SOS 520

Principle of Soil Conservation and Management

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Recommended Texts:

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Lal, R. 1990. Soil erosion in the tropics. Principles and management. McGraw Hill, Inc., New York, USA. 580 pp.

Troeh, R.F., Hobbs, J.A., Donahue, R.L. 1991. Soil and water conservation. Second edition. Prentice, Engelwood Cliffs, New Jersey, USA. 529.

General text:

Brady, N.C. and Weil, R.R. 1999. The nature and properties of soils. 12th edition. Prentice Hall, New Jersey, USA. 881 pp.

1.0 INTRODUCTION

1.1 Soil Conservationist

Soil Conservationist: Plans and develops coordinated practices for soil erosion control, moisture conservation, and sound land use: Conducts surveys and investigations on rural or urban planning, agriculture, construction, forestry, or mining on measures needed to maintain or restore proper soil management. Plans soil management practices, for example crop rotation, reforestation, permanent vegetation, contour plowing, or terracing as related to soil and water conservation. Prepares soil conservation plans in cooperation with state, county, or local government, farmers, foresters, miners, or urban planners to provide for use and treatment of land according to needs and capability. Applies principles of two or more specialized fields of science, for example agronomy, soil science, forestry, or agriculture to achieve objectives of conservation. May also develop or participate in environmental studies.

1.2 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) Acidification- Cropping intensification, Wrong use of fertilize

Nutrient Depletion-Cropping intensification, no or low input technologies,

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

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

(vi) 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.

Today's society often times focuses on sensational news and short term crises which surround us. By constantly dwelling in the present, many people ignore the long term problems that compound slowly until they reach a crisis level, and may then be very difficult or impossible to correct. **Soil erosion** is a continuing long term problem. Natural processes such as the production of soil occur at an alarmingly slower rate than soil can be lost. It is estimated that over 3 billion metric tons of soil are eroded off of our fields and pastures each year by water erosion alone.

The main variables affecting water erosion are **precipitation** and **surface runoff**. Raindrops, the most common form of precipitation, can be very destructive when they strike bare soil. With impacts of over 20 mph, raindrops splash grains of soil into the air and wash out seeds. Overland flow, or surface runoff, then carries away the detached soil, and may detach additional soils and then sediment which can be deposited elsewhere.

Sheet and **interrill erosion** are mainly caused by rainfall. However, some of the more severe erosion problems such as **rill erosion**, **channel erosion**, and **gully erosion** all result from concentrated overland flow. Other types of erosion by water include **landslides**.

3.2 The concept of Soil loss tolerance

This is defined as the maximum rate of soil erosion that will economically and indefinitely sustain crop productivity. The extent of erosion problem in any area depends on whether this limit is exceeded naturally. Some emphasized that erosion can only be considered very serious in any area if the residual soil productivity cannot be restored by improved soil management practices. Where the fertility levels and the physical conditions of the removed top soil are the same with those of exposed subsoil, crop yield may not be depressed as a result of erosion.

Four major factors affecting the rate of erosion that can be tolerated without permanent loss of soil productivity are:

- Depth of soil
- Types of parent materials
- Relative productivity of top soil and subsoil in relation to nutrients distribution
- Amount of previous erosion

Although it is not desirable to loose any amount of soil, scientific research has shown that certain amount of erosion can be tolerated while maintaining optimum productivity of soil. In the United States where the concept of tolerable soil loss was evolved for soil and water conservation planning, the upper limit is given as 11.2 t ha^{-1} y^{-1} or 12 t ha^{-1}. This value is deemed inappropriate for tropical soils, for which it is often argued that tolerable soil loss limit is below 2.0 t ha^{-1} y^{-1}.

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. Agriculture contributes a significant proportion to soil erosion but in our environment its seems careless construction activities and urban planning are major causes of soil erosion. Flooding and erosion, for instance, occur in most urban areas because of disposal of refuse in drainage channels.

Detachment process

When a raindrop falls, it accelerates until it reaches a terminal velocity. This terminal velocity is the speed at which the friction between the drop and air balances the force of gravity. Large raindrops fall faster, about 2 to 3 times as fast as a person can run. As the speeding raindrop impacts the soil with explosive force, it uses two-third of its kinetic energy in loosening the soil particles and creating a crater. The remaining kinetic energy is used to disperse the loosened particles. Therefore, raindrops impact 3 important effects:

- 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. When the water film further thickens, it will become rivulets which having stronger tractive force can move not only soil but also gravel. The water moving the soil from place to place is called runoff. This phenomenon is so familiar that many people commonly believe that the process of transportation is the only process of soil erosion. It must however be noted that it is through the transportation process that severe soil erosion occurs.

