DIRECTOR

SAMETI, Kudumiyanmalai.

DEPARTMENT OF AGRICULTURE

UNDER SSEPERS – ATMA -2021-2022

SOIL AND WATER CONSERVATION

TRAINING MANUAL

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STATE AGRICULTURAL MANAGEMENT AND EXTENSION TRAINING INSTITUTE (SAMETI)

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Foreword

Soil and water conservation is - in its outlines- a worldwide strategy in the context of sustainable and poverty-orientated natural resource management . Soil and water conservation are those activities at the local level which maintain or enhance the productive capacity of the land including soil, water and vegetation in areas prone to degradation through prevention or reduction of soil erosion, compaction, salinity; conservation or drainage of water and maintenance or improvement of soil fertility.

Soil and water conservation is an integral part of Watershed Management. Although Watershed Management was formerly considered to be nearly synonymous with soil and water conservation, it goes far beyond it today, comprising a variety of further activities that attempt to improve the living conditions of the people living within the respective watershed. Therefore conservation, development and management of the available resources are the foundation for food, ecological, environmental and economic security of the country.

In this connection, State Agricultural Management and Extension Training Institute (SAMETI), Kudumiyanmalai organize the training on "Soil and water conservation" for the extension functionaries of Dept.of Forestry, which will be very useful to the extension functionaries so as to disseminate the technologies to the farming community. I am pleased to place record to all the contributors of technical material for the preparation of Manual. As well, I appreciate the technical staff of SAMETI for coordinating to bring the training manual as an informative record.

with best wishes

Date:- 24-09-2021

Place:- Kudumiyanmalai

Director,
STMETI Kudumiyanmalai

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SOIL HEALTH MAINTENANCE FOR SUSTAINABLE AGRICULTURE

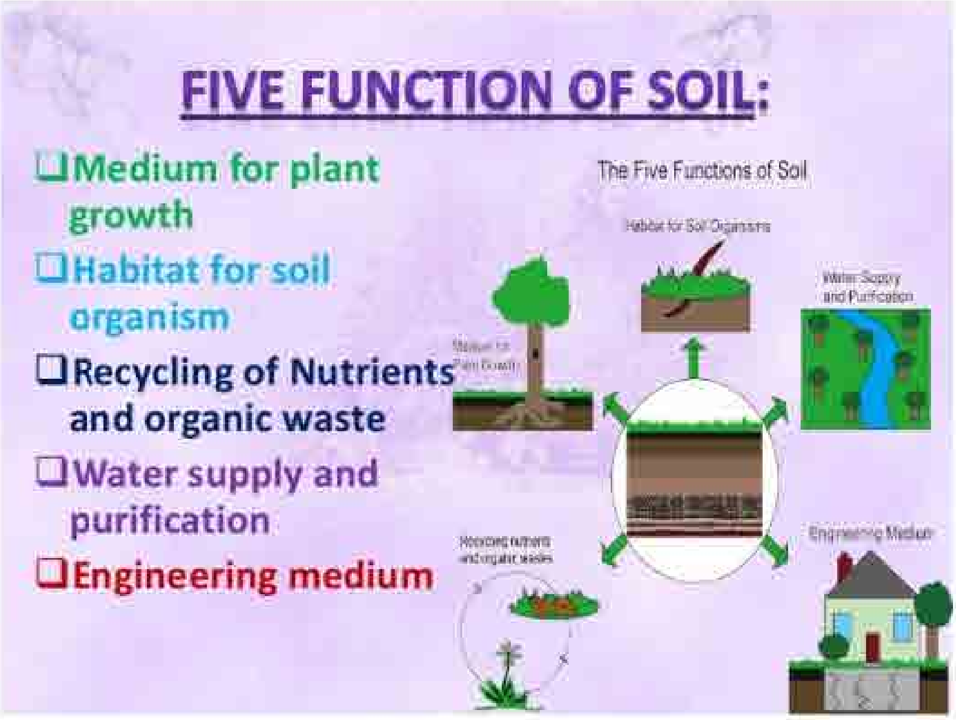
"There can be no life without soil and no soil without life" they have evolved together Charles E.Kellogg, 1902-1980, Soil Scientist

Soil health, also referred to as soil quality, according to NRCS, USDA is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. This definition speaks to the importance of managing soils so they are sustainable for future generations. To do this, we need to remember that soil contains living organisms that when provided the basic necessities of life - food, shelter, and water - perform functions required to produce food and fiber.

Ecosystem services provided by soil

Healthy soil gives us clean air and water, bountiful crops and forests, productive grazing lands, diverse wildlife, and beautiful landscapes. Soil does all this by performing five essential functions:

- Regulating water - Soil helps control where rain, snowmelt, and irrigation water goes. Water and dissolved solutes flow over the land or into and through the soil.
- Sustaining plant and animal life - The diversity and productivity of living things depends on soil.
- Filtering and buffering potential pollutants - The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits.
- Cycling nutrients - Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled in the soil.
- Physical stability and support - Soil structure provides a medium for plant roots. Soils also provide support for human structures and protection for archeological treasures.



Inherent and Dynamic Properties of Soil

Inherent soil quality is a soil's natural ability to function. For example, sandy soil drains faster than clayey soil. Deep soil has more room for roots than soils with bedrock near the surface. These characteristics do not change easily.

Dynamic soil quality is how soil changes depending on how it is managed. Management choices affect the amount of soil organic matter, soil structure, soil depth, and water and nutrient holding capacity. One goal of soil health is to manage soil in a way that improves soil function. Soils respond differently to management depending on the inherent properties of the soil and the surrounding landscape. Understanding soil health means assessing and managing soil so that it functions optimally now and is not degraded for future use.

Focus of soil health management for sustainable agriculture

Only "living" things can have health, so viewing soil as a living ecosystem reflects a fundamental shift in the way we care for our nation's soils. Soil is not an inert growing medium, but rather is teaming with billions of bacteria, fungi, and other microbes that are the foundation of an elegant symbiotic ecosystem. So really people concerned with soil health management for sustainable agriculture should have a focus shift from soil chemical health alone to soil physical and biological health.

Typical Numbers of Soil Organisms in Healthy Ecosystems

		Agricultural Soils	Prairie Soils	Forest Soils
Bacteria	Per teaspoon of soil (one gram dry)	100 million to 1 billion.	100 million to 1 billion.	100 million to 1 billion.
Fungi	Per teaspoon of soil (one gram dry)	Several yards. (Dominated by vesicular-arbuscular mycorrhizal (VAM) fungi).	Tens to hundreds of yards. (Dominated by vesicular-arbuscular mycorrhizal (VAM) fungi).	Several hundred yards in deciduous forests. One to forty miles in coniferous forests (dominated by ectomycorrhizal fungi).
Protozoa	Per teaspoon of soil (one gram dry)	Several thousand flagellates and amoebae, one hundred to several hundred ciliates.	Several thousand flagellates and amoebae, one hundred to several hundred ciliates.	Several hundred thousand amoebae, fewer flagellates.
Nematodes	Per teaspoon of soil (one gram dry)	Ten to twenty bacterial-feeders. A few fungal-feeders. Few predatory nematodes.	Tens to several hundred.	Several hundred bacterial- and fungal-feeders. Many predatory nematodes.
Arthropods	Per square foot	Up to one hundred.	Five hundred to two thousand.	Ten to twenty-five thousand. Many more species than in agricultural soils.
Earthworms	Per square foot	Five to thirty. More in soils with high organic matter.	Ten to fifty. Arid or semi-arid areas may have none.	Ten to fifty in deciduous woodlands. Very few in coniferous forests.

Courtesy: https://www.nrcs.usda.gov

Soil health Indicators and Relationship to Soil Health

- Soil organic matter => nutrient retention; soil fertility; soil structure; soil stability; and soil erosion
- Physical: bulk density, infiltration, soil structure and macropores, soil depth, and water holding capacity => retention and transport of water and nutrients; habitat for soil microbes; estimate of crop productivity potential; compaction, plow pan, water movement; porosity; and workability
- Chemical: electrical conductivity, reactive carbon, soil nitrate, soil pH, and extractable phosphorus and potassium => biological and chemical activity thresholds; plant and microbial activity thresholds; and plant available nutrients and potential for N and P loss
- Biological: earthworms, microbial biomass C and N, particulate organic matter, potentially mineralizable N, soil enzymes, soil respiration, and total organic carbon => microbial catalytic potential and repository for C and N; soil productivity and N supplying potential; and microbial activity measure

Sustainable practices for soil health management

Managing for soil health (improved soil function) is mostly a matter of maintaining suitable habitat for the myriad of creatures that comprise the soil food web. This can be accomplished by disturbing the soil as little as possible, growing as many different species of plants as practical, keeping living plants in the soil as often as possible, and keeping the soil covered all the time.

1) Manage More by Disturbing Soil Less

Soil disturbance can be the result of physical, chemical or biological activities. Physical soil disturbance, such as tillage, results in bare and/or compacted soil that is destructive and disruptive to soil microbes, and it creates a hostile environment for them to live. Misapplication of farm inputs can disrupt the symbiotic relationships between fungi, other microorganisms, and plant roots. Overgrazing, a form of biological disturbance, reduces root mass, increases runoff, and increases soil temperature. All forms of soil disturbance diminish habitat for soil microbes and result in a diminished soil food web. Conservation tillage and minimum tillage is one practice which ensures minimum disturbance to the soil.

2) Diversify Soil Biota with Plant Diversity

Plants use sunlight to convert carbon dioxide and water into carbohydrates that serve as the building blocks for roots, stems, leaves, and seeds. They also interact with specific soil microbes by releasing carbohydrates (sugars) through their roots into the soil to feed the microbes in exchange for nutrients and water. A diversity of plant carbohydrates is required to support the diversity of soil microorganisms in the soil. In order to achieve a high level of diversity, different plants must be grown. The key to improving soil health is ensuring that food and energy chains and webs consist of several types of plants or animals, not just one or two. Crop rotation and companion planting ensures diversification of organisms.

Biodiversity is ultimately the key to the success of any agricultural system. Lack of biodiversity severely limits the potential of any cropping system and increases disease and pest problems. A diverse and fully functioning soil food web provides for nutrient, energy, and water cycling that allows a soil to express its full potential. Increasing the diversity of a crop rotation and cover crops increases soil health and soil function, reduces input costs, and increases profitability.

3) Keep a Living Root Growing Throughout the Year

Living plants maintain a rhizosphere, an area of concentrated microbial activity close to the root. The rhizosphere is the most active part of the soil ecosystem because it is where the most readily available food is, and where peak nutrient and water cycling occurs. Microbial food is exuded by plant roots to attract and feed microbes that provide nutrients (and other compounds) to the plant at the root-soil interface where the plants can take them up. Since living roots provide the easiest source of food for soil microbes, growing long-season crops or a cover crop following a short-season crop, feeds the foundation species of the soil food web as much as possible during the growing season. Healthy soil is dependent upon how well the soil food web is fed. Providing plenty of easily accessible food to soil microbes helps them cycle nutrients that plants need to grow. Sugars from living plant roots, recently dead plant roots, crop residues, and soil organic matter all feed the many and varied members of the soil food web.

4) Keep the Soil Covered as Much as Possible

Soil cover conserves moisture, reduces temperature, intercepts raindrops (to reduce their destructive impact), suppresses weed growth, and provides habitat for members of the soil food web that spend at least some of their time above ground. This is true regardless of land use (cropland, hayland, pasture, or range). Keeping the soil covered while allowing crop residues to decompose (so their nutrients can be cycled back into the soil) can be a bit of a balancing act. Producers must give careful consideration to their crop rotation (including any cover crops) and residue management if they are to keep the soil covered and fed at the same time.Soil cover will prevent erosion which is a major problem in soil deterioration.

5) Biological Nitrogen Fixation

All plants need relatively large amounts of nitrogen (N) for proper growth and development. Biological nitrogen fixation (BNF) is the term used for a process in which nitrogen gas (N_2) from the atmosphere is incorporated into the tissue of certain plants. Only a select group of plants is able to obtain N this way, with the help of soil microorganisms. The group of plants known as legumes (plants in the botanical family Fabaceae) are well known for being able to obtain N from air N_2 with the help of symbiotic bacteria called Rhizobium.Non symbionts like Azospirillum, Azotobacter, Blue green algae also contributes to Nitrogen fixation in other crops.

Type of fixation	N_2 fixed (10^{12} g per year, or 10^6 metric tons per year)
Non-biological	
Industrial	about 50
Combustion	about 20
Lightning	about 10
Total	**about 80**
Biological	
Agricultural land	about 90
Forest and non-agricultural land	about 50
Sea	about 35
Total	**about 175**

Data from various sources, compiled by DF Bezdicek & AC Kennedy, in *Microorganisms in Action* (eds. JM Lynch & JE Hobbie). Blackwell Scientific Publications 1998.

6) **Reduce application of external inputs**

"Low Input Farming Systems (LIFS) or Low External Input Sustainable Agriculture (LEISA) focuses to optimise the management and use of internal production inputs (*i.e.*, on-farm resources) and minimise the use of production inputs (*i.e.*, off-farm resources), such as purchased fertilisers and pesticides, wherever and whenever feasible and practicable, to lower production costs, to avoid pollution of surface and groundwater, to reduce pesticide residues in food, to reduce farmer's overall risk, and to increase both short- and long- term farm profitability. It involves mixed crop livestock farming, crop rotation, use of manures, crop residues. Use of non monetary inputs in agriculture including selection of quality seeds, timely sowing and operations constitute this operation.

Emerging Issues and Conclusions

1. 1.Maintaining soil health shall depend on the basic premise that the amount of nutrients removed through crop removal should be replenished to the soil. Thus,efficient recycling of nutrients from available organic residues,manures and composts should be an integral part of the nutrient management strategy so as to contain nutrient mining.
2. Resource conserving technologies, such as conservation agriculture, soil conservation measures and use of crop residues, organic manures and biofertilisers need to be promoted so as to integrate them with the nutrient management schedules at the farmers field.
3. Soil organic matter is a key indicator of soil health and thus necessary investment needs to be made and programmes need to be launched to promote generation of organic residues and green biomass *in situ*.
4. As routine laboratory analysis for the key soil quality indicators is very expensive and time consuming, it is desirable to identify few suitable indicators which can give a fairly good idea about the soil health.
5. Improving net work of soil testing and soil testing needs to present overall soil health rather than few soil parameters and made comprehensive involving key physical, chemical and biological soil properties
6. Assessment of soil health for the major crop producing regions of the country needs to be taken up urgently, which shall provide the baseline or the first estimate. Periodic assessment of soil health shall provide information about the improvement or decline in the soil health and thus shall assist the policy planners for developing optimum land management plans

EFFECTS OF CLIMATE CHANGE ON SOIL AND WATER RESOURCES

Introduction

About 97.5% of the water on earth is salt water which is present in the seas and the oceans. Fresh water accounts for only 2.5%. Of this fresh water, 68.6% is in the form of ice and permanent snow cover in the Arctic, the Antarctic, and mountain glaciers. 30.1% is in the form of fresh groundwater. Only 0.3% of the fresh water on Earth is in easily accessible lakes, reservoirs and river. Globally, changes in water vapour content of the atmosphere, cloud cover and ice influence the radiation balance of the earth and thus play an important role in determining the climate response to increasing greenhouse gas emissions The global water stress increasing from time to time. For instance, in 1955, only seven countries were found to be with water stressed conditions. In 1990 this number rose to 20 and it is expected that by the year 2025 another 10–15 countries shall be added to this list.

Global warming increases the evaporation of water into the atmosphere and changes the patterns of major air streams and ocean currents such as El Nino and La Nina. This in turn alters the distribution of precipitation, so some regions experience greater rainfall and flooding while others become more prone to droughts. In recent years the study of the effects of climate change on the quantity and quality of water resources has attracted a great deal of attention, particularly at a regional and global scale (IPCC, 2014). The most recent report of the Intergovernmental Panel on Climate Change (IPCC) indicates that the average global
temperature will probably rise between 1.1 and 6.4°C by 2090–2099 as compared to 1980–1999 temperatures, with the most likely rise being between 1.8 and 4.0°C

Water and food security are the key challenges under climate change as both are highly vulnerable to continuously changing climatic patterns. Africa which is one of the world's driest continents is facing a very severe water crisis. Over 90% of Sub-Saharan Africa agriculture is rain-fed, and mainly under small holder management Current scientific research shows that climate change will have major effects on precipitation, evapotranspiration, and runoff and ultimately on the nations water supply. The practical expression of climate change seems more visible through its effects. Nevertheless, these effects are widely spread at different levels of terrestrial and social systems . The rises of global temperature as the primary impact of climate change, and then derive different levels of impacts (Figure 1).

