COURES CODE: *SOS 520*

COURSE TITLE: *Principle of Soil Conservation and Management*

NUMBER OF UNITS: *3 Units*

COURSE DURATION: *Three hours per week*

COURSE DETAILS:

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COURSE CONTENT:

Concept of soil conservation and management; soil degradation and rehabilitation. Accelerated soil erosion by water and wind; processes and factors of soil erosion; Measurements: quantitative evaluation of soil erosion using factor and process based models, e.g., Revised Universal Soil Loss Equation (RUSLE), Wind Erosion Equation (WEQ), Water Prediction Erosion Project (WEPP) etc.; field measurements. Cultivation and tillage; conservation tillage; crop residue management; cover crops and agroforestry. Irrigation and drainage; Soil salinity and alkalinity management. Nutrient management; macronutrients and micronutrients. Pollution and waste management.

COURSE REOUIREMENTS:

This is an elective course for all Soil Science students in the final year in COLPLANT. In view of this, students are expected to participate in all the course activities and have a minimum of 70 % attendance to be able to write the final examination.

READING LIST

1. Boardman, J., and Evans, B. (2006). Britain. *In "Soil erosion in Europe" (J. Boardman and J. Poesen, eds.). John Wiley and Sons.*
2. Brady, N. C. and R. R. Weil. *The Nature and Properties of Soils*. 12th ed. Prentice-Hall, New Jersey: Prentice-Hall Incorporated, 1999.
3. Hudson, N. 1995. Soil conservation. BT Batsford Limited, London. 391 pp.
4. Lal, R. 1990. Soil erosion in the tropics. Principles and management. McGraw Hill, Inc., New York, USA. 580 pp.
5. Troeh, R.F., Hobbs, J.A., Donahue, R.L. 1991. Soil and water conservation. Second edition.

LECTURE NOTES:

1.0 Concept of soil conservation

Soil and water conservation is necessary for sustained productivity of land. Soil erosion is prevented or reduced to a tolerable level, and water is conserved for judicious utilization. Sustainable production implies that agricultural practices would lead to economic gains without impairing environmental quality and the usefulness of the soil for future generation. Therefore, the objectives for soil and water conservation are:

- promotion of proper land use
- prevention of soil erosion
- restoration of the productivity of eroded land
- maintenance of soil productivity
- control of runoff, and regulation of water resource through irrigation and drainage
- maintenance of environmental quality by preventing land and water pollution

2.0 Land degradation (soil degradation)

Land degradation results in a reduced productive potential and a diminished capacity of land to produce benefits for humanity. Or, it can be described as process by which one or more of the potential ecological functions of the soil are harmed. The causative factors of land degradation are:

(i) Improper land clearing methods, non use of conservation agriculture

(ii) Soil compaction from mechanization,

(iii) Organic matter and soil biota depletion-Improper land clearing methods; Cropping intensification, non-return of residues, non practice of conservation or organic agriculture, acidification

(iv) Salinization-common in arid areas, arises from inherent soil properties during irrigation,

(v) Desertification

3.0 SOIL EROSION

The two main agents of soil erosion are water and wind. Soil erosion in the field can be assessed at the scale of a watershed. A watershed refers to a delineated area with a well-defined topographic boundary and a water outlet. It contains a complex of soils, landforms, land uses, and vegetation. A watershed is a hydrologic unit in which all hydrological processes are related. The terms watershed, catchments and basin are used interchangeably.

3.1 Broad classification of soil erosion

Geological or natural or normal erosion:

Erosion can occur naturally, transforming soil into sediment. This naturally occurring erosion devoid of man's influence is called **geological or natural or norm**al erosion. Under this erosion type, the process of soil erosion is balanced by the process of soil formation, creating a state of equilibrium.

Accelerated erosion:

When the process of soil erosion is influenced by human activities, it is **accelerated**. Such accelerated erosion is caused by removal of vegetation, and improper land use and management.