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. Typically the delivery ratio is larger for small watershed than for large ones.

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 of about 0.1 to 3.00 mm thick. 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.

Sheet erosion is the uniform removal of soil in thin layers by the forces of raindrops and overland flow. It can be a very effective erosive process because it can cover large areas of sloping land and go unnoticed for quite some time.

Sheet erosion can be recognized by either soil deposition at the bottom of a slope, or by the presence of light - colored subsoil appearing on the surface. If left unattended, sheet erosion will gradually remove the nutrients and organic matter which are important to agriculture and eventually lead to unproductive soil.

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. Gullies have different shapes, depending on soil texture, and bedrock characteristics. They can be shallow troughs, V-shaped, U-shaped or complex in shape. A gully is active when its walls are free of vegetation and inactive when they are stabilized. Apart from shapes, gullies can also be classified according to depth.

Small gully < 1 m deep

Medium gully: 1-5 m deep

Large gully: > 5 m deep

A channel is concentrated flow path for water leaving a field or watershed. Channels may be permanent waterways or may be tilled across (see ephemeral gully).

Erosion in channels is mostly caused by downward scour due to flow shear stress. Side wall sluffing can also occur during widening of the channel caused by large flows.

Channel erosion can be the first stage in development of a classical gully.

Classical gullies are an advanced stage of channel erosion. They are formed when channel development has progressed to the point where the gully is too wide and too deep to be tilled across. These channels carry large amounts of water after rains and deposit eroded material at the foot of the gully. They disfigure landscape and make land unfit for growing crops.

Ephemeral Gullies:

Ephemeral gullies, on the other hand, can be plowed in and tilled across depending upon their depth and width. They are somewhat transitory rather than permanent like classical gullies. Ephemeral gullies are produced by concentrated flow in topographically controlled locations. Meaning they will reform in the same location in a field where flow from upslope regions concentrates. Creation of a grass waterway where an ephemeral gully forms can often control this type of erosion.

Landslides:

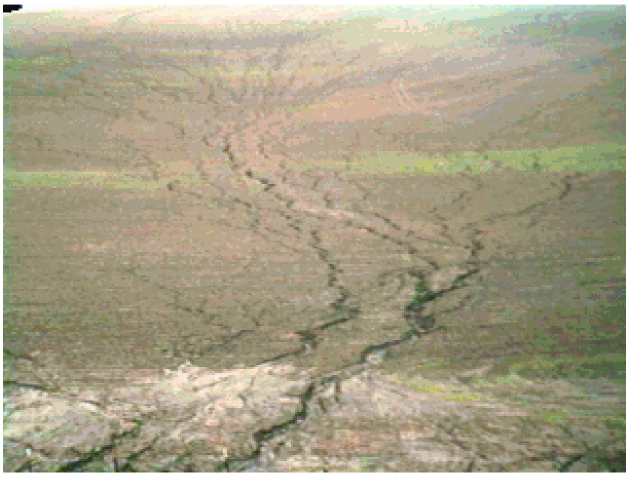
Landslides, and other mass failures, occur when the underlying layers of soil are more saturated and erodible than the outer layers. Gravity moves soil directly. Soil movement caused by gravity is known as landslide, mudflow, slip, slump, soil creep, and surface creep. As water seeps through the surface it acts as a lubricant and causes the outer layers to detach. Then gravitational forces take over and cause the mass to slide rapidly to the foot of the hill or the bottom of the gully. Soil covered by natural forest even on steep slopes is usually in equilibrium with its environment, and this makes soil movement to be extremely low. When soil cover is destroyed or greatly reduced by overgrazing, logging, cultivation, surface mining or construction, the development of excess moisture in the soil after heavy rainfall events causes normal friction between the underlying material and the semi viscous soil mass to reduce, and the mass slowly or rapidly slides downhill.

