterway that exists in Open Street Map.

The main waterway=* values are distinguished according to the flowing regime as follow:

	Waterways
Man made	canal (useful water)
	Ditch
	drain (superfluous water)
Natural	River
	Stream
	tidal channel

The only questions to ask to get the difference between free flow and Pipe flow is *Does water flow inside a closed space and can air get inside the conduit?* If yes, the water can't be pipe flow and you'll have to choose for an according waterway=* value from the table. Even if waterway=* values can be refined or replaced, it would be really nice to preserve the distinction between free/open channel and pipe flow features. It's really important data for water management and resource planning.

Key	Value	Comment	Photo
waterway	river	For narrow rivers which will be rendered as a line. For larger rivers see also waterway=riverbank (Other languages).	
waterway	riverbank	Used for larger rivers in addition to waterway=river, to define an area between the opposite riverbanks. Also see water=river with natural=water.	
waterway	stream	A naturally-formed waterway that is too narrow to be classed as a river. An active, able-bodied person should be able to jump over it.	
waterway	tidal channel	A natural tidal waterway within the coastal marine environment with bi-directional flow of salty water which depends on the tides.	
waterway	wadi	A natural, dry (ephemeral) riverbed that contains water only during times of heavy rain or simply an intermittent stream, in semi-arid areas. Also known as a "Wash" in the deserts of America. It has been recommended to stop using this tag. For intermittent waterways use waterway=river/waterway=stream + intermittent=yes. For valleys natural=valley.	
waterway	dry stream	Dry stream bed - negative forms of erosion relief formed by the activity of temporary streams. Don't use this tag. For intermittent waterways use waterway=stream + intermittent=yes. For valleys use natural=valley.	
waterway	canal	An artificial open flow waterway used to carry useful water for transportation, waterpower, or irrigation. (Other languages).	
waterway	pressurized	A waterway where water is flowing in a fully enclosed conduit and subject to pressure; this includes gravity-driven penstocks and siphons and pump-driven pipelines, for example.	
waterway	drain	An artificial free flow waterway used for carrying superfluous water like storm water or industrial discharge, usually lined with concrete, stones or similar.	
waterway	ditch	A small artificial free flow waterway used for carrying superfluous water for drainage purposes, usually unlined.	
waterway	fairway	A navigable route in a lake or sea marked by buoys. The navigable area marked by the buoys can be mapped with seamark: type=fairway.	
waterway	dock	An 'enclosed' area of water used for building or repairing ships.	

waterway	boatyard	Boat yard – a place for constructing, repairing and storing vessels out of the water.	
waterway	dam	A wall built across a river or stream to impound the water. A dam normally does not have water flowing over the top of it.	
waterway	weir	A barrier built across a river to control speed and depth. Water can still flow over the top.	
waterway	waterfall	A waterfall, use in combination with natural=cliff	
waterway	lock gate	To mark the position of gates at each end of a lock. Alternatively, for smaller locks use a single lock=yes node in the middle of the lock.	
waterway	turning point	A place to turn the driving direction for vessels, where the boats are longer than the river/canal is wide. Use max length=* to denote the maximum length of the vessel.	
waterway	water point	A place to fill fresh water holding tanks of a boat.	
waterway	fuel	A place to get fuel for boats.	
intermittent	yes	Indicates that the waterway is sometimes dry and sometimes contains water.	
seasonal	yes, spring, summer, autumn, winter, wet season, dry season	Indicates that a waterway has a seasonal (yearly cyclic) flow, usually flowing continuously for at least some part of the year.	
destination	name	Name of the body of water the linear feature flows into.	
lock	yes	A lock is used for moving boats between waterways at two different levels. Can tag either the section of the way between the gates (detailed) or just a single node in the waterway (less detailed).	
mooring	yes, private, no	A length of bank where boats are explicitly permitted to moor. Max stay=* should be used for timing information.	
usage	transmission, irrigation, headrace, tailrace, penstock	A waterway=canal may have one (or more; separate with semicolons) uses.	
tunnel	culvert	A short tunnel usually installed under roads, railways or building. Its size doesn't allow human to get inside and is as narrow as the structure is supposed to go under. For streams passing under a road in culverts	

		use tunnel=culvert+layer=-1 on the section of stream passing under the road. Don't use either of these tags for streams passing under bridges.	
tunnel	flooded	A long (> 100 m) tunnel where flowing water or other fluid prevent humans from safely walking inside despite its appropriate diameter or size. Water inside can be pressurized or not, used in combination with any waterway=* linear value.	
bridge	aqueduct	A bridge which conveys an artificial waterway over a road, valley or another waterway.	

Self-Check -4	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Define a water ways (5pts.)

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

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

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

Information Sheet-5	Checking soil moisture status and level of ground water

1.1 Checking soil moisture status and level of ground water

1.1.1 Checking soil moisture status

To determine the required depth of irrigation water to be applied at any given time, the irrigator should first estimate or measure the amount of available moisture in the soil within the root zone depth. There are several methods of doing this.

- **Soil sampling and drying**

This method involves sampling each type of soil in the field at desired depths and at several locations. The soil samples are weighed, dried, and weighed again. The difference in weight is equal to the weight of the moisture. Usually this is expressed as a percentage of the weight of the dry soil.

- **Tensiometer**

A device for estimating soil moisture levels by measuring the negative hydraulic pressure of water in soil; a porous, permeable ceramic cup connected through a tube to a manometer or vacuum gauge.

The most commonly read gauge on a farm, is normally that of a tensiometer & pressure gauges Irrigation requires a relatively high investment in equipment, fuel, maintenance and labour, but offers a significant potential for increasing net farm income. Frequency and timing of water application have a major impact on yields and operating costs.

To schedule irrigation for most efficient use of water and to optimize production, it is desirable to frequently determine the soil water conditions throughout the root zone of the crop being grown.

A number of methods for doing this have been developed and used with varying degrees of success, but the two methods, which have proven most practical for field use, are tensiometers and electrical resistance meters.

A tensiometer is a sealed water-filled tube, equipped with a porous tip installed in the ground to the desired root zone (Figure 7). In dry soil, water is drawn out of the instrument, reducing the water volume in it and creating a partial vacuum. This is registered on the gauge. The drier the soil, the higher the reading. Irrigation reverses this action. The vacuum created by dry soil draws water back into the instrument from the soil. This in turn results in a lower gauge reading.