The aim of this review paper is to describe the brief impacts of climate change on soil and water resource and their future adaptation strategies

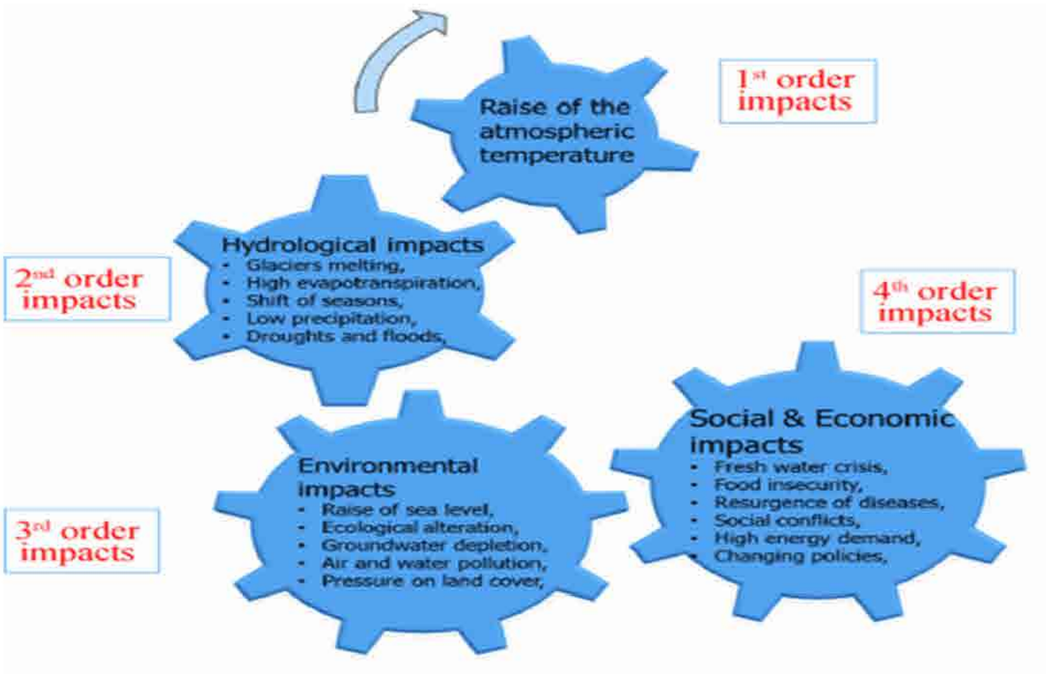


Figure 1: Hierarchy of the impacts of climate change focusing on the hydrologic .

Here we target the rise of global temperature as the primary impact of climate change, and then we derive different levels of impacts.

The Hydrological Cycle and Climate Change

Hydrologic or water cycle describes a natural set of continuous and dynamic processes through which water masses in the form of liquid, vapor or solid, move, circulate and are stored within the earth system (IPCC, 2013). It is continuous circulation of water between ocean, atmosphere and land. The main components of hydrology cycle are the precipitation, evaporation, runoff, groundwater, and soil moisture, and it is liked with changes in atmospheric temperature and radiation balance . The water cycle is a key process upon which other cycles of the climate system operate. Water is transferred through physical processes like evapotranspiration, precipitation, infiltration and river runoff. It defines the sequence of transitions where the Earth’s water (i.e., oceanic, cryospheric, and continental moisture) evaporates into and travels in the atmosphere, condenses to form clouds, returns to the earth surface as precipitation, runoff to the oceans as stream flow, and ultimately evaporates again.

Changes in climate, with resultant increasing temperatures and changing rainfall patterns may alter hydrological responses. Therefore, changes in the water cycle, which are consistent with the warming, observed over the past several decades, results in: Changes in precipitation patterns and intensity, Changes in the occurrence of drought, Widespread melting of snow and ice, Increasing atmospheric water vapor, Increasing evaporation, Increasing water temperatures, Changes in soil moisture and runoff and in general change in water resources availability.

Increases in temperature and reduced rainfall for instance cause reduced stream flows in major catchments, reduced recharge of groundwater, reduced inflows to water storages, or intensified droughts. Water resources are believed to be particularly vulnerable to increased temperature and alternations in precipitation patterns. Precipitation is the main driver of variability in the water balance over space and time. Changes in precipitation have very important implications for hydrology and water resources. Climate change over the 21st century is projected to reduce renewable surface water and groundwater resources in most dry subtropical regions.

The global ocean will continue to warm during the 21st century. The strongest ocean warming is projected for the surface in tropical and Northern Hemisphere subtropical regions

Climate change leading to increased surface temperatures, melting of snow and glaciers, rise in sea level and an increase in extreme weather events such as droughts and floods, can significantly affect water resources. The potential effects of climate change on water resources in Africa include: flooding, drought, change in the frequency and distribution of rainfall, drying-up of rivers, melting of glaciers, receding of water bodies, landslides, and cyclones among others) . In relation to water quantities, changes in temperatures, precipitation patterns, including intensity and seasonality of rain events, snow cover, erosion etc., will have various impacts on river flows, groundwater recharge, lake levels, soil moisture, timing of and vulnerability to extreme events, and more globally impact water resource. With respect to water supply, it is very likely that the costs of climate change will outweigh the benefits globally. One reason is that precipitation variability is very likely to increase, and more frequent floods and droughts are anticipated.

Climate Change and Soil resources are now recognized to be in the 'front line' of global environmental change and we need to be able to predict how they will respond to changing climate, vegetation, erosion and pollution (FAO and ITPS, 2015). This requires a better understanding of the role of soils in the Earth system to ensure that they continue to provide for humanity and the natural world

Soils are both affected by and contribute to climate change (FAO, 2014). The carbon that is fixed by plants is transferred to the soil via dead plant matter including dead roots and leaves. This dead organic matter creates a substrate which soil micro-organisms respire back to the atmosphere as carbon dioxide or methane depending on the availability of oxygen in the soil. Some of the carbon compounds are easily digested and respired by the microbes, resulting in a relatively short residence time. Others become chemically and/or physically stabilized in soils and have longer residence times. Soil organic carbon can also be thermally decomposed during fire events and returned to the atmosphere as carbon dioxide.

DRAINAGE

Drainage is the artificial removal of water from the cropped fields within the tolerance limit of the crops grown in the area under consideration. Drainage problem may be caused by excess rain fall or by over irrigation of upper fields or by the raising ground water table. The excess rain/irrigation water will normally drain in to the lower fields by the action of gravity. When the lower fields does not have proper drainage facility water logging condition occurs. Presence of ground water table in the root zone affects the growth of roots.

The tolerance limit of the crops varies with their physiological characters. Paddy is likely to tolerate submergence for a week or so whereas many field crops have a tolerance of about one to three days.

Drainage is also required for special requirements like leaching and reclamation of problem soils. Salt affected soils are to be amended with chemicals and the diluted salts are to be leached by stagnating water in the field and then draining them by surface or subsurface drainage system. For example, the saline soils are reclaimed by incorporation of gypsum in the field with standing water and draining the field after three days. When salts are to be leached through the soil column the subsurface system is engaged.

BENEFITS OF PROPER DRAINAGE: The benefits of drainage are given below based on the stage of the crop.

1. When drainage is proper, the length of the growing season is more. This results in selection of better and high yielding long duration crop variety with higher net returns. The cultivation operations can be commenced timely. At times this will ensure more then one crop in a season.
2. The proper drainage prevents slippage of wheels of the machines used for land preparation. Properly drained and dried field is easier to plough. This results in saving of fuel, energy and the cost of land preparation.
3. When the soil moisture is optimum, the seeds germinate better. This ensures proper germination and coverage of crops.

4. The applied fertilizers will be useful to the crops, only if drainage problem does not occur. An increased supply of nitrogen can be obtained from the soil when drainage lowers the water table in the root zone. De-nitrification occurs in soils with poor drainage.

5. The roots also need oxygen for its growth and development. Under water logged condition, oxygen travels about 10000 times slower towards roots when compared to well aerated condition. Hence proper drainage helps in better root development and transport of applied fertilizers to the crop.

6. The inter cultural operations like weeding, application of fertilizers and pesticides will be easier only under well drained condition.

7. Heavy winds will uproot the plants and grassing animals also eat the plants with roots under wet soil condition. Better drainage ensures proper hold for the plant roots.

8. Weed problem is minimised and its control is easier with good drainage since shallow rooted weeds and undesirable grasses often thrive in wet soil, crowding about the planted crop.

9. Mechanical harvesting is difficult under slippery conditions. Also the harvester should have better ground support during operation. This is possible only under well drained conditions.

10. Reclamation of saline and alkaline soils is possible only with proper drainage facility.

11. Plant roots require certain temperature conditions for better microbial activity which results in better nutrient uptake. Seed germination is also influenced by the soil temperature.

12. Good drainage reduces diseases that thrive on wet land. These include foot rot and liver fluke that affect live stock, and diseases carried by mosquitoes to both live stock and human beings. The plant diseases such as root rot, stem rot, etc., are also reasonably controlled.

13. Soil erosion is controlled under subsurface drainage. The sediments are filtered out.

Soils requiring reclamation

- Native problem soils
- Over irrigated problem soils
- Over fertilized problem soils
- Water logged problem soils

- Drained water problem soils
- High infiltration problem soils
- Low infiltration problem soils
- Salt affected problem soils

Properties used to classify salt affected soil

Soil salinity/sodicity type	Electrical conductivity (EC)	Exchangeable sodium percentage (ESP)	Sodium adsorption ratio (SAR)*	pH	Physical condition
	dS m^{-1}	%			
Typical agricultural soil	< 4	< 15	< 13	< 8.0	good
Saline soil	> 4	< 15	< 13	< 8.5	good
Sodic-only soil	< 4	> 15	> 13	> 8.5	poor
Saline-sodic soil	> 4	> 15	> 13	< 8.5	poor to good

**SAR of the soil water extract*

Management of problematic soils:

For the management of problematic soils, some general principles have to be considered for proper implementation of the reclamation measures. Water flows through the soil in the direction of maximum decrease of hydraulic head and the flow velocity is proportional to the hydraulic gradient. The design and layout of drainage system are controlled by this principle.

The Salt concentration in soil solution upward movement of salts and their accumulation increase with an increase in the evaporation and transpiration from the surface of the soil and the vegetation, especially when the ground water table is shallow.

Increase or decrease of salts in the root zone depends upon whether the salt inputs are higher or lower than the salt outputs.

Management of Saline and Non- saline alkali soil

Chemical Method:

Some chemicals are added to the soil as an integral part of the reclamation program adopted to improve the saline and alkali soils. These are known as chemical amendments. The principal purpose of the amendments is to furnish soluble calcium to replace exchangeable Na or to neutralize alkaline salts with acid. The various chemicals suitable for different soil conditions are:-

Gypsum: Gypsum a natural sulphate of calcium is found in large deposit in various parts of Rajasthan. It reacts with exchangeable Na with getting converted into sodium sulphate. Sodium sulphate is from the soil to reduce pH. The addition of gypsum improves the physical conditions of soil. Soils become flocculated and drainage improves.

$$CaSO_4 + 2\ Na\ X = Ca\ X + Na_2SO_4$$

Sulphur: Sulphur is a very effective chemical amendment to replaces exchangeable Na. Theoretically, one atom of sulphur replaces four Na ions by calcium. But under field conditions approximately, three exchangeable Na ions per atom of sulphur are replaced from the soil colloids.

Iron sulphate: Iron sulphate is sometimes used as a chemical amendment for improving alkali soil. Iron sulphate forms sulphuric acid, which is converted into calcium sulphate. Calcium sulphate, thus formed replaces exchangeable sodium as indicated by following equations.

$$FeSO_4 + H_2O \text{ ----- } H_2SO_4 + FeO$$

$$H_2SO_4 + CaCO_3 \text{ ------- } CaSO_4 + H_2O + CO_2$$

Lime stone: Ground limestone is applied to the soil having pH at 7.0 to 7.5. Since Calcium carbonate become insoluble as the pH increases, it is not effective on soils having pH more than 7.5. Following the reaction takes place:

$$2NaX + CaCO_3 \text{ --------} CaX_2 + Na_2CO_3$$

When lime stone is applied to the soil, it gets dissolved in the soil solution. The Calcium of the lime stone reacts as with the spoil complex and replaces Na and Na combines with carbonate and form sodium carbonate which is leached down by flooding.

Mechanical method:

Flooding and leaching down of the soluble salts. The leaching can be done by ponding the water on the land and allowing it stand there for a week. Most of the soluble salts would leach down and below the root zone. After a week standing water is allowed to escape, such 2 to 3 times treatments given to reclaim highly saline soils. Sometime gypsum is also added to flood water when the soluble salts are low in Ca to check the development of alkalinity.

Scraping of the surface soil when the soluble salts accumulate on the soil surface, scraping helps to remove salts. This is a temporary cure and salinity again develops on such soils.

Cultural method

- Providing proper drainage if the soil is not free draining artificial drains are opened or tile drains laid underground to help wash out the salts.
- Few of salt free irrigation water good quality of irrigation should be given.
- Proper use of irrigation water, it is known that as the amount of water in the soil decrease the concentration of the salts in the soil solution of the salts in the soil solution is increasing thus moisture should be kept at optimum field capacity.
- Use of acidic fertilizes: In saline soil acid fertilizers such as ammonium sulphate should be used
- Use of organic manures: When sufficient amount of manures is added the water holding capacity of soil increased and as a result the conductivity of the soil solution decreases.
- Ploughing and levelling of the land: Ploughing increasing the infiltration and percolation rate. Therefore salts leached down to the lower levels.
- Returning of water evaporation: Mulching with crop residues or plastic sheet helps in decrease evaporation.

Growing of the salt tolerance Trees

Management of Organic Soils:

All sorts of vegetable crops may be grown on organic soils. In some cases peat is used for field crops, but the higher valued vegetables and nursery crops are more common. In fact, almost any crop will grow on organic soil if properly managed.

Structural Management:Ploughing is not necessary every year since peat is porous and open unless it contains considerable silt and clay. The longer a peat has been cropped the more important compaction is likely to be a cultivation tends to destroy the organic granular structure, leaving the soil in a powdery condition when dry. It is then susceptible to wind erosion a very serious problem.

Use of lime: Lime, which so often must be used on mineral soils. Ordinary is less necessary on organic soils unless they have developed in regions low in calcium in the surrounding uplands. On acid mucks containing appreciate quantities of inorganic matter, however, the situation is quite different. The highly acid conditions result in the dissolution of Fe, Al, and Mn in toxic quantities. Under these conditions large amounts of lime may be necessary to obtain normal plant growth.

Commercial fertilizers: Of greater important than lime or commercial fertilizers. In fact, these materials are needed for crop production especially vegetables. As organic soils are very low in phosphorus and potash these elements must be added. Since vegetables usually are rapid growing plants succulence often being an essential quality, large amounts of ready available nitrogen are necessary. Newly cleared peat soil requires at the beginning only a small amount of nitrogen with the phosphorus and potash.

Micronutrients: Peat soils are in need of not only N, P and K but also often some of the trace elements as well. Copper sulphate and salts of manganese and Zinc are used to meet plant needs on peat and muck soils. Boron deficiency is also becoming evident.

Management of waterlogged soils:

Water logged soils are managed in the following ways:

Drainage: drainage removes excess water from the root zone that is harmful for the plant growth. Land can be drained by surface drainage, sub-surface drainage and drainage good method.

Controlled irrigation: Excess use of water in the irrigation results in water logged area.

To check the seepage of canal: Due to seepage land becomes water logged.

Flood control measures: Construction of bund may check water flows river of the cultivated land.

Plantation of trees having a higher evaporation rate: Transpiration rate of certain trees like Eucalyptus, Acacia is very high. In transpiration process the underground water is consumed by trees, thus lowering the ground water table.

Selection of crops and their varieties: Certain crops like paddy, water nut, jute and Sesbenia can tolerate waterlogged conditions. In trice crop sub-merged varies from variety to variety. Generally lowland and deep water varieties can tolerate water logging, but upland varieties do not have this capacity.

Methods of sowing: In water logged areas, sowing should be done on bunds or ridges. In this method there is a scope of good aeration near the root zone.

Nutrient management: Low nitrogen fertility is an important constraint in the waterlogged soil. The predominant form of nitrogen in water logged soils is NH_4.

Management of calcareous soils:

Management and reclamation of calcareous soils are not difficult because the pH in such soil is not very high. Generally, this is no need of chemical amendments for reclamation of calcareous soil. The calcareous soils can be managed in the following ways:

- ***Tillage operation:*** Light (Sandy) calcareous soil develops a large number of pore spaces due to flocculation. This type of soil has poor water holding capacity. Therefore, such types of soils are needed compaction by plank and roller to increase the water holding capacity.
- ***Application of organic manure:*** When sufficient amount of farmyard manure composts and green manure is added, the amount of carbon dioxide and acid increase and as a result pH of soil decreases.
- ***Use of chemical fertilizers:*** Availability of phosphorus is less in calcareous soil. To increase the availability of P, the phosphorus fertilizers should be used in the following manner
    - Phosphatic fertilizers should be used near the root of the plant.
    - Use of Phosphatic fertilizer in ball form also increases the availability of P.
    - P may be used in split form.
- ***Use of micronutrients:*** Addition of micronutrients like Zn, Fe and Cu would be helpful in increasing the yield.