Pictures of types of erosion

Sheet erosion:

Interill erosion:

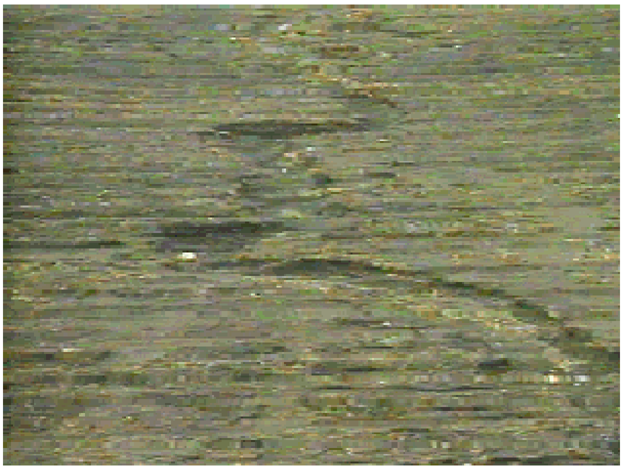
Rill erosion:



Channels:

Classical Gully:

Ephemeral Gully:



Landslides:

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

Rainfall amount, duration and intensity are obtained from measurements carried out with rain gauges. There are clock driven rain gauges from which duration of rainfall at short intervals of a few minutes can be obtained. Thus, it is possible and desirable to calculate rainfall intensities at such short intervals interval when evaluating its erosivity. Rainfall amount distribution also influences its erosivity. In an annual rainy season, the distribution can be unimodal (one peak of monthly rainfall amounts is attained in a year) or bimodal (two peaks of monthly rainfall amounts are attained in a year.

Rainfall intensity is:

Amount/duration = mm/h.

Rainfall intensities exceeding 150 mm h^{-1} are found regularly in the tropics whereas in temperate regions, rainfall intensity hardly exceeds 75 mm h^{-1}. Therefore, rainfall erosivity is considered higher for topical rains than temperate rains. For soil erosion studies, it is preferable to measure rainfall intensities at short intervals (e.g., less than 10 minutes) so that short-interval or instantaneous intensity which depicts its erosivity better than long-interval intensity (e.g., the usual practice of calculating intensity based on daily rainfall amount).

Drop size and drop size distribution are measured using:

- Drop-stain method in which an absorbent paper is dusted with powdered dust stain on which raindrops are collected
- Flour-pellet method which basically assesses the size of drops from size of pellets made
- Use of pressure transducers r acoustic device to measure impact of raindrop
- Photographic method in which photographs of falling raindrops were used.

In these different methods, drop size and distribution would still have to be evaluated from the data generated.

Large drops have higher terminal velocity than small drops. Raindrop size hardly exceeds 5 mm size, but when they coalesce they momentarily exceed this value. Since rainfall is made up of all possible drop sizes, the proportion of the different drop sizes in a particular event is of interest. Drop size distribution of rainfall can be described by a parameter called the median drop size or median volume drop diameter (D_{50}). D_{50} refers to the drop diameter at which 50 percent of the volume of the rain falls in the shape of drops with a smaller diameter and 50 percent as bigger drops. It seems that rains in the tropics have relatively bigger drops than those in temperate regions. The median drop size is affected by factors such as type of rain, amount of rain, duration of rain, rainfall intensity and wind velocity accompanying rain. High rainfall intensity may cause high median drop size or form more drops per unit area per unit timer. Median drop size generally increases with increases in rainfall intensity up to a certain limit according to the relationship:

$$D_{50} = 2.23I^{0.182}$$

Generally the relationship is written as

$$D_{50} = aI^{b}$$

because the constants will vary with rain types. The relationship is also believed to be valid up to 75 mm h^{-1} rainfall intensity.

Terminal velocity: A body falling freely under the force of gravity will accelerate until the frictional resistance of the air is equal to the gravitational force and the body will then continue to fall at that speed. Under natural condition, terminal velocity increases with an increase in drop size. Most drops attain terminal velocity in about 10-m fall under gravity.

Wind velocity: Strong wind adds a horizontal velocity component to raindrop. Wind partially reduces air resistance by moving air horizontally away from the drop. This reduced resistance and the actual drop of the wind combine to accelerate the drop. Wind also tends to break large drops (> 5 mm) into smaller pieces. Wind-driven rains are usually more erosive than non-wind-driven rains. The magnitude of the difference depends on wind velocity, rainfall intensity, and slope characteristics. Peak wind velocity does not usually coincide with peak rainfall intensity because of time lag between the two.

