Subject: **Soil and Water Conservation Engineering**

Class: **First Year, II Semester**

Topic: **Introduction to soil and Water conservation**

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Introduction to Soil and Water Conservation Engineering

Why Soil and Water Conservation?

Soil and water are two important natural resources and the basic needs for agricultural production. During the last century it has been observed that the pressure of increasing population has led to degradation of these natural resources. In other words increase in agricultural production to feed the increasing population is only possible if there sufficient fertile land and water are available for farming. In India, out of 328 million hectares of geographical area, 68 million hectares are critically degraded while 107 million hectares are severely eroded. That's why soil and water should be given first priority from the conservation point of view and appropriate methods should be used to ensure their sustainability and future availability. Status of global land degradation is shown in Fig. 1.1.

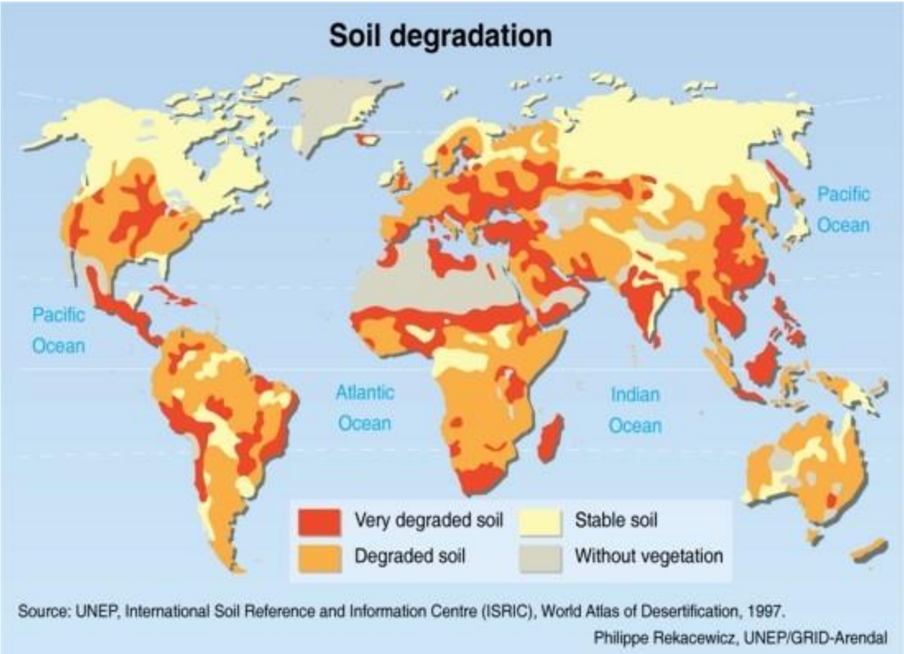

Fig. 1.1 Global soil degradation map

(Source: UNEP, International Soil Reference and Information Centre (ISRIC), World Atlas of Desertification, 1997)

Water conservation is the use and management of water for the good of all users. Water is abundant throughout the earth, yet only three percent of all water is fresh water, and less than seven-tenths of freshwater is usable. Much of the usable water is utilized for irrigation. Detailed analysis will show that in about fifteen years, about two-thirds of the world's population will be living in some sort of water shortage. Water is used in nearly every aspect of life. There are multiple domestic, industrial and agricultural uses. Water conservation is rapidly becoming a hot topic, yet many people do not realize the importance of soil conservation.

Soil conservation is defined as the control of soil erosion in order to maintain agricultural productivity. Soil erosion is often the effect of many natural causes, such as water and wind. There are also human factors which increase the rate of soil erosion such as construction, cultivation and other activities. Some may argue that since it is a natural process, soil erosion is not harmful. The truth is that with the removal of the top layer of soil, the organic matter and nutrients are also removed.

Conservation is not just the responsibility of soil and plant scientists, hydrologists, wildlife managers, landowners, and the forest or mine owner alone.

All citizens should be made aware about the importance of natural resources as our lives depend on that and everyone should be involved in the process of caring of these resources properly and using them intelligently.

What is Soil Erosion?

The uppermost weathered and disintegrated layer of the earth's crust is referred to as soil. The soil layer is composed of mineral and organic matter and is capable of sustaining plant life. The soil depth is less in some places and more at other places and may vary from practically nil to several metres. The soil layer is continuously exposed to the actions of atmosphere. Wind and water in motion are two main agencies which act on the soil layer and dislodge the soil particles and transport them. The loosening of the soil from its place and its transportation from one place to another is known as soil erosion.

The word erosion has been derived from the Latin word 'erodere' which means eating away or to excavate. The word erosion was first used in geology for describing the term hollow created by water. Erosion actually is a two phase process involving the detachment of individual soil particle from soil mass, transporting it from one place to another (by the action of any one of the agents of erosion, viz; water, wind, ice or gravity) and its deposition. When sufficient energy is not available to transport a particle, a third phase known as deposition occurs. In general, finer soil particles get eroded more easily than coarse particles (silt is more easily eroded than sand). Hence soil erosion is defined as a process of detachment, transportation and deposition of soil particles (sediment). It is evident that sediment is the end product of soil erosion process. Sediment is, therefore, defined as any fragmented material, which is transported or deposited by water, ice, air or any other natural agent. From this, it is inferred that sedimentation is also the process of detachment, transportation and deposition of eroded soil particles. Thus, the natural sequence of the sediment cycle is as follows:

Soil → Detachment → Transportation → Deposition

Detachment is the dislodging of the soil particle from the soil mass by erosive agents. In case of water erosion, major erosive agents are impacting raindrops and runoff water flowing over the soil surface. Transportation is the entrainment and movement of detached soil particles (sediment) from their original location. Sediments move from the upland sources through the stream system and may eventually reach the ocean. Not all the sediment reaches the ocean; some are deposited at the base of the slopes, in reservoirs and flood plains along the way. Erosion is almost universally recognized as a serious threat to human well being. Erosion reduces the productivity of crop land by removing and washing away of plant nutrients and organic matter. Distribution of global sediment load is presented in Fig. 1.2.