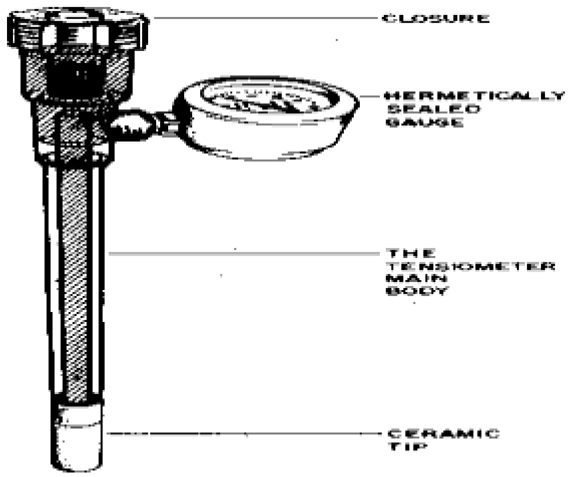


Figure 7. Typical tensiometer and its parts. Source: James (1988).

The instrument is in effect a “dummy root,” equipped with a gauge that continuously registers how hard the roots are working. A gauge reading of 50 indicates the same amount of moisture whether in sandy or clay soil. Because of the tensiometer’s unique principle of operation, it needs no calibrations, under normal operating conditions, for various types of soil. The extension worker or grower can plot the tensiometer readings on a graph during the growing season. Such a record is useful in planning future irrigation requirements and making year-to-year comparisons. Generally, tensiometers continuously show the available soil moisture in the crop’s root zone. The tensiometer covers the entire range of soil moisture required for maximum growth. Growers quickly learn the range of tensiometer readings in which they should start or stop irrigation to produce best results for their crops and conditions. The following interpretations of tensiometer readings have proven practical or useful under field conditions (also see Figure 2).

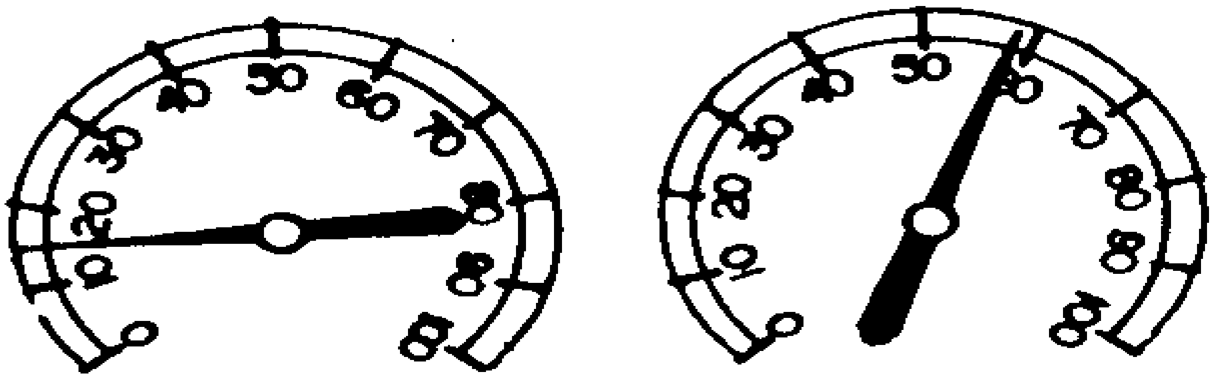


Figure 8. Tensiometer readings. Source: James (1988). Note: The reading on the left says soil has adequate water; the one on the right says soil moisture is low.

Readings 0 - 10: Saturated soil - These readings often occur for a day or two following irrigations. Continued readings in this range indicate over irrigation, danger of waterlogged soils, inadequate root aeration, root rot, or high water table.

Readings 10 - 30: Field capacity - Growers should discontinue irrigations when readings in this range occur, to prevent waste of water through percolation and waste of nutrients through leaching.

Readings 30 - 60: Usual range for starting irrigations - Root aeration occurs anywhere in this range. In general, in hot dry climates or coarsetextured soils, farmers should start irrigating when they see readings in the lower part of this range; in the upper part of this range, in cool, humid climates or soils with high water-holding capacity. Starting irrigations in this range ensures readily available soil moisture at all times, which is essential for maximum growth. It also provides a safety factor, with a reserve of soil moisture to compensate for such practical problems as delayed irrigations or inability to obtain a uniform distribution of water to all portions of the crop.

Readings 70 and higher: Stress range - A reading of 70 does not necessarily indicate that the crop is using all available moisture, but that readily available moisture is getting dangerously low for ensuring maximum growth.

Readings of 80 - 85: Top range of accuracy of the tensiometers – The number of tensiometers for an installation varies widely with crop and local conditions.

Measuring soil moisture with tensiometers

The position in the field where the tensiometers will be installed must represent large sections of a field. Three tensiometers, one each, at a depth of 30, 60, and 90cm etc. in accordance with the effective root zone must be installed in a group to form a measurement station.

Note the following important points when installing tensiometers:

Step:	Action:
1	Fill the tensiometers with water that was boiled and then cooled. They must then be left for a few days until all the pores in the ceramic tip are saturated with water.
2	Use a soil auger to make a hole slightly shallower than the length of the tensiometer. In the bottom of this hole a small hole is pressed using a metal pipe of the same diameter as that of the tensiometer. The full length of the ceramic tip must fit into the small hole.
3	Press the tip of the tensiometer into the small hole. For accurate readings, the ceramic tip must be in close contact with the soil. Fill the opening around the shaft with moist soil and ram the soil down so that water penetration will be normal.
4	Fill the tensiometer with water that was boiled and then cooled. The water in the tensiometer must be replenished daily after a reading was taken. Use a small vacuum pump for sucking air out of the tensiometer.
5	Record the suction tensions early in the morning of every day and plot the values on a graph.

The tensiometer indicates the stress experienced by the plant while it absorbs water. Young crops must be irrigated as soon as the tensiometer at a depth of 30 cm, registers a value of 35 kPa. Older cotton must be irrigated as soon as the tensiometer at a depth of 60 cm registers a value of 4O kPa. The tensiometer at the maximum depth is used to indicate over irrigation and it must always register a value larger than l0 kPa. Tensiometers can also be calibrated to indicate the amount of water required to wet the soil profile to field capacity.

