23

SOIL EROSION AND CONSERVATION

Soil erosion is a process of detachment and transportation of soil by natural agencies (water or wind). Under normal physical, biotic and hydrological equilibrium in nature, the erosion that takes place is *normal, natural* or *geological*. Where soil removal is fairly balanced with soil formation processes. When erosion exceeds this normal rate due to removal of vegetation and becomes unusually destructive, it is referred to as *accelerated erosion*.

AGENCIES OF SOIL EROSION

Water and wind are two main agencies of soil erosion.

WATER EROSION

Factors Affecting Soil Erosion by Water

The factors influencing erosion are :

1. Rainfall. Precipitation is the most forceful factor causing erosion. Raindrop impact exerts three important influences (*a*) it detaches soil; (*b*) its beating tends to destroy granulation; and (*c*) its splash, under certain conditions, affects an appreciable transportation of soil. Soil granules are loosened, detached and separated into fine particles by the action of dashing rain. Dispersed soil particles are removed by run-off that causes erosion is dependent on amount, duration, intensity and frequency of the rainfall. The chance of erosion is greater where the rainfall is not only heavy but concentrated in short time rather than light showers distributed over a long period of time. In the latter case there is time available for the rain water to infiltrate into the soil. In former case, infiltration is very less, so that run-off (surface flow) is high which causes removal of soil.

2. Slope of the Land. Slope accelerates erosion as it increases the velocity of the flowing water. The steepness, length and shape of the slope all determine the amount of soil erosion. Of these three factors, steepness of slope is the most influential. In general, the greater the slope the greater the amount of erosion.

3. Vegetation. The type of vegetative cover and its condition aids in controlling water erosion in the following ways : (*a*) Vegetative cover protects the soil from the beating and dispersing action of the raindrops by forming a canopy over the soil surface. (*b*) Vegetation provides a mechanical obstruction to flowing water thus reducing their velocity and soil carrying capacity. (*c*) The root helps in the building of better structure *i.e.*, Sphere-like that increases infiltration and reduces a surface run-off, and (*d*) Roots help in opening the soil and thereby aid in increasing water absorption and in reducing surface run-off.

4. Tillage. The infiltration and permeability of the soil is improved by the practice of proper tillage and thereby reducing the erosion. Soil erosion by running water is only possible when there is excess water over surface for free run-off. High infiltration and permeability results in rapid water absorption by the soil and hence, little run-off.

5. Nature of the Soil. Erodibility of soil is influenced by the nature of the soil, particularly its texture, structure, organic matter, amounts and kinds of salts present, presence of hard pan in the soil and sub-soil and presence of high water table.

(*i*) **Texture.** In sands and other coarse-textured soils, high infiltration and permeability results in rapid water absorption and hence, in little erosion. Permeabilty in heavy soil is much low as compared to light soils and hence more erosion.

(*ii*) **Structure.** In fine-textured soils such as in clay loams, the structure is an important factor in determining erodibility. A soil with a granular structure, in which the fine particles are arranged in clusters or aggregates, absorbs water readily and is resistant to erosion.

(*iii*) **Organic Matter.** It helps in formation of better and more stable aggregates and thus, in keeping the permeability high. When the organic matter decreases as a result of growing cultivated crops the erodibility of the soil increases.

(*iv*) Presence of Hard Pan (Layer). Presence of hard pan in the soil or sub-soil checks downward movement by water thus, resulting into run-off.

6. Presence of High Water Table. Presence of high water table checks the infiltration and permeability thus resulting into more flow of water on the surface.

Types of Water Erosion

There are following seven types of water erosion :

1. Splash Erosion. Falling raindrops splash soil. Raindrops fall

at a speed of about 20 miles per hour. The raindrop splash beats the bare soil into flowing mud. A single raindrop may splash wet soil as much as two feet high five feet away.

2. Sheet Erosion. By this erosion, soil is removed uniformly in thin layer from the entire surface area. Movement of soil by splash erosion is the primary cause of sheet erosion.