4.0 SOIL EROSION BY WATER

Soil erosion occurs through a 3-stage process, namely,

- detachment
- transportation
- deposition

Soil erosion by water can be primarily linked to rainfall, although water in motion erodes soil, rivers scour soil away, and waves erode shores. Therefore, soil erosion can be defined as the detachment and movement of soil particles by the erosive forces of wind or water. Soil detached and transported away from one location is often deposited at some other place. While soil erosion can be controlled, it is almost impossible to completely stop.

Detachment process

When a raindrop falls, it accelerates until it reaches a terminal velocity, capable of following processes -

- it detaches the soil
- it destroys granulation or aggregation
- it splashes particles

Loosening of soil particles and their suspension in a water film by raindrops constitute detachment of soil.

Transportation

As precipitation progresses, water film on the soil surface thickens particularly when the infiltration capacity of the soil has been exceeded. This water film slides down slope, and as it moves it carries with it soil particles. The water moving the soil from place to place is called runoff.

Deposition

When runoff reaches flat lowland, the current slows down depositing its content. This is the last stage of accelerated erosion. Deposition usually occurs in depressions or at the foot slope. The amount of soil delivered into a stream divided by the amount eroded is termed the delivery ratio.

4.1 Types of Water Erosion

Splash erosion: Raindrops hitting soil aggregates tear it apart by its kinetic energy. The soil particles are splashed as a consequence of this action

Sheet erosion: When precipitation exceeds soil permeability, excessive water will form a thin sheet or film. This film of water or film current moves over the soil, sometimes with small ripples. In the process, splashed soil is removed more or less uniformly. This is termed sheet erosion. Sheet erosion removes fine particles and organic matter without any easily detectable trace.

Rill and Interill erosion: Rills are channel which could be obliterated easily by normal tillage operations. A rill is always no more than 30 cm depth and 100 cm in width. They are formed when water has accumulated on the ground, and the film of water becomes streamlets which have greater scouring action than sheet flow. Rills can easily be formed along furrows planted along slopes.

Interrill (between rills) erosion is sometimes referred to as sheet erosion; but technically, interill erosion is the detachment and transport of particles by rain impact and shallow overland flow.

Gully erosion: When rills advance, gullies are formed. These are erosion channels too large to be obliterated by ordinary tillage. In gullies, runoff develops as powerful torrents with enhanced capability of erosion

4.2 Factors influencing soil erosion by water

The following are the factors which influence soil erosion by water

- Climate; rainfall
- Soil: its characteristics
- Topography: slope length, slope steepness and slope shape
- Vegetation: presence of crop, forest, and vegetation management
- Human behavior; land exploitation and management

Rainfall

The potential ability of rainfall to cause soil erosion is called erosivity. In evaluating rainfall erosivity, rainfall should first be perceived as an aggregation of different drops of water. Then it can further be perceived in amount as the summation of the amount of individual drops. Individual drops play a significant role in detaching the soil, and the cumulative drops as runoff transport and deposit detached soil. Therefore rainfall characteristics which influence it erosivity are:

- Amount, duration and intensity
- Drop size and drop size distribution
- Terminal velocity
- Kinetic energy

Soil

The vulnerability of the soil to erosion is called soil erodibility. Erodibility of the soil can be influenced by the inherent characteristics of the soil, the topographic features- slope, and the management of the soil.

Soil texture and particle size distribution are important in sediment detachment, dispersion and transportation. The bigger the particle the more the force required for its transportation

4.3 SOIL EROSION ASSESSMENT

Measurement of Water Erosion

Universal Soil Loss Equation (USLE) -predict annual soil loss by water –Wischmeier and Mannering, (1969).

A = R K L S C P

Where, A= the predicted soil loss (kgm^2s^{-1}) is a product of:

R= rain fall erosivity

K= soil erodibility

L= slope length

S= slope gradient or steepness

C= cover and management

P= erosion control practices

Limitations of the USLE

1. The USLE was designed to predict the amount of soil loss by sheet and rill erosion in an average year for a given location

2. It cannot predict the extent of gully erosion.
3. It cannot predict sediment delivery to streams
4. It is applicable to a plot size of 9% slope and 22 m long

Other prediction models have been developed, which are referred to as the process-based models, Process-based models or analytical component models: They explain mathematically each of the separate physical processes and then combine the separate effects. Such models often require the use of computers to facilitate their use. These include the following:

1. **Revised Universal Soil Loss Equation**

- RUSLE (Renard*et al.*,1997), is the successor of the USLE
- The USLE was updated and computerized in the early 1990's to create an erosion prediction tool called the RUSLE.
- The RUSLE uses the same basic factors of the USLE. However, some factors are better defined and improved the accuracy of soil loss prediction
- This computer software package is constantly being improved and modified for better prediction.

