Soil and Water Conservation
Lecture - 1

Soil and water conservation science is deal with two conservation branches :

1- Soil conservation, and
2- Water conservation

Soil conservation :

Definition :

----------------Using the land in such away that keep its soil permently productive.

Erosion is the most dominent conservation problemon most soils of arable land .It reduces the productivity of most arable lands.

Soil Erosion

----------------- mean the removal of soil surface materials by wind or water,therefore ,there are two types of soil erosions depending on the forces :

1- Wind Erosion , which mean that the wind is the force factor in removal soil surface , and
2- Water erosion , which mean that the rainfal is the force factor in removal soil surface , therefore the water erosion also called Rainfall Erosion

Soil erosion can be determined in term of soil loss.

Soil loss , estimated in unit of (mass / area / period), this unit can be trnslated ito customary and SI unit, like:

Tonne / hectar / year = t / ha./yr or

Meqa gramm/ hectar /year

Tonne = mass unit = 1000 kg = 10^3 kg

Meqa gramm=mass unit = *M*g =10^6 gm = tonne = 10^3 kg

Hectar = area unit = 10000 m^2 = 10^4 m^2

Year = constant period unit= 365 days

Or

Pound/ acre /year = Ib = acre=yr

Pound = 0.435 kg

Acre = 4046.8 m2

ha =2.47 acre

The results of many researches show that the the soil oss from any soil should be less than acceptale soil loss from any soil of arable lands . This accepable called T-value, (Tolerence soil loss Value) which equal to 11.2 t/ha/yr.This mean that if;

annual soil loss > Tvalue, it diversly effect crop growth and soil need conservation practices to reduce the soil loss to value equal or less than T-vlue).

annual soil loss < Tvalue, to be (the soil did not effect crop growth and not neddded conservation practices).

Tolerence soil loss value (T-value), mean the acceptable annual soil loss (Erosion rate) that keep the soil is productive and crops grow in safety condition.,

Soil and Water Conservation

Lec. 2

Water Erosion

Water erosion
--------------- is removal of soil materials by two main forces ;

1- **Directly by rainfall impact** : Raindrops can both destroy soil aggregates and transport soil for small distances, and

2- **Indirect by Flowing water (runoff water)**: Which is result from rainfall transports the detached particles down hill.

Rainfall characteristics which effect soil water erosion

Rainfall characteristics is a commonly used as climatic parameters for the prediction of soil erosion by water . Therefore the rainfall data analysis and determind the physical characteristics of rainfall are very important in designing and planning of soil and water conservation practices to reduce the soil water erosion. These physical characteristics are :

1- **Rainfall depth** (mm):
-----------------------------Rainfall depth is the total rainfall accumulated at a given point . It expressed in mm or cm or inch. Rainfall depth can be obtained direcly from rainfall gauges which presented in any metrological station .

2-Rainfall intensity (mm/hr) ;

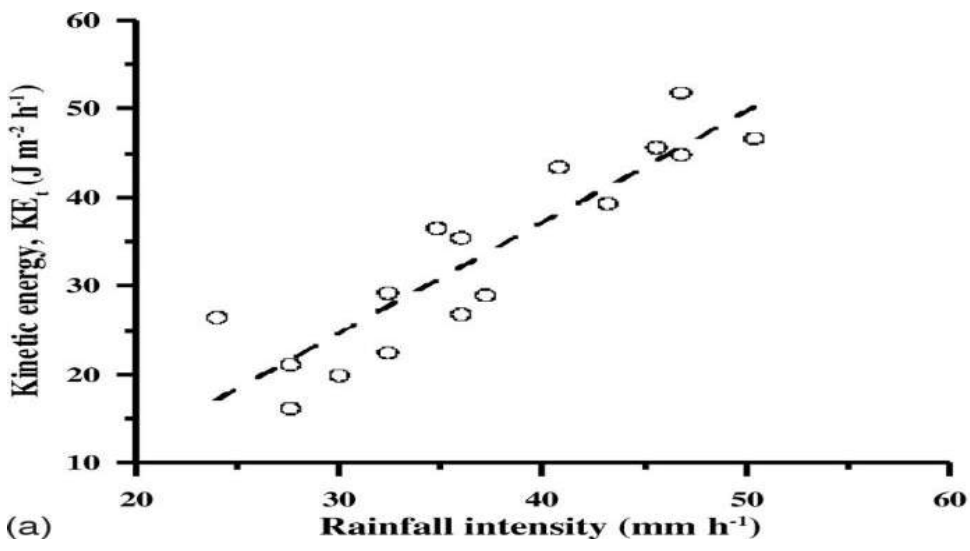
------------------------------------ Rainfall intensity is a measure of the amount of rain (mm) that falls over time (hr). It is the ratio of total amount of **rain** (rainfall depth) falling during a given period to the duration of the period. It is expresse in depth units per unit time, usually as mm per hour (mm/h) or Cm per hour (Cm / hr). Therefore two type of raingauge :

a- Simple raingauge , which give only rainfall depth in mm

b- Recording raingauge,which give rainfall depth and time of rain

2- Rainfall Kinetic energy (KE):

-- The rainfall kinetic energy is a commonly used climatic parameter for the prediction of soil erosion by water. Such a parameter is difficult to measure and is usually estimated from relationships established between rainfall energy and rainfall intensity.It was found that there is a close relationship between kinetic energy (KE) and intensity (I) of rainfall as shown in the following figure:



Fig; Shows the relatioship between rainfall kinetic energy and rainfall intensity

Therefore the kinetic energy and intensity are commonly used factors to predict soil erosion by water. Empirical relationships between kinetic energy and rainfall intensity have been developed which is **:**

KE = 210 + 89 Log I

Where : KE = Rainstorm kinetic energy J/m^2 /hr

I = Rainfall intensity (cm / hr)

Ex (1) : Analyze the following rainstorm:the two colums in the table were obtained from raingauge

Time hr:min	Rainfall depth (mm)
14:15	0
14:20	2
16:00	4
16:30	1.5
17:10	2.8
17:20	3
17:50	6
18:15	5

Analyze of rainfall data need to obtain the time interval (in mm/hr) and then calculate the rainfall intensity (in mm/hr) using the following expression :

Rainfall intensity (I) = Raifall depth (in mm) / time of duration (in hr)

Colum 1	**Colum 2**	**Colum 3**	**Colum 4**
Time	**Time Interval (Min.)**	**Rainfall depth (mm)**	**Rainfall Intensity (I) mm/hr**
14:15	**0**	**0**	**0**
14:20	**5**	**2**	**24**
16:00	**100**	**4**	**2.4**
16:30	**30**	**1.5**	**3**
17:10	**40**	**2.8**	**4.2**
17:20	**10**	**3**	**18**
17:50	**30**	**6**	**12**
18:15	**25**	**5**	**12**
	240	**24.3**	

Colum 1 from raingauge

Colum 2 :from colum 1 (first time – second time)

Colum 3 :also from rain gauge

Colum 4 : (Colum 3 / colum 2) * 60

Ex- 1: find the total time of of storm = 240 min.