Leaching Requirement:

Leaching is the process of dissolving and transporting soluble salts by downward movement of water through the soil. The leaching of soluble salts from the root zone is essential in irrigated soils. When the soils are highly alkaline, or irrigated with saline water, some more water is to be added to leach out the excessive salts or to avoid accumulation of salts. Without leaching, salts accumulate in direct proportion to the salt content of the irrigation water and the depth of water applied. The concentration of salts in the soil solution results principally from the extraction of moisture from the soil by the process of evaporation and transpiration.

Biochar

The mineral and organic components of soil contribute to soil water holding capacity.Water is held more tightly in small pores, so clayey soils retain more water. The lower soil bulk density generally associated with higher soil organic matter is a partial indication of how organic matter modifies soil structure and pore size distribution. The intrinsic contribution of biochar on soil physical parameters such as wetability of soil, hydraulic conductivity, water infiltration, water retention, macroaggregation and soil stability are invariably related to Soil Agreegates, porosity, Bulk density and aggregate stability and are critically important in tropical environments in combating erosion, mitigating drought and nutrient loss and in general to enhance groundwater quality.

Need for recycling of crop and agroforestry residue into biochar for use in Indian agriculture:

To improve soil physical properties viz., bulk density, porosity, water holding capacity, drainage etc, through incorporation of biochar Substantial amounts of carbon can be sequestered in soils in a very stable form. Addition of biochar to soil enhances nutrient use efficiency and microbial activity. To enhance soil and water conservation by using the biochar in rainfed areas. Minimize reliance on external amendments for ensuring sustainable crop production. Mitigation of greenhouse gas emissions by avoiding direct crop residue burning by farmers . To enable destruction of all crop residue borne pathogens Conversion of residues into biochar helps to reduce the bulkiness both in terms of weight and volume and make the product easier to handle compared with that of fresh and uncarbonized crop and agroforestry residue

Hydrogels

Hydrogel agriculture technology involves gel forming polymers that are insoluble water absorbing polymers designed exclusively for agricultural use by the late 1980's. They were developed to improve physical properties of soil to:

1. Increase water holding capacity
2. Increase water use efficiency
3. Enhance soil permeability and infiltration rate
4. Reduce irrigation frequency
5. Reduce compaction tendency

6. Stop soil erosion, farm run-off & surface leaching
7. Increase plant performance, particularly in structure-less soils stressed with drought condition

Hydrogels as they are commonly called are cross-linked three-dimensional networked water absorbent polymers. Three main types of Hydrogels have so far been found appropriate for agricultural use:

1. Starch-graft copolymers
2. Cross-linked Polyacrylates
3. Cross-linked Polyacrylamides & Acrylamide-acrylate copolymers

Potassium Polyacrylate is the principle material used in Super Absorbent Polymer industry and marketed as hydrogel for agricultural use because of its longer retention and high efficiency in soil with nil toxicity issues. They are prepared by polymerizing Acrylic acid with a cross linker. Cross-linked polymers can hold water 400 times their own weight and release 95% of that to growing plants. Use of Hydrogel leads to increased water use efficiency by preventing leaching and increasing frequency for irrigation. During summer months particularly in semi arid regions, lack of soil moisture can cause plant stress. Moisture released by hydrogel close to root area helps reduce stress and increase growth and plant performance. Hydrogels can reduce fertilizer leaching and reduce application of pesticides.

Agriculture specific applications of Hydrogel

Hydrogel application in agriculture in terms of proposed practices and their advantages are summarized herein.

1. **Conservation in Agricultural Lands**
2. **Drought Stress Reduction**
3. **Enhanced Fertilizer Efficiency**

Application rates

.Type of Soil	Suggested dosage of Hydrogel
Arid & Semi-arid Regions	4-6g/kg soil
For all level of water stress treatment and improved irrigation period	2.25-3g/kg soil

To delay permanent wilting point in sandy soils	0.2-0.4g/kg OR 0.8% of soil whichever is more
To reduce irrigation water by 50% in loamy soil	2-4g/ plant pit
To improve relative water content and leaf water use efficiency	0.5-2.0g/pot
To reduce drought stress	0.2-0.4% of soil
To prohibit drought stress totally	225-300kg/ha of cultivated area
To decrease water stress	3% by weight

Mulching

- Mulch is a layer of material applied to the surface of an area of soil.
- Mulching helps prevent soil erosion
- Mulching adds organic matter to the soil
- Mulching feeds soil life and improves soil structure
- Mulching adds nutrients to the soil
- Mulch decreases water loss due to evaporation

What materials can be used as mulch?

You can mulch with whatever organic matter is readily available and transportable. Common materials include compost, manure, straw (crop stems and stalks), dry grass clippings, sawdust, leaves, and other left-over crop residues. Alternative mulching materials include, newspaper or cardboard. However these materials do not add nutrients to the soil or improve its structure. It's better not to use plant material from the same type of crops that you are growing. For example, maize residue should not be used as a mulch for maize as it might still be carrying insects or diseases of maize. Green vegetation is not normally used as it can take a long time to decompose and can attract pests and fungal diseases. Experiment to see which mulches in your area last the longest. The longer the mulch lasts the less often you have to apply it

How do you apply mulch?

For large plants, spread the mulch between the rows and around each plan. For small plants or seedlings apply it between the rows, not directly around the plants. In this way you will not encourage disease, but you will still reduce weeds and add organic matter to the soil. Try different thicknesses of mulch to see which works best for your crops Always apply mulches to a warm, wet soil. Mulch applied to a dry soil will keep the soil dry.

Isn't mulching a lot of extra work?

Actually, by improving the soil and helping to fight weeds, mulching can save gardeners time and work in the long run. You will spend less time weeding and because a soil with lots of organic matter is looser, those weeds that do grow are a lot easier to pull out. Digging in a looser soil is also a lot easier. Plus, as mulching prevents water from evaporating from the surface of the soil, less watering is necessary. However, it's true to say that it would be a lot of work to carry in enough mulching material to cover an entire field. Sometimes farmers simply cut the weeds in their fields, right before planting, to form a mulch for their crops. Other farmers grow cover crops, which they chop up and leave as a mulch just before food crops are planted.

Vertical Mulching

Vertical mulching is the creating of holes around the base of a tree or shrub that is stressed. The holes are filled with a mixture of organic material. The back fill and aeration can dramatically improve root growth and reduce or eliminate stress caused in a lawn environment or construction damage

Some of the benefits are

- Reduced compaction
- Increased drainage
- Increased oxygen to the root system
- Introduction of organic mater to existing soil
- Increased soil organisms
- Increased water retention

Vertical mulching is one of the most effective ways to treat stressed trees and shrubs. The aeration and soil treatment create an environment that mimics nature and allows for greater nutrient uptake, increased root growth and the potential regeneration of a damaged root system.

WATERSHED, CONCEPT, PLANNING, MANAGEMENT PLAN

Watershed definition:

The watershed is also nomenclature as drainage basin, catchment or drainage area refers to the area drained by a stream in such a way that all flow originating in that are is discharged through a single outlet.

The topographic divide or watershed boundary line, which covers the watershed designates the area in which the over land flow approaches towards the drainage system (stream) which finally becomes as surface runoff at the outlet.

The groundwater flow may not conform to the surface drainage boundaries because the phreatic divide does not always coincide with the topographic divide.

Small and large watersheds

1. Small watershed – varies from few acres to 100 acres. Overland flow is more predominant in small watershed, as there is less network of drainage system
2. Large watershed – size exceeds 100 acres. Channel flow is predominant.

Watershed characteristics

The various characteristics are,

1. Size:

The size of watershed has significant effect on its function. A small watershed is pronounced by overland flow which is main contributor to result a peak flow. Large watershed has no overland flow, but channel flow is main. Large watersheds are affected by basin storage.

2. Shape

The common shapes are

1. Square
2. Rectangular
3. Triangular etc.,

3. Basin shape:

It is referred as shape of outline of watershed or drainage basin.

4. Drainage Density:

The drainage density (D_d) is defined as the ratio of total length of all stream segments (i.e cumulative length of stream segments of all order) within the specified basin to the basin area projected on horizontal surface.

The prediction of drainage density is carried out from the basin map, using the instruments as planimeter and chartometer.

The planimeter measures the basin area from the map and chartometer measures the stream length

Slope:

The average slope of watershed can be determined from the topographic map of the watershed.

Time of concentration:

The time taken by water to travel from the most distant point of the watershed to the outlet or some other down-stream point of reference is called as “Time of Concentration”. It can be determined by using the nomograph.

Concept of Watershed

Soil, vegetation and water are most important vital natural resources for the existence of the man and his animals. These three interdependent resources can be managed collectively, conveniently, simultaneously and efficiently on watershed basis (unit of management).

1. Watershed is a geo hydrological unit or piece of land that drain at a common point.
2. A watershed is defined as any spatial area from which rain or irrigation water is collected and drained through a common point.
3. The watershed and drainage basin are synonymous term indicating an area surrounded by a ridge line that is drained through a single outlet.

TYPES OF WATERSHED

- Watersheds is classified depending upon the size, drainage, shape and land use pattern.

  1) Macro watershed (> 50,000 ha)

  2) Sub-watershed (10,000 to 50,000 ha)

  3) Milli-watershed (1000 to10000 ha)

  4) Micro watershed (100 to 1000 ha)

  5) Mini watershed (1-100 ha)

Watershed Development

Watershed development refers to the conservation, regeneration and the judicious use of all the resources - natural (land, water, plants, animals) and human - within a particular watershed. Watershed management tries to bring about the best possible balance in the environment between natural resources on the one side, and human and other living beings on the other.

Components of watershed development

- Human Resource Development (Community Development)
- Soil and Land Management
- Water Management
- Crop Management
- Afforestation
- Pasture/Fodder Development
- Livestock Management
- Rural Energy Management
- Farm and non-farm value addition activities

All these components are interdependent and interactive.

WATERSHED MANAGEMENT

The watershed management implies, the judicious use of all the resources i.e. land, water, vegetation in an area for providing an answer to alleviate drought, moderate floods, prevent soil erosion, improve water availability and increase food, fodder, fuel and fiber on sustained basis. Watershed to achieve maximum production with minimum hazard to the natural resources and for the well being of people. The management should be carried out on the watershed basis. The task of watershed management includes the treatment of land by using most suitable biological and engineering measures in such a manner that, the management work must be economic and socially acceptable

Principles of Watershed Management

The main principles of watershed management based on resource conservation, resource generation and resource utilization are:

- Utilizing the land based on its capability
- Protecting fertile top soil
- Minimizing silting up of tanks, reservoirs and lower fertile lands
- Protecting vegetative cover throughout the year
- In situ conservation of rain water
- Safe diversion of gullies and construction of check dams for increasing ground water recharge
- Increasing cropping intensity through inter and sequence cropping.
- Alternate land use systems for efficient use of marginal lands.
- Water harvesting for supplemental irrigation.

- Maximizing farm income through agricultural related activities such as dairy, poultry, sheep, and goat forming.
- Improving infrastructural facilities for storage, transport and agricultural marketing,
- Improving socio - economic status of farmers

Objectives of watershed management

The different objectives of watershed management programmes are:

1. To control damaging runoff and degradation and thereby conservation of soil and water.
2. To manage and utilize the runoff water for useful purpose.
3. To protect, conserve and improve the land of watershed for more efficient and sustained production.
4. To protect and enhance the water resource originating in the watershed.
5. To check soil erosion and to reduce the effect of sediment yield on the watershed.
6. To rehabilitate the deteriorating lands.
7. To moderate the floods peaks at down stream areas.
8. To increase infiltration of rainwater.
9. To improve and increase the production of timbers, fodder and wild life resource.
10. To enhance the ground water recharge, wherever applicable.

Factors affecting watershed management

a) Watershed characters

i) Size and shape

ii) Topography

iii) Soils

iv) Relief

b) Climatic characteristic

i. Precipitation

ii. Amount and intensity of rainfall

c) Watershed operation

d) Land use pattern

i. Vegetative cover

ii. Density

e) Social status of inability

f) Water resource and their capabilities.

Watershed management Plan or Steps in watershed management

1. Recognition of problem
2. Analysis to determine the causes of watershed problem
3. Development of alternative solutions for the objectives formulated to solve the problem
4. Selection of best solution
5. Application of selected solution
6. Protection and improvement of works, which have already been implemented

The above steps can further be grouped in following four phases,

(a) Recognition phase
(b) Restoration phase
(c) Protection phase
(d) Improvement phase

(a) Recognition phase:

Under this phase, the recognition of watershed problems, their probable causes and development of alternatives for them are described. It is carried out by conducting several surveys.

(i) Soil survey
(ii) Land capability survey
(iii) Agronomic survey
(iv) Forest land under permanent vegetation survey
(v) Engineering survey
(vi) Socio-economic survey

(b) Restoration phase:

This phase covers the task of selection of best solutions and their applications for watershed management. Treatment measures are applied to the critical areas for the recognized problems identified earlier.

(c) Protection phase:

It is the third phase of watershed management, in which general health of watershed is taken care off and its normal working is also ensured. The protection of watershed against all those factors which cause deterioration is also carried out under this management phase.

(d) Improvement phase:

This is the last phase. The overall improvements made during management of watershed are evaluated for all the lands covered. In addition attention is also given to make improvement on agricultural land, forest land, forage production, pasture land and socio-economic status of the people.

Watershed Improvement Techniques

Nature of Terrain	Improvement Techniques
• Hill tops and upper reaches of watershed	Afforestation
• Steep hill slopes a little lower down	Development of grass lands
• Lower parts of watershed	(i) Contour bunding and terracing of agricultural fields (ii) Contour trenching (iii) Contour cultivation (iv) Strip cropping (v) Gully plugging (vi) Stream bank protection against erosion (vii) Farm ponds (viii) Control & regulation of grazing

Watershed management plan (Biological)

In brief various control measures are:

I. Vegetative measures (Agronomical measures)

1. Strip cropping
2. Pasture cropping
3. Grass land farming
4. Wood lands

Watershed management plan - Engineering

II. Engineering measures (Structural practices)

1. Contour bunding
2. Terracing
3. Construction of earthern embankment
4. Construction of check dams
5. Construction of farm ponds
6. Construction of diversion
7. Gully controlling structure
    - Rock dam
    - Establishment of permanent grass and vegetation
8. Providing vegetative and stone barrier
9. Construction of silt tanks detention

Influence of soil conservation measures and vegetation cover on erosion, Runoff and Nutrient loss. Rainwater harvesting is the main component of watershed management.

Watershed problems:

1. Flood damage
2. Sediment damage
3. Erosion damage

Delineation procedure of watershed:

Watershed delineation is to describe or sketching out the area bounded by ridge line, contributing runoff at common point and dividing or separating it from the adjoining area.

The delineation of priority area can be performed to some extent by reconnaissance survey and study of toposheets. However, this technique is slow and also not provides very accurate information. Normally, the photographs of 1:15,000 can also be used for the purpose.

The demarcation of priority areas should be accomplished on watershed basis, because a comprehensive watershed management approach is essential for carrying out for proper soil conservation measures. It is also necessary that, that the size of watershed to be delineated should be ranges from 10,000 to 20,000 ha, because for small watershed the formulation of soil conservation working plans and their execution over reasonable period is practically possible and easy, too.

The steps for demarcation of small size watershed are described as under:

1. Divide the entire watershed into different sub-watersheds following important tributaries.
2. Again, divide each sub watershed into small size, following distinct tributaries and streams passing through respective sub watershed.
3. further, sub-divided each small part of watershed [as obtained in step (2) in size ranges from 10,000 to 20,000 ha.]

Causes of watershed Deterioration:

Deterioration of watershed takes place due to faulty and bad management through the activity of man and his animals. These activities are:

1. Faulty agriculture, forestry and pasture management leading to degradation of land.
2. Unscientific mining and quarrying.
3. Faulty road alignment and construction.
4. Industrialization
5. Fire.
6. Apathy of the people.

Results of watershed Deterioration:

1. Less production from agriculture, forests, grass lands etc.
2. Erosion increases and decreases biomass production
3. Rapid siltation of reservoirs, lakes and river beds.
4. Less storage of water and lowering of water table.
5. Poverty as a result of less food production.

People's participation in watershed management

- People and their environment are interdependent. Any change in the surrounding environment directly affects the people living therein. A degraded environment results in a degraded quality of life of the people. Thus efforts to reduce poverty and improve the standard of living of the people must aim at improving the environment they live in. The environment does not recognize people determined administrative boundaries. A watershed provides a natural environmental unit for planning a developmental initiative.
- The environment is a living space on which the human community living within that area depends on for its livelihood. When the economic condition of a community deteriorates it leads to over-exploitation and degradation of natural resources which, in turn, further worsen poverty. It is thus necessary for people to see the relationship between their poverty and the degraded environment they live in.
- Thus, just as human beings and their activities are the cause of environmental destruction, it is only they who can restore to health the ruined environment. Hence there can be no sustainable natural resources management unless it involves the participation of all the inhabitants of the concerned environment / area in an active manner.
- For a successful watershed development, team work is very essential. A task of this nature requires community efforts. With the responsibility shared and the drive towards a common goal, the fruits of labour can be enjoyed by all.
- Farmers owning land or having access to public land can seek the assistance of a watershed team, voluntary agencies and banks. For optimum results plant protection seed protection and processing, utilisation of ground water recharge, etc., have to be taken up on a group basis in the watershed.
- Organization of inputs like improved seeds, fertilisers, etc., organising bio-mass planning, and ensuring timely operation of critical elements in the watershed, can best be taken up on a community basis. Such a group can also act as an intermediary between banks and farmers.