2. Water Erosion Prediction Project (WEPP) model -The Water Erosion Prediction Project was initiated in 1986 (Foster et al., 1989).
3. EUROSEM (Morgan *et al* . 1992).
4. GUEST (Misraand Rose 1996; Rose *et al* . 1997)
5. Erosion Productivity Impact Calculator (EPIC) model (Sharpley and Williams, 1990)

6. Modified Universal Soil Loss Equation (MUSLE) : The MUSLE equation was developed by J. R.Williams1975 as a method to estimate sediment delivered from small watersheds for individual storms

Water Erosion Prediction Model (WEPP)

The objective of WEPP is to develop a new generation of erosion prediction technology for use by conservation planner at the field level. The technology is based on fundamentals of erosion and hydrological sciences, and it is computer-driven. WEPP is a simulation model that computes on a daily basis, the rates of hydrologic, plant-growth, and even litter-decay process.

Soil Erodibility

Soil erodibility values were obtained directly from measurements on soil conservation experiment stations. They can be determined using rainfall simulators on small plots. Still they can be determined from relationships between soil properties and soil erodibility as developed in the Wischmeier nomograph. To use the nomograph the following parameters are needed -

- % silt + % very fine sand
- % organic matter
- % sand (0.10 to 2.00 mm)
- Class of soil structure
- Class of permeability

Slope factor (LS)

Slope length is the horizontal distance downslope from point where overland flow begins to where runoff enters a waterway or where deposition starts. Erosion is proportional to slope length raised to a power, *m*. Values of m range from 0.02 to > 0.8 slope steepness. The standard slope length used in determining K values is 22.1 m (72.6 ft).

Slope steepness is defined as the gradient expressed in units of vertical rise or fall per unit of horizontal distance (decimal fraction). It is convenient in the field to determine slope as the vertical fall per unit of distance along the land surface. Differences are negligible for gentle grades, but increase as slopes become steeper.

Cover-Management Factor

Cover-management effects on erosion are complex and diverse. Type of crop, stage of growth, and crop and soil management are important. Some crops and crop sequences maintain good soil cover; others leave the land bare for extended periods.

Supporting Practice Factor (P)

Special practices are frequently needed in addition to the protection provided by normal crop and soil management practices. Most common practices are contour cultivation, contour strip cropping, terracing.

5.0 SOIL EROSION BY WIND

Wind erosion processes (detachment, transportation and deposition) are similar to that of water erosion. However, soil movement by wind is different. The basic causes of wind erosion are:

- Loose, dry and finely divided soils
- Smooth and bare soil surface
- Strong wind
- Large field

Wind erosion can be eliminated or curtailed whenever:

(i) The soil is compacted, kept moist or made up of stable aggregates or clods large enough to resist the force of the wind

(ii) The soil surface is roughed or covered by vegetative residue

(iii) The wind velocity near the ground is somewhat reduced.

5.1 Types of Soil Movement

Saltation, surface creep, and suspension are the three types of soil movement which occur during wind erosion. While soil can be blown away at virtually any height, the majority (over 93%) of soil movement takes place at or below one meter.

Saltation: Soil particles move in a series of short leaps pr bounces. Saltation means ‘to jump’. The jumping grains gain a great deal of energy, and may knock other grains into the air or bounce back themselves. The particles remain close to the ground as they bounce. The particles are often stopped by obstructions or reduced wind velocity. The major fraction of soil moved by the wind is through the process of saltation.

Surface creep: This is the rolling and sliding along the surface of the larger particles. Soil grains larger than 0.5 mm cannot be lifted. This causes them to roll and slide along the surface after coming into contact with saltating particles.