➢ **Electrical instruments**

Electrical instruments operate on the principle that a-- change in moisture content produ.ces changes in some electrical property of the soil or of an instrument inserted in the soil. In most cases this property is electrical conductivity.

Electrodes are permanently mounted in conductivity units. These units are usually blocks made of nylon, fiberglass, or gypsum. These blocks are buried at the desired depth, and changes in the moisture content of the soil are reflected by changes in the electrical resistance in the blocks. Resistance or conductance meters are used to measure the resistance. It is necessary to calibrate the blocks in the field by comparing the resistance readings with the soil moisture contents determined by ovendrying samples taken from the same relative position as the blocks.

- **Gas pressure instruments**

Instruments such as the carbide moisture tester utilize the principle of chemical drying of the sample. A reagent such **as** calcium carbide is mixed with the moist soil **sam**ple within a sealed chamber. The chemical reaction of the reag- ent and the soil moisture produces acetylene gas. The gas pressure regikers on a gage that is calibrated to indicate the wet weight moisture percentage of the soil. Convenient table are available to convert these values to dry weight moisture percentages. The reaction and readings normally require about 3 min per sample.

- **Evaporation pan method.**

This method uses the relationship of crop consumptive use to the evaporation from standard evaporation pans. Evaporation pan data are approximations of Consumptive use and are not measurements of soil moisture. The amount of soil moisture used in a given period must be calculated. This calculation is made by applying a factor to the crop that is to be irrigated to the depth at which water evaporated from the pan during that period. This calculated amount then represents the soil moisture used by the crop.

- **Moisture accounting method**

Consumptive use values are used to maintain a daily inventory of the remaining soil moisture. Starting at a time when the moisture level in the soil is known, a "bookkeeping" system is set up whereby the computed Consumptive use is subtracted daily from the recorded available moisture in the soil. Rainfall and irrigation amounts are added to the moisture balance when received. The success of this method depends on accurate measurements of the water-holding capacity of the soil, determination of daily consumptive use rates, and measurement of rainfall and irrigation amounts.

- **Direct Inspection**

The least expensive methods rely on digging up soil samples in the field and then inspecting, feeling, or weighing and drying them.

- **Feel and Appearance Method**

Take walnut-sized soil samples from various locations and depths in the fi eld, appropriate to your crop’s root zone. Then use the table above to estimate the soil water content of your samples. With practice and diligence, the feel and appearance method can be accurate enough for most irrigation management decisions.

This method is rather widely used to estimate the amount of available moisture in the soil. Samples are taken from various depths and at several locations in the field. A soil sampling tube, auger, or post-hole digger is used. The feel and appearance of the samples are compared with a table, or a guide such as exhibit 15-5, and the soil moisture level is thus estimated. With practice and experience the irrigator should be able to estimate the moisture level within 10 to 15 percent.

A soil probe, auger, or core sampler is far superior to a shovel, especially for retrieving deep soil samples.

- **Hand-Push Probe**

You can use a hand-push probe (sometimes called a *Paul Brown Probe* or *Brown Moisture Probe*) to determine the depth of wetted soil and also to retrieve soil samples. These extremely useful probes and are among the fastest and easiest ways to check moisture anywhere in your fields. To determine the depth of wetted soil, push the probe vigorously into the soil by putting your weight on the handle *without turning*. The probe will stop abruptly when it reaches dry soil. (Rocks and gravel will also stop the probe, but these are easily detected by a metallic click.) Check the mark on the probe shaft to determine the depth of the wetted soil. To obtain a soil sample, twist the probe after pushing it into the ground. The probe will be full of soil when you pull it up. Then use either the "feel and appearance" method or gravimetric weight method to estimate soil moisture.

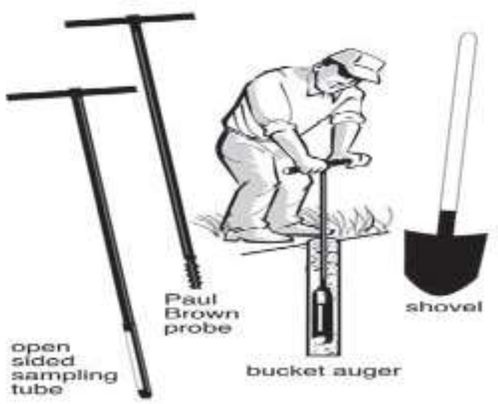


Figure 9. Soil Sampling Tools

- **Gravimetric Weight Method**

The gravimetric method involves weighing soil samples, drying them in an oven, weighing them again, and using the difference in weight to calculate the amount of water in the soil. While too time consuming to be used for day-to-day managemen decisions, this highly accurate and lowcost method is often used to calibrate other tools. Your local Extension or NRCS offi ce may be able to provide instructions for this technique, or you can fi nd the instructions on the Internet.

- **Meters and Sensors**

More sophisticated devices measure some physical property that is correlated with soil moisture. Some portable sensing tools are pushed directly into the soil or into an access tube implanted in the soil. Other systems rely on buried sensors that are either hard-wired to a fixed meter or else have long attached wires (electrodes) that are left above-ground.

- **Soil Moisture Blocks**

The most common sensors, *electrical resistance blocks*, work on the principle that water conducts electricity. The wetter the soil, the lower the electrical resistance and the better the block conducts electricity.

The two most common types of electrical resistance blocks are *gypsum blocks* (with a life of as little as one year but a cost of only $5 to $15 apiece) and *granular matrix sensors* (lasting three to seven years or more and costing $25 to $35 each). Freezing can cause cracking and premature aging in gypsum blocks, but will generally not hurt granular matrix sensors.

Electrical resistance blocks work by absorbing water from the surrounding soil. They need to be buried carefully, with snug soil contact and no air pockets—something that may be difficult to achieve in coarse or gravelly soils. Over the past several years, the National Center for Appropriate Technology (NCAT) has installed hundreds of granular matrix sensors. We have found the number one problem to be poor soil-to-sensor contact, usually in coarse or gravelly soils.

When burying any soil moisture sensing device, minimize soil compaction and disturbance to the surrounding soil and canopy cover. Your goal is to install each sensor in surroundings that are representative of the field.