WATER HARVESTING

Water harvesting

In general, water harvesting is the activity of direct collection of rainwater. It means capturing rain where it falls or capturing the run off in the watershed and taking measures to keep that water clean by not allowing polluting activities to take place in the catchment. The rainwater collected can be stored for direct use or can be recharged into the groundwater.

Therefore, water harvesting can be undertaken through a variety of ways

- Capturing runoff from rooftops
- Capturing runoff from local catchments
- Capturing seasonal floodwaters from local streams
- Conserving water through watershed management

These techniques can serve the following purposes:

- Provide drinking water
- Provide irrigation water
- Increase groundwater recharge
- Reduce stormwater discharges, urban floods and overloading of sewage treatment plants
- Reduce seawater ingress in coastal areas.

Water harvesting Techniques

The harvesting techniques are classified as,

I. **Roof harvesting**

II. **Runoff harvesting**

a.Short term runoff harvesting techniques	b. Long term harvesting techniques:
1. By contour bund: 2. By semi-circular hoop: 3. By trapezoidal bunds: 4. By graded bunds: 5. By rock catchment: 6. By ground catchment:	1. Dug out ponds 2. Embankment type reservoirs *a) Irrigation dam* *b) Silt detention dam* *c) High level bund* *d) Farm pond* *e) Water harvesting ponds* *f) Percolation dam*

III. Flood water harvesting

IV. Flood water harvesting

a. By diverting to graded bund
b. By check dam
c. By sand dam
d. By subsurface dam
e. Flood control reservoir:

I. Roof harvesting:

Roof top rainwater harvesting (RTRWH):

It is a system of catching rainwater where it falls. In rooftop harvesting, the roof becomes the catchments, and the rainwater is collected from the roof of the house/building. It can either be stored in a tank or diverted to artificial recharge system. This method is less expensive and very effective and if implemented properly helps in augmenting the ground water level of the area.

Components of the roof top rainwater harvesting system

- Catchment
- Transportation
- First flush
- Filter

The surface that receives rainfall directly is the catchment of rainwater harvesting system. It may be terrace, courtyard, or paved or unpaved open ground. The terrace may be flat RCC/stone roof or sloping roof. Therefore the catchment is the area, which actually contributes rainwater to the harvesting system.

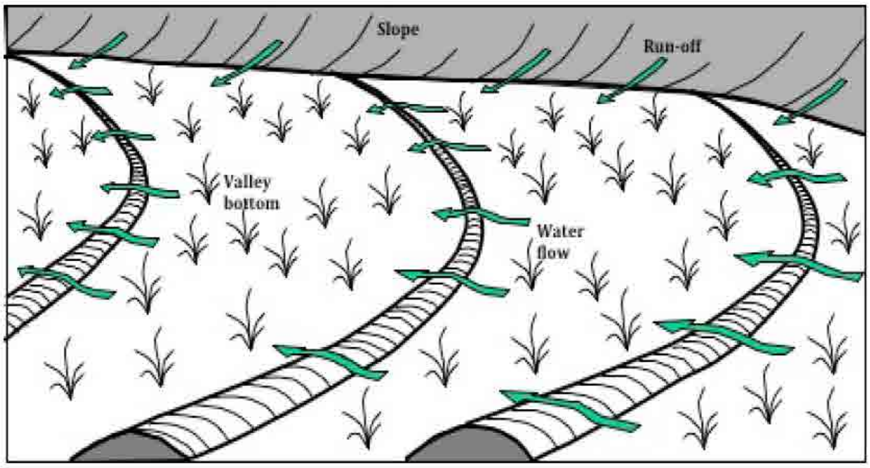
II. Runoff harvesting

Runoff harvesting for short and long term is done by constructing the structures, given as under

a. Short term runoff harvesting techniques

1. By contour bund:

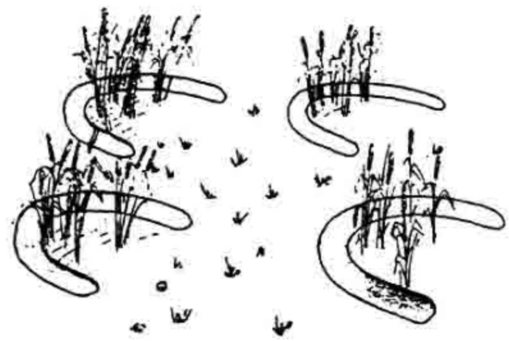
This method involves the construction of bunds on contour of the catchment area. These bunds hold the flowing surface runoff through the area into surrounded space of two adjacent bunds. The height of contour bund ranges from 0.30 m to 1.0 m.



Contour bund

2. By semi-circular hoop:

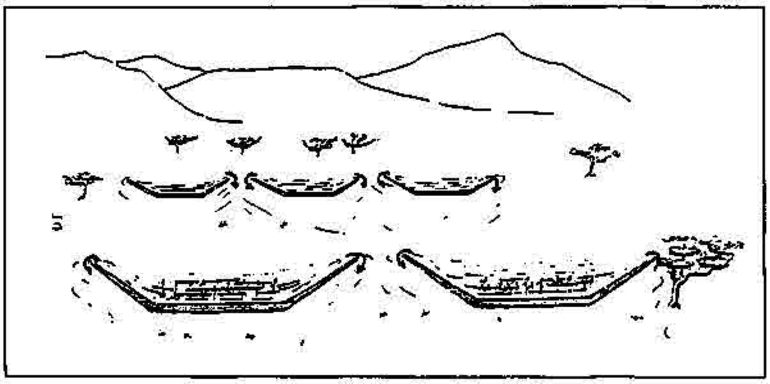
The structure consists of an earthen embankment, constructed in the shape of semi-circle. The tips of the semi-circular hoop is furnished on the contour. The water contributed from the area is collected within the hoop to a maximum depth equal to the height of the embankment. Such type of structures are mostly used for irrigation of grasses, fodder, shrubs or trees etc.



Semi-circular hoop

3. By trapezoidal bunds:

Such bunds also consist of an earthen embankment, constructed in the shape of trapezoids. The tips of the bund wings are placed on the contour. The height of trapezoidal bund ranges from 0.3 m to 0.6 m and width across the tip varies from 40 m to 160 m. trapezoidal bund technique is suitable for that area where rainfall intensity is too high and causing surface flow at peak rate which damage the contour bund. Such type of structures are mostly used for irrigation of crops, grasses, shrubs or trees etc.



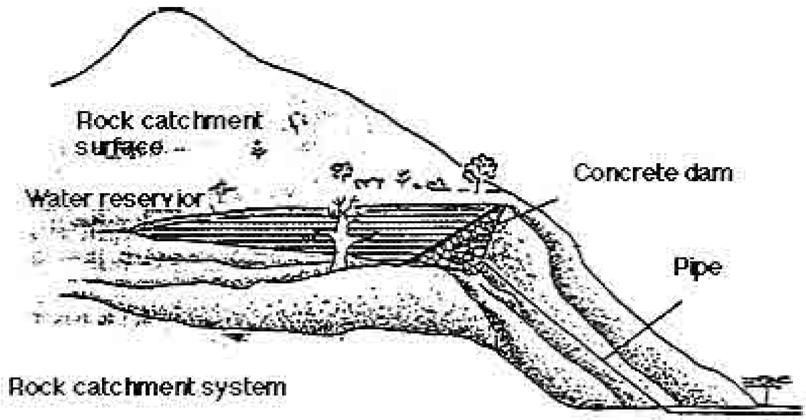
Trapezoidal bund

4. By graded bunds:

Sometimes graded bunds are also referred as off contour bund. They consist of earthen or stone embankment has the slope ranges from 0.5 to 2%. The height of the graded bund ranges form 0.3 to 0.6 m. The bunds constructed below consists of a wing which helps to intercept the overflowing water from the above bunds. This makes just like an open ended trapezoidal bund, that is why this is also known as modified trapezoidal bund. This is used for irrigating the crops.

5. By rock catchment:

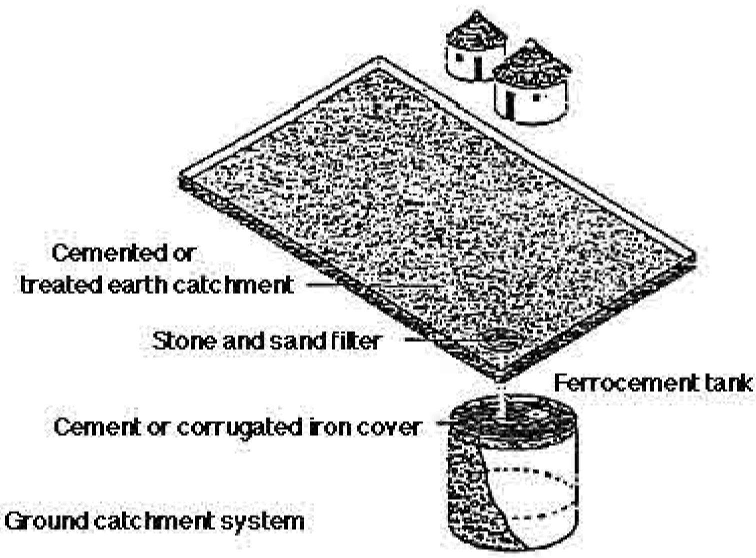
The rock catchments are the exposed rock surfaces used for collecting the runoff water into a part as depressed area. The area of the rock catchment may vary from a hundred sq.m to few thousand sq.m. The runoff formed so, is drained towards the lowest point called as storage tank and is harvested there. The water collected in the tank can be used for domestic stock or irrigation purposes.



Rock catchment

6. By ground catchment:

In this method a large area of ground is used as catchment for runoff yield. The ground is cleared from vegetations and compacted very well



Ground catchment system

b. Long term harvesting techniques:

The long term runoff harvesting is mainly done for building a big water stock for the purpose of irrigation, fish farming, electricity generation etc. It is done by constructing the reservoirs and big size ponds in the area.

Most common long term runoff harvesting structures are of two types,

1.Dug out ponds

2. Embankment type reservoirs

1. Dug out ponds:

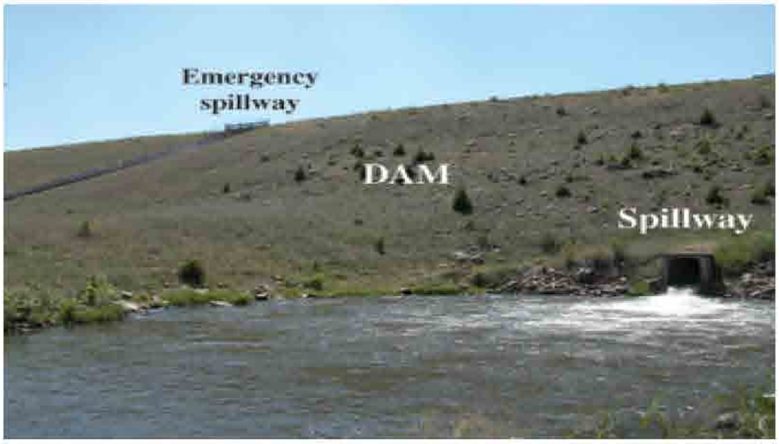
The dugout ponds are constructed by excavating the soil from the ground surface. These ponds may be fed by ground water or surface runoff or by both. It is suitable for land slope less than 4% and where water table lies within 1.5 to 2.0 meters depth from the ground surface. Design of pond is based on the several constraints like desired storage capacity, water depth, catchment area, amount of runoff yield form the area and its peak rate, subsoil conditions, stability of side slopes, suitability of the site and economics of construction.

Dug out pond

2. Embankment type reservoir:

This type of reservoirs are constructed by forming the dam or embankment around the valley or depression of the catchment area called as reservoir. The runoff water is collected into these reservoirs. The storage capacity of the reservoir is determined on the basis of water requirement for various demands and available surface runoff from the catchment.

Embankment type reservoirs are again classified according to the purpose for which they are meant.



Embankment type

a. Irrigation dam:

The irrigation dams are mainly meant to store the surface water for irrigating the crops.these dams have the provision of gated pipe spillway for taking out the water from the reservoir. Spillway is located at the bottom of the dam.

b. Silt detention dam:

This dam detains the silt load coming along the runoff from the catchment area. The location of the dam is at the lower reaches of the catchment. There is a provision of outlet for taking out the water for irrigation purposes.

c. High level bund:

Such dams are located at the head of the velley to form a shape of water tank or pond. The stored water is used to irrigate the areas lying below it.

d. Farm pond:

Farm ponds are constructed for multipurpose objectives, such as for irrigation, livestock, water supply to the cattle feed, fish productions etc.

e. Water harvesting ponds:

The farm ponds can be considered as water harvesting ponds. They must be dugout or embankment type. Their capacity depends upon the size of catchment area.

f. Percolation dam:

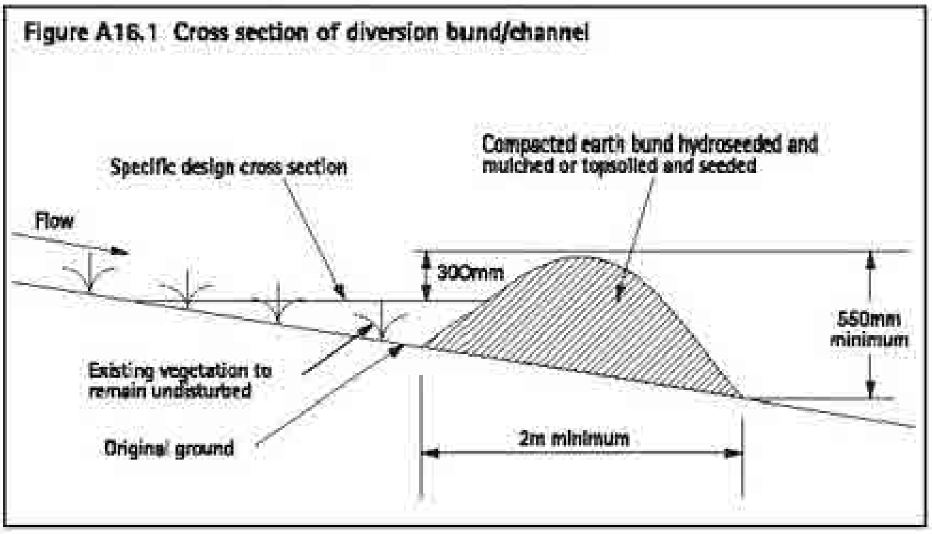
These dams are generally constructed at the valley head, without the provision of checking the percolation loss. The growing crops on downstream side of the dam, receive the percolated water for their growth.

III. Flood water harvesting:

To harvest flood water, the wide vallies are reshaped and formed in a series of broad level terrace and flood water is allowed through them. The flood water is spread on these terraces, where some amount of it is absorbed by the soil, which is used lateron by the crops grown in the area. However, the following techniques are used for flood water harvesting.

a. By diverting to graded bund:

Runoff water is diverted to the area covered by graded bunds by constructing the diversion structure such as diversion drain, which leads to the basin through channels, where crops are irrigated by flooding.



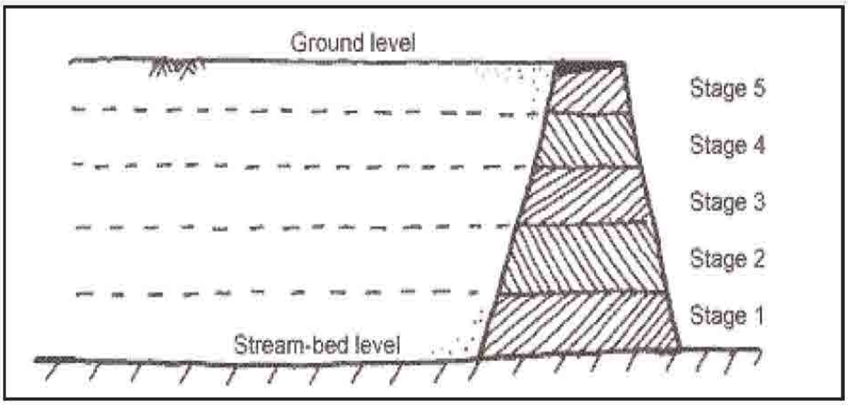
b. By check dam:

In this method the small rock or concrete check dams are constructed across the river or depression to check the flow and allowing for the infiltration into the alluvium under the bed and also replenish the aquifer. Water stored in the aquifer is used by abstracting through the wells or bore holes.