Suspension: This occurs when very fine dust particles are lifted into the wind. Soil particles less than 0.05 mm in diameter, such as, silt size and smaller are kept suspended by the turbulence of air currents. These particles only drop out of air if rain washes them or wind velocity reduces drastically. They can be thrown into the air through impact with other particles or by the wind itself.

5.2 Factors affecting wind erosion

Soil moisture: Wet soil does not blow because of the adhesion between water and soil particles. Dry winds generally lower soil moisture to below wilting point before wind erosion takes place.

Wind velocity: The rate of wind movement, especially gusts having greater than average velocity will influence wind erosion. Standard wind velocity is measured at a fixed height of 9 m above the ground.

Height: Velocity of even a steady wind increases dramatically above the ground surface. Wind velocity over a bare surface is zero at a height close to the surface below the tops of irregularities.

Wind turbulence: Wind strong enough to cause erosion is always turbulent, with eddies moving in all directions at a variety of velocities. Turbulence increases with increases in friction velocity, with increasing surface roughness, and with pronounced changes in surface temperature. Turbulence is important in keeping soil grains suspended in air.

Surface roughness: Wind velocity is less severe when the surface is rough. This can be achieved by tillage, ridging and/or mulching

Soil properties: Apart from soil water content, other soil properties which influence wind erosion are (i) stability of soil aggregates, (ii) size of erodible soil fractions. The presence of clay, organic matter and other cementing agents enhance aggregate stability

Vegetation: Vegetation or residue mulch especially those with rows running perpendicular to the prevailing wind direction reduce wind erosion. Wind velocity approaches zero near the soil surface in a vegetated area. In addition, plant roots bind the soil.

Length of exposed area: Soil drifting increases substantially with increasing length of the eroding strip

5.3 PREDICTING WIND EROSION

A wind erosion prediction equation (WEQ) has been in use since the late 1960s:

E = *f*(ICKLV)

The predicted wind erosion E is a function *f* of:

I = soil erodibility factor

C = climate factor

K = soil-ridge-roughness factor

L = with of field factor

V = vegetative cover factor

The WEQ involves the major factors that determine the severity of the erosion, but it also considers how these factors interact with each other. It is not possible to predict wind erosion by simply multiplying the factors as in USLE.

The soil erodibility factor I relates to the properties of the soil and the degree of the slope in question.

The soil-ridge-roughness factor K takes into consideration the cloddiness of the soil surface, vegetative cover V, and ridges on the soil surface

The climatic factor C involves wind velocity, soil temperature, and precipitation (which controls soil moisture)

The width of field factor L is the width of a field in the downwind direction. Naturally the width changes as the direction of the wind changes, so the prevailing wind direction is used.

The vegetative cover V relates not only to the degree of soil surface covered with residues, but to the nature of the cover-whether it is living or dead, still standing or flat on the ground.

5.4 WIND EROSION CONTROL

The factors of wind erosion give clues to methods of reducing it. Little can be done to change climate in an area, but it is possible to alter one or more of the other factors

Soil surface management: Tillage. To minimize wind erosion, the surface should be rough, in cloddy condition and with surface residues. Tillage should be carried out when the soil moisture is adequate.

Soil water management: Water conservation practices which reduce loss of water through evapotranspiration include weeding, conservation tillage, and reduction of runoff through surface roughness or terraces

Altering length of field: The length of eroding field can be altered by strip cropping or by installing wind breaks perpendicular to the direction of the prevailing wind.

Planting rows of shrubs or trees to serve as windbreaks or shelterbelts is effective in reducing wind erosion. Local recommendations for appropriate species should be followed with vegetative windbreaks. The distance protected by a windbreak may be 6 to 15 times the height of the barrier, with effectiveness decreasing with distance.

Vegetation management: Closely spaced crops are more effective than row crops. Alternating rows of crops such as cotton which is less-wind resistant with sorghum which is more resistant to wind is important. Residues should be left on the fields.

6.0 Cultivation and tillage – types of tillage

The type of tillage practiced can be evaluated by the amount of crop residue managed at the soil surface.