Electrical resistance blocks may be read either with a data logger (see below) or with a portable hand-held meter. Hand-held meters, costing $150 to $600, generally either give electrical resistance readings in ohms or else convert resistance to *centi-bars.* (See text box below.)

Hand-held meters have their advantages. You don't need to bury cables in the field. And because the meter is portable, you can check moisture at an unlimited number of sites, wherever your soil moisture blocks are buried. A disadvantage of hand-held meters, though, is that each monitoring site must be marked in some way, so you can find the electrodes in the field and hook them to the meter.

- **Bulk density**

Measurements of bulk density are commonly made by carefully collecting a soil sample of known volume and then drying the sample in an oven to determine the dry weight fraction. Then the dry weight of the soil, $\mathbf{W}_b$ is divided by the known sample volume, **V**, to determine bulk density, γ_b:

$\gamma_b = \mathbf{W}_b\ \mathbf{V}$ (12)

Most methods developed for determining bulk density use a metal cylinder sampler that is driven into the soil at a desired depth in the profile. Bulk density varies considerably with depth and over an irrigated field. Thus, it is generally necessary to repeat the measurements in different places to develop reliable estimates.

- **Field capacity**

The most common method of determining field capacity in the laboratory uses a pressure plate to apply a suction of -1/3 atmosphere to a saturated soil sample. When water is no longer leaving the soil sample, the soil moisture in the sample is determined gravimetrically and equated to field capacity.

A field technique for finding field capacity involves irrigating a test plot until the soil profile is saturated to a depth of about one meter. Then the plot is covered to prevent evaporation. The soil moisture is measured each 24 hours until the changes are very small, at which point the soil moisture content is the estimate of field capacity.

- **Permanent wilting point**

Generally, at the permanent wilting point the soil moisture coefficient is defined as the moisture content corresponding to a pressure of -15 atmospheres from a pressure plate test. Although actual wilting points can be somewhere between -10 and -20 atm, the soil moisture content varies little in this range. Thus, the -15 atm moisture content provides a reasonable estimate of the wilting point.

An example problem on soil moisture

A cylindrical soil sample 10 cm in diameter and 10 cm long has been carefully taken so that negligible compaction has occurred. It was weighed before oven drying (1284 grams) and after (1151 g). What soil parameters can be identified?

1. Bulk Density:

$y_b = \mathbf{W}_b / \mathbf{V}$
$= 1151 \text{ g} / [(3.14 * (10 \text{ cm})^2/4) * 10 \text{ cm}] = 1.466 \text{ g/cm}^3$

2. Dry Weight Moisture Fraction:

$$W = \frac{\textbf{Wet Weight} - \textbf{Dry Weight}}{\textbf{Dry Weight}} =$$

= (1284 g / 1151 g) / 1151 g = 0.116

3. Volumetric Moisture Content:

$$\theta = \frac{\gamma_b}{\gamma_w} W$$ = (1.466 g / 1.0 g/cm^3) * 0.116 = 0.170

4. Water Content Expressed as a Depth:
Depth of Water = □ * Depth of Soil
= 0.17 cm of water per cm of soil.

Now suppose the soil sample is carefully rewetted to the saturation point, utilizing 314 9 of water to do so. What other soil properties are identified?

5. Porosity:
□ = $\mathbf{V}_p$ / **V** (1)

$$= \frac{\text{g of water} * 1.0\,\text{cm}^3/\text{g}}{(\pi * (10\,\text{cm})^2 * 10\,\text{cm})/4} = 0.40$$

6. Initial Soil Saturation:
S = □ / □ = 0.170 / 0.40 = 0.425

7. Specific Weight of the Soil Particles:

□ $_S$ = □ $_b$ / (1 - □) = 1.466 / 0.60 = 2.44 g/cm^3

Finally, suppose the sample is allowed to drain under conditions where it does not dry due to evaporation until the water in the sample is under a negative pressure of -1/3 atm so that one can assume it is at field capacity. The water draining from the sample was collected and weighed 160 g. What other evaluations are now possible?

8. Field Capacity Volumetric Moisture Content:

□ $_{fc}$ = □ $_b$ $\mathbf{W}_{fc}$ / □ $_w$ (8)

$$= 1.466 * \frac{(314 - 160)}{1151} = 0.196$$

9. Soil Moisture Depletion at the Time of Sampling:
SMD = (□ $_{fc}$ - □ $_i$)* **RD** = (0.196 - 0.170) **RD** = 0.026 **RD**

If the root depth is 100 cm,
SMD = 2.6 cm

1.1.2 Checking level of ground water

Searching for water located below the earth's surface, in phreatic layers or aquifers, in order to pump it. This is done with the utmost care and precision, using appropriate techniques, in order to dig or drill wells in the best possible places and thereby avoid costly, discouraging failures.

These methods make it possible to locate aquifers with more precision, and they are much more efficient in assessing their size, volume, quality and sustainability.

Topography

Analyzing maps and local vegetation gives a first indication of the presence of water. In the case of large-scale investigations, a global geological analysis can even be carried out through the interpretation of satellite images or aerial photos. These can highlight the presence of the major geological outlines liable to give rise to fractures with an identifiable direction or outcrops.

Hydro geophysics

Geophysical methods are now the main methods of investigation and detection of underground aquifers. The method chosen mainly depends on the geological context. With these methods, we strive to study the soil's physical properties and in particular its electrical properties**.** The aquifers are most often trapped between rock layers. All rocks conduct a certain amount of electricity, but their conductivity and resistivity vary according to their type: compact rock, dry rock, fractured rock, wet rock, permeable structures or impermeable ones. A material's electrical resistivity is its capacity to oppose the flow of electric current. These methods are thus based on the capacity of the soil or rock to conduct electricity and the measurement of their conductivity or resistivity (the opposite of conductivity).

From these measurements, the type, size and quality of the aquifer is deduced and specified, or perhaps only presumed, but with a high probability.

There are two main types of methods, which are sometimes used successively:

b) The measurement of electrical resistivity using direct current.