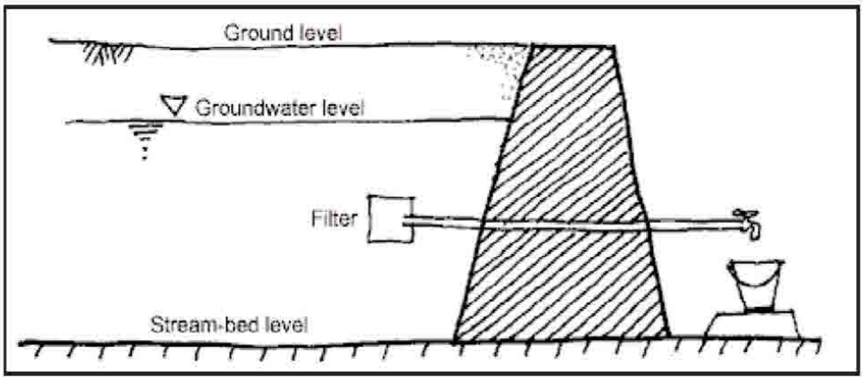
Check dam

c. By sand dam:

Sand dam consists of constructing a dam across the valley or depression for the purpose of reducing the flow velocity of water mixed with sand, by this effect the silt load of runoff tends to deposit over the bed. After some time the bottom of valley is raised due to deposition of sand particles. The silted part of the area covered with dam is known as sand reservoir.



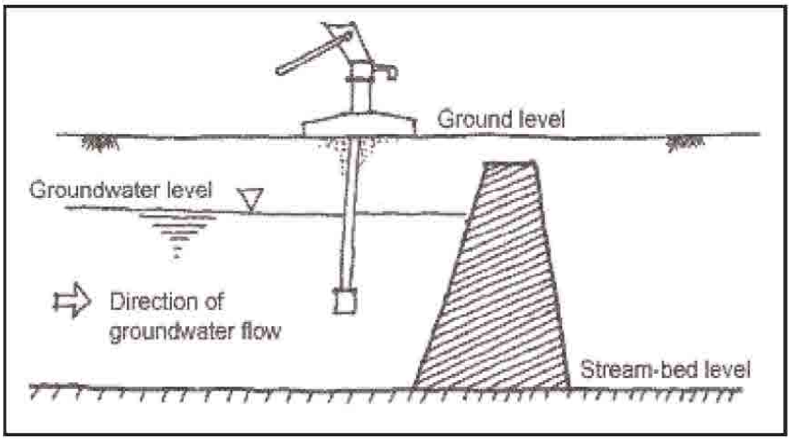
Sand dam built up layer by layer (Image: Rainwaterharvesting.org)



A sand dam with downstream collection point (Image: Rainwaterharvesting.org)

d. By subsurface dam:

It consists of subsurface vertical barriers which are constructed across the valley, down the bed. These barriers intercept the flowing water within the alluvium. The water flow through the valley is stored in sub surface reservoirs created by barriers.



Sub-surface dam (Image: Rainwaterharvesting.org)

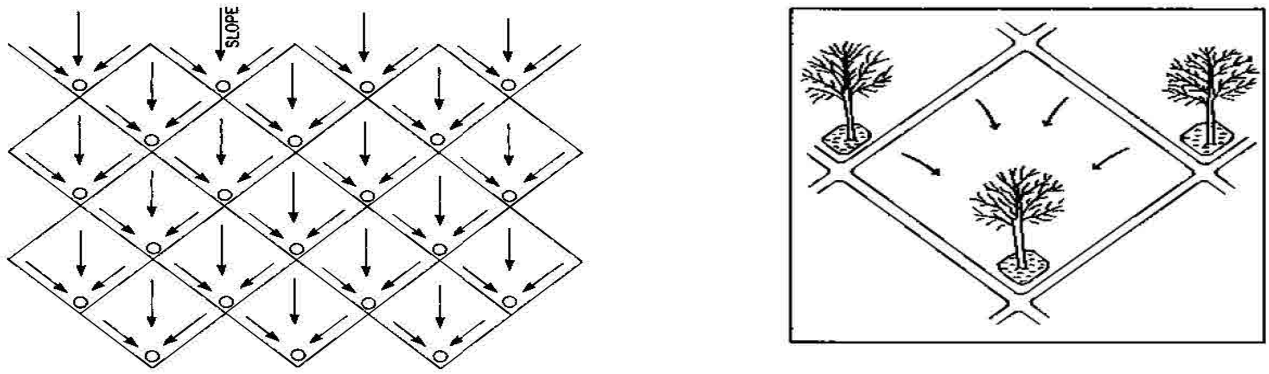
e. Flood control reservoir

The reservoirs constructed at suitable site for controlling the flood are known as flood control. They are well equipped with self operating mechanical outlets for letting out the harvested water into the stream or canal below the reservoir.

Water harvesting for trees and shrubs

Micro catchment system

The micro catchment system is successfully used for the establishment of tree crops. A basin of 250 sq.m is taken as the catchment area surrounded by a low earth bank. At the lowest point within the basin, a deeper basin is excavated about 3.5 m x 3.5 m in which one tree seedling is planted.



Micro catchment system

MICRO IRRIGATION METHODS FOR EFFECTIVE WATER SAVING

Micro-irrigation system is a modern method of irrigation. In, this method which we deliver water slowly. Usually delivered in the form of discrete droplets, continuous drops, streams, etc. Micro-irrigation system is popular these days for its low cost and water-efficiency.Micro-irrigation system is popular these days for its low cost and water-efficiency. We shall get to know more about it in this blog post.

Types of Micro Irrigations System

There are mainly Five Types of Micro Irrigations System

1. Sprinkler Irrigation

Sprinkler Irrigation is a system or a device that delivers water for irrigation. It works in a pressurized form similar to natural rainfall. This form of irrigation provides water efficiently. In addition, this ensures improvement in crop yield. Devices used in this irrigation include high-pressure sprinklers, sprays, or guns. They supply the plant with the exact amount of water necessary for their optimum growth.

2.Drip Irrigation

In Drip Irrigation, Emitters directly deliver water to the plant root into the soil. These emitters optimize and distribute the pressure from the water source using vents, twisters, and convoluted or long flow paths which allows only a limited amount of water to pass through. You can place the emitters on the ground and also planted deep in the soil. The water flowing through emitters moves with no barrier at the desired pace.

3. Spray Irrigation

You can use a jet spray to deliver water and it is in wide use. It can move about easily in any size and you can place it in a lawn or use large farms to watering the crops.

4. Subsurface Irrigation

In this irrigation system, it applies water to plants from below the soil's surface. This micro-irrigation is beneficial and highly efficient. It needs only low levels of water pressure to perform effectively. In this system, tubes and pipes are hidden under the soil for water delivery, which means there is no wastage of water at all.

It uses if the size of the subsurface irrigation system, water application can be exceedingly efficient and uniform. Subsurface irrigation prevents disease and weeds by eliminating stagnation of surface water.

A well- designed subsurface irrigation system can enhance the efficiency of water and fertilizer applications for the better quality of crop yields.

5. Bubbler Irrigation

You can install this system in the area where water needs are high. It applies the water through small streams and fountains, which dissipate water at the rate of approximately 230 liters per hour. It is preferred in which a large amount of water needs to be applied in a short span of time.

Cost of the Micro Irrigation System

The investment cost of micro-irrigation depends on the area that has to be irrigated. Here is a list of micro-irrigation system kits available in the market at different rates for various purposes.

1. Bucket Kit System

A Bucket Kit System- you can use it for smallholdings and gardens. It is suitable for small-scale farmers. It involves a bucket of 15-liter capacity, a 10-meter long drip line tailored with drippers, which can irrigate about 100 plants in approximately 15 meters square area. You can place a bucket at the height of three feet, and you need to fill the water for 3 to 5 times daily.

2. Drum Kit System

A Drum Kit System is suitable for small-scale commercial fruit, flowers, and vegetable farmers. The Drum has a capacity of approximately 200 liters. It can supply water to nearly 500 plants. This system can cover an area of 120- square meters.

3. Micro Sprinkler System

This kit system is ideal for farmers as it comes with the feature of accessing pressurized water. They are beneficial for plantations like groundnut, vegetables, nurseries home gardens, and lawns, etc.

You can link it to tap from an overhead tank or a domestic water drive. It comprises 15 micro-sprinklers. With pipes watering an area of a 250-meter square.

Advantages of Micro Irrigation System

Micro-irrigation systems have gained immense popularity for their efficiency and cost-effectiveness. It lists the advantages of the micro-irrigation systems below

1. Saves water and produces higher yields

Micro-irrigation conserves water as they use pipes or underground tubes. It delivers water directly to the soil surface close to the plant roots – avoiding wastage of water through evaporation or flooding.

Micro-irrigation systems ensure uniform distribution of water by delivering water only wherever necessary. Finally, there will be less evaporation and runoff from both the soil and leaves. According to the experts, micro-irrigation compared to other irrigation methods uses between 30 to 50% less water.

2. Ideal for all soils

The best part of the micro-irrigation system is that it suits every type of soil. For instance, clay soil requires a slow procedure to avoid surface water collection and runoff.

It is possible through micro-irrigation. In addition – sandy soils, need higher emitter discharge rates to ensure sufficient wetting of the soil.

3. An easy way to undertake Fertigation and Chemigation

What is Fertigation?

Fertigation is a method that mixes fertilizer and water that deliver it into plants and crops via an irrigation system. This is a very efficient method as it prevents soil erosion. In other Words, it minimizes the risk of root-contracting and soil-borne diseases.

It also reduces water consumption, use of fertilizers and increases the number of nutrients absorbed by the plants.

What is Chemigation?

Chemigation is the application and delivery of crop chemicals- compost, soil enhancing remedies, growth regulators, sewage, and manure water using an irrigation system. Both these processes require an irrigation system that can distribute the fertilizer or chemical directly into the soil.

This process also gave uniform distribution through the irrigation method. According to the surveys by experts, Micro Irrigation raises the efficiency of fertilizer and chemicals delivery by at least 35 %.

Reduction in resources needed

It is water efficient micro-irrigation helps in cut-down of the labors. One can achieve it via a tube and pipe mechanism-based system.

The automation of the system results in faster and healthier growth of plants and crops. Quick yields result in more immediate returns on investment.

SOIL CARBON SEQUESTRATION TECHNIQUE AS CLIMATE RESILIENT TECHNOLOGY

Carbon sequestration (CS) is an important strategy for the mitigation of climate change (CC) as well as for improving the soil fertility of agricultural soils. Carbon sequestration in crop lands and range lands requires a certain amount of organic matter (OM) presence in the soil called soil organic matter (SOM).

Organic amendments like animal and poultry manures, the incorporation of different crop residues, different types of compost, sugarcane bagasse, peat soils, different wood chips, biochar and good agricultural practices like cover crops, nutrient management, mulching, zero and no-tillage techniques, soil biota management and mulching are effectively used for this purpose. These enhance the SOM and improve the soil's physical and chemical properties which help to sequester more Carbon in soil which ultimately contributes towards CS and CC mitigation.

Atmospheric C removal and storing it in the soils is one of the best options. From soils, agricultural soils are thought to be a major sink and can sequester more and more quantities of C if we adopt agroforestry. It has received widespread credit due to its advantages of helping in agricultural sustainability CC mitigation.

Overall, the agriculture sector has a great potential for CS in the soil as well as in crop plants. Changes in agricultural practice and managements can also result in enhanced CS in them. Application of organic amendments and N fertilizer incurs C emissions to the atmosphere, which must be deducted by increasing SOM.

Carbon sequestration (CS) potential by agroforestry is well understood in semiarid, sub-humid, humid and temperate regions, respectively. Another advantage of agroforestry is soil property enhancement which also enhances the CS in plants and soils. Agroforestry systems are important C sinks but intensively managed agroforestry practice in combination with annual crops is like conventional agriculture which does not contribute in CS. Agricultural practices like conservation tillage is effective in enhancing CS.

Agriculture practices which involve CS

Agricultural practices help in sequestering C in soils such as zero or reduced tillage, crop residue incorporation in fields, nutrient management, preventing OM loss, supplying nutrients and maintaining soil microbes, soil erosion control, vegetation or revegetation, cover cropping, green manuring, crop rotations, agro-forestry, soil rehabilitation, reclamation and use of salt-affected soils for forest plantations and crop production.

Zero tillage and conservation agriculture

Zero tillage is the type of conservation agriculture which does not disturb the soil comprising minimum soil disturbance, crop residues, cover crops and their diversification; this is also promoted for reducing soil disturbance and improving SOM and its sustainability as well as it also mitigates the climate change(CC).

Conservation tillage

Soil organic matter (SOM) is considered as C pool as well as its source while it decomposes. Primary method is to conserve SOM by not ploughing.. Conservation tillage is highly recommended in crop lands as a means of enhancing CS in these soils.

Nutrient management

Agricultural soils can be a sink for atmospheric C concentrations by CS. It is accomplished by the formation of SOM or humus which is limited by the availability of nutrients such as nitrogen (N). Optimization of N can be a good mean for CS. Practices that enhance N in soil are no or reduced tillage and increased crop intensity. Nitrogen additions are important for increasing biomass yield and hence crop residues' decomposition in soil which increases SOM concentration. Increases in SOM were directly related to the tillage practice and N fertilizer application.

Cropping system and intensity

Any modification or change of land use or land management can induce variations in soil C stocks. Intense cropping systems always cause depletion of SOM but applying crop residues, balanced fertilization with NPK and use of organic amendments can increase CS levels. As these amendments also contain 10.7–18% C in them, they also help in CS.

Mulching

Carbon concentration and SOM is increased by adding mulch, and crop residues are widely applied in the form of mulch for CS and crop protection against cold stress. Mulch can increase CS in agricultural soils and additionally, the soil's physical and chemical properties are also improved.

Residues and nutrient management

Crop residues and nutrients especially N help in sequestering C in soils up to 21.3%–32.5% and simultaneously improve soil quality and plant growth. The use of crop residue as a source of CS and keeping the soil in good quality helps in nutrient management and conservation.

Soil biota management

Biological CS is accomplished by microbial activities. Carbon sequestration was recorded higher in soils which were rich in soil microbes like fungi and soil bacteria.

Cover crops

The use of cover crops for the maintenance and restoration of SOM and soil productivity is a popular option. Planting cover crops is a promising option to sequester C in cropping systems by the implementation of recommended management practices.

Organic amendments

Animal manure

Animal manure is the source of C and the addition of animal manure to different crop fields has impacts on C contents. The long-term application of manure increases the SOM significantly

Crop residues

The crop residues are the remains of the agricultural crops. The intensive agriculture system increases the crop residue production significantly. This may increase the SOM and soil aggregation and hence C storage. Agricultural practices such as the addition of crop residues increase the SOM as well as nutrients contents in the soil by integrated nutrient management.

Composting

Composting is the systematic and controlled breakdown of different types of organic matter including animal manure, woody material and other organic waste. Compost application increases Carbon sequestration

Bagasse

The application of different types of biomass in soil is the best technique to enhance CS in the agricultural sites. The application of bagasse as a biomass in the field showed that bagasse has the potential to sequester C at about 1200–1800 t C year−1.

Wood chips

Wood is mostly used as a fuel to cook food and considered as a renewable energy source. Tree plantation can sequester C and fix it by producing high biomass. This biomass can be used to generate chips and pellets and as the alternative of fuel; as a result, it can sequester.

Biochar

Biochar (B) is usually obtained by the breakdown of crop residues, wood chips, at a low temperature range (350–600°C) in the atmosphere having very little or no oxygen. It has long-term benefits including increase in soil pH , increases in crop yield, maintaining the cation exchange capacity, nutrient retention and water-holding capacity. Biochar also reduces the emissions of others greenhouse gases like methane and nitrous oxides

ROLE OF AGROFORESTRY MEASURES FOR SOIL AND WATER CONSERVATION

Soil and water conservation has been a global concern in this millennium. Increase in mainly two principal anthropogenic activities, i.e. land use and fossil fuel burning has caused the soil and water degradation. Soil and water degradation are very crucial issues in the modern era . Soil and water are the major input of agricultural production. With degraded land and polluted water, survival of human being is in danger. Soil and water degradation are connected to total environmental existence. Greenhouse effect & water pollution are two major concerns of global consequence. Therefore, to resolve these problem sustainable soil and water conservation option is given due emphasis like that of agroforestry.

"Agroforestry is a collective for land-use systems in which woody perennials are grown in association with herbaceous plants or livestock in a spatial arrangement, a rotation or both". It has both productive and services function. Among the productive function 3Fs (fuelwood, fodder and fruit) are the most important besides construction wood, gums, resins, medicines, fibres and a host of other economic base and greater food security.

Agroforestry is a combination of agricultural and forestry technologies to create combined, diverse and productive land-use systems. A broader field is that of soil and water conservation is reduction in water loss through runoff is an integral part of soil conservation. In turn, soil and water conservation aim is the conservation of natural resources which covers also the conservation of other resources including vegetation (forests, pastures) and wildlife.

Concept of soil and water conservation

Soil conservation is described as soil fertility maintenance through control of erosion, maintenance of organic matter, soil physical properties, nutrients and avoidance of toxicities. Soil and water are conserved through reduction in soil loss from runoff and increasing of infiltration rate. The only crop is not enough to lower the velocity of runoff. When trees are grown with crops gives much strength to the soil through the permeability of water, as a result, water is also conserved. Trees with deep root system improve groundwater quality through trapping of nutrient, metals which are deposited in surface and subsurface of soil. As a result, soil fertility become enriched.