Kinetic energy: This is the product of the mass of rain falling per unit time and the square of its terminal velocity

$$E = \sum ½mv^2$$

Bigger drop size makes the energy load of tropical rainstorms high. The kinetic energy of rainfall can be measured directly using equipment with (1) acoustic sensors (2) piezoelectric sensors, and (3) pressure transducers. However, it is not often measured routinely. Therefore, empirical equations have been developed to estimate it. The most commonly used of these equations was developed by Wischmeir and Smith (1958), and it is

$$e_m = 0.119 + 0.0873 \log_{10}(i_m) \quad im \leq 76 \text{ mm h}^{-1}$$

$e_m = 0.283 \quad i_m > 76 \text{ mm h}^{-1}$

where em has units of MJ/ha. mm or MJ.ha^{-1}.mm^{-1}). Note that the equations are based on the principle that drop size will not increase above 75 mm h^{-1} intensity. Second, is the fact that e_m is energy of a unit component of a rainfall event not total energy E of the event.

Soil

The vulnerability of the soil to erosion is called soil erodibility. Note that we talk of rainfall erosivity, and soil erodibility. Erosivity is a characteristic of the rain while erodibility is a characteristic of the soil.. Erodibility of the soil can be subdivided into three parts: (I) the fundamental or inherent characteristics of the soil- the mechanical, chemical and physical composition which can be measured in the lab, (ii) the topographic features- slope, and iii) the management of the soil.

Mechanical soil properties: 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. In view of the relationship found in soil erosion and texture, the erodibility of soils has been evaluated with texture-based indices. Some of the indices often used are as flows:

Bouyoucos (1935) index: %sand + %silt/% clay

Dispersion ratio: (silt + clay in undispersed sample/ silt + clay in dispersed sample)*100

Erosion ratio: (dispersion ratio) ÷(colloid content/moisture equivalent)

Clay ratio or mechanical ratio: sand/(silt+clay)

4.3 MODELS FOR SOIL EROSION ASSESSMENT

Historical Issues: Quantitative assessment of soil erosion started as long as 1877 but the lead in the research has been provided since 1915 by scientists in the United States of America. This lead has resulted in the development in 1954 of the Universal Soil Loss Equation (USLE). This was based on 10000 plot-years of basic runoff and soil loss data, which were summarized into an empirical equation. This phase ushered in the phase of quantitative scientific evaluation. As expected, opinions were divided on the usefulness of the Universal Soil Loss Equation in regions outside the place of its development. A major recent shift has been `toward using process-based models rather than empirical models like the USLE. On popular process-based model is the Water Erosion Prediction Project (WEPP).

It is often found convenient to estimate the effect of a physical process by using equations or formula or charts and diagrams based on experience. It is now common to refer to such as models these days. The advent of computers has made it possible to find easy solutions to hitherto complex models, and this has tended to lead to development of more complex ones. Models or equations can be categorized as follows:

Empirical models are based on observations or experiments, and not derived from theory. Prediction with such a model is based on already known facts in the circumstances under which it was developed. The ideal thing is to use such a model for prediction under similar circumstances as it was developed, but this is hardly the case in reality. A factor model is an empirical model where each of the variables is represented by a quantified factor, and then the factors are combined, for example by adding them up or multiplying them. The USLE is based on this approach.

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.

Stochastic models are useful particularly in hydrological studies and are based on probabilities of occurrence of events in a long time series. They are commonly used in hydrology

Processed-Based Models

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. There are:

WEPP hill slope model

WEPP watershed model

The profile version replaces USLE as an estimator of erosion on a uniform hill slope, with addition of an element for deposition. The watershed version extends to a field size watershed such as a terraced field. The grid version is for areas where boundaries do not coincided with watershed boundaries, and which can be broken into separate elements.