Find the total rainfall depth = 24.3 mm

Find the maximumm intensity ($I_m = I_{24}$) = 24 mm/ hr

Find the maximumu intensity at 30min.(I_{30}) = 12mm/hr

Ex - 2:Calculate the kinetic energy (KE) of the above rainstorm:

1- Transfer the rainfall intensty in the colum 4 from mm/ hr to cm/hr

2- We can find the kinetic energy by the following equation :

$$KE=210 + 89\log I$$

Where (I) is the rainfall intensity in cm /hr

Time	Time Interval (Min.)	Rainfall depth (mm)	Rainfal Intensity (I)		Kinetic Energy (KE)
			mm/hr	Cm / hr	
14:15	0	0	0	0	0
14:20	5	2	24	2.4	176.1
16:00	100	4	2.4	0.24	154.8
16:30	30	1.5	3	0.3	163.4
17:10	40	2.8	4.2	0.42	176.4
17:20	10	3	18	1.8	232.7
17:50	30	6	12	1.2	217.0
18:15	25	5	12	1.2	217.0
	240	24.3			1337.4

Soil and Water Conservation

Lec. 3

Runoff

---------- is a portion of rainfall which flow as a surface or sub-surface and ending to to water collection (lake, sea or ocean).

The term runoff usually mean surface runoff .

Factor affecting surface runoff:

1-Soil texture:

Fine textured soil > Coarse textured soil

Low infiltration rate > High infiltration rate

2-Surface crust :

Crusted soil > Non -crusted soil

3-AMC (Antecedent Moisture Condition):

Moist soil > Dry soil

4-Landscape (Slope):

Slope land > Level land

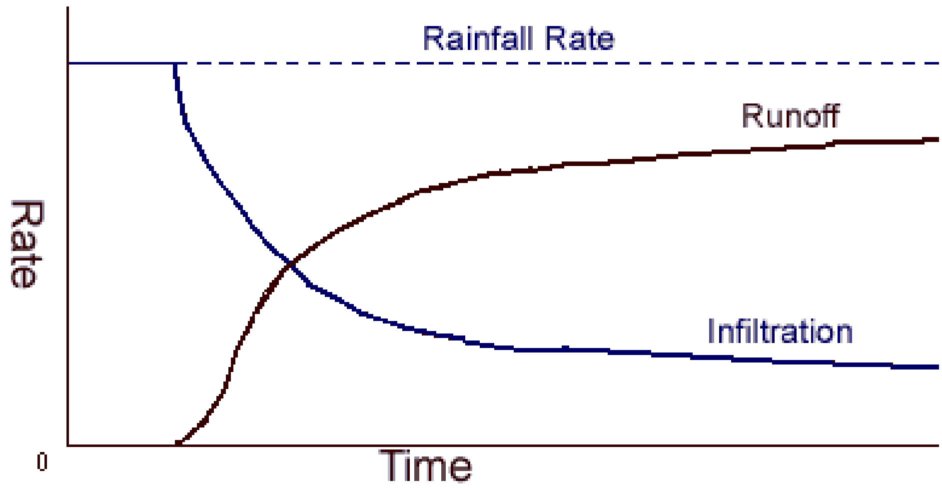
5-Rainfall duration:

Long rainfall duration > Short rainfall duration

6-Rainfall intensity:

High rainfall intensity > Low rainfall intensity

Rainfall intensity > Soil infiltration rate



Main Relatioship between runoff rate and soil infiltration rate

Types of Flow :

-------------------------There are two types of flow:

1-Overland flow : runoff water flow as alaminar .

2- Chanell flow : runoff water flow in well defined channel .

Runoff velocity of each the two types of flow can be estimated using Manning Equation:

1- Overland flow :

$$V = 1/n \ (Y)^{2/3} \ X \ S^{1/2} \quad \text{------------------------------(1)}$$

Where :

V= Flow Velocity (m/s)

n= Manning roughness coefficient

Y= Fow depth (m).

S= Land slope

2- Channel flow :

$$V = 1/n \ (R)^{2/3} \ X \ S^{1/2} \quad \text{--------------------(2)}$$

V= Flow Velocity (m/s)

N= Manning roughness coefficient

S= Land slope

R= Hydraulic Radius of channel (m).

R = A / P

A= Area of channel cross section (m^2)

P = Wetted perimeter of channel (m)

Therefore, Eq. 2 can be written as follows:

$$V = 1/n \ (A / P)^{2/3} \ X \ S^{1/2} \quad \text{-------------------(3)}$$

Channel may be Square , Rectangular or Circular

Soil and Water Conservation
Lecture - 4

Runoff Data Analysis

There are **two** methods to formulate the runoff data analysis:

First : Method for formulate the runoff as a depth or volume :

This methods are used to formulate the runoff data analysis into as a depth or volume which is particularly important to planning and design of various soil conservation practices to control the water erosion damage in cultivated land **.** The main common method of this type of formulation are includes:

1-Statistical Method

2-US Soil Conservation Service Method

3-TRRL Method, Izzard's Method

Second : Method for formulate the runoff as a peak flow:

This methods are used to estimate the peak flow of runoff which is particularly important to design various soil and water conservation structures. The main common method of this type of formulation are includes:

1-Rational Method

2-Cook's Method

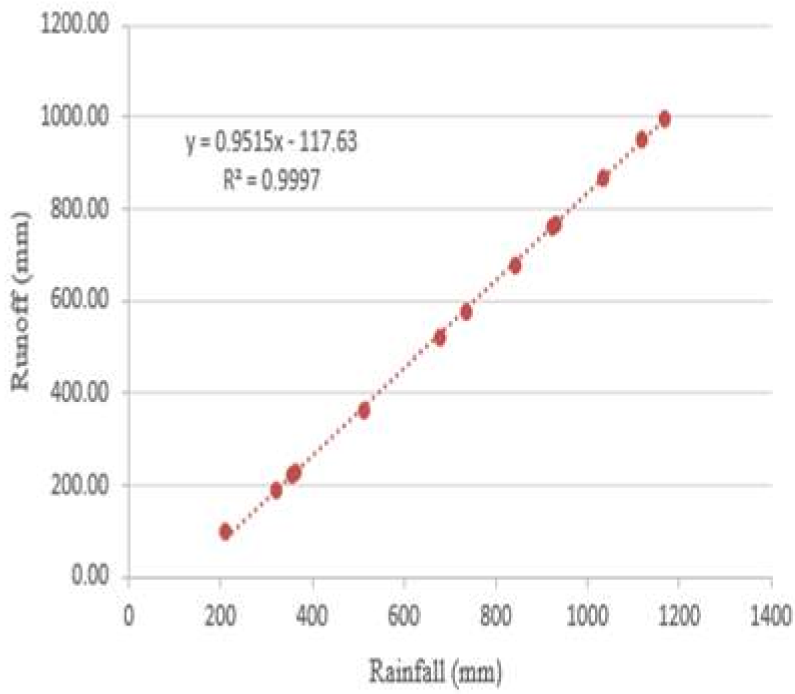
3-TRRL Method

4-Izzard's Method

First : Method for formulate the runoff as a depth or volume

1- Statistical Method:

Long term of rainfall-runoff relationship records are analyzed and relationships for runoff opprediction are developed . This method is relaible of sufficient records over stable runoff and watershed condition remined approximate the same .



Runoff depth (mm) = 0.9515 (Rainfall depth in mm) – 117.66

2-Direct Method : In this method ,we translate the rainfall depth to runoff depth using multiple correlation analysis . This method account for

A- Total rainfall .

B- Iintial rainfall abstraction.

C- Antecedent soil moisture cntent .

(3)

-- Lab 3 --

Direct runoff analysis

Data from gauged watersheds in the U.S showed the following basic relationship between rainfall and runoff :

$$\frac{P - Ia - Q}{S} = \frac{Q}{P - Ia} \quad \text{------}(1)$$

Where P = Precipitation from the storm being analyzed .