Positive effects of agroforestry on soil and water

Based on various experimental facts, beneficial effects of agroforestry on soil, such as:-

- Reduction in loss of soil as well as nutrients through reduction of run-off
- Addition of carbon and its transformation through leaf, twig and bark fall etc.
- Nitrogen improvement by fixation of nitrogen- fixing trees, shrubs etc.
- Enhancement of physical conditions of soil such as permeability, water holding capacity, and drainage etc.
- Release and reutilizing nutrients by moving biochemical nutrient cycling
- More microbial associations and addition of more root biomass
- Moderately effect on extreme conditions of alkalinity & soil acidity
- Lowering effect of the water table in areas where the water table is high

Agroforestry for erosion control

Alley cropping or hedgerow cultivation is very effective in controlling soil erosion in the hilly area.

- Leucaena leucocephala
- Gliricidia sepium
- Indigofera tysmani
- Fleminigia spp.
- Desmodium rensonii

Grass species for controlling runoff and erosion in the hilly area.

- Vetiver zizanoides and
- Thysanolaena maxima

It was found that runoff and soil loss significantly reduced when small watersheds with agriculture were replaced either by trees and grasses (silvipasture) or with mechanical measures.

Agroforestry for improving soil fertility

The effects of long-term cultivation of crops under different agroforestry systems as compared to crops alone as:

- The total content of N was higher in soil tree crop stand as compared to crop systems in topsoil (0-15 cm).
- The C: N ratio was narrow in tree species system as compared to sole crop stand.

Nitrogen fixation and nutrient cycling

- Nitrogen-fixing trees can make substantial nitrogen and extensively increase nitrogen inputs to agroforestry systems.
- Increase in nutrient use efficiency through agroforestry can be achieved by increasing the cycling of nutrients from tree litter, which reduce, by leaching and erosion losses.
- The deep rooting system of trees help in absorbing nutrients from the deep soil that crop roots cannot reach and recycle them to the surface 15 cm soil layers through the addition of litter and have a potential to capture and recycle a larger amount of nutrients.
- It is observed that woody species in Alley cropping provide higher amount of nutrients than other species in shade system and infertile soil with Alley cropping system.

Agroforestry Systems as carbon Sink for soil fertility

- In India, average sequestration potential in agroforestry has been estimated to be 25 ton C ha-1 over 96 mha, but there is a considerable variation in different regions depending upon the biomass production.

Changes in chemical properties of the soil

- The Nitrogen content and Cationic Exchange capacity(CEC) increases with L. leucocephala as alley crop. Addition of organic matter through nitrogen fixation, significantly increase N in soil and other chemical properties like CEC, organic carbon, pH and nutrients availability.

Changes in physical properties of the soil

- Trees can improve the physical properties by adding organic matter like soil structure, porosity, and water holding capacity etc.; modify the temperature by shading; and litter cover and tree species enrich the soil by adding both above and below-ground biomass into the soil system.
- The effect of tree species on bulk density (BD), organic carbon (OC) and porosity of the soil is significant. The water-stable aggregates (> 0.25 mm) increases significantly under the different multipurpose tree species as well as Soil erodibility decreases.

Water conservation through Agroforestry

- Tree species improve moisture retention capacity of the soil and hydraulic conductivity as well as moisture storage in both dry season and the rainy season .

Agroforestry system in improving soil water quality

- Agroforestry practices such as windbreaks and shelterbelts reduce wind velocity and thus limiting wind erosion.
- Excess fertilizer is washed away from agricultural fields via surface runoff or leached into the subsurface as a result contamination of water sources and deterioration of water quality.
- Agroforestry system help clean runoff water by reducing the velocity of runoff by promoting infiltration, sediment deposition, nutrient retention and improve groundwater quality by capturing nutrients.

Soil conservation is the maintenance of soil fertility which requires control of erosion, maintenance of organic matter, soil physical properties, nutrients and water is also stored through reducing the erosive force of rainfall as well as enhancing infiltration rate. Effects of different multipurpose trees on soil physical properties, soil water retention and nutrient availability of soil are superior as well as organic carbon is higher in different agroforestry system than sole cropping system. Agroforestry is a sustainable land-use system that has the potentiality to conserve soil and water for the production practice.

INDIGENOUS TECHNICAL KNOWLEDGE ON SOIL CONSERVATION

SOIL AND WATER MANAGEMENT

- For soil improvement in 'theri' lands of Tuticorin district, 200 tonnes of tank silt are applied per acre followed by 50 tonnes per year for the next few years.
- About 10 kg. of neem cake is soaked in 10 lit. of cow urine along with ½ kg. of waste asafoetida and left over night. In the next day, it is sprayed for 1 ac. after dilution as liquid manure.
- Outer shells of tamarind fruits are applied in the field to control Cyperus rotundus.
- About 10kg. of dried cow dung is ground into fine powder and mixed with ash (obtained from brick kiln) dusted in the early morning, to control pests and diseases.
- Consolidation of lands gives better results even they are less fertile.
- Fields which are nearer to rivers will give lesser yield
- Better yield is obtained from the wetlands near water sluice of canals and the dry lands near foot hills.
- Laying stone bunds around the fields across the slope for preventing soil erosion and for conserving moisture.
- Planting vettiver *(Vetiveria zizanoides)* slips across the slope or around the fields to prevent soil erosion.
- To minimize soil erosion perennial vegetation is grown on the field bunds.
- New garden land and old wetland will yield better.
- Intensive care is required for wetland crops as compared to the garden land crops.
- Water logged dry lands are unsuitable for cultivation.
- Soil character decides the choice of crops for cultivation.
- Red soil is suitable for continuous cropping.
- Black soil has more water holding capacity than the red soil.
- Sandy soil is less suitable for the cultivation of many crops.
- Excessive application of farm yard manure (FYM) improves the soil texture.
- Tank silt is applied to increase the soil texture.
- Manures and fertilizers are applied based on soil character.
- If the weed growth is profuse after the rains, it indicates high soil fertility.
- However the low soil fertility is indicated by the growth of the weed Aduthinnapalai*(Aristolochia bracteolata).*

- Addition of red soil to black soil increases the fertility of the black soil and vice versa.
- Practicing sheep/cattle penning during summer season to improve the soil fertility.
- Practicing mixed cropping or inter cropping of legumes in rain fed areas to maintain the soil fertility.
- Cultivating Kolingi *(Tephrosia purpurea)* in between the fruit trees in sloppy lands to prevent soil erosion and to improve soil fertility.
- High moisture content in the soil is identified with the occurrence of 'Nuna' tree *(Morinda tinctoria).*
- For moisture conservation deep Ploughing is done during summer.
- Land is well ploughed and powdered to conserve more moisture.
- Application of tank silt (taken from black soil tanks) on the red soil fields to increase the water holding capacity of the red soil.
- Raising and Ploughing daincha *(Sesbania sp.)* and sun hemp *(Crotalaria juncea)* the field before flowering increase water holding capacity at the soil.
- It is better to grow sorghum, finger millet and chilies if the water is saltish.
- Irrigation is given to any crop at a stage that while walking on the fields, our foot should not create any print on the soil, which is taken as the indication.
- Growing 'Poovarasu' *(Thespesia populnea)* tree near the wells reduces water loss through evaporation.
- Wetlands having 'Aarai' weeds (Mars/tea *quadrifolia)* and garden lands having 'Arugu'*(jlfanodan dactylon)* weeds give better yields.
- Red soils having 'Arugu1 *(Cyanodan dactylon)* weeds and black soils having nut grass*(Cyperus rotandus)* weeds are the best of their kind.
- Sowing densely the daincha *(Sesbania sp.)* green manure and ploughing in-situ at its flowering to correct alkaline soils.
- Growing sun hemp *(Crotalaria juncea)* in alkaline soils and ploughing in-situ before flowering to rectify its alkalinity.
- Application of 'Pirandai' *(Cissus quadrangularis)* to reduce alkalinity.
- Neem leaves are applied to correct alkalinity.
- Application of shells of neem seed to reduce salinity in soils.
- Application of neem cake to correct salinity.
- Palmyra *(Borassas flabelliter*) leaves are cut into pieces and applied in large quantity to correct alkalinity.
- To correct alkaline soils, pungam *(Pongamia pinnata)* leaves, or outer shells of tamarind fruits are applied.

- Mixing and applying coir waste with compost to correct alkalinity.
- Application of sugarcane bagasse and sediment after extraction of country sugar to correct alkaline soils.
- Putting leaves and branches of Indian gooseberry *(Phyllanthus distichus)* in the wells reduce salinity in water.

Other Important ITKs

- Achieving fine tilth is better than applying manures.
- It is better to plough intensively than extensively.
- It is better to have deep ploughing rather than shallow ploughing for good crop growth.
- Plough four times for garden land and seven times for wetland.
- Summer Ploughing gives good crop in the ensuing season.
- Tying paddy straw around the sole of country plough to make a wider furrow while forming broad bed and deep furrows.
- Garden lands are ploughed deep to conserve more moisture.
- Yield of almost all the crops depends on seed quality.
- Even if it is a quality seed, it should be a dried one because well dried seeds will have higher longevity and keeping quality.
- Atis better to change the seeds at least once in two years.
- To maintain the seed viability and prevent it from outside damage, the outer shell is not separated.
- The seeds are generally stored along with the leaves of neem *(Azadirachta indica), pungam(Pongamia pinnata)*, notchi *(Vitex npgundo)* and thulasi *(Leucas aspera).*
- Six weeks nursery period is enough for *six* months duration of the crop.
- Shallow sowing is followed in dry lands.
- Severing the broadcasted seeds in dry lands with soil.
- Dragging, over the fields, the thorny branches with weight over them for covering seeds the sown on dry lands.
- It is better to start planting from 'Sani moolai' (north east) of the field to get higher yields.
- It is better to perform sowing and planting operations during evening hours.
- Even if the seeds are of good quality, they must be sown in the right season only.
- Sowing in the right season is better even on a poor land.
- The best seasons for crop cultivation/sowing are the Tamil months viz.. 'Chittirai' (Apr.), Aadi (Jut.), Aavani (Aug.) and Thai (Jan.).

- Crops sown on eighteenth day *(Aadipperukku)* and new moon day of the Tamil month 'Aadi' (Jul.-Aug.) yield better.
- On new moon day or up to 48 hours before the new moon day, it is better to do sowing/planting crop and cutting a tree.
- During 'Keelnokku' days (i.e. when moon moves from north east to south east direction) it is better to do sowing/planting/ harvesting of crops that bear under ground, starting preparation of compost and application of compost to field, pruning and cutting of trees, planting tree , seedlings and ploughing the fields.
- During 'Melnokku' days (i.e. when moon moves from south east to north east direction) it is better to do budding and layering operations, sowing/planting and harvesting of crops that bear above the ground.
- Seeds sown 48 hours before full moon day germinate quicker and grow faster.
- It is better to avoid sowing on Ashtami (eighth) and Navami (ninth) days from full moon and new / moon days.
- Sowing is done on Tuesdays and Saturdays.
- The crop sown on new moon day escapes from pest and diseases.
- Higher yield of tamarind is considered as an indication for good agricultural season and higher yield of mango for poor season.

RECLAMATION OF DEGRADED LAND THROUGH FORESTRY PRACTICES

INTRODUCTION

Land, a non-renewable resource, is vital for all primary production systems. Pastures and crops are the two most extensive forms of land use, occupying 25% and 12% of the global land surface. The land also serves as storage for water and nutrients required for all living micro- and macro-organisms. However, fast depletion of natural resources such as forest soil, water, minerals and exponential increase in population rate are the serious constraint◇ in environmental conservation, as well as land restoration. The increasing demand for food, energy and other human requirements depends upon the preservation and improvement of the productivity of land but, as above said, land resources are limited. India, alone is the home of 16 % of global population however, it accounts for only 2.42% of the total land area. The per capita availability of land has declined from 0.89 hectare in 1951, to 0.37 hectare in 1991 and is projected to slide down to 0.20 hectare in 2035.

Land degradation

Land degradation also refers to means loss of biological or agricultural productivity or erosion in the land's capacity to support desirable vegetation (i.e. crops, forests, pastures) and to maintain the yield level over the years of use .

According to the National Remote Sensing Agency and Forest Survey of India, 60% of the total area under cultivation is substantially degraded. Most of this damage is in the form of loss of topsoil. With all these facts the present chapter will focus on the causes and types of land degradation and their possible sustainable restoration strategies using forestry practices and their potential benefits effects on environment.

CAUSES OF LAND DEGRDATION AND ITS TYPES

Land degradation may occur through different physical, chemical and biological processes which are directly or indirectly induced by human activities.

These include soil erosion, compaction, acidification, leaching, salinization, decrease in cation retention capacity, depletion of nutrient, reduction i n total biomass carbon and decline in biodiversity. Soil structure is major factor for all forms of degradative processes. it also affects the provision of ecosystem services. Anthropogenic activities are mainly responsible, not only for the degradation of land hut also important for improvementof land

i. **Climate:** higher evaporation than precipitation, drought, short duration rain fall with high intensity, high velocity winds, storms etc.

ii. **Soil factors:** Slope, course texture, water impermeability, compactness etc.

iii. **Management factors:** Improper land use and cropping system without soil conservation measures, excessive use of chemicals, shifting cultivation, deforestation etc

iv. **Socio economic and policy factors:** Population pressure, pove1ty, declining land: population ratio, ineffective land policies etc.

The following are the various types of land degradation

a) **Wind erosion***:* When soil is devoid of vegetation, it is left exposed to other elements, leaving it hare and loosening the soil pa1ticles. The top soil is then blown away by air, leaving poorer quality sub-soil to remain.

b) **Water Erosion:** Water erosion is similar to wind erosion, except instead of wind removing the pa1ticles; it is due to the force of running water and heavy rainfall. Such events include flash flooding, where water due to abrupt rainfall can sweeps down, taking with it everything in its path. The uproot trees, move boulders and demolish bridges and buildings, along with the precious topsoil. These floods are very dangerous.

c) **Overgrazing:** Overgrazing is a common problem in many parts of world. It is caused by animals, generally sheep, cattle, or other wild animals, all concentrated in the one area, all feeding on the grass and shrubs. Grass and shrubs hold the soil firmly together. The removal of grass and shrubs leaves the soil hare and susceptible to wind and water erosion. The soil can he broken up or compacted by hooves, this makes the problem worse. It also increases runoff where water is not absorbed into the ground hut it runs off.

d) **Dry land Salinity:** When land is cleared from all the natural vegetation, groundwater can slowly rise to the surface of the soil because trees intercept the rain water, therefore the water table doesn't rise. The water table rises, as the roots from trees keep it down. The water is very salty and only certain trees can withstand the salinity le vel. When the water table rises, the salt kills trees and crops that cannot survive the concentration of salt in the water. When the water has evaporated, all that remains is the salt, therefore rendering the soil useless.

e) **Soil Acidification:** When ce1tain chemicals are used on the soil, for various reasons including pesticides; removal of salt from the surface and the soil; acid rain; the growth of ce1tain crops; ce1tain animal wastes; etc, these chemicals are often absorbed into the soil and become pmt of the soil-structure. With these chemicals now part of the soil, the soil may become acidic and therefore crops and pastures will not grow. Soil acidification can lead to a productivity decline up to and equal to 50%.

f) **Irrigation Salinity and Water logging:** Irrigation salinity is when the irrigation water, used to provide water for crops and pasture, seeps down to the water table, with all the dissolved salts, rises and kills the crops and grass, as they are not used to the salty soils.

g) **Water logging:** it is very similar to irrigation salinity. The only thing that is different is that the fanner i1Tigates his crops excessively, to the point whereby the water then seeps down to the water table whilst all this extra water saturates the surface, there is more water in which the salts are able to he dissolved.

h) **The Replacement of Natural Vegetation with Pasture:** With new pasture, come new irrigation and more water. The natural vegetation is more adapted to the salinity of the soil and the water table. Most native trees have deep roots that keep the water table down, hut if these deep roots are removed then the water table will rise due to more water and by the time that the water table reaches the roots, the pasture will die and the water evaporate, leaving behind salt pans, a crusty formation of salt on the surface. With saltpans on the surface, it is very hard to try and remove the salt from the surface and the soil.

i) **Soil-Structure Decline:** Soil-structure is a complex soil composition.

This comprises of air, organic matter, water, mineral particles, nutrients, etc. The different types of organic matter, mineral particle and nutrients make the soil-structure types more diverse. Soil- structure declines when all these different types of nutrients and organic matter are somehow drawn from the soil and limited nutrients are left in the soil. Things that can cause soil-structure decline, are erosion of any kind, some agricultural cultivation practices, over worked soils that do not have time to replace nutrients etc; the use of pesticides can affect the soil-structure, as the insects' dead bodies, and wastes contribute to the soil-structure diversity; and the chemicals in some pesticides may have effects on the soil and the structure of the soil, short-term and long-term.

The term 'desertification' does not refer that; desert are steadily advancing or taking over neighboring land. According to United Nations Convention, 'desertification' is a process of "land degradation in arid, semi- arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities". Patches of degraded land may develop hundreds of kilometers far from the nearest desert. These patches can expand and join together, creating desert-like conditions. Desertification contributes to other environmental crises, such as the loss of biodiversity and global warming.