3. Rill Erosion. It takes place when run-off water laden with soil flowing along the slopes forming small finger-like channels. Rill erosion is an intermediary stage between sheet erosion and gully erosion.

4. Gully Erosion. As the volume of concentrated run-off increase and attains more velocity on slopes, it enlarges the rill into gullies. Gullies often starts along bullock cart tracks or burrows of animals (Fig. 23.1).

Fig. 23.1. Gully erosion.

At an advanced stage, gullies result in ravines which are sometimes 50 to 10 feet deep. In India, ravines cover about 6 million acres.

5. Slip Erosion. Landslides cause slip erosion, big masses of soil and rock bodily slipdown damaging the field. The effects of slip erosion are localized.

6. Stream Bank Erosion. Streams and rivers change their course by cutting one bank and depositing silt loads on the others. During flash floods, the damage is very much accelerated. The *Kosi* river in Bihar is reported to have changed its course westward by 65 miles within the last 100 years.

7. Sea-shore Erosion. Sea-shore erosion is caused by the striking action of strong waves.

8. Puddle Erosion And Fertility Erosion.

The splash erosion process produces three different types of erosional damage :

(*a*) Puddle erosion, (*b*) fertility erosion, and (*c*) sheet erosion.

(a) Puddle Erosion

The raindrops beat on the naked earth surface, shatters the clods and soil crumbs and break down the soil structure into puddle condition. The beating and churning action of raindrops make the soil into an impervious layer of surface mud.

The soil surface layer is made dense and compact. Eventually, porosity of this surface layer is reduced by the infiltration of muddy surface materials. Then the important entrance channels to deep soil are closed. The soil profile material can no longer absorb air freely nor can it receive and store abundant supplies of rainfall. A single storm leaves visible effects of this puddling only on the surface of the soil.

Control of Puddle Erosion. The secret of controlling this erosion is to prevent and reduce the force of raindrops on the surface of the soil. The puddle erosion may be controlled by growing cover crops and grasses; and by the use of organic matter and stubble mulch.

(b) Fertility Erosion

When raindrops loosen the soil and splash it into the air, nearly all of the particles that are dislodged seem to be 2 mm or less in diameter. They also splash some particles larger than this. As these splashes fall back into the surface water, many of the finer particles are carries away and the coarser material settle out after being moved a short distance downhill. This produces what is known as fertility erosion. It results in the accumulation of excessive coarse material on the surface within a short time after the beginning of rainfall. Even though the land is practically level, much of the organic matter and fertility bearing elements of the soil may be floated away.

Control of Fertility Erosion. It may be controlled by the following conservation methods : (1) mulching (2) vegetative cover (3) strip-cropping (4) organic matter (5) tillage (6) bunding (7) terracing (8) outlet channel.

SOIL AND WATER CONSERVATION

Conservation of water and conservation of soil are closely related. Water is lost from the soil in four ways : (1) Surface run-off, (2) Peroclation, (3) Transpiration, and (4) Evaporation. Out of these sources by which the water is lost run-off is usually the largest and most damaging as it causes erosion.

The main factors in conserving moisture relate to increasing infiltration and storage capacity of soil and reducing run-off and evaporation.

Untamed water is the main cause of soil erosion. Almost all the methods that deal with soil conservation are principle methods to control and conserve water. Measures to control soil erosion also result in the conservation of water.

Principles of Water Erosion Control. The main objectives in controlling soil erosion caused by water are :

(i) to reduce surface run-off,

(ii) to put mechanical obstruction in the way of flowing water, and

(iii) to reduce dispersion of soil particles.

Conservation Methods for Water Erosion

There are two methods for the control or management of land eroded by water : (a) Biological Method, and (b) Mechanical Method.

A. Biological Method. I. Agronomial method, and II. Agrostological method.

I. Agronomical Method. 1. Growing Cover Crops. Sod-like crops, such as grass, sannhemp, berseem, groundnut offer excellent soil protection against erosion by water. Such crops are effective primarily because they provide a cushion against the raindrops. The denser the vegetation the more effective is the cushioning effect. Close growing crops also help to control erosion by providing root channels through which water moves downwards more freely. In addition, plant roots aid in making a desirable soil structure.