Examples of existing models

Empirical:

- RUSLE
- The Soil Loss Estimation Model for Southern Africa (SLEMSA): It is a modification of the USLE: SOILOSS developed in New South Wales, Australia
- Soil Changes Under Agroforestry (SCUAF)

Process-based or Physically-Based Models

European Soil Erosion Model (EUROSEM): This is developed with the objective of assessing erosion on field and catchment scale

Erosion related models

Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS): It is used mainly to compute the loss of pollutants from field scale agricultural areas, but the erosion components can be modeled separately

Areal Non-point Source Watershed Environment Response Simulation (ANSWERS): The aim is to assess sediment yowled from whole watershed (a nonpoint source) as opposed to that from field-size areas (a point-source) and to assess cost effectiveness of possible land use treatments within the watershed.

Productivity models: Models to estimate the loss of productivity also exist now. Most of these models start by estimating the amount of soil loss, and then as an additional stage assess the effect of this loss on productivity. One of such models is the 'Erosion Productivity Impact Calculator (EPIC). EPIC is a combination of empirical and physically based components.

Surface runoff can be predicted and hydrologic phase weather, percolation, drainage, and evapotranspiration. Erosion estimates are made, and plant nutrients considered are nitrogen and phosphorus.

It should be clear that no matter how good a model is, it is only useful with a good database. Quite often, this is lacking in many developing countries

Using Revised Universal Soil Loss Equation (RUSLE) for Soil Loss Evaluation

RUSLE has the same basic structure as the USLE as follows:

A = RKLSCP

where

A is the soil loss in t ha^{-1} yr^{-1} or $Mg.ha^{-1}.yr^{-1}$

R is the rainfall erosivity factor in $MJ.mm.ha^{-1}.h^{-1}$

K is soil erodibility factor which is also the soil rate per erosion index for a specified soil loss as measured on s standard plot (22.1 m length of a uniform 9% slope in continuous clean-tilled condition). In SI units, it is measured in t.ha.h. ha^{-1} $MJ^{-1}.mm^{-1}$.

L is the slope length factor which is the ratio of soil loss from field slope length to soil loss from a 22.1 m length under identical conditions (dimensionless)

S is slope steepness factor which is the ratio of soil loss from the field slope gradient to soil loss from a 9 % slope under identical conditions (dimensionless)

C is cover-management factor

P is support practice factor and it is the ratio of soil loss with a support practice like contouring, strip cropping or terracing to soil loss with straight row farming up and down the slope.

Maximum possible erosion occurs when C and P have a value of 1 each, implying that the soil was bare with no land management practice to control erosion. Also the standard plot is a reference point as it is customary in science when a standard is required to measure an event. It was as a result of historical development of the USLE. As stated, a standard plot is 22.13 m long, on a uniform lengthwise slope of 9%. It is tilled up and down the slope and in bare for at least two years. The calculations in RUSLE are more involved than those in the USLE and are facilitated by a computer program

RUSLE is designed to predict the longtime average annual soil loss (A) carried by runoff from specific field slopes in specified cropping and management systems as well as from rangeland. It is also applicable to nonagricultural conditions such as construction sites. RUSLE users should note that, A, is also the average soil loss over a field slope ant that the losses at various points nay vary greatly from one another. RUSLE does not address the estimation of soil loss from disturbed forested land as does the USLE.

Predict average annual soil loss from a field slope with specific land use conditions

guide the selection of cropping and management systems, and conservation practices for specific soils and slopes predict the change in soil loss that would result from a change in cropping or conservation practices on a specific field determine how conservation practices may be applied or altered to allow more intensive cultivation estimate soil losses from land use areas other than agricultural provide soil loss estimates for conservationists to use for determining conservation needs.

Limitiations include inability of nomograph to predict soil erodibility of tropical soils (Oxisols, LAC (Alfisols) accurately. Also, soil erodibilty of subsoils are not accurately predicted

Sample calculations of erosivity from rainfall records

1	2	3	4			
Time	Depth or amount of rain (mm)	Duratio n (min.)	Amount (mm)	Intensit y (mm h^{-1}	Energy per unit rainfall, e_m (MJ.ha^{-1})	Energy for storm increment (MJ/ha)
4:00	0					
:20	1	20	1	3	0.161	0.16
:27	3	7	2	17	0.226	0.45
:36	9	9	6	40	0.259	1.55
:50	27	14	18	77	0.283	5.09
:57	30	7	3	26	0.243	0.73
5:05	32	8	2	15	0.222	0.44
:15	32	10	0	0	0	0
:30	33	15	1	4	0.219	0.22
Totals		90	33			8.64

The E for this storm is 8.64 MJ/ha

I_{30} is 2 (27) = 52 mm h^{-1}.