Ia = Precipitation abstraction . mm

Q = Total runoff . mm

S = Max. potential difference between P and Q at the beginning of the storm . mm

Equation 1 may be written as :

$$Q = \frac{(P - Ia)^2}{P - Ia + S} \quad \text{----------------}(2)$$

Data also showed that :

$$Ia = 0.2\,S \quad \text{------------------}(3)$$

Hence :

$$Q = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} \quad \text{----------------}(4)$$

For convenience , an orbitrary quantity called curve number " CN " was chosen such that :

$$CN = \frac{25400}{S + 254} \quad \text{------------------}(5)$$

Where S is measured in (mm)

When S → % , CN → 0 which means there is no runoff .

When S → 0 , CN → % and all rainfall becomes runoff in an ideal situation .

4

Selection of a curve number (CN)

The 1st watershed factor affecting CN is soil type . Soils varies from group A with the lowest runoff potential to group D with the highest runoff potential .

The 2nd factor is the antecedent soil moisture condition or AMC.

AMC is classified as follow :

AMC – I : Soils are dry but moisture is above the wilting point .

AMC – II : Average condition usually precedes the occurrence of the max. annual flood .

AMC – III : Soils are nearly saturated .

EX . The 50 yr - 24 h storm in Mosul is 80 mm . Calculate total runoff for the three conditions of soil moisture . Mosul soil is clay loam .

(assuming good pasture) .

Table 4.2 Hydrologic Soil Group Conversion Factors

Cover and hydrologic condition	Factors for converting the runoff coefficient C from group B soils to[a]		
	Group A	Group C	Group D
Row crop, poor practice	0.89	1.09	1.12
Row crop, Good practice	0.86	1.09	1.14
Small grain, poor practice	0.86	1.11	1.16
Small grain, good practice	0.84	1.11	1.16
Meadow, rotation, good	0.81	1.13	1.18
Pasture, permanent, good	0.64	1.21	1.31
Woodland, mature, good	0.45	1.27	1.40

[a] Factors were computed from Table 4.3 by dividing the curve number for the desired soil group by the curve number for group B.

Table 4.3 Runoff Curve Numbers for Hydrologic Soil-Cover Complexes for Antecedent Rainfall Condition II, and $I_a = 0.2S$

Land Use or Cover	Treatment or Practice	Hydrologic Condition	*Hydrologic Soil Group			
			A	B	C	D
Fallow	Straight row	—	77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Terraced	Poor	66	74	80	82
	Terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Terraced	Poor	61	72	79	82
	Terraced	Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Terraced	Poor	63	73	80	83
	Terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79

Table 4.3 (Continued)

Land Use or Cover	Treatment or Practice	Hydrologic Condition	*Hydrologic Soil Grou		
			A	B	C
Meadow (permanent)		Good	30	58	71
Woods (farm wood-lots)		Poor	45	66	77
		Fair	36	60	73
		Good	25	55	70
Farmsteads		—	59	74	82
Roads and right-of-way (hard surface)		—	74	84	90

*Soil Group	Description	Final infiltrat Rate (mm/h
A	*Lowest Runoff Potential.* Includes deep sands with very little silt and clay; also deep, rapidly permeable loess.	8–12
B	*Moderately Low Runoff Potential.* Mostly sandy soils less deep than A, and loess less deep or less aggregated than A, but the group as a whole has above-average infiltration after thorough wetting.	4–8
C	*Moderately High Runoff Potential.* Comprises shallow soils and soils containing considerable clay and colloids, though less than those of group D. The group has below-average infiltration after presaturation.	1–4
D	*Highest Runoff Potential.* Includes mostly clays of high swelling percent, but the group also includes some shallow soils with nearly impermeable subhorizons near the surface.	0–1

Source: U. S. Soil Conservation Service, *National Engineering Handbook, Hydrology*, Se (1972) and U. S. Dept. Agr. ARS 41-172 (1970).

The rational method is developed from the assumptions that: (1) r occurs at uniform intensity for a duration at least equal to the time of co tration of the watershed, and (2) rainfall occurs at a uniform intensity ov entire area of the watershed. If these assumptions were fulfilled, the rainfa runoff for the watershed would be represented graphically by Fig. 4.3*a* figure shows a rain of uniform intensity for a duration equal to the ti concentration, T_c. If a storm of duration greater than T_c occurred, the r rate would be less than q because the rainfall intensity would be less than Chapter 2 for relationships between rainfall intensity and duration). A r

For convenience in evaluating antecedent moisture, soil conditions, land use, and conservation practices, the U.S. Soil Conservation Service (1972) defines

$$S = \frac{25\,400}{N} - 254 \qquad (4.7)$$

where N = an arbitrary curve number varying from 0 to 100.

Thus, if

$$N = 100, \text{ then } S = 0 \text{ and } I = Q.$$

Curve numbers can be obtained from Table 4.3. These values apply to antecedent rainfall condition II, which is an average value for annual floods. Correction factors for other antecedent rainfall conditions are listed in Table 4.4.

Table 4.4 Antecedent Rainfall Conditions and Curve Numbers (for $I_a = 0.2S$)

Curve Number for Condition II	*Factor to Convert Curve Number for Condition II to*	
	Condition I	*Condition III*
10	0.40	2.22
20	0.45	1.85
30	0.50	1.67
40	0.55	1.50
50	0.62	1.40
60	0.67	1.30
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1.00	1.00

Condition	*General Description*	*5-Day Antecedent Rainfall (mm)*	
		Dormant Season	*Growing Season*
I	Optimum soil condition from about lower plastic limit to wilting point	<13	<36
II	Average value for annual floods	13–28	36–53
III	Heavy rainfall or light rainfall and low temperatures within 5 days prior to the given storm	>28	>53

Source: U. S. Soil Conservation Service, *National Engineering Handbook, Hydrology*, Section 4 (1972).

Soil and Water Conservation
Lecture - 5

Runoff Data Analysis

Second : Method for formulate the runoff as a peak flow:

These methods are used to estimate the peak flow of runoff which is particularly important to design various soil and water conservation structures. The most common models type of this formulation are:

1-Cook's model 2-Rational Method

1-Cook’s model, this model is used to estimate runoff rate from a small agricultural watershed (up to about 400 ha). In this method, the peak runoff value is modified for frequency and geographic rainfall characteristics by the formula:

$$q = PRF$$

where,

q = peak runoff rate for a specified geographic location and return period

R=geographic rainfall factor

P = peak runoff rate from a watershed of a given hydrologic characteristics, assu

F = return period factor , For accurate estimation of peak runoff rate.

1- **Rational Method** :This method is used to estimate the design peak runoff rate for soil and water conservation structures of less than 1000 ha . In SI units, the equation of rational method that relates the area of watershed (A) in ha, and rainfall intensity (i) in mm/hr for a duration equal to time of concentration, Tc with some dimensionless coefficients (C) to peak flow rate (q) in m^3/s .

(1)
(6)

-- Lab 2 --

Soil and water conservation

The rational method

The rational method is simple and theoretically sound method for peak runoff analysis . The equation presented here may be use in design of soil and water conservation structures in watershed of less than 1000 (Ha) .

Peak runoff rate is determined from:

$$q = 0.0028CiA \ldots\ldots\ldots\ldots (1)$$

where q = design peak runoff rate m^3 / s

C = runoff coefficient

i = rainfall intensity for the design return period and for a duration equal to the time of concentration of the watershed mm \ h .

A = watershed area (Ha)

Time of concentration (Tc) : the time required for water to flow from the most remote point of the watershed to the outlet point .

$$Tc = 0.0195L^{0.77} * S^{-0.385} \ldots\ldots\ldots\ldots (2)$$

Where Tc = time of concentration in min .

L = max. length of flow (m) .

S = average watershed gradient .