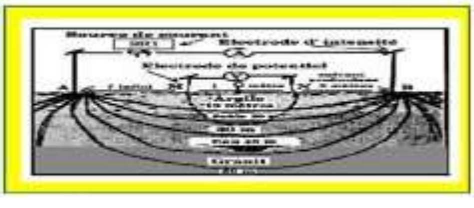


Fig.10. (Source: - http://forage.puit.sourcier.pagespe)

This is the most widely used method as it is suited to the greatest number of situations. It consists in sending direct current into a geological structure on a given site (50 to 400 volts depending on its resistivity - conductivity) using two electrodes (A and B).

There are several possible electrode arrays (Wenner, Schlumberger, 4 terminals, etc.).

The area investigated must not be too large and must be relatively flat and free of buildings which may cause interference and would make it impossible to have AB lines of the required length (over 300m).

c) Methods for measuring this reactivity by magnetic means

Easier to implement, such as the Slingram and VLF methods, these methods measure electromagnetic signals due to magnetic induction phenomena. They don’t need any contact with the ground and thus no electrodes. They make it possible to measure the soil’s reactivity to electromagnetic excitation. However, they cannot be used on all types of grounds or for aquifers over 20 metres deep, or even less. Their use seems to have dwindled.

Search for water using the magnetic resonance method in Tchad
Photo Iris Instrument

Fig- 11 Methods for measuring this reactivity by magnetic means

- **Proton Magnetic Resonance (PMR)**

This is a direct water detection method. It consists in sending electric currents into the ground, then measuring the signals emitted by the nuclei of hydrogen atoms in water molecules. It requires sophisticated equipment including proton magnetometers which can measure electromagnetic fields; their recordings can be interpreted on site and, most importantly, the quantity of groundwater present in the rock can be deduced in a few seconds.

- **The isotope method**

This method is mainly useful for tracing the water flow and to estimate the age of the groundwater. We know that the phreatic layer is renewed by the infiltration of water through the inflow area, where the aquifer’s geological structure is exposed to the surface.

Investigations using the isotope method can often give useful indications. If there are infiltrations, they can be detected and assessed by analyzing the variations in the isotope content of the damp soil above the phreatic layer. The most used isotopes are tritium, deuterium, oxygen 18 and carbon 14. The results have shown that this method is reliable and promising, in particular if it is used with the physical models describing the water flow.

Self-Check – 5	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What is the important of measuring of soil moisture? (5 pts.)
2. List out methods for Checking of soil moisture status (5 pts.)

Note: **Satisfactory rating - 10 points** **Unsatisfactory - 10 points**

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

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-6	Identifying appropriate practices to recharge underground water table

6.1 An Introduction to Recharge

One result of the growing competition for water is increased attention to the use of artificial recharge to augment ground water supplies. Stated simply, artificial recharge is a process by which excess surface water is directed into the ground—either by spreading on the surface, by using recharge wells, or by altering natural conditions to increase infiltration—to replenish an aquifer. Artificial recharge (sometimes called planned recharge) is a way to store water underground in times of water surplus to meet demand in times of shortage. Water recovered from recharge projects can be allocated to non-potable uses such as landscape irrigation or, less commonly, to potable use. Artificial recharge can also be used to control seawater intrusion in coastal aquifers, control land subsidence caused by declining ground water levels, maintain base flow in some streams, and raise water levels to reduce the cost of ground water pumping.

It is useful to think of the entire artificial recharge operation as a water source undergoing a series of treatment steps during which its composition changes. The constituents of potential concern depend not only on the character of the source water, but also on its treatment prior to recharge (pretreatment), changes that occur as it moves through the soil and aquifer (soil-aquifer processes), and treatment after withdrawal for use (post treatment).

Fundamentally, wastewater used to recharge the ground water must receive a sufficiently high degree of treatment prior to recharge so as to minimize the extent of any degradation of native ground water quality, as well as to minimize the need for and extent of additional treatment at the point of extraction.

After pretreatment, the water is ready for recharge, either through surface spreading and infiltration through the unsaturated zone or by direct injection into ground water. Recharge by infiltration takes advantage of the natural treatment processes, such as biodegradation of organic chemicals that occur as water moves through soil. The quality of the water prior to recharge is of interest in assessing the possible risks associated with human exposures to chemical toxicants and pathogenic microorganisms that might be present in the source water. Although one can reasonably expect that such constituents will often be reduced during filtration through the soil, as well as subsequently in the aquifer, a conservative approach to risk assessment would assume that toxicants and microorganisms are not completely removed and some are affected only minimally prior to subsequent extraction and use. Thus when recharge water is withdrawn later for another purpose, it may require some degree of post treatment, depending on its intended use.

6.1.1 Artificial Recharge

Artificial recharge is the process of spreading or impounding water on the land to increase the infiltration through the soil and percolation to the aquifer or of injecting water by wells directly into the aquifer. Surface infiltration systems can be used to recharge unconfined aquifers only. Confined aquifers can be recharged with wells that penetrate the aquifer. Well recharge is also used for unconfined aquifers if suitable land for infiltration systems is not available.

Artificial recharge can be done using any surplus surface water. When low quality water is used for recharge, the underground formations can act as natural filters to remove many physical, biological, and chemical pollutants from the water as it moves through. Often, the quality improvement of the water is actually the main objective of recharge, and the system is operated specifically using the soil and the aquifer to provide additional treatment to the source water. Systems used in this way are called soil-aquifer treatment (SAT), or geo-purification, systems.

The water extracted from SAT systems often can be used without further treatment to support recreation, landscape irrigation, and other non-potable purposes. Potable use may require more treatment. Because aquifers usually are much comer than vadose zones, the quality improvement of the water is much less in the aquifer than in the vadose zone. Thus, recharge using wells in confined aquifers cannot be expected to produce major improvements in the quality of the water. If low-quality water is to be used for well injection, it must be treated to meet the desired reuse qualities before injection. In addition, adequate treatment of the water before recharge is necessary to reduce clogging of the recharge wells.

6.1.2 Groundwater Recharge

Recharging groundwater is a new concept in rainwater harvesting. But there are several groundwater recharging techniques.