RECLAMATION OF DEGRADED LANDS

There are number of alternative methods of reclaiming degraded land The selection of a reclamation technique depends on the types of degraded land, degree of degradation, and costs and benefits involved in the process. Afforestation has been identified as economically viable and ecologically appropriate method and must be implemented in a proper way depending on local physical and human environmental condition. However, afforestation on a large scale requires huge investment .Some of the methods dealing with reclamation of degraded lands through forestry practices are

a. Reclamation of Degraded Land through Agro forestry Practices

Agro forestry has attracted considerable interest in recent years as it can help low resource farmers with physical and socioeconomic constraints to maintain or increase agricultural productivity. Agro forestry is particularly beneficial in rain fed systems where high energy input and large scale farming is practically impossible. Agro forestry practices not only minimize the land degradation but also increases the overall production of the system. The components of agro forestry exploit different vertical layers both above and below ground which signifies greater resource utilization efficiency for optimizing resource use. Ecologically smn1d agro forestry is a useful path, in comparison to chemical fertilizers, enhancing soil fertility leading to global food security and environmental sustainability.

There are numerous advantages of agro forestry systems like these systems have higher productivity than mono-specific system-;, especially on degraded sites . In agro forestry practices trees can add a significant amount of nutrients into the soil. The productivity and fe1tility of soil is mostly related to the growth of nitrogen-fixing trees or deep-rooted trees and shrubs plantation of leguminous tree is encouraged as they fix a substantial amount of nitrogen from the atmosphere and also buildup soil organic matter. Rate of nitrogen fixation by leguminous herbs varies from 40-200 kg N ha^{-1} $year^{-1}$. Trees improve the physical prope1ties like structure, porosity, and water holding capacity etc. of soil by addition of organic matter and also modify the temperature via shading and litter cover. Agro forestry systems have the potential to control erosion, improve soil fe1tility, and subsequently lead towards sustainable land use. It has been reputed that financial returns generated from agro forestry system are usually much higher than return from continuous unfertilized food crops around the developing world.

Although trees are expected to improve soil fertility, the extent to which different agro forestry practices depend on tree species, stocking level, growth rate and the input of litter. The general belief is that agricultural crops grow poorly beneath or near trees. This is considered an expression of competitive interaction between trees and crops grown together and is viewed as a negative aspect of agro forestry. Indeed, this view has led to the argument that one should shy away altogether from simultaneous agro forestry systems, especially in drier climatic zones and focus on fallow rotations .Such arguments do not, however, consider the system productivity and value from a holistic viewpoint.

Achieving synchrony in nutrient release through organic matter turnover is yet another challenging task. Below-ground interactions are the most important aspect concerning yield reduction in the semi-arid tropics where water is the prime factor limiting crop growth. it is therefore import to select for trees with appropriate root architecture in order to achieve spatial complementarily and avoid major crop yield losses.

Tree species for agro forestry practices are selected on the basis of potential survival growth, tolerance ability sodicity, and ameliorative capability without using chemical amendments. Trees have multiple functions in any ecosystems and there is no alternative in the maintenance of ecosystem balance. Success or collapse of the ecosystem management depends on the site conditions, selection of plant species, and planting techniques.

Plant species suitable for alkaline, sodic and acidic soil

Soil Types	Soil characteristics	Suitable plant species
Saline soils	High salt content. high water table. pH < 8.2 > 7.0	*Atriplex, Prosopis, Tamari.r, Casuarina, Kochia, Zizyphus, Salvadora and Acacia, Termnalia arjuna, Albizzia procera, Eucalyptus* 'hybrid'. *Leucaena leucocephala,*
Alkali or sodic soils	Contains excess soluble sodium salts capable of alakaline hydrolysis. pH> 8.2.	**Plants tbat can tolerate more tban pH 10.0** *Prosopisjiliflora, Acacia nilotica, Casuarina equisetifolia, Tamari.r articulata, Achras japot, Tamarir aphylala etc.*
		Plants tbat can tolerate pH 9.1 to 10.0 *Pitchecellobium dulce, Salvadora persica, Salvadora oleoides, Capparis decidua, Terminalia arjuna,Cordia rothii, Albizzia lebbek, Pongramia pinnata, Sesbania sesban, Eucalyptus tereticornis, Parkinsonia aculeata, Cassia carandus, Psidium guajava, Zizyphus mauritiana, Aegle marmelos, Emblica officina/is, Punica granatum, Phoenix dactylifera, Tamarindus indica, Syzygium cumuni, Eucalyptus microtheca, Casurina equisetifolia* etc.
		Plants tbat can tolerate up to pH 9.0 *Acacia auriculiformis, Azadirachta indica, Melia azaderach, Populus deltoides, Grewia asiatica, Vitis vinifera, A4angifera indica, Kijellea pinnata, A4oringa oleifera, Grevillia robusta, Butea monosperm, Pyrus communis, Sapindus laurifolius, Ficus sp.* etc.
Acidic soil		**Well adapted** *Alnus nepalensis, Parkiajavanica, Parkia facataria, A4ichelia oblonga, Melenia arborea* **Moderately adapted** *Acacia auriculiformis, Michelia alba, Michelia lenigata* **Less adapted** *Leucaena leucocephala, Robinea pseudoacacia, Oyptomeria japonica, Oyptomeria torulosa, Pinus kesiya* etc

The initiation of ago-forestry programme minimizing the land degradation. Research is needed in specific land degradation situation to generate appropriate technologies. For reclamation of saline soils plant species which can withstand high salt content and thrive under high water table conditions should be selected for planting. In India reported that Acacia *nilotica* and *Euca yptus terticornis* can lower the soil pH from 10.5 to 9.5 in five years and lower electrical conductivity from 4 to 2 with tree establishment assisted by addition of gypsum and manure .For acidic soils suggested plantation of *Alnus nepalensis, Parkia javanica, Parkia facataria, A.fichelia ohlonga* and *Afelenia arhorea*, as these trees are highly adapted to acidity of soil

The tree species like *Prosopis jillflora, Acacia nilotica, Casuarina equisetfflhlia, TamarLt articulata, Achras japota* etc. can tolerate more than pH 10.0 and these trees are recommended for reclamation of alkali soi ls. Local connnunities play major role in reclamation and rehabilitation of degraded lands in both developed and developing countries. Alkali / sodic soil contain excess soluble salts which interferes the crop plant" growth as they are capable of alkaline hydrolysis. Some trees like *Prosopis jullflora, Acacia nilotica, Casuarina equisetiolie, Tamarix articulata, Achras japota* etc are capable of tolerating pH more than that of 10 Trees such as *Terminalia arfuna, Salvadoraper sica, Cordia rothii, Euca yptus terecornis, Zizyphus mauritiana, Emhlica rdficinalis, Phoenix daczyl(fera, Tamarindus indica, . yzygium cumuni* etc can tolerate pH 9.1- 10.0. However, *Azadirachta indica, Afelia azaderach, Aforinga ole(fera, Vitis vinfera*, Butea *monosperma, Ficus sp.* etc. can tolerate up to pH 9.0 (Dagar et al., 1994; Hasan and Alan1, 2006)

Perennial woody vegetation are capable of recycling nutrients, maintaining soil organic matter and protecting the soil from surface, erosion, and runoff, agro forestry systems are the appropriate management of acid soils. Tree species like *Alnus nepalensis, Parkiajavanica, Parkiafacataria, Michelia ohlonga, Afelenia arhorea* etc.are highly adapted to acidic soil, whereas *Acacia auricul(fhrmis, Afichelia alba, Afichelia lenigata* etc. and less adapted eg. *Leucaena leucocephala, Rohinea pseudoacacia, Cryptomeriajaponica, Cryptomeria torulosa, Pinus kes(va* etc. are moderately adopted. The involvement of local comnmnities and their knowledge of tree characteristic is the essential element of restoration success. The restoration programs provide a number of ecosystem services with high value for supporting human livelihoods viz. carbon storage, regulation of climate and water flow, provision of clean water, and maintenance of soil fertility

Reclamation of Degraded Land through Bioenergy Plantation

Bio energy plantation is increasing attention around the world since it might offer new opportunities for sustainable development, hut on the other hand it also cat Ties significant risks. The rise of commodity prices, the negative impact on food security and climate change represent different challenges to he overcome before the full potentials of bio energy can he realized. In the context of the development of bio energy, issues relating to agriculture need special attention. Bio energy development is always linked with food security. Farmers, having the choice to conve1t their food crops to fuel crops, naturally expect a high return from their farm land, thereby generating a scenario where food production falls. Bio energy is one of the most important potential sources of sustainable rural development for developing countries. if bio-energy plantation is combined with restoration and reclamation processes it provides benefits related to secure and economically viable energy supply, climate and soil protection and social development and equity. The most of the bioenergy plants like *Jatropha, Simmondsia chinesis, Pongamia pinnata, .Aforinga ole(fera, .Afadhuca indica, Ricinus communis, Citrullus colocynthis* etc. have an advantage especially where soil quality is poor and barely sustains other crops. Jatropha can he easily grown on heavy metal contaminated soil by adding dairy sludge and biofertilizer to soil. The reclamation of such soil can he done by using bio energy plantation as the outputs of these systems do not enter into human food chain. These bio-energy plantations can flourish on poor soils in arid or semi-arid environments and are able to withstand long drought and build pavement to restoration of degraded ecosystems particularly in arid and semi arid regions. it is reported that bio energy plantation like Jatropha is suitable for reclaiming marginal land were crop cultivation is not possible and convert it into arable land. However, the oil seed production under marginal conditions is not yet validated . Establishing large-scale bio fuel plantations on these lands is promoted as a potentially sustainable alternative to conventional energy crops on productive arable lands .

Three different types of production systems are of most interest: the first comprises the cultivation of oil-bearing plants, to be used for the generation of biodiesel, a first-generation biofuel. Relevant crop species are Jatropha *(.Jatropha curcas* L.), Castor *(Ricinus communis* L.), Pongamia *(Pmrgamia pimrata) and* oil palms *(Elaeis* sp.) . The second, crop mixtures of perennial grasses short-rotation woody crops forest plantations, and agroforestry systems may he established on degraded lands as feedstock for the production of second-generation biofuels, e.g. (ligno)cellulosic ethanol (besides more conventional food, fodder and timber uses). The third, production system of most interest features crop species with novel traits which may he developed using modern plant breeding technology; for example, high-yielding, N-fixing warm season grasses with improved biomass quality might he used as substrates for designer fuel production .

About 75% of the world's dry lands (45,000,000 km^2) are affected by desertification, and every year 6,000,000 hectares of agricultural land are lost and converted to virtual desert. The United Nations Environment Programme has estimated that 4.5 billion dollars will he needed to he spent every year for the next twenty years to prevent the process of desertification. The main cause of desertification is the removal of vegetation, which in turn leads to unprotected, dry soil surfaces, which may blow away with the wind or are washed away by flash floods, leaving in fertile lower soil layers that hake in the sun and become an unproductive hardpan. However, the other factors that can trigger desertification are the overgrazing, cultivation in marginal lands (i.e. lands on which there is a high risk of crop failure and a very low economic return), growing population that increase pressure on fragile land resources and inappropriate agricultural technologies.

BENEFICIAL EFFECTS OF FORESTRY PRACTICES

Forestry practices are the best possible way for the reclamation of degraded lands worldwide through improving the quality of forests and re- green degraded land provides much scope for carbon sequestration. Such afforestation programmes are also advantageous to arrest soil degradation, to improve soil fertility, to provide renewable fuel timber and non-timber forest products as well as to provide livelihood to millions of poor people worldwide. The anthropogenic emissions due to fossil fuel combustion and cement manufacture are estimated at – 30 Pg C between 1850 and 2006, and an additional 158 Pg from land use change and soil cultivation. Additionally, the emissions due to fossil fuel combustion have increased to be 7.0 Pg yr^{-1} in 2000 to 8.4 Pg yr^{-1} in 2006 . The concentration of atmospheric CO_2 in 2006 of 381 ppm is the highest since several million years. Total emissions due to anthropogenic activity are estimated to he 7.0 Pg C yr^{-1} for 1970-1999, 8.0 Pg C yr^{-1} for 1990-1999, and 9.1 Pg C yr^{-1} for 2000-2006. For the aforesaid periods, the atmosphere has absorbed 3.1 Pg/yr, 3.2 Pg yr^{-1} and 4.1 Pg/yr, respectively. The capacity of the natural sinks (e.g., land, ocean) was 56.3%, 60.0% and 54.9% for 1970-1999, 1990-1999 and 2000-2006 periods, respectively. The capacity of land sink alone for the same period was 28.1 %, 27.2% and 24.2%, respectively. Thus, the progressively decline in capacity of land as sink has been reported this is probably because of an increase in the extent and severity of dese1tification and degradation of world soils and ecosystem-; .There is a close relationship between global warming and dese1tification process. The process of dese1tification is likely to he exacerated by the current and projected global warming. it has been estimated that land-use change in developing countries could contribute to global emissions to the extent of about 1.6 billion tonnes of carbon .Money spent by various agencies which account to he about Rs.50 billion) per year on degraded land development is shown in Table 3. If all the efforts at afforestation were to succeed, India's net emission of CO_2 could come down significantly. Improving the soil quality with the help of resorting degraded soils bas the important benefit of achieving food security by improving agronomic biomass production and increasing use efficiency of input (e.g., fertilizers, irrigation, and energy). Significant employment opportunities is generated by afforestation activities on degraded land, as 70–80% of the expenditure incurred on plantations is constituted in form of wages to laborers .

ECO-RESTORATION OF DEGRADED LANDS THROUGH MICROBIAL BIOMASS

INTRODUCTION

Soil ecosystem changes with the degree of disturbance. Biotic and physical environment and processes such as transfer of energy and material between organism and the physical environment characterized the ecosystem. Among the physical, chemical, biological, hydrological and geological part of earth, the basic micro-counterpart i.e. microorganism plays a significant role in the terrestrial ecosystems. Microorganisms are ubiquitous in the environment that are found on the earth where there is water, hot springs on the ocean floor and deep inside rocks within the earth"s crust. Microbes act as a source and sink of nutrients and play critical role in nutrient conservation in dry tropical environment. More than 40 % of the terrestrial vegetated surface of the earth has been Corresponding Author directly disturbed and reduced natural productive capacity through overgrazing, deforestation, agriculture, overexploitation for fuel wood, urban and industrial use.

In order to improve world food security and maintain environmental quality many studies have been investigated the consequences of land degradation. It is well known that land degradation decreases soil fertility as a result of loss of soil organic matter and nutrients and reduces soil microbial biomass and activity Restoration practices, such as improving soil properties and increasing vegetation cover, may be a promising approach for the restoration of soil productivity and sustainability. Also, land restoration can alter ecosystem function by changing biological status i.e. changes in microbial biomass and organic matter decomposition. In order to obtain stabilization, pollution control, visual improvement and removal of threats to human beings, restoration of a degraded land can be done by microorganisms.

SOIL MICROBES

Micro-fauna (mites, collembolan and nematodes) recycle organic matter that is trapped in bacteria, fungi and protozoa. They create more surface area for fungi and bacteria to act upon by breaking down organic matter. It makes nutrients in more stable form and therefore the nutrients are easily available for plant uptake. Degraded lands when added with bacterial and fungal feeding nematodes can be restored in less period of time than the soil without the nematodes. The feeding material for fungi and bacteria are the dead cells from the plant roots as well as sugars, amino acids and organic acids that leaks from roots. To keep the plant roots healthy and aid them to grow faster on degraded lands, some of the microorganisms produce antibiotic compounds and hormones to recycle nutrients more rapidly. In legumes, VAM fungi supply the phosphorus required by rhizobium bacteria to fix nitrogen efficiently. Soil microbe populations are one of the important soil components.

It plays a major role in aggregate stabilization which consequently maintains suitable structural conditions for cultivation and porosity for crop growth . Their activity declines when soil layers are disrupted and is slow to resume independently. Soil microbes include several bacterial species active in decomposition of plant material as well as fungal species whose symbiotic relationship with many plants facilitates uptake of nitrogen and phosphorus in exchange of carbon. They produce polysaccharides that improve soil aggregation and positively affect plant growth. Sites with an active soil microbe community exhibit stable soil aggregation, whereas sites with decreased microbial activity have compacted soil and poor aggregation .

Bacteria

Bacteria play an important role in decomposition of organic materials, especially in the early stages of decomposition when moisture levels are high. In the later stages of decomposition fungi tend to dominate. Rhizobia are single celled bacteria, belongs to family of bacteria Rhizobiacea, form a mutually beneficial association, or symbiosis with legume plants. These bacteria take nitrogen from air (which plant cannot use) and convert it into a form of nitrogen called ammonia (NH_4^+) used by plants . Free living as well as symbiotic plant growth promoting rhizo-bacteria can enhance plant growth directly by providing bio available P for plant uptake, fixing N for plant use, sequestering trace elements like iron for plants by siderophores, producing plant hormone like auxins, cytokinins and gibberlins, and lowering of plant ethylene levels . When soil layers are removed and stockpiled, the bacteria inhabiting the original upper layers end up on the bottom of the pile under compacted soil. A flush of activity occurs in the new upper layer during the first year as bacteria are exposed to atmospheric oxygen. After two years of storage there is little change in the bacterial numbers at the surface, but less than one half the initial populations persist at depths below 50 cm .