EI_{30} = 8.64 x 52 = 449.28 MJ.mm/ha.h

KE > 25 = 1.55 + 5.09 + 0.73 = = 7.37 MJ ha^{-1}

Using EI method

Intensity (mm/h)	Amount (mm)	Energy[1] $J/m^2/mm$	Total (Col 2 x Col 3)
0-25	30	22.0	660
25-50	25	26.0	650
50-75	15	28.0	420
> 75	10	28.3	283
			2013 J/m^2

Calculated from e = 11.9 + 8.7 log I

$I_{30} = 52\ mm\ h^{-1}$

$EI_{30} = 2013 \times 52 = 104676\ J.\ mm/m^2.\ h$

Using KE > 25 method

Intensity (mm/h)	Amount (mm)	Energy[2] $J/m^2/mm$	Total (Col 2 x Col 3)
0-25	30	-	-
25-50	25	25.2	630
50-75	15	27.8	417
> 75	10	29.0	290
			1337 J/m^2

[2:] **$e = 30 – 125/I$**

Table 1: Rain and throughfall drop sizes in relation to splash erosion in south-central Nigeria[#]

	Drop size (mm)		Splashed sand (g)	
Type	Median	Maximum	Fine sand	Medium sand
Rainfall	2.3	5.1	35	28
Gmelina arborea throughfall	3.6	5.3	33	43
Senna siamea throughfall	3.2	5.2	30	37
Natural forest throughfall	4.0	5.3	40	46

[#] Source: Akinnifesi and Salako (1997)

In Nigeria, the following relationships have been found between measured kinetic energy (E in $J\ m^{-2}$) of rainfall and daily rainfall amount (A in mm):

Northern Nigeria (Kowal and Kassam, 1976)

$E = 41.4A - 120$ $r = 0.99$ (1)

Southwestern Nigeria (Lal, 1998)

$E = 25.8A + 54.58$, $r = 0.95$ Season 1 for the bimodal annual rain (2)

$E = 29.86A - 43.18$, $r = 0.98$ Season 2 for the bimodal annual rain (3)

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 we need

% silt + % very fine sand

% organic matter

% sand (0.10 to 2.00 mm)

Class of soil structure

Class of permeability

Obi et al. (1989) reported a soil erodibility value of 0.007 $t\ .h.\ MJ^{-1}.\ mm^{-1}$ for an Ultisol in southeastern Nigeria.

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).

Thus

$$L = (\text{field slope length}/72.6)^m$$

Slope steepness is defined as the gradient expressed in units of vertical rise or fall per unit of horizontal distance (decimal fraction) or 100 units of distance (percent). 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.

S in the LS factor is based on the percent slope as calculated by the land surface approach adjusted so that the standard 9 % slope has a value of 1.0. S can be calculated from the equations

$$S = 10.8s + 0.03 \quad s < 9\ \%$$

$$S = 16.8s - 0.50 \quad s \geq 9\ \%$$

Slope length and steepness are combined into a single LS factor which is

$$LS = (\text{field slope length}/72.6)^m\ (10.8s + 0.03) \qquad s < 9\%$$

$$LS = (\text{field slope length}/72.6)^m\ (16.8s + 0.50) \qquad s \geq 9\%$$

Slope lengths used in the development of the equations were relatively short and uniform. Derived LS values work well for ordinary field conditions. Where slopes are very gentle, complex, or unusually long, values may not be accurate.

Shapes of slopes also affect average soil loss and relative loss from different segments of an irregular slope. Convex surfaces cause greater losses than uniform surfaces of the same average gradient; concave slopes cause smaller losses

Values for topographic factor (LS) for moderate-ratio rill to interrill erosion, such as for row-cropped agricultural and other moderately

consolidated soil conditions with moderate cover

	Slope length (m)											
Slope (%)	**7.5**	**15**	**22.5**	**30**	**45**	**60**	**90**	**120**	**150**	**180**	**240**	**300**
8	0.53	0.74	0.91	1	1.3	1.4	1.8	2	2.2	2.5	2.8	3.2
10	0.67	0.97	1.2	1.4	1.7	2	2.4	2.8	3.2	3.5	4.1	4.6
12	0.84	1.2	1.5	1.8	2.2	2.6	3.3	3.8	4.3	4.8	5.6	6.3
14	1	1.5	1.9	2.2	2.8	3.2	4.1	4.8	5.4	6.1	7.2	8.1
16	1.2	1.7	2.2	2.6	3.3	3.9	5	5.9	6.5	7.4	8.8	10

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.