6.1.3 Groundwater recharge pit

If the quantity of rooftop water collected is sufficient, pits are dug depending near the buildings but away from foundations and concrete structures. The proper design will include the following considerations :

The pits are preferably located near the courtyard of the house or around the house in the garden and are filled with layers of permeable materials (as a filter), such as pebbles, gravel, and sand, for better percolation. Recharge pits are constructed to recharge the shallow aquifer. (See figure (4.1))

Process of recharging pits:

- ✓ Recharge pits are constructed to recharge the shallow aquifer.
- ✓ They are generally 1m to 2m wide and 2m to 3m deep
- ✓ After excavation, the pits are refilled with layers of pebbles, gravel, and coarse sand.
- ✓ Water to be recharged should be silt free (filtered of fine material).
- ✓ The pit should be cleaned periodically.
- ✓ Pits are suitable for small buildings with rooftop areas up to 200m2.
- ✓ Recharge pits may be of any shape e.g., circular, square, or rectangular.
- ✓ If the pit designed as a trapezoid, the side slopes should be steep enough to avoid silt deposition.

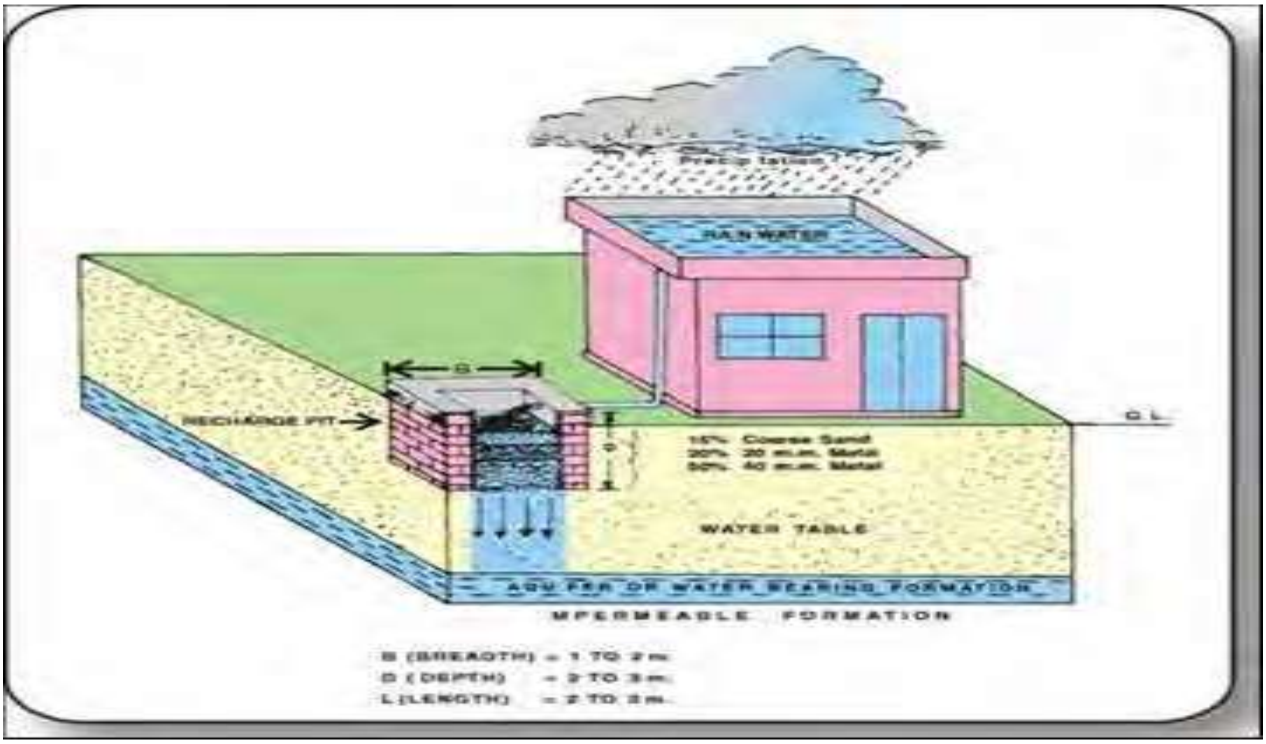


Figure 12. Rainwater harvesting recharge pit

a. Groundwater recharge trench

Groundwater recharge trenches are shallow trenches filled with pebbles and boulders constructed across the land slope. (See figure (4.3))

- ✓ Recharge trenches are suitable for buildings with roof areas of 200-300 m2 and where permeable strata are available at shallow depths.
- ✓ Trenches may be 0.5m to 1m wide, 1m to 1.5m deep and 10m to 20m long depending on the availability of water to be recharged.

- ✓ Trenches are backfilled with boulders (5cm-20cm), gravel (5mm-10 mm), and coarse sand (1.5-2 mm) in graded form, with boulders at the bottom, gravel in the middle, and coarse sand at the top so that the silt content that comes with runoff will be at the top of the sand layer and can easily be removed.
- ✓ Mesh should be installed on the roof so that leaves and solid waste/debris are prevented from entering the trenches, and a desilting/collection chamber may also be provided on the ground to arrest the flow of finer particles to the trench.
- ✓ Bypass mechanisms can be installed before the collection chamber to reject water from the first rain showers.
- ✓ The top layer of sand should be cleaned periodically to maintain the recharge rate.

b. Groundwater recharge through abandoned dug wells

Once cleaned and with all deposits removed, dry/unused dug wells can be used as recharge structures. Pipes guid recharge water to the bottom of the well or below the water level to avoid scouring the bottom and trapping air bubbles in the aquifer. Recharge structures should be cleaned regularly to ensure that recharge water remains silt free. These structures are suitable for large buildings with roof areas of more than 1,000 m2. Chlorination should occur periodically to prevent bacteriological contamination. (See figures (4.7) and (4.8))