The runoff coefficient (C) is the ratio of peak runoff rate to the rainfall intensity . Enclosed are 3 tables needed to estimate(c) . In the first table soils are classified into 4 groups depending on their runoff producing potential .The second table Lists c values for different cropping systems and rainfall rate for soil group B . The third table correct these values for other soil groups .

Table 4.2 Hydrologic Soil Group Conversion Factors

Cover and hydrologic condition	Factors for converting the runoff coefficient C from group B soils to[a]: Group A	Group C	Group D
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		Good	25	55	70
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C	*Moderately High Runoff Potential.* Comprises shallow soils and soils containing considerable clay and colloids, though less than those of group D. The group has below-average infiltration after pre-saturation.	1–4
D	*Highest Runoff Potential.* Includes mostly clays of high swelling percent, but the group also includes some shallow soils with nearly impermeable sub-horizons near the surface.	0–1

Source: U. S. Soil Conservation Service, *National Engineering Handbook, Hydrology*, Se (1972) and U. S. Dept. Agr. ARS 41-172 (1970).

The rational method is developed from the assumptions that: (1) ra occurs at uniform intensity for a duration at least equal to the time of co tration of the watershed, and (2) rainfall occurs at a uniform intensity ov entire area of the watershed. If these assumptions were fulfilled, the rainfa runoff for the watershed would be represented graphically by Fig. 4.3*a* figure shows a rain of uniform intensity for a duration equal to the ti concentration, T_c. If a storm of duration greater than T_c occurred, the r rate would be less than q because the rainfall intensity would be less than Chapter 2 for relationships between rainfall intensity and duration). A r r once in 10 years; expensive, permanent structures will be designed for ffs expected only once in 50 or 100 years. Selection of the design return d, also called recurrence interval, depends on the economic balance be- n the cost of periodic repair or replacement of the facility, and the cost of ding additional capacity to reduce the frequency of repair or replacement. me instances the downstream damage potentially resulting from failure of tructure may dictate the choice of the design frequency.

Rational Method. The rational method of predicting a design peak f rate is expressed by the equation

$$q = 0.0028\, CiA \tag{4.1}$$

vhere q = the design peak runoff rate in m³/s,
C = the runoff coefficient,
i = rainfall intensity in mm/h for the design return period and for a duration equal to the "time of concentration" of the watershed,
A = the watershed area in hectares.

e time of concentration of a watershed is the time required for water to rom the most remote (in time of flow) point of the area to the outlet once il has become saturated and minor depressions filled. It is assumed that, the duration of a storm equals the time of concentration, all parts of the shed are contributing simultaneously to the discharge at the outlet. One of ost widely accepted methods of computing the time of concentration was oped by Kirpich (1940),

$$T_c = 0.0195\, L^{0.77} S^{-0.385} \tag{4.2}$$

/here T_c = time of concentration in min (see Appendix A),
L = maximum length of flow in m,
S = the watershed gradient in m per m or the difference in elevation between the outlet and the most remote point divided by the length, L.

drologists are not in agreement as to the best procedure for computing the f concentration. Mockus (1961) prepared a nomograph (see Appendix A) mputing the time of concentration which considers length of the main el, topography, vegetal cover, and infiltration rate. Horn and Schwab found that Mockus' values of watershed lag gave slightly better esti- of the actual runoff than several other methods when taken equal to the f concentration.

. SCS (1972) developed the "Upland Method" for estimating time of ntration. With this method the length of flow is divided by an estimated velocity of flow to obtain the travel time. The sum of the travel times for overland flow (sheet runoff) and for all channel flow equals the time of concentration. For such estimates the flow path is taken from the most remote point in the watershed to the outlet. In small watersheds of a few hectares, where a well-defined channel does not exist, runoff occurs mostly as overland flow. The upland method should be limited to small watersheds less than 800 hectares (2000 acres). Manning's equation (see Chapter 7) is suitable for estimating flow velocities. Overland flow velocities are difficult to estimate as the rainfall intensity will influence the flow depth. U.S. SCS (1972) has developed velocity-slope curves for several watershed conditions. Better methods for determining time of concentration are needed.

The runoff coefficient C is defined as the ratio of the peak runoff rate to the rainfall intensity and is dimensionless. Estimates of the runoff coefficient from small single-crop watersheds at Coshocton, Ohio, showed that the primary effects were attributed to the infiltration rate, surface cover, and rainfall intensity. These estimates are presented in Table 4.1 for hydrologic soil group B. The runoff coefficient can be converted to other hydrologic soil groups by referring to Table 4.2. These soil groups are defined in Table 4.3.

Equation 4.1 may not appear to be dimensionally correct. In English units i is specified in inches per hour and numerically 1 inch per hour is nearly equal (1.008) to cubic feet per second per acre. The constant 0.0028 converts the equation to SI units.

The rational method assumes that the frequency of rainfall and runoff are similar, which has been confirmed by Larson and Reich (1973). The method is a great oversimplification of a complicated process. However, the method is considered sufficiently accurate for runoff estimation in the design of relatively inexpensive structures where the consequences of failure are limited. Application of the rational method as presented here is normally limited to watersheds of less than 800 ha (2000 ac).

Table 4.1 Runoff Coefficient "C" for Agricultural Watersheds (Soil Group B)

Cover and hydrologic Condition	Coefficient C for rainfall rates of		
	25 mm/h (1 iph)	100 mm/h (4 iph)	200 mm/h (8 iph)
Row crop, poor practice	0.63	0.65	0.66
Row crop, good practice	0.47	0.56	0.62
Small grain, poor practice	0.38	0.38	0.38
Small grain, good practice	0.18	0.21	0.22
Meadow, rotation, good	0.29	0.36	0.39
Pasture, permanent, good	0.02	0.17	0.23
Woodland, mature, good	0.02	0.10	0.15

Source: Horn and Schwab (1963).

Soil and Water Conservation
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Soil Water Erosion

Water Erosion is the removal of the surface soil materials by rainfall or runoff

Mechanics of water erosion

---------------------------- three basic processes include:

1- Detachment of soil particles by rainfall and runoff.

2- Transporting of detached soil particles by runoff.

3- Deposition of the tranporting soil particles.

Detachment

---------------- causing by rainfall and runoff, therfore it depend on :

1- Rainfall intensity , detachment rate increases as rainfall intensity increases.

2- Runoff depth , detachment rate increases as the flow depth inreasess.

3- Soil type , detachment rate increases with decreasing the soil aggregation.

Transporting

------------------ Three types of soil particle movement:

1- Suspended — Clay praticles

2- Saltation — Silt + Very fine sand particles

3- Creep — Sand particles + soil aggregates

Deposition

---------------- deposition begins when :

1- Slope be flatten
2- Sediment load > tranporting capacity
3- When the flow enter a dense grasses

Types of water erosion

1- Sheet erosion :removal of thin uniform layer from area by rainfall drops or flow water

Sheet Erosion

Rill erosion small channels formed by runoff espacially in recently cultivated soils

Rill Erosion

3-Gully erosion :it is a deep and wide channels in natural depression of the land by runoff water.

Gully Erosion

Damages of water erosion :

1- Soil loss : It ranges from 5 t/ha/yr for grass-land to 50 t/ ha/yr for cultivated land .
2- Nutrients loss causing ferility erosion.
3- Textural change by removal of fine particles .
4- Structural change by formation a crusted layers.
5- Damage of engineering structures.
6- Damage of water resources.

Ex:Calculate the removal depth from soil has a *30 t/ha/yr* with bulk density = *1.5 kg/m³*.

$30 \text{ X } 10^6 / 10^4 = 3000\ gm/m^2$

$3000/(1.5 \text{ X } 10^6) = 0.002m = 2\ mm$

Soil and Water Conservation
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Erosion and soil productivity

Soil productivity of any cultivated soil is a function of soil properties and the surrounding ecological factor which formed it.