In West Africa, the following C factors have been reported by Roose (1977) as follows:

Practice	Average annual C factor
Bare Soil	1
Forest or dense shrub, high mulch crop	0.001
Savanna, in good condition	0.01
Crop cover of slow development or late planting: 1st year	0.3 to 0.8
Crop cover of rapid development or early planting: 1st year	0.01 to 0.01
Crop cover of slow development or late planting: second year	0.01 to 0.10
Corn, sorghum, millet	0.4 to 0.9
Rice	0.1 to 0.2

Canopy density depends on planting method and soil productivity. Tillage affects soil permeability and residue disposition. The cover-management factor (C) is the ratio between the amount of soil lost under specific crop-cover management conditions and that lost when soil is bare, and cultivated regularly up and down the slope. Soil loss from cropped field is usually smaller than that from a continuously bare field.

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. The P factor indicated the fractional amount of erosion that occurs when these special practices are used compared with what it would be without them.

5.0 SOIL EROSION BY WIND

Wind erosion is the process of detachment, transportation nd deposition of soil materials by wind. The basic causes are:

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

Wind erosion can be eliminated or curtailed whenever:

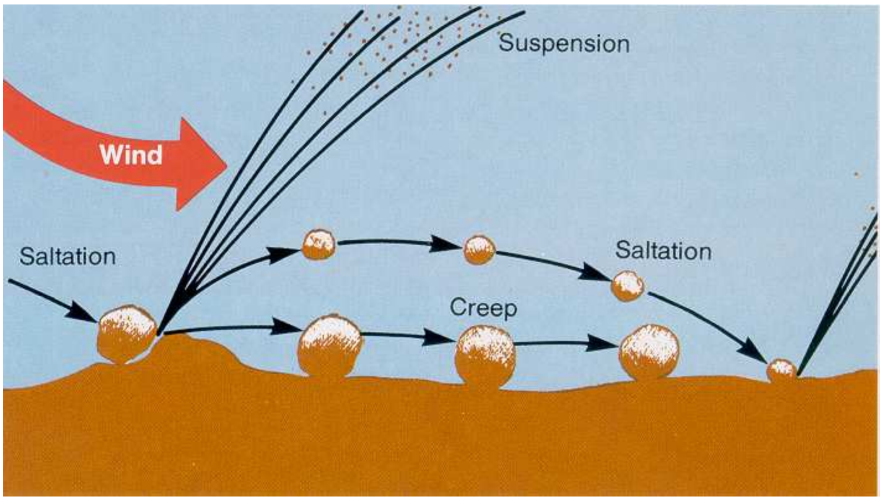
(i) The soil is compacted, kept moist or made up of stable aggregates or clods large enough to resist the force of the wind

(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

Suspension, saltation, and surface creep 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.



Suspension: Soil particles and aggregates less than 0.05 mm in diameter (silt size and smaller are kept suspended by the turbulence of air currents, after being dislodged by saltating particles. These particles only drop out of air if rain washes them or wind velocity reduces drastically. **Suspension** occurs when very fine dirt and dust particles are lifted into the wind. They can be thrown into the air through impact with other particles or by the wind itself. Once in the atmosphere, these particles can be carried very high and be transported over extremely long distances. Soil moved by suspension is the most spectacular and easiest to recognize of the three forms of movement.

Saltation: This the process in which fine particles (0.05 (0.1) to 0.5 mm in diameter) are lifted from the soil surface by wind turbulence and follow distinct trajectories under the influence of wind forces, air resistance, and gravity. In other words, the particles move in a series of short leaps. 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. **Saltation** - The major fraction of soil moved by the wind is through the process of saltation. In saltation, fine soil particles are lifted into the air by the wind and drift horizontally across the surface increasing in velocity as they go. Soil particles moved in this process of saltation can cause severe damage to the soil surface and vegetation. They travel approximately four times longer in distance than in height. When they strike the surface again they either rebound back into the air or knock other particles into the air.