1. Conventional Tillage

- Utilizes the mouldboard plough + harrow
- Extensive field research has shown that conventional mouldboard plough systems leave only 1 to 5% of the soil covered with crop residues.
- The soil is left unprotected during the time of year when runoff and erosion pressures are greatest.

2. Conservation Tillage Practices

- System involves less tillage.
- At least 30% of the crop residue must be maintained on the soil surface.
- This system minimizes opportunity for erosion.

Types of Conservation Tillage Practices

a) **No-till or "No-tillage" –**This is a system whereby no primary tillage is done and a crop is planted directly into a seedbed . 50 to 75% of the land is left covered with residue.
b) **Mulch tillage –**The soil is prepared or tilled in such a way that the plant residues or other materials are left to cover the surface.
c) **Reduced tillage or minimum tillage –**This system consist of minimum soil manipulation necessary for crop production. Leaves between 15 to 25% soil cover.
d) **Contour tillage –**The tillage is done at right angles to the direction of the slope

e) **Contour strip cropping –**This is layout of crops in narrow strips in which the farming operations are performed approximately on the contour. Usually strips of grass and close-growing crops are alternated with those of cultivated crops.

f) **Strip cropping –**This is the practice of growing crops that require different types of tillage, such as row and sod in alternate strips along contours or across the prevailing direction of wind.

7.0 irrigation and drainage

7.1 Irrigation

The most limiting factor to all year round food production in the tropics is lack of water in the dry season. This problem is most severe in the arid and semi-arid regions. This problem can be reduced are by conserving as much water in the soil as possible, and irrigation. The irrigation water used must be free of salts, especially those containing sodium.

Irrigation is a method by which water is artificially applied to an area. The methods and manner of application of water include;

- Check basin
- Flooding
- Drip
- Furrow
- Sprinkler
- Border strip
- Center pivot

Conserving soil moisture during the dry season by the use of suitable agronomic practices is most appropriate since irrigation entails high financial investments.

7.2 Drainage

A significant drainage problem is present, when water levels are too high and/or proper leaching of the soils cannot take place. However, some agricultural practices required some form of control of the water table. Drainage involves provision of channels, such as open ditches or drain tile, so that excess water can be removed by surface or internal flow. This also involves losing water by percolation. Drainage becomes a problem also when land use adjustment is not feasible, for example switching to rice crops and range lands

It is necessary to determine a cost effective type of drainage method and system. The main objective of drainage is to lower the moisture content of the upper layers of the soil so that oxygen can be available to the crop roots and carbon dioxide can diffuse from the roots.

Two types of drainage systems are used:

i. Surface drainage (e.g., open ditches)

ii. Subsurface drainage system, (e.g., mole drainage, clay tile)

8.0 Salinity and alkalinity management

Saline and alkaline soils are commonly found in the arid regions. Their use for agricultural purposes requires irrigation water, consequently the management of these soils are extremely important.

For effective management of these soils, the following must be considered:

i. The quality of water, especially in relation to its salt content must be properly examined.
ii. Water high in sodium salts can bring about harmful effects.
iii. Knowledge of the quality of irrigation water is a requisite for good management of saline soils.

Three types of general management practices have been employed, namely

a) Eradication – underdrainage, leaching or flushing.
b) Conversion – conversion of some of the salts to less injurious forms
c) Control – involves keeping the salt so well distributed throughout the soil that there is no toxic concentration within the root zone.

9.0 Nutrient management

9.1 Macronutrients

Management practices should include improving soil conditions that support good plant growth through adequate availability of macronutrients.

- Proper liming
- Adequate fertilizer application and placement
- Proper soil organic matter maintenance

9.2 Micronutrients

Although the characteristics of each micronutrient are quite specific, some generalizations with respect to management practices are possible.

- Soil acidity change – This can be corrected by liming and by appropriate fertilizer addition, since toxicities of iron and manganese are likely to occur in acid soils.

- Soil moisture – Drainage and moisture control can influence micronutrient solubility in soils. Improving the drainage of acid soils can encourage the formation of the oxidized forms of iron and manganese.
- Fertilizer applications – Application of some commercial fertilizers is a common management practice to overcome micronutrient deficiencies.