Soil productivity = f (Soil ,Climate , Slope , Management…etc.,)

How erosion reduces soil productivity ?

1-Decreasing soil depth by removing the soil surface layer causing a reduction in water holding capacity and rooting depth.

2-loss of organic matter and soil nutrients by runoff and eroded soil .This processe called *fertility erosion* .

3-Causes a textural change due to removing the fine particles causing a coarse texture and low aggregates soil.

4-Cause a soil structural change by increasing surface crust formation resulting in less porosity and low infiltration rate soil surface.

Relative productivity (Pr):

Relative productivity(Pr) is a ratio between the crop yield of eroded soil to the yield of uneroded soil .

$$Pr = \frac{C\,e}{Cu}$$

Where :

Ce = Crop yield from eroded soil

Cu = Crop yield from uneroded soil

Types of soil productivity Criteria *:*

--- There are two criteria methods used to determine the productivity of any cultivated soil :

1-Actual soil productivity

2- Potential soil productivity

1-Actual soil productivity :

------------------------------ Actual productivity of any cultivated soil can be drived from the mean annual yield that these soil produce over a 10 year period with moderately managed crops

2-Potential soil productivity :

------------------------------------This criteria can be used to measure the yield potential of soil using a selected model that related the productivity with specified physical and chemical soil properties under optimal management .

i.e. *Pierce model* ,which used the productivity index (PI)as a function for soil productivity:

PI = (Ai * Bi * Ci * Ri)

Where :

PI = Productivity Index 0 < PI > 1

Ai = Sufficieny of potential available water for soil layer

Bi = Sufficiency of soil bulk density of the soil layer

Ci = Sufficiency of soil reaction pH in soil past of the soil layer

PI (Productivity Index) is used to measure the yield potential of soils

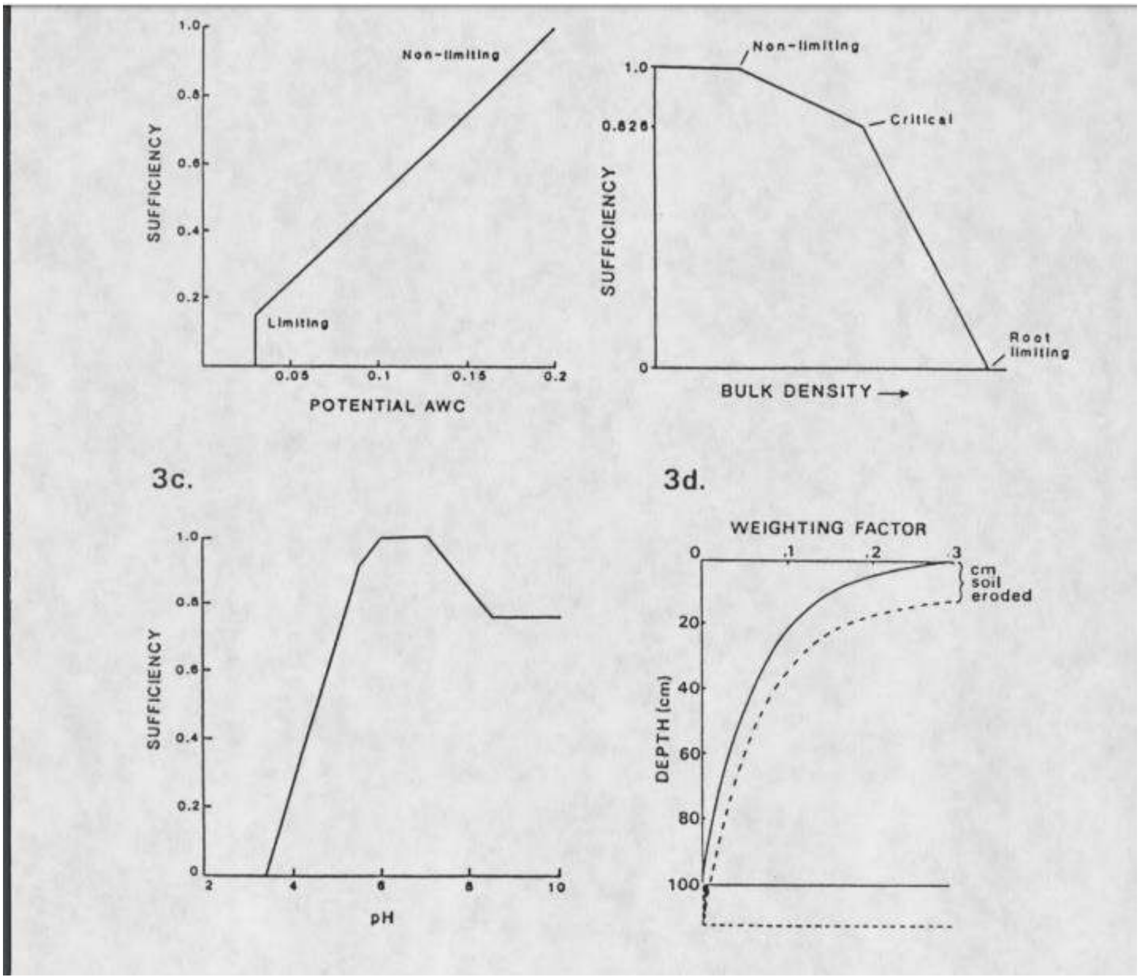

Fig. (   ) : Sufficiency standard curves for *Pierce model*

Soil Loss Tolerence Value (T – value):

T-value is the maximum amount of soil loss which can removed before natural productivity is adversely affected. Generally that deep soil have been assumed to have a high tolerence value than the shallow soils.

Soil and Water Conservation
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WATER EROSION PREDICTION

Soil and water conservation planning needs an estimate for the amount of erosion occuring in the field . The mathematical formula used to predict erosion are called *MODEL*.

The most common water erosion model is the Universal Soil Loss Equation (USLE) which covers all geographic region and can be applied in addition to agricultural field areas to estimate the soil loss from cultivated , forest , and range lands using the following formula :

$$A = R * K * L * S * C * P .$$

Where :

A = Mean annual soil loss t / ha. / yr

R= Rainfall – runoff erosivity factor .

K = Soil erodibility factor

L = Slope length factor.

S= Slope steepness factor.

C= cropping system and soil management factor.

P = Supporting practices factor.

Threrfore ,we can use the Universal Soil Loss Equation (USLE) to predicts the long-term average annual rate of water erosion (A) on a field slope based on rainfall pattern (R) , soil type (K) , topography factor (LS) , crop system and management practices (C) with supporting engineering practices factor (P).

Rainfall – runoff erosivity factor (R)

The simplist method used to estimate the R-factor is using the modified Fourneir Index model , which expressed by the following formula:

$$R = 0.0302 \left(\frac{\Sigma^{n} \; Pi^{2}}{P} \right)^{1.93}$$

R= Rainfall – runoff erosivity factor .

Pi = Average monthly rainfall depth (mm).