Figure 13. Abandoned Dug Well

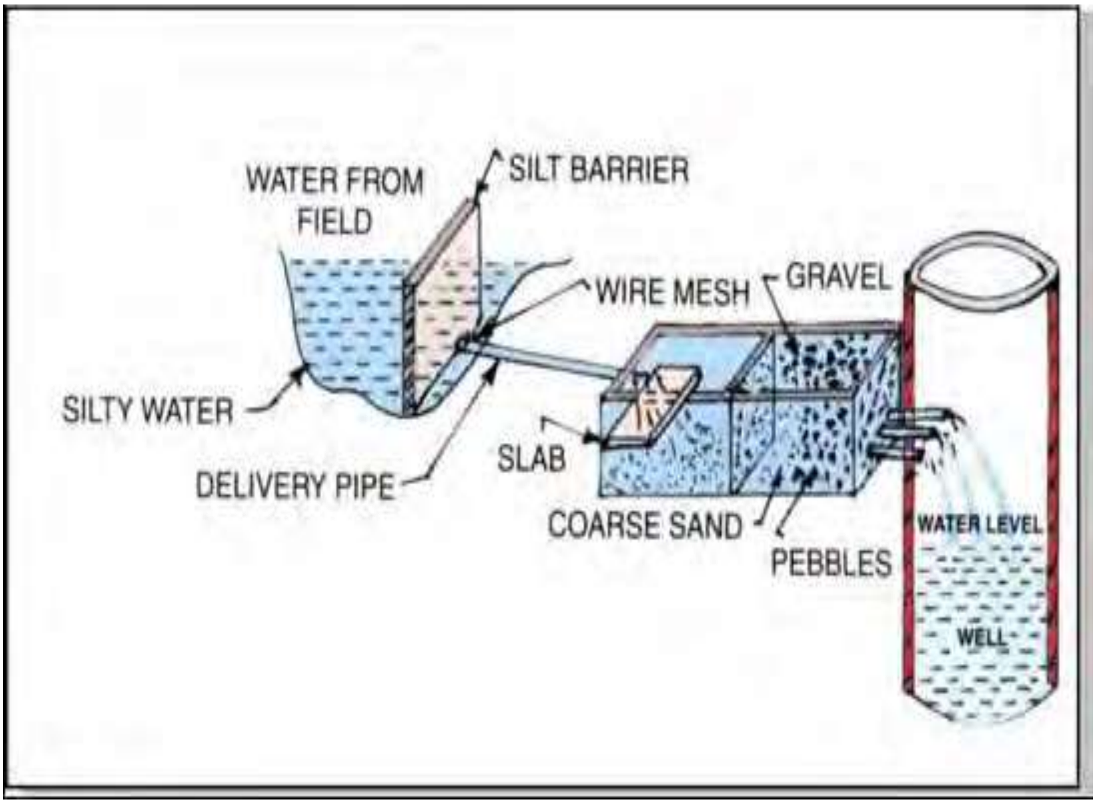


Figure 14. Roof rainwater process for harvesting recharge through a dug well

Measures to improve infiltration and water storage

Contour system for moisture retention by increasing infiltration

- **Contour ploughing**

Contour ploughing forms a series of furrows close to each other's; these should be kept as horizontal as possible. Contour ploughing ensures that rainfall and runoff water are spread evenly over a field by making furrows parallel to the contours. Contour ploughing may be done on slopes with a gradient of less than 10%. On steeper slopes it is better to combine contour ploughng with other measures such as terracing or strip cropping. Contour ploughing is practical on fields with even slopes. On very irregular slopes it is too time consuming to follow the contours when ploughing. Strip cropping is then often more effective.

- **Strip cropping**

Strip cropping means cultivating different types of crops in strips following the contours. Generally a good ground cover crop is alternated with a crop that provides little ground cover. The ground cover strips slows down the flow of rainwater down the slopes and prevents it from washing away valuable to soil. The after can then be used by the crops in the next strip.

- **Ridging tied-ridging**

Ridging is done by constructing small earth banks parallel to the contours of a slope. The water accumulates above the ridges and is thus allowed to infiltrates in to the soil. An alternative to ridges is construction small earth mounds.

This method of soil moistures conservation is used on slopes with a gradient of up to 7%.

- **Broad-bed and furrow**

The purpose of a broad-bed and furrow system is to increase the amount of water that infiltrates in to the soil and that is stored in both bed and furrow. It also makes heavy soils more workable by improving drainage and extending the time of infiltration. When rainfall is very heavy, the (grassed) furrows carry runoff water away, because they slope down with a slight gradient.

- **Cover crops**

Cover crops are usually creeping legumes which cover the ground surface b/n a widely spaced perennial crop, such as young fruit trees, coffee, cacao, and oil palms. Cover crops are often combined with mulching. Grass is also used as ground cover b/n orchard terraces, i.e. narrow terraces for fruits trees, with intermittent uncultivated strips.

- **Cover crops provide the following benefits:-**

  - ✓ Protect the soil from splashing raindrops
  - ✓ Protect the soil from too much heat from the sun
  - ✓ They build up organic matter in the soil
  - ✓ They improve soil structure
  - ✓ They may increase soil fertility through nitrogen fixation
  - ✓ Cover crops also suppress weed growth

- **Mulching**

Mulching is done by covering the soil b/n crop rows or around trees with grass, straw, crop residues, or other plant material. When crop residues are left on and in the soil after harvesting, this is called stubble mulching.

- **The mulching layer**

- ✓ Inhibits runoff
- ✓ Protects the soil from splash erosion
- ✓ Prevents the formation of a crust
- ✓ Reduces evaporation
- ✓ Keeps soil temperature constant
- ✓ Keeps down weed growth

- ✓ Provide decomposed layer for surface rooting crops
- ✓ Reducing evaporation losses and optimizing the use of soil moisture

- ➢ **Wind breaks**

Windbreaks can be non-living structures such as brushwood and woven palm-frond fences or living hedges such as lines of shrubs, trees or tall grasses which are at right angle to the prevailing damaging winds. They give shelter to crops and reduce evaporation of soil moisture because wind low to the ground is prevented.

- ➢ **Fallow**

Leaving soil fallow means that the land is left uncultivated for a season or for one or more years. Weeds are removed. A fallow period may restore the availability of water in the root zone, as well as soil fertility. The top layer dries out, but sub soil moisture is conserved. More water will then be available for the next crop grown on the soil.

- **Conditions of use**

Fallow is a suitable practices for some semi-arid areas, but not all. it is particularly useful on checking clay soils. in areas with more than 500mm rain fall the usefulness of fallow is subject to debate, as soils cannot hold that much water in their root zone.

Self-Check -6	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What is artificial recharge? (5pts.)
2. What are Measures to improve infiltration and water storage? (5pts.)
3. List down techniques of groundwater recharging (5pts.)