Vegetation also encourages the growth of earthworms and other desirable forms of soil life. These in turn help to keep the soil open and receptive to raindrops.

2. Strip Cropping. This practice consists of growing erosion-permitting crops (*e.g.*, jowar, bajra, maize), in alternate strips with erosion checking close-growing crops (*e.g.*, grasses, pulses). The erosion checking strips check and held the flowing water and soil (Fig. 23.2).

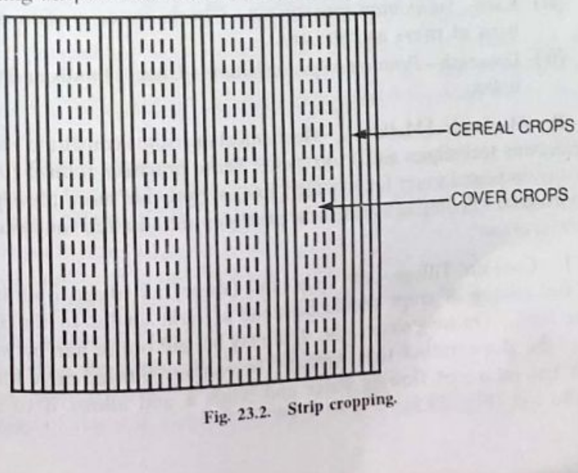

Fig. 23.2. Strip cropping.

Contour strip cropping is one of the type of strip cropping. Contour stip cropping is the growing of erosion-permitting and erosion-resisting crops alternately in strips across the slope and on the contour.

3. Crop Rotation. Growing of two more different crops in sequence in a field for maintaining the soil fertility. Continuous growing of clean-cultivated crops (*e.g.*, tobacco) causes more erosion. A good rotation should include densely planted small grains, spreading legume which may check soil erosion.

4. Mulching. Mulches of different kinds minimise evaporation and increases absorption of moisture. Stubble mulching is based on merely stirring the soil with implements that leaves considerable part of vegetative materials *i.e.*, crop residue or vegetative litter on the land as a surface protection against erosion and for conserving moisture by favouring infiltration and reducing evaporation.

5. Organic Manures. Incorporation of organic manures in the soil improves the soil structure. Granular and crumby structures increase infiltration and permeability in the soil and conserve soil water.

11. Agrostologial Method. Dense canopy and profuse root system of grasses tightly bind the soil against erosion. Grasses increase water infiltration and improve physical conditions of soil.

Grasses can be grown on lands which are otherwise not suitable for cultivation. They are also used in protecting bunds, waterways, badly eroded areas and gully control. The grasses commonly grown are :

(*i*) Dub – *Cynodon dactylon* – Checks run-off water.

(*ii*) Kudzu vine – Checks gully erosion.

(*iii*) Kans – *Sachharum spontaneum* – Checks water erosion on the bank of rivers and streams.

(*iv*) Dinanath – *Pennisetum pedicellatum* – Checks bunds and water outlet.

B. Mechanical Methods. Mechanical measures constitute various engineering techniques and structures. These practices reduce run-off velocity, impound water for a longer time and provide more absorption opportunity. Following mechanical practices are adopted for checking water erosion.

1. Contour Tillage. On hilly land (slope) all tillage operations and the sowing of crops should be done at right angles to the slope of the land. On long slopes, the field may be laid out in narrow strips across the slope rather than with it. In contour tillage, each furrow which lies intercept flowing water and holds it and allows it to soak into the soil (Fig. 23.3).