P = Average annual rainfall depth (mm).

n = number of rainy months

Ex: Calculte the rainfall erosivity factor (R) for Mosul city during the following rainy months were :

Month	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**
Rainstorm (mm)	**10**	**18**	**20**	**20**	**40**	**25**	**10**	**5**

$$R = 0.0302 \left(\frac{\Sigma^n \; Pi^2}{P} \right)^{1.93}$$

$$R = 0.0302 \left(\frac{10^2 + 18^2 + 20^2 + 20^2 + 40^2 + 25^2 + 10^2 + 5^2}{10 + 18 + 20 + 20 + 40 + 25 + 10 + 5} \right)^{1.93}$$

$$R = 0.0302 \left(\frac{3573}{148} \right)^{1.93}$$

$$R = 0.0302 \left(24.15 \right)^{1.93}$$

$$R = 0.0302 * 461.1$$

R = 13.92 metric unit

Soil Erodibility Factor factor K

Soil Erodibility (K - factor) in the Universal Soil Loss Equation (USLE) represents the susceptibility of the soil to the erosion process. The soil erodibility factor (K), which depends on properties involved

1- Particle size distribution of (% Sand ,% very fine sand , and %silt)
2- % Soil organic matter
3- Soil structure
4- Soil permeability

All the above soil properties were collected in to special curves called erodibility - nomgraph which was publishid by Wischmeier and Smith (1978)

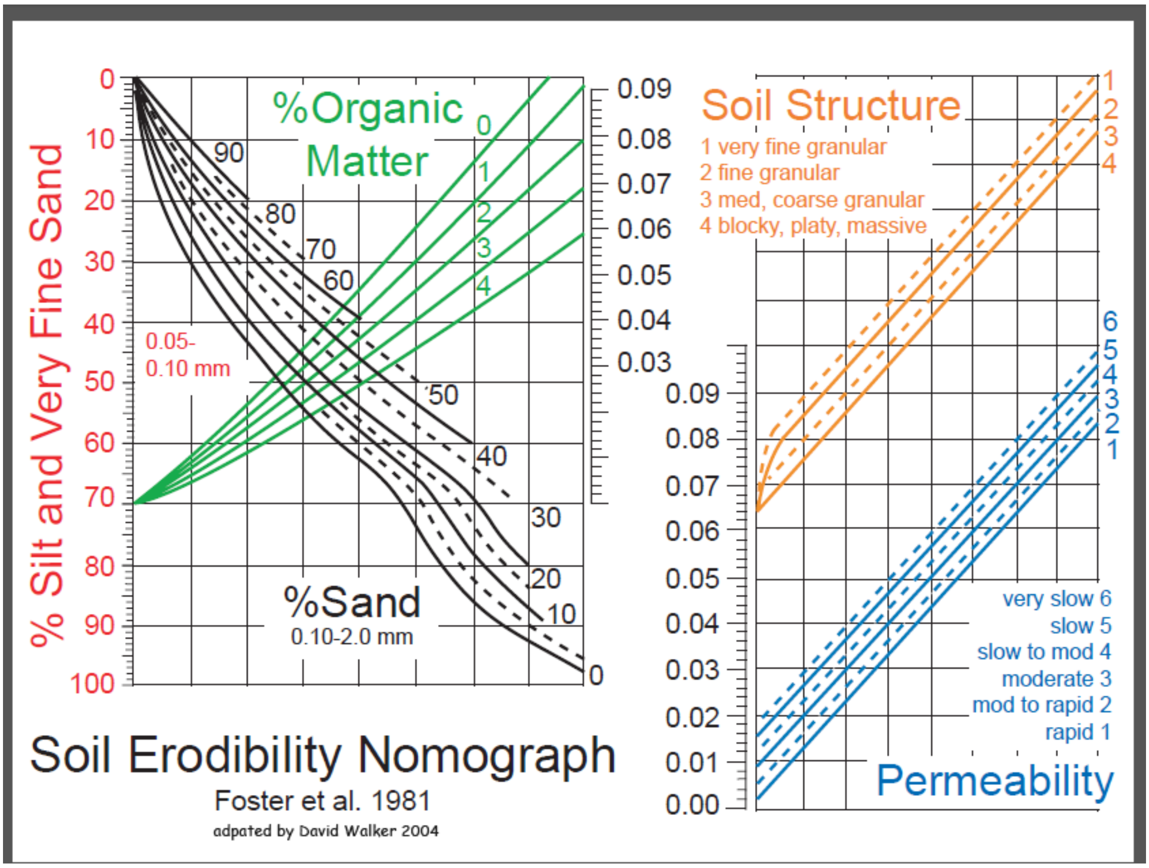

Fig ( ): Nomograph for k-factor calculation

From this nomograph we can conludede that the soil erodibility depend mainly on the three soil physical proerties (texture , structure and permeability) with one soil chemical (% organic matter). Many studies showed that the soil texture is the main factor which dtermined the suspility of soil to water erosion. The following table lists the values of K-factor from the fine soil texture (higher erodibility) to more coarser textures soils (lower erodibility).

K-Factor for some soil textures

Soil type	*K* Factor (ton ha) (ha hr/MJ mm)
Clay	0.042–0.065
Clay loam	0.030–0.047
Sandy clay	0.031–0.043
Sandy clay loam	0.028–0.059
Sandy loam	0.004–0.036
Silt loam	0.014–0.027
Silty clay loam	0.032

The new preceedudure to calculate the soil eodibility index (EI) is using the EI_{ROM} equation which is more reliastic and significat of soil erodility index.

$$EI = \frac{\text{Sand + \% Silt \%}}{2\ (\text{\% Clay})}$$

EI < 1.5 ----Low Erodibilty soils

EI > 12.5 …Very high erodibilty soils

Soil and Water Conservation
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Cropping System and Soil Management factor (C) :

USLE model:

$$A = R * K * L * S * C * P.$$

Where :

A = Mean annual soil loss t / ha. / yr

R= Rainfall – runoff erosivity factor .

K = Soil erodibility factor

L = Slope length factor.

S= Slope steepness factor.

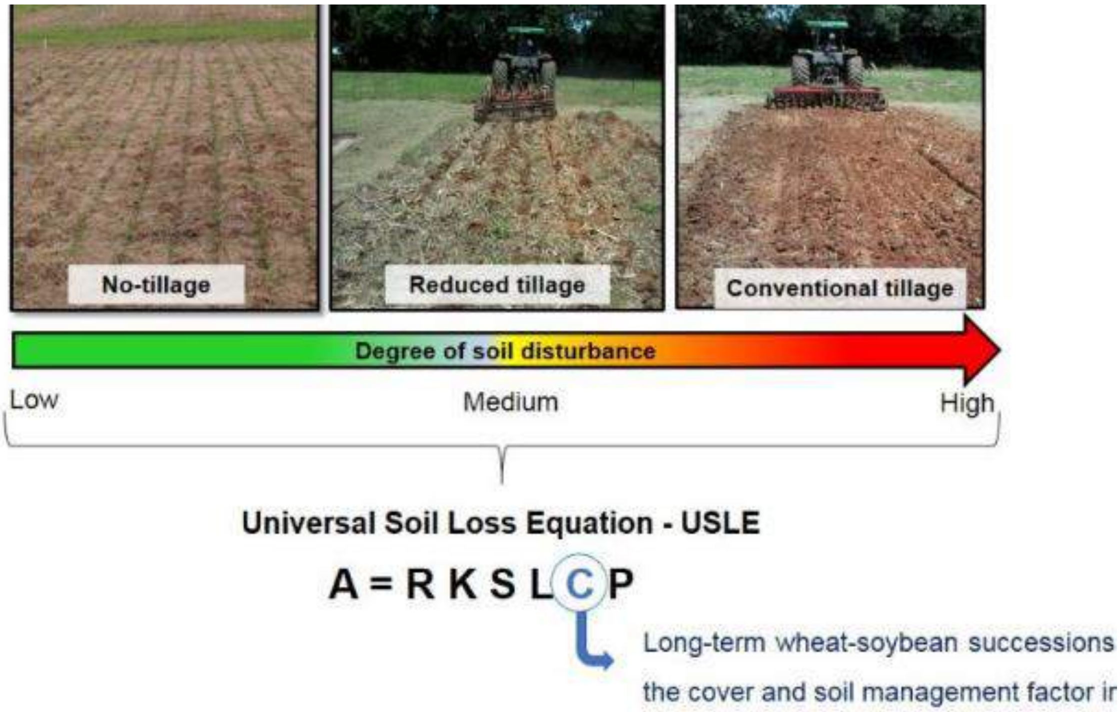
C= cropping system and soil management factor.