Note: **Satisfactory rating - 15 points** **Unsatisfactory – below 15 points**

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

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-7	Identifying trees species for afforestation purpose on degraded land

7.1 **Trees species for afforestation purpose**

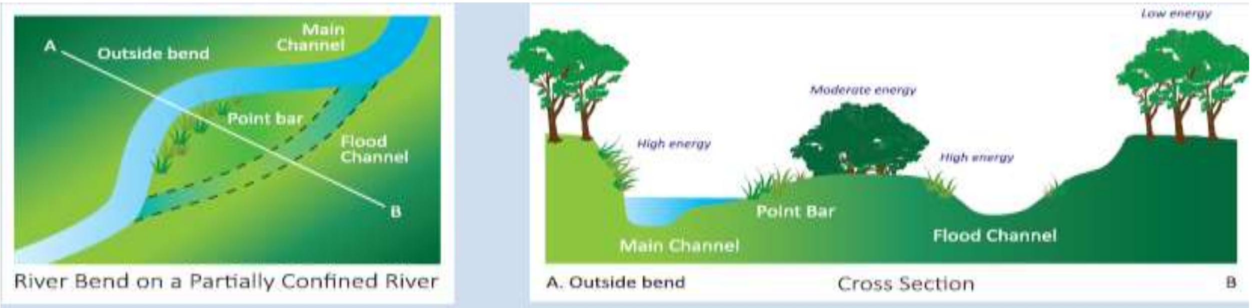
Native vegetation plays a vital role in maintaining the health of waterways. Existing native species should be maintained and where appropriate actively encouraged to recolonize areas along waterways. This can be achieved by reducing grazing pressure using livestock fencing, allowing early colonizing plants such as Silver Wattle to establish particularly in erosion prone areas. In some cases natural re-colonization by native species is likely to be hindered by the presence of ongoing disturbance and invasive weeds. Re-vegetation work may need to be carried out in such circumstances and often plays an integral role in restoring the health of waterways. Establishing suitable native vegetation is particularly important in erosion-prone areas where bare ground requires immediate stabilization. Re-vegetation should be carried out in conjunction with the removal of weeds, such as willow and to support newly established erosion control structures. However it is essential that certain factors are taken into consideration when planting native plants along waterways, including the choice of species and where they are situated in and around the channel zone.

It is important that any re-vegetation work carried out within the stream channel zone takes the different energy settings into account (see 'Healthy Waterways' factsheet for more information) Some key considerations are:

- ✓ Before carrying out re-vegetation works within the channel zone try to find a section of river similar to the one you propose to carry out works on, but with a good cover of native vegetation. Look carefully to work out what native plants grow where e.g. which ones seem to be able to tolerate high tractive stress? What plants only seem to grow in areas of low tractive stress?
- ✓ Plan your re-vegetation works around your observations – only put plants with a high tractive stress tolerance in high energy areas e.g. on the face of an outside bend.
- ✓ It is important to maintain a sufficient width of channel without the restrictions caused by larger shrubs or trees. This is required for the channel to retain its hydraulic efficiency e.g. its ability to convey flood flows. Planting large shrubs and trees on point bars, or within the flood channel zone is not a good idea as this will restrict the channel width over time.

What should i plant where?

Some plant species can hold on in the highest energy areas e.g. on the outside of a bend, while others can only grow where the energy level is low. The following diagrams show the typical variation in water energy flow across the channel of a partially confined watercourse (see 'Healthy Waterways' factsheet for more information).



The following table provides examples of Tasmanian native plants that are suitable for re-vegetating land adjacent to and within creeks lines and indicates where particular species should be planted, based on their ability to cope with different levels of energy flow within a waterway (see 'Healthy Waterways' factsheet for more information on river dynamics and vegetation).

ENERGY LEVEL	TYPICAL CHANNEL ZONE LOCATIONS	TYPICAL RIPARIAN PLANTS
High	The outside of bends. Flood channels. Some bank attached bars. Some mid-channel islands.	Woolly Tea tree (Leptospernum lanigerum) River Tea tree (Leptospernum riparium) Bottlebrush (Callistemon spp.) Mat Rush (Lomandra spp.) Rushes (Juncus spp.) Sedges (e.g. Carex spp.)
Medium	Banks along straight river reaches. The back of point bars.	Blackwood (Acacia melanoxylon) Silver wattle (Acacia dealbata)
Low	Upper bank locations. Floodplains.	Black gum (Eucalyptus ovata) White gum (Eucalyptus viminalis)

*Plant Tasmanian native plants that grow in your local area. Some native plant nurseries may be able to grow native plants with longer root systems on request; these plants are grown in deep tube pots, specifically for the purpose of revegetating riparian areas.

Many species of Mat Rush (Lomandra spp.) are able to grow in areas of a stream channel that experience high energy water flows. The leafy crown offers little resistance to flood flows while the extensive, fibrous root network is highly effective at binding soil together. *Lomandra longifolia* can often hold fast as the bank it was growing on has eroded. It can sit in the channel in a supporting column of soil that its roots still hold firm. This is an ideal plant for re-vegetation work in high energy flow areas of the channel.

Fig-15 Species of Mat Rush (Lomandra spp.)

Wherever possible, preserve and improve existing native riparian vegetation to provide a minimum 10 meter width upslope (away from) the top of the bank. Where no vegetation is present, re-plant native species, (especially ground covers), so that this vegetation forms a 10 meter riparian buffer. For maximum trapping of sediment, nutrient and other contaminants, combine the 10 meter riparian vegetation buffer with a grass filter strip.

Self-Check -7	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Why we choose tree species for afforestation? (5 pts.).

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

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

Answer Sheet

Score = ____________
Rating: _____________

Name: ___________________________ Date: ________________

Reference

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Postel, Sandra. 1999. Pillar of Sand. Worldwatch Books, New York. 313 pages.

Web sites

2. NRCS Irrigation Page
3. USDA-Natural Resources Conservation Service
4. *www.wcc.nrcs.usda.gov/nrcsirrig*
5. *A comprehensive source for irrigation reports, guides, statistics, photos, and links.*
6. Riparian factsheets kit: http://lwa.gov.au/files/products/river-landscapes/
7. http://www.derwentestuary.org.au/stormwater-factsheets
8. Australian River Restoration Centre: http://arrc.com.au/
9. River Styles web page http://www.riverstyles.com/