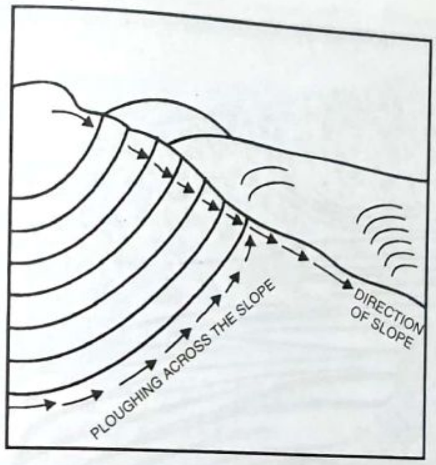

Fig. 23.3. Contour tillage

2. Contour Bunding. The slope of the land is broken up into smaller, more level compartments by constructing earthen embankments of suitable size on contours. Each bund thus, holds the rain water within each compartment.

Farmers in the plains could raise level bunds around their fields for holding the rain water and conserving the soil. The maintenance of bunds is very important. Planting useful grasses, strengthening the bunds at weak points, closing rat holes and closing small breaches in time are the most important items in bund maintenance.

3. Terracing. On steeper slopes terraces or flat platforms are constructed in steps like series across the slope. It is like a level benches or table top for retaining and distributing rainfall for controlling run-off (Fig 23.4).

4. Outlet Channel. For safe removal of excess run-off water, it is essential to provide suitable outlet structure at proper places so that no harmful effects of water-logging, eroding, gullying or damage to other conservation structures are caused. Some of the important surplusing arrangements are grass waterways and diversion ditches.

5. Basin Listing. Scooping out small basins at regular intervals on slopes, checks run-off.

6. Pan Breaking and Sub-soiling. Pan breaking and sub-soiling permit infiltration and percolation. This increases the water storage capacity of the soil, thus, decreasing run-off and erosion.

Fig. 23.4. Terracing.

Diversion channel
(2) Prevention of channel over

7. Water Harvest. At suitable places with possibilities of storing water, ponds and tanks are recommended water conservation practices. They are also very useful to some extent as flood control measures (see 'Water harvest technique' in the last of this chapter).

8. Conservation Tillage Practice. In the **conventional tillage** practice, run off and erosion pressure is greatest due to extensive soil tillage and the soil remain bare after ploughing. The **conservation tillage** system vary from **no-tillage** (zero-tillage) to reduced tillage system. This system permits direct sowing or planting in the residue of the pervious crop and uses only that localized tillage necessary to plant the seed.

A prime objective of the conservation tillage is to keep some plant residues on the soil surface. Surface run off is decreased due to soil cover by the plant residues, simultaneously, soil erosion is reduced.

No-tillage or reduced tillage plots are generally somewhat higher in soil water, especially in the upper portion of the profile, than the conventionally tilled plots. This is likely due to increased water infiltration from no-tillage systems and reduced evaporation losses, which

are characteristics of any residue-covered plots. Organic matter are higher in the upper few centimeters of no-tillage and reduced tillage plots.

The conservation tillage systems also can significantly reduce losses of nitrogen and phosphorus. The finer fractions of soils, which are among the first to be carried away through erosion, contain most of these nutrients.

Control of Gully Erosion. Gully control is necessary in order to prevent complete destruction of cultivated lands and grasslands. In the first step, water flowing into the gully should be diverted away by means of a bund. The second step is to build several obstructions in the gully such as rock dams. Invariably, the gullies should be established under permanent grass and tree vegetation. Sometimes a gully may be adequately established by converting it into a paddy field.

WIND EROSION

Factors Affecting Wind Erosion

Susceptibility to wind erosion is related rather definitely to the moisture content of soils. Wet soils do not blow. Soil erosion by wind occurs under dry conditions and high wind velocity. Following factors affect soil erosion by wind :

1. Tillage. As the soils are loosened by the excess tillage the blowing wind removes finer particles. On an untilled surface wind erosion is very less in comparision to tilled surface.

2. Structure. Soils with single-grained structure (structureless) is more prone to wind erosion than aggregate structure.

3. Organic Matter Content. Soils with low organic matter have low amounts of water stable aggregate thus facilitating wind erosion.

4. Barren Surface. The presence of vegetation will reduce wind erosion hazards. This effectively presents a barrier to wind movement. In addition, plant roots help bind the soil and make it less susceptible to wind damage.