P = Supporting practices factor.

C= cropping system and soil management factor **(** C-fator) is the 5^{th} facor of the USLE model. It is defined as the ratio of soil loss under specified cover and management to the soil loss under continous bare from fallow soil, and always is less than 1 and unitless**.**

$$C = \frac{\text{Soil loss under specified cover and management}}{\text{Soil loss under continous bare fallow}}$$

And should be less or equal to1 . Specified cover and management mean the type and density of vegetative cover on the soil as well as all related management practices, such as, weed control, tillage, watering, fertilization, crop residues treatments etc.



C Cover Management Factor

Cover Management Factors for Construction Sites		
Vegetative Cover	**C factor**	**Percent Reduction of soil loss**
None (fallow ground)	1.0	0
Native vegetation (undisturbed)	0.01	99
Temporary Ryegrass, 90% (perennial)	0.05	95
Temporary Ryegrass, 90% (annuals)	0.1	90
Permanent Seedlings (90%)	0.01	99
Sod (laid immediately)	0.01	99
Mulching (for slopes 2:1 or less)		
Hay (0.5 tons/acre)	0.25	75
Hay (1.0 tons/acre)	0.13	87
Hay (1.5 tons/acre)	0.07	93
Hay (2.0 tons/acre)	0.02	98
Wood chips (6 tons/acre)	0.06	94
Wood cellulose (1.75 tons per acre)	0.10	90
Other		
Competent gravel layer	0.05	95
Rolled erosion control fabrics	(for slopes greater than 2:1)	variable C value by type

P - the conservation practice factor

The P-factor (6th factor of USLE) is the ratio of the erosion resulting from the described practice to that which would occur with up-and-down slope cultivation. It recognizes the influence of conservation practices, such as contour planting, strip cropping, terracing and combinations..

Soil loss from the described practice to

P = -- < 1

Soil loss from the described practice to

Practices included in this term are:

1- contouring,

2-strip cropping (alternate crops on a given slope established on the contour),

3- terracing.

This practices will reduce the velocity of runoff directly down-slope reduce the P factor and therfore reduces the soil erosion .P-factor always considerd as the weakest factor in the USLE model and always substituted by 1 in most cultivated soils •

Land use type	slope(%)	*P* factor
Agricultural land	0—5	0.11
	5—10	0.12
	10—20	0.14
	20—30	0.22
	30—50	0.31
	50—100	0.43
Other land	all	1.00

Example :

R- value is 100 for Mosul

K- from Soil Survey is 0.024 ,

LS- 1.2

C = 0.7

P- 1

A = R* K * L * S * C * P

A= 100 * 0.024 * 1.2 * 0.7 * 1 = 2.16 t/ ha./yr

Soil and Water Conservation
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Slope length factor (L) and Slope Steepness (S)

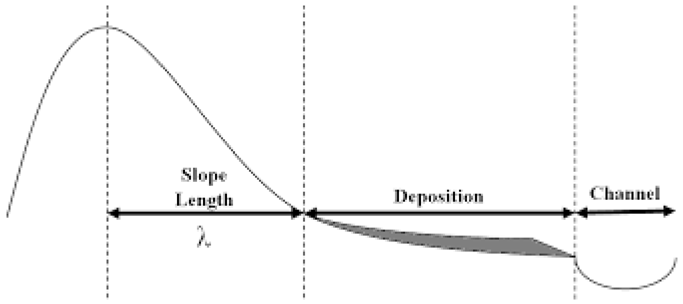
The combination of L and S factors express the influence of the topographic factor on soil erosion.

L + S = LS → Topographic factor

The increasing of the slope length factor (L) is caused to increase the soil erosion due to a progressive accumulation of runoff in the direction of downslope. The increasing the slope steepness factor (S) is increased the soil erosion to cause of increasing in the velocity of runoff and therefore the soil water erosion .

Slope length (L) :

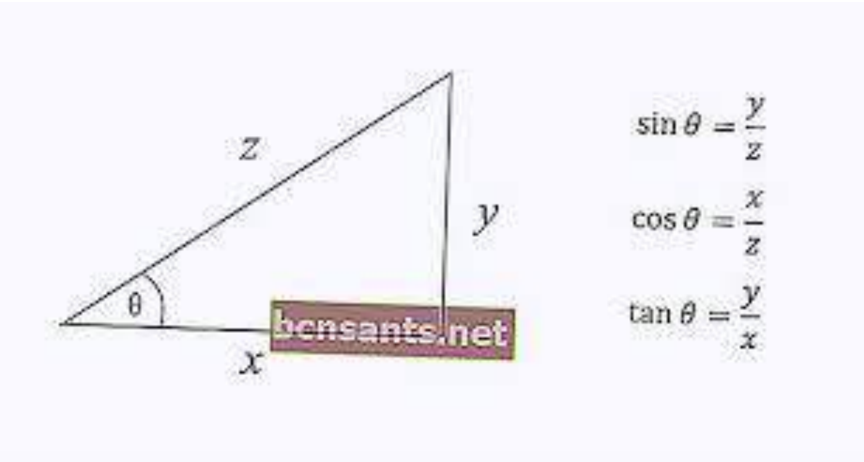
---------------------- the horizontal distance from the original of surface land flow to point where either the slope gradient decreases enough , or the runoff water enter a well defined channel.



Slope Gradient :

---------------------- is the tan of the slope of slope angle (Or is the ratio between the vertical distance, , divided by the horizontal distance between two points in a field .

In cultivated soil the slope gradient is equal to sine of aslope angle ,because the slope of this slope of this is low to moderate

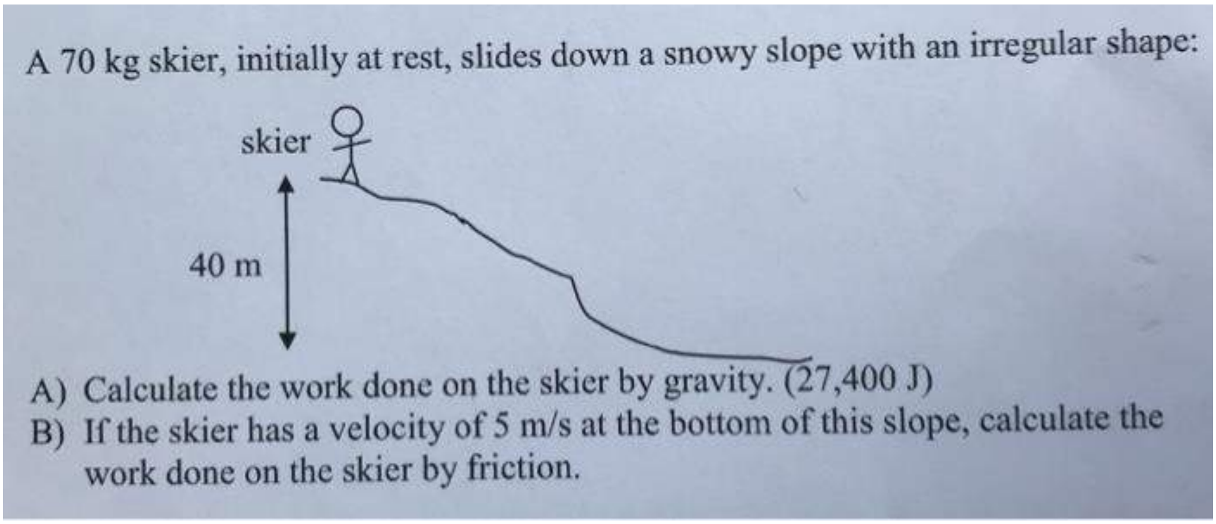


Type of slopes :