Arbuscular Mycorrhizal Fungi

Arbuscular Mycorrhizal (AM) fungi stabilize the soil and enhance plant growth by alleviating nutrient and drought stress. Their contributions to agriculture are well- known. Usually, an evaluation of the mycorrhizal status of degraded land is recommended as a first step in rehabilitation and restoration. It contributed the restoration process by stabilizing windborne soil that settles under dense plant canopies and enhancing establishment of colonizer plants in bare soils of disturbed areas. Mycorrhizal fungi strengthen soil structure in both physical and chemical manner. Physically, the hyphal network of these fungi link soil particles to each other and to plant roots. Chemically, AM fungi produce glomalin, a sticky substance that is important in soil aggregation . Glomalin naturally binds soil aggregates together while still allowing water, nutrients, roots and soil fauna to move within the soil . Some experiments were conducted to evaluate the importance of AM fungal inoculum for the establishment of six species of cactus under native mesquite (*P. articulata*) trees. The results suggested that AM fungal inoculum potential in these hot desert soils and it was also concluded that AM fungal inoculum density is not the primary factor for the establishment of cactus seedlings and that favorable edaphic factors probably play a more important role.

AM fungi are common in harsh and limiting environments because they mitigate plant stress. Their hyphae permeate large volumes of soil, interconnect the root systems of adjacent plants to facilitate exchange of nutrients between them, and contribute to soil structure. AM fungi are an essential component of plant–soil systemsof deserts and have been detected worldwide. Mycorrhizal colonization apparently enhances water and nutrient uptake in dry environments for the succulent *Agave deserti* and the cacti *Ferocactus acanthodes* and *Opuntia ficus-indica*. Artificial inoculation of these plants with field-collected AM fungi increased the phosphorus content of roots and shoots compared with uninoculated plants. Lateral root hydraulic conductivity in *A. deserti* was significantly higher for inoculated plants .

The destruction of mycorrhizal fungal network in soil system is the vital event of soil disturbance, and its reinstallation is an essential approach of habitat restoration. Successful revegetation of severely disturbed mine lands can be achieved by using “biological tools” mycorrhizal fungi inoculated tree seedlings, shrubs, and grasses.

Rhizobacteria

In the process of land rehabilitation plant growth promoting bacteria deserve special attention as they are actively involved in plant and soil interactions. Generally, the bacteria that are plant-associated migrate from the bulk soil to the rhizosphere of living plant and aggressively colonize the rhizosphere and roots of plants. Rhizobacteria such as *Achromobacter, Arthrobacter, Azotobacter, Azospirillum, Bacillus, Enterobacter, Pseudomonas* and *Serratia* [29], as well as *Streptomyces* sp. have been found to have beneficial effects on various soil .

Other compounds produced by rhizobacteria that are beneficial include enzymes, osmolytes, biosurfactants, siderophores, nitric oxide, organic acids and antibiotics. These may be responsible for suppression of pathogenic and deleterious organisms , improved mineral uptake, associative nitrogen fixation tolerance to abiotic stresses or production of phytohormones. Therefore, for knowing the status of rehabilitation of degraded lands, for promoting plant growth and health, extensive research efforts are to be made to explore microbial diversity, their distribution, as well as function insoils of degraded lands.

ROLE OF SOIL MICROBIAL BIOMASS INRESTORATION OF DEGRADED LANDS

The mineral content and its physical structure are important for balanced condition of soil. In native soil the soil biota includes vast numbers of microorganisms that naturally reside in soil and perform a wide range of functions which are essential for a normal and healthy soil, whereas in a disturbed soil the micro-organism decreases in number. Main role of soil microbes is to decompose organic matter and release nutrients into plant available forms. It also regulates the production and destruction of pollutant like nitrous oxides, methane, nitrates and other biologically toxic compounds. It influences the weathering and solubilization of minerals and contributes to soil structure and aggregation. They also form the symbiotic associations with roots. All organisms in the biosphere depend on microbial activity because it leads to the degradation of organic materials and provide food . Many anthropogenic activities like city development, agriculture, mining, use of pesticides andpollution can potentially affect soil microbial diversity.

Microbial biomass is one of the components to measure the restoration progress of the degraded areas. To assess soil development, the microbial properties such as the amount of soil microbial biomass, soil respiration rate and metabolic quotient have been used . For various chronosequences of restored degraded soils a gradual increase of organic carbon and microbial biomass has been reported . With increase in soil organic carbon and microbial biomass the functional diversity of soil microbial communities may increase that consequently increases the functionality and stability of soil ecosystems. Role of soil microbes in the establishment of biogeochemical cycles, for energy transfer and formation of soil is well known, but standard quantitative information is lacking for optimum level of soil microbial biomass which is requisite for the soil development in the degraded areas.

The soil microbial population consisting of bacteria, fungi and micro fauna (Micro means microscopic that one can not see with naked eyes and fauna means animals) are termed as soil microbial biomass (SMB) and it is closely related to the soil organic matter (SOM). It is measured as the amount of C and N in the SMB thus the terms SMB-C and SMB-N. During decomposition the SMB assimilates complex organic substrates for energyand biomass carbon with excess inorganic nutrients being released to the soil.

Ecosystem would remain in degraded condition without the natural processes of soil development. At the early stages of ecosystem development soil act as a critical controlling component. Soils are made up of four basic components minerals, air, water and organic matter. It is a natural medium in which microbes live, multiply and die. Organic matter, mineral nutrients and microbial nutrients decrease in disturbed soil. During restoration of degraded lands, it is necessary to establish and maintain a vegetation cover without the use of top soils or other bulky amendments. To recover the fundamental functionality of the soil ecosystem it is requisite to make an effective strategy to catalyze the natural return of some of the basis for further restoration processes. The cycling of nutrients regulates the sustainability of any plant community. Without cycling, nutrients will be lost or immobilized and plant community will not be capable of regeneration. Destruction of soil properties causes reduced soil productivity

APPLICATION OF AMENDMENTS FOR TREE CROPS AND TREE SPECIES FOR DIFFERENT SOIL TYPES

Non Calcareous Alkali Soil

The Gypsum may be recommended for planting / cultivating fruit crops and detailed below.

Example :	The pit size	:	1M x 1M x 1M
	pH	:	9.0
	Gypsum	:	1000 (Kg / Ac) = 250gm / 1M^3 Pit ------------- 4000 m^2

pH	Gypsum kg / ac	Gypsum gm/1M^3 Pit	
8.5 to 9.0	500	125	Note : Gypsum should be mixed with good soil, Farm Yard Manure and red earth and applied before 5-10 days of planting and forked.
9.0	1000	250	
9.1	1400	350	
9.2	1800	450	
9.3	2200	550	
9.4	2600	650	
9.5	3000	750	
9.6	3400	850	
9.7	3800	950	
9.8	4200	1100	
9.9	4600	1200	
10.0 and above	5000	1250	

a) Acidic Soil

Soil pH	Lime kg / ac	Lime gm/1M^3 Pit (rounded)	
5.9	455	150	Note : For planting saplings, Lime should be mixed with good soil, Farm Yard Manure and red earth and applied inputs 15-20 day before planting and forked.
5.8	680	200	
5.7	905	250	
5.6	1133	300	
5.5	1360	350	
5.4	1590	400	
5.3	1815	450	
5.2	2040	500	
5.1	2260	550	
5.0 and	2495	650	

TREE SPECIES FOR DIFFERENT SOIL TYPES

There are numerous constraints like non – availability of appropriate tree species during the planting season, limitations imposed by depth of soil, problem soil and vagaries of mansoon. The need to know different tree species that can be successfully grown in various soil conditions to keenly felt by for proper planning of planting operations. Suitable species for difference soil situations are as hereunder.

i. Coastal alluvium :

The soil is porous, low on nitrogen, phosphorus and organic matter content, lying as a long and narrow stretch all along the coastal region. The pH range exceeds 6.5 and soil is loam supported by a high water table and high variable rainfall. Soil is occasionally flooded during monsoon and needs species that can tolerate short form drainage.

The most adaptable species are

1. *Calophyllum inophyllum*	(Punnai)
2. *Casuarina equisetifolia*	(Chavukku)
3. *Thespesia populnea*	(Poovarasu)
4. *Bambusa aamboo*	(Peru moongil)
5. *Samanea saman*	(Thoongumoonji)
6. *Borassus flabellifer*	(Panai)
7. *Anacardium occidentale*	(Munthiri)
8. *Terminalia arjuna*	(Neermarudhu)
9. *Acacia auriculiformis*	(Kathivel)
10. *Eucalyptus terelicomis*	(Thilamaram)

ii. River alluvium :

The soil is confined to the river beds which is rich in high deposits of organic matter and adequate levels of N.P and K. The pH of soil ranges from 6.0 to 7.5 and the moisture retention capacity is high enough to leave a continuous moist subsoil even during the summer periods. The predominant species for this soil type are

1.	*Dalberrgia sissoo*	(Sissumaram)
2.	*Casuarina equisetifolia*	(Chavukku)
3.	*Bambusa bamboo*	(Perrumoongil)
4.	*Terminalia paniculata*	(Pillaimarudhu)
5.	*Madhuca latifolia*	(Illuppai)
6.	*Eugenia Jambolana*	(Naval)
7.	*Swietenia mahogany*	(Mahagoni)
8.	*Albizia falcataria*	(Albiziathadi)
9.	*Eucalyplus camaldulensis*	(Thilamaram)
10.	*E.tereticonis*	(Thailamaram)

iii. Red soil :

This is the most widely distributed soil type in the state with its depth varying the shallow to considerably deep. However, a further subdivision is needed as follows to the appropriate species according to the soil characteristics.

a. Skeletal Soil :

Soil depth hardly exceeds 15 cm and is embedded with small to large pebbles Rainfall is about 500-700 mm and pH is about 7.0-7.5 low in nutrients, organic matter as N and P. Most suitable species for this soil are.

1. *Annona squamosa* (Seethapazham)
2. *Hardwickia binata* (Achan)
3. *Albizia amara* (Ucil / Arappu)
4. *Acacia mellifera* Kokkivel)
5. *A.ferrugenea* (Parambai)
6. *A.blanifrong* (Odai)
7. *Wrightia tincloria* (Veppalai)
8. *Azadiracta indica* (Vembu)
9. *Agave sisalana* (Sisal kathazhai)
10. *Delonix eleta* (Vadhanarayanan)
11. *Ailanthus excelsa* (Perunmarram)

b. Laterite soil :

These are deep soils having a pH range from 5.5 to 7.0. They receive an average rainfall of 800-1000 mm brought by both the monsoons. The nutrient levels of the soil is equally with low organic matter, Nitrogen and phosphorus. The species suited for these soil are.

1. *Eucalyptus spp* (Thailamaram)
2. *Acacia auriculiformis* (Kathivel)
3. *A.holosericea* (Mansevivel)
4. *Albizia lebbeck* (Vagai)
5. *Tectona grandis* (Thekku)
6. *Anacardium occidentale* (Munthiri)
7. *Dalbergia latiffolia* (Rosewood)
8. *Bambusa bamboo* (Peru moongil)
9. *Gelina arborea* (Kumiz maram)
10. *Eugenia jambolana* (Naval)
11. *Artocarpus integrifolia* (Pala)

c. Sandy red loam :

The soil is comparatively better than lateritic soil having high. The pH ranges from 6.5-7.5 and nutrients are scantly. The species recommended are.

1.	*Acacia auriculiformis*	(Kathivel)
2.	*Casuarina equisetifolia*	(Chavukku)
3.	*Pongamia pinnata*	(Pongam)
4.	*Samania saman*	(Thoongumoonji)
5.	*Tamarindus indica*	(Puli)
6.	*Albizia lebbeck*	(Vagai)
7.	*Ceiba pentandra*	(ilavam panju)

iv. Black soil :

Rainfall ranges from 700-900 mm mostly brought in by northeast monsoon. The soil pH ranges from 7.0 to 8.5 and the nutrient level is poor. Due to higher percentage of clay content and higher organic matter the moisture retention capacity of these soils is high. High Calcium content increases soil pH. Hard pan at lower depths may pose problems for root growth. The species that can be grown in such soils are.

1.	*Acacia nilotica*	(Karuvel)
2.	*A.leucophloea*	(Valval)
3.	*Azadirachta indica*	(Vembu)
4.	*Albizia lebbeck*	(Vagai)
5.	*Acacia albida*	(Albida)
6.	*A.tortilis*	(Israel – Karuvel)
7.	*Morinda tinctoria*	(Nuna)
8.	*Moringa oleiferra*	(Murungai)
9.	Prosopis juliflora	(Velikaathan)

v. Tree species for Wasteland reclamation :

Waste lands can be successfully reclaimed by proper understanding of suitability of tree species to different agro climatic conditions that would result in proper growth, development and yield. Species like *Acacia planifrons* and A.suma have shown high survival in the adverse conditions of wastelands. *Acacia auriculiformis, A.Crassicarpa, Brachillelia molli and Eucalyphts tereticomis* etc., are better to wastelands having medium rainfall situations. Though propopis juliflora and prosopis cineraia put forth less growth, both species are suitable for reclaiming wastelands. Australian phyllodious acacias like *A. crassicarpa. A.holosericca* and Central American species like *Senna atomeria* and *Glyricidia sepium* are highly adapted to semiarid situations.

Acacia nilotica, prosopis juliflora and Albizia lebbeck are promising shellter belts and road side plantation. Lasirus indicus (Sewan) Comes up well in dunes with low rainfall. Rocky areas can be planted with *Acacia senegal* (Kumat) and with *Prosopis juliflora*. In degraded soils *candilila* plant (Exphorbia antisyph) guayule (Parthenium argentatum) which is a good source of natural rehabilitation.

2.5 Afforestation of coastal areas and problem soils :

a. Saline and alkaline soils:

The soil have pH exceeding 8.0 and the nutrient availability is poor. The rainfall received ranges from 700-1000 mm Tolerant species are :

1. *Albizia procera* (Selavagai)
2. *Thespesia populnea* (Poovarasu)
3. *Terminalia arjuna* (Neermarudhu)
4. *Casuarina equisetifolia* (Chavukku)

b. Mined out areas :

This soil is turned over from the bottom and the lower and upper horizons are complete mixed altering the physical and chemical properties of these soil to a level of unsuitability for cultivation. Water holding capacity of such soils is poor. Species that can tolerate these adverse conditions are

1. *Ailanthus excelsa* (Perunmaram)
2. *Acacia holosericea* (Maansevivel)
3. *A.auriculiformis* (Kathivel)
4. *Leucaena leucocephala* (Subabul)
5. *Albizia saman* (Thoongumoonji)

c. Theri soils:

These are slow moving red sandy deposits peculiar to some pockets where the rainfall is scanty in the range of 400-500 mm. The soil is very porous and moisture is held only for a limited period. The pH ranges from 7.0-7.5 and nutrient levels are very low. Species that can be recommended for this area are.

1. *Acacia Senegal* (Senegal velamaram)
2. *A.tortilis* (Isreal Karuvel)
3. *Anacardium occidentale* (Mundhiri)
4. *Casuarina equisetifolia* (Chavukku)
5. *Thespesia populnea* (Poovarasu)
6. *Ziziphus jujuba* (Elendhai)
7. *Acacia plamitra* (Palmoyrol)

d. Calcareous soil :

Some pockets of wastelands harbor deposits of calcium carbonate causing bind hinderance for any agricultural or horticultural cultivation. These area support very restriped number of species.

The exploitable species are :

1. *Acacia leucophloea* (Velvel)
2. *Azadirachta indica* (Vembu)
3. *Tamarindus indica* (Puliam)
4. *Ailanthus excelsa* (Perunmaram)

மண்ணுக்கேற்ற மரங்கள்

1	கரிசல் மண்	:	கருவேல் சவுண்டல், வேம்பு, புளி, புங்கம், இலந்தை, சீதா, இலுப்பை, ஆலமரம், வேலிக்கருவேல், நுணா
2	செம்மண்	:	வாகை, வேம்பு, ஆச்சா, புரசு, குடைவேல், அயிலை, தனக்கு, மான்காதுவேல், வெண்ணேறு, புளி, தைலம், சவுக்கு, இலவம், பரம்பை, அரப்பு பூச்ச கொட்டை மரம், சைமரூபா
3	வண்டல் மண்	:	தேக்கு, மூங்கில், புளி, வேம்பு, கருவேல், வாகை சவுண்டல், தைலம், இலுப்பை, புங்கம், சைமரூபா
4	செம்பொறை மண்	:	தைலம், முந்திரி, மாமரம்
5	களர்நிலம்	:	சீமைக்கருவேல், புங்கம், இலவம், புளி, வேம்பு
6	உவர் நிலம்	:	சவுக்கு, சீமைக்கருவேல், புங்கம், இலவம், புளி வேம்பு
7	அமில நிலம்	:	தைல மரம், கத்திவேல், சைமரூபா