5. Continuous Dry Weather. Continuous dry weather will increase wind erosion because soil particles are loosened due to lack of moisture. In wet and moist soils the finer particles are held together, hence, no danger of soil erosion by wind.

6. Wind Velocity and Turbulence. Obviously, the rate of wind movement, especially gusts having greater than average velocity, will influence erosion.

Mechanism and Types of Wind Erosion

The loss of soil by wind movement involves two processes :

(*a*) detachment, and (*b*) transportation. The abrasive action of the wind results in some detachment of tiny soil grains from the granules or clods of which they are a part. When the wind is laden with soil particles, however, its abrasive action is greatly increased. The impact of these rapidly moving grains dislodges other particles from soil clods and aggregates.

The transporation of the particles once they are dislodged takes place in three ways. The types are :

(*i*) **Saltation.** In saltation soil particles of medium size (0.10-0.15 mm diameter) are carried by wind in a series of short bounces. These bounces are caused by the direct pressure of the wind on soil particles.

(*ii*) **Soil Creep.** Saltation also encourages soil creep (rolling or sliding) along the surface of the large particles (0.5-1.0 mm diameter). The bouncing particles carried by saltation strike the large aggregates and speed up their movement along the surface.

(*iii*) **Suspension.** When the particles of soil are very small (less than 0.1 mm) they are carried over long distances. Finer suspended particles are moved parallel to the ground surface and upward.

CONTROL OF WIND EROSION

Principles of Wind Erosion Control

(*i*) To reduce the erodibility of the soil.

(*ii*) To reduce wind veloicty at ground level.

The following principles and practices should be adopted for the management of eroded land wind :

1. Conservation of Moisture. Obviously, if the soil can be kept moist there is little danger of wind erosion. This can be done by polughing of the lands during rains, levelling, bunding and terracing of the land and water harvest.

2. Vegetative Cover. a vegetative cover discourages soil blowing by providing a mechanical obstruction to erosive winds thus reducing their velocity and soil carrying capacity. The roots help in binding the soil particles together, in this way they resist erosion by wind.

3. Mulching. Stubble mulch has proved to be effective in controlling wind erosion.

4. Rough Surface. Wind is more effective on smooth surface than on rough surface. Hence, if no mulch is possible then the surface should be left rough during the period of high winds.

5. Trash Tillage. Tillage operations that leave the clods and trash at the surface and are desirable in controlling wind erosion. The trash should not be burried but mixed with the surface soil so that it is not easily flown away, but will obstruct the movement of the soil in a lose condition and without a good cover is liable to lead heavy wind erosion. Opening ridges and furrows at right angles to the prevailing winds is desirable to a certain extent.

6. Organic Matter. This is desirable for increasing the stability of the soil structure, for improving water-holding capacity of the soil and for building up its fertility. Using green manure crops is a desirable practice for this purpose. Crop residues should be left on the soil and not removed for use as fuel.

7. Regulating Grazing. Probably the most important cause of wind erosion is overgrazing. There must be grazing regulations to restrict the use of grazing lands.

8. Strip Cropping. Strip cropping is an effective method for controlling the wind erosion. *Wind strip cropping*, one of the types of strip cropping is especially suitable for the land which is susceptible to wind erosion. In wind strip cropping normal crop row should be alternated with tall crop or plant, at right angles to the direction of the prevailing winds.

9. Vegetative Barriers. To cater the need of small farmers, vegetative barriers (also known as live-funds) for rain water conservation and to regulate overland flows are useful. Important vegetative barriers are :

Khus (Vetiveria Zizanioides)
Anjan grass (Cenchrus ciliaris)
Lemon grass (Cymbopogan flexuosus)
Broom grass (Thysanolaena maxima)

Vegetative barriers have not been widely acceptated by the famers. Acceptance can be enhanced by selecting the species which can yield fodder for the cattle or loppings to maintain soil fertility (Fig. 23.5).