There are two types of slope :

1-Unform slope: the slope of nearly constant (it has one slope angle)

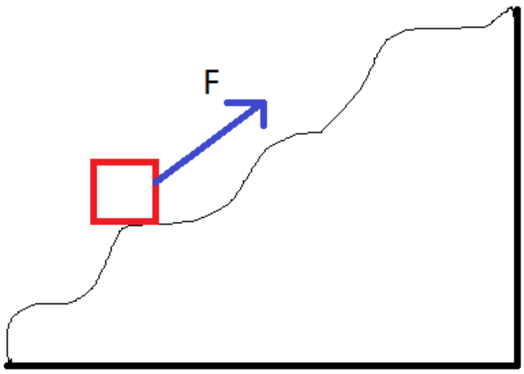
2-Irregular Sope : this slope has a many slope angle (cocave slope + convex slope).



A 70 kg skier, initially at rest, slides down a snowy slope with an irregular shape:

A) Calculate the work done on the skier by gravity. (27,400 J)

B) If the skier has a velocity of 5 m/s at the bottom of this slope, calculate the work done on the skier by friction.



How to calculate the LS of the USLE:

A = R * K *L*S *C * P

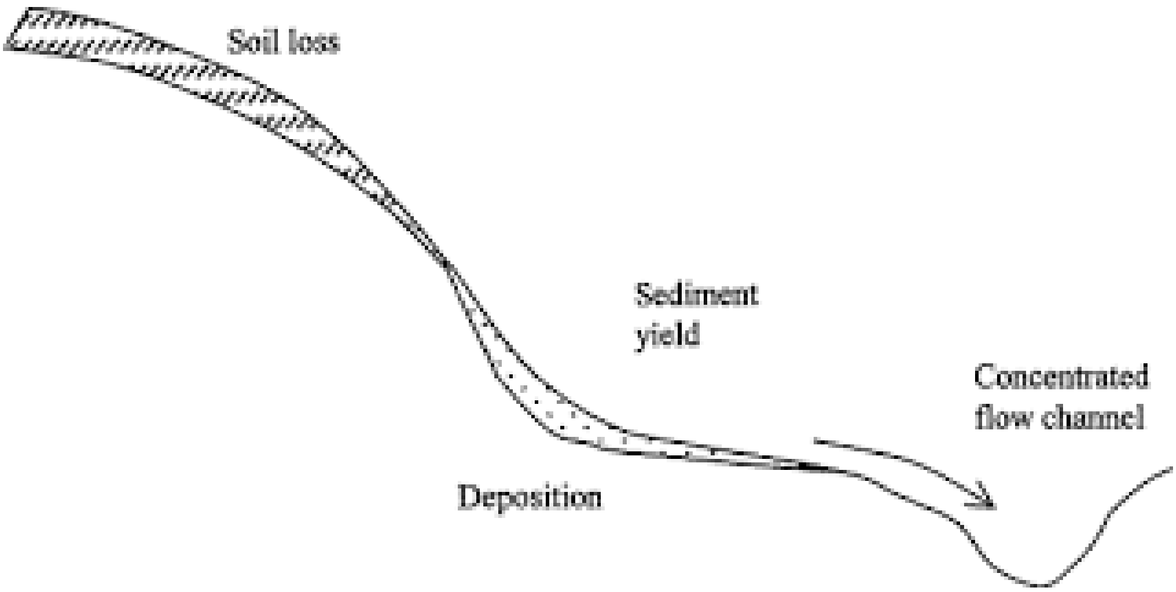
LS=

$$LS=\left(\frac{\lambda}{22.1}\right)^{m}\left\{65.41\ \sin^{2}\theta + 4.56\ \sin\theta + 0.065\right\}$$

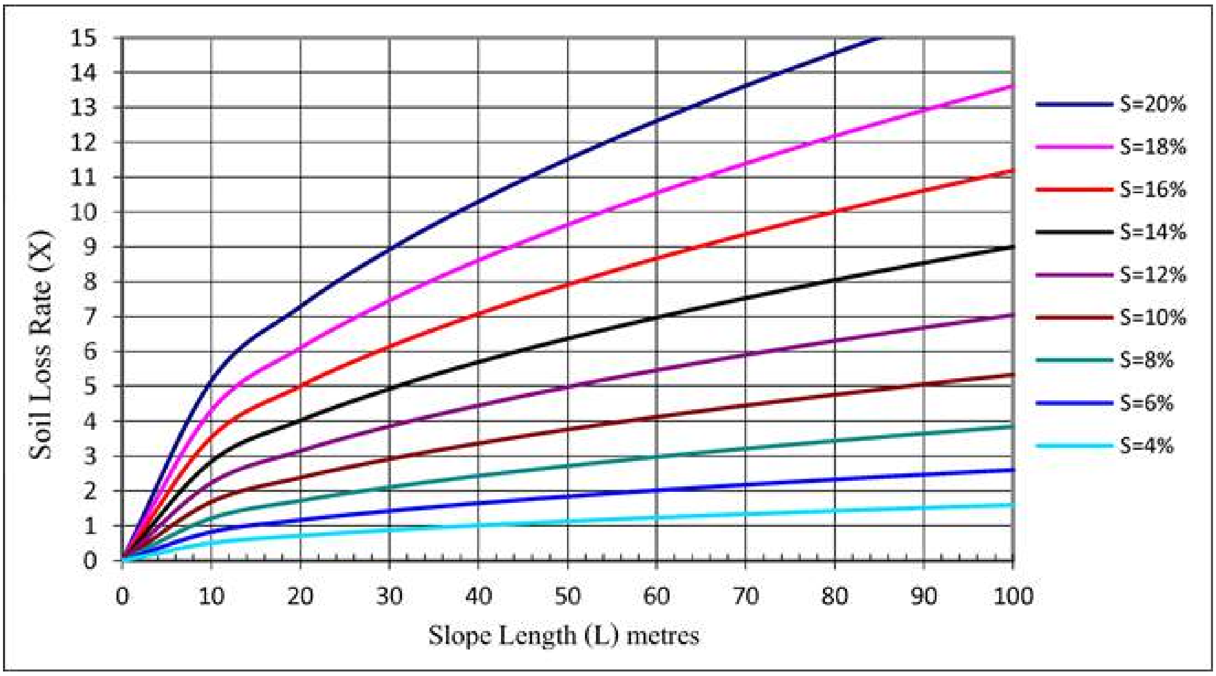
Where λ =slope length(m), θ =angle of slope and m=0.5 if the percent slope is 5 Or more, 0,4 on slopes of 3.5 to 4.5 perc., 0.3 on slopes of I-3 perc. and 0.2 on slopes of less than I%.

Relation between topographic factor and soil loss by water erosion:

Uniform **slope** produces more runoff and **soil erosion** than others, while in irregular slope the concave **slope** produces the least but convex slope produce a high runoff and soil loss



Soil Loss by as a function of LS water erosin may be calculated by the following grapgh



By plotting the slope length in meter on the X-axis and slope gradient on the y-axis as percent we can obtained the soil loss for any

FIGURE 62
Combined slope/length factor in the USLE (from USDA 1978)