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. The soil aggregates or gravel which cannot be eroded are left in place to provide a cover called *desert pavement or lag gravel.*

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. It is more pronounced near the soil surface than higher in the wind stream. 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 METHODS OF SOIL WATER CONSERVATION

6.1 Introduction

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.

Two methods by which crop damage due to drought can be reduced are by:

- Conserving as much water in the soil as possible
- Irrigation

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

- Reducing evaporation from water surface
- Reducing seepage losses from reservoirs
- Reducing evaporation from soil surface
- Reducing deep percolation losses from crop land
- Utilizing stored water efficiently

6.2 Reducing evaporation from water surface:

Methods used to reduce evaporation losses from storage reservoir include:

- Covering the water surface with barriers that prevents vaporization using a cover or liquid chemicals such as aliphatic alcohols and wax.
- Blocks, rafts, beads that are capable of floating.
- Sand-and-rock-filled dams.

The main focus of evaporation prevention by any of these methods is reduction in the area where vaporization can occur. This is to prevent direct rays of sun from heating the water surface.

Advantages:

i. Requires little construction

ii. By reducing evaporation in water stored in earthen dams, high salt concentration which results from evaporation is reduced.

iii. By cutting off light from the water surface by floating devices, the growth of algae and submerged aquatic weeds is reduced

Limitations:

i. Such devices can only be used in small storage tanks and ponds.
ii. Sand storage tanks are difficult to construct hence technology for building them has not been widely acceptable

6.3 Reducing seepage losses from reservoirs:

This can only be prevented or reduced by making the walls and conduits water tight or impermeable.

Some of the methods to designed to achieve this are:

- Compacting the soil
- Chemical treatment of the soil with some soil covers such as
    - Butly rubber
    - Plastic sheet
    - Asphalt reinforced with plastic or fiberglass or ferrocement
- Where seepage due to flocculated clays caused by calcium ions are problem like in arid region, treatment with sodium carbonate will help to deffloculate the clays.
- Reservoir that do not contain any rock and are not more than 300 cm deep can be made impervious by using cheap polyethylene or polypropylene films.

  Limitation:

  The greatest disadvantage to the use of these materials is cost.

6.4 Reducing evaporation from soil surface:

This is achieved by:

- Covering the soil surface with large amount of water-tight or water-retardant mulches
- Windbreaks with trees and fences to reduce wind velocity

Some of the materials used as mulches are:

- Paper asphalt, latex, oil plastic films and metal foils – these are non-porous materials.
- Plant residues like sawdust, straw and wood bark

Conservation by plant residues is achieved most if there are standing residues covering at least 90% of the total area.

Advantages:

i. Reduces erosion by water and wind
ii. Increases soil temperature which beneficial to germination and early seedling growth.
iii. Improves the quality of some fruits such as tomato, pepper by preventing contact with soil
iv. Plastic and oil mulches can be used for water harvesting

Limitation:

The main limitation is the cost of mulching materials especially chemical and plastic mulches

6.5 Reducing deep percolation losses from crop lands:

Losses of water through percolation from croplands are problems in humid regions where irrigated agriculture is practiced. Such losses become a problem if the soils have low water holding capacity such as the coarse-textured soils of West Africa.

The common way of reducing deep percolation losses is by placing moisture barriers horizontally about 60 cm below the soil surface. In addition, these barriers prevent nutrients from being lost through deep drainage. Some of these materials are:

- Plastic sheets
- Thick layers of compost manure
- Asphalt barriers
- Another approach, especially in sandy soils, is addition of materials that could absorb large amount of water. Typical example of these is copolymer of starch and acrylonite known commercially as “Super-slurper”

Limitation:

Cost

6.6 Utilizing stored water efficiently:

Losses of water in storage can also be reduced by:

- Reducing transpiration losses by use of windbreaks or anti-transipirants and control of weeds and unwanted crops.
- Planting at optimum seeding rates
- Growing crops that utilize moisture efficiently
- Growing crops when there is some chance that the water will carry the crops through the season.

Limitations:

The problems with the use of anti-transipirants are:

i. Toxic tom plants and animals
ii. Restrict gaseous and vapour exchange
iii. Highly impermeable to wavelength of light needed for photosynthesis
iv. Not flexible enough to allow for leave motion and expansion
v. Easily degraded by sunlight and microorganisms
vi. Not economically attractive