10. Wind Break and Shelterbelt. Trees and shrubs, commonly planted in rows at right angles to the prevailing winds are called shelterbelts. A recommended shelterbelt to control wind erosion may be made by planting three rows of trees and shrubs, the control row to consist of tall trees and the two outside rows to consist of smaller dense shrubs.

Fig.23.5. Landscape watershed units efficiently conserve land and water resources as they are spatially laid from ridge to valley

Example of Tall Trees

(i)	*Acacia arabica*	Babul
(ii)	*Dalbergia sisso*	Shisham
(iii)	*Eucalyptus rostrata*	Eucalyptus
(iv)	*Azadirachta indica*	Neem
(v)	*Albizzia lebbek*	Siris

Example of Bushy Shrubs

(i) *Cassia auriculata*
(ii) *Dondoned viscosa*
(iii) *Glyricidia maculata*
(iv) *Saccharum munja*
(v) *Zizyphus species.*

Stabilizing of Drifting Sand Dunes

The deposition of sand on cultivated land happens usually in the neighbouring of sand dunes or the tract of blowing sand, from which sand is easily blown on the good cultivated land. The only method by which this can be prevented consists likewise in establishing some soil or and binding vegetation on these dunes. Suitable grasses, generally with a creeping habit, and trees which can grow in sandy situations have to be planted sand their growth encouraged and the drifting of the sand prevented thereby. The cashewnut tree and the screw pine

are common trees for this purpose. The others sand binding trees are *Acacia arabica, Agave americana, Andropogon laniger* etc.

CAUSES OF SOIL EROSION

The supreme cause of excessive erosion is removal of vegetational cover from the soil. The important causes are :

(*i*) **Deforestation.** The destruction of forest covers leads to increased run-off of rain water and diminished storage in the soil. The structure of the soil suffers due to lack of organic matter thus run-off increases. The water develops power enough to cause devastating floods. In natural forest, when rain falls gently, the whole is absorbed and violent flood is lessened.

(*ii*) **Destruction and Overgrazing of Pastures.** A properly managed, lightly grazed pasture might form a permanent protection to the soil because it provides an efficient cover for preventing erosion and reducing run-off. But when there is overgrazing by cattle, goats and sheep, the soil becomes uncovered as the grass overgrazed. Raindrops begin to fall directly on the soil puddling the surface and clogging up the pores with mud, infiltration into the soil is reduced and the run-off of the water increases, thus causing soil erosion.

(*iii*) **Shifting Cultivation.** Man's ruthless destruction of the forest for shifting cultivation has also decreased the area under forest. Shifting or jhuming cultivation is chiefly practiced by the tribal communities for raising food for them. According to this system of farming, the forests are cleared and cultivated for 2-3 years. After two or three year's crop, the soil is exhausted and then another felling of forest takes place and the first is abandoned for 5-15 years.

(*iv*) **Faulty Methods of Cultivation.** When the virgin land is ploughed and naked soil is exposed to the rain the loss of the fertile soil is enormous, particularly on the steeper slopes. On the slopes or hills, tillage practices along the slope increases run-off and erosion.

Magnitude of Soil Erosion Problem and Effect of Erosion.

While it takes nature 100 to 400 years to build one centimeter of top soil and man can often destroy it almost overnight by hapazard land use and improvement in husbandry. By erosion the soil is lost and its fertility deleted. It is reported that the annual loss of fertility by erosion is 20 times faster than what is removed by the crops. (Fig. 23.6).

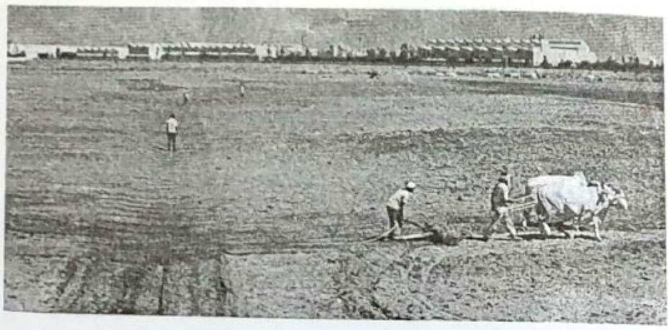

Fig. 23.6 About 80 per cent of India's cultivated lands is being slowly reduced to unproductive parched terrain due to wind and water erosion.

It has been estimated that the loss of soil through erosion of arable land is of the order of 6,000 million tonnes a year, with a total annual depletion of nitrogen to the extent of nearly 2.5 million tonnes, valued at Rs. 1,000 crores of rupees.

According to an estimate "on an average area of 10,000 hectare is affected by erosion every year, involving an average loss of Rs. 500 lakhs."

Investigations have shown that in the bare fallow fields in the foothills of northern India (except properly levelled rice land) a single storm leads to the loss of soil at the rate of 14 tonnes per acre; While in Bombay-Deccan there is a loss of 133 tonnes of soil per acre per year from a field of jowar.

Along most of the bigger rivers soil erosion has led to the formation of a vast and intricate network of fissures and finger gullies and the loss of invaluable agricultural land so that soil erosion is responsible for 3.67 million hectares of ravine lands in Uttar Pradesh, M.P., Rajasthan, and Gujarat along the banks of rivers flowing in north central direction *viz.*, the Yamuna, the Chamal, the Mahi and the Sabarmati. On a conservative estimate the country is losing a total output worth about Rs. 157 crores annually by failure to reclaim and develop the ravines.

Wind erosion is generally found in the desert areas of Punjab, Haryana, Western U.P., and western and north Rajasthan. In the desiccated area of Rajasthan the wind erosion has removed as much as 6 crores maunds of soil per square mile in certain places during the last hundred years. Wind borne sand encroaches arable lands of Rajasthan and makes them unfertile. Crops in many parts of western Rajasthan are frequently damaged by sand storms.

EFFECTS OF SOIL EROSION

1. Loss of Soil. The top soil is lost by erosion which is fertile soil. Due to formation of gullies and ravine valuable agricultural lands are lost.

2. Effect of Erosion on Organic Matter and Soil Structure. Erosion of upper layer of the soil decreases the content of organic matter. The structure of the soil becomes bad.

3. Loss of Nutrient. As the water continues to carry away the top soil, the nutrients of land declines. It is estimated that the annual loss of fertility by erosion is 20 times faster than what is removed by the crops.

4. Effect of Soil Loss on Yield. When soil is removed bodily from a field, both available and potential plant food alongwith mineral material is carried away. As erosion progresses, compact soil of relatively low infiltration capacity is appraoched. The ability of the land to suply moisture for plant growth is decreased, the beneficial activity of microorganism lessened. Due to these bad effects the yields are lowerd.

5. Hinderance of Farming Operations. When a field is cut by rills and gullies, the difficulties of ploughing and other farm operations are considerably increased.

6. Deposition of Sand and Gravel on Agricultural Lands. Wind borne sand encroaches arable lands and makes them unfertile. Crops are damaged by sand storms. Water may also deposit sand and gravel on the agricultural lands.

7. Heavy Floods in the River. The destruction of the forest in the catchment areas of the rivers and their tributaries has caused rapid run-off and erosion leading to the deposit of an increasing mass of debris on river beds in lowlands thus increasing the damage from floods.

8. Affect on Transportation. Roads and railway lines are eroded by flood water thus creating hindrance in transportation.

9. Destruction of Vegetation. In wind erosion the large soil particles (or sand particles, have a cutting effect on tender plants). Dust laden winds burn up the grasses. Destruction of vegetation by water is a frequent phenomena in flood prone areas.

LAND USE CAPABILITY CLASSIFICATION

Land use capability classification indicating the suitability of various kinds of soil for agricultural purpose. The classification system has been developed by soil conservation service. Grouping soils on the basis of erosion hazards and other limitations, so that suitable cropping systems may be planned, is an important step in developing a soil erosion control programme. At the same time, this procedure also provides