Source: Peter H. Gleick, *Water in Crisis*, New York Oxford University Press, 1993.

Fig.1.2. Global sediment loads. Due to high monsoon rainfall, Asia has the highest suspended sediment discharge. (Source: Peter H.G., 1983)

Problems Arising due to Soil Erosion

Balanced ecosystems comprising soil, water and plant environments are essential for the survival and welfare of mankind. However, ecosystems have been disturbed in the past due to over exploitation in many parts of the world, including some parts of India. The resulting imbalance in the ecosystem is revealed through various undesirable effects, such as degradation of soil surfaces, frequent occurrence of intense floods etc.

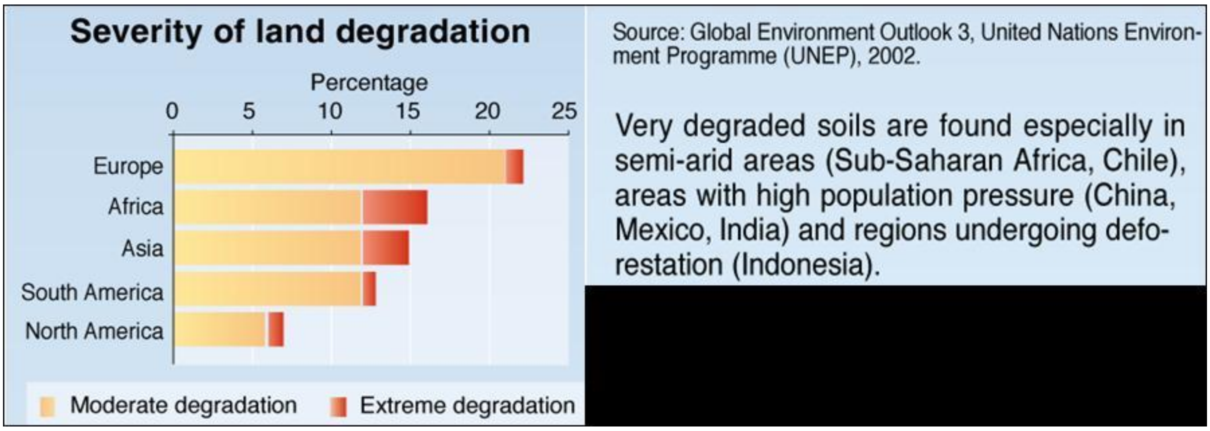

Fig. 1.3. Severity of land degradation at continental scale. (Source: Peter H.G., 1983)

Vast tracts of land have been irreversibly converted into infertile surfaces due to accelerated soil erosion caused by the above and other factors. These degraded land surfaces have also become a source of pollution of the natural water. Deposition of soil eroded from upland areas in the downstream reaches of rivers has caused aggradation. This has resulted in an increase in the flood plain area of the rivers, reduction of the clearance below bridges and culverts and sedimentation of reservoirs. Severity of land degradation at a continental scale is shown in Fig. 1.3.

The major land degradation problems due to sedimentation are briefly discussed as below:

- Erosion by wind and water: Out of 144.12 M-ha areas affected by water and wind erosion. About 69 M-ha is considered to be critical and needs immediate attention. Wind erosion is mainly restricted to States of Rajasthan, Gujarat and Haryana. The severity of wind erosion is inversely related to the rainfall amount, lesser is the rainfall more would be the wind erosion.
- Gullies and Ravines: About 4 M-ha is affected by the problem of gullies and ravines in the country covering about 12 states. Ravines are mostly located in the states of Uttar Pradesh,

Madhya Pradesh, Rajasthan and Gujarat. Gullies on the other hand are seen in the plateau region of Eastern India, foot hills of the Himalayas and areas of Deccan Plateau.

- Torrents and Riverine Lands: Problem of Riverine and torrents is spread over an area of 2.73 M-ha in the country. Torrents are the natural streams which cause extensive damage to life and property as a result of frequent changes in their course and associated flash flows with heavy debris loads. The unfertile material or debris transported by torrents is sometimes deposited on the fertile plains, thus ruining the land for ever.
- Water logging: Water logging is caused either by surface flooding or due to rise of water table. An area of 8.53 M-ha has been estimated to be affected by water logging. Water logging due to surface flooding is predominant in the states of West Bengal, Assam, Bihar, Orissa, Andhra Pradesh, Uttar Pradesh, Kerala, Punjab and Haryana.
- Shifting Cultivation: Shifting cultivation, also known as 'jhuming' is a traditional method of growing crops on hill slopes by slash and burn method. The method involves selection of appropriate site on hill slopes, cleaning of forest by cutting and burning, using the site for cultivation for few years and later on abandoning it and moving to a fresh site. The jump cycle has gradually declined from 20-30 years to 3-6 years due to increasing population pressures. The problem is more serious in North Eastern region and in the states of Orissa and Andhra Pradesh.
- Saline soil including coastal areas: Saline soils are prevalent both in inland as well as coastal areas. About 5.5 M-ha area is affected by this problem in the country which includes arid and semi-arid areas of Rajasthan and Gujarat, black soil region and coastal areas. This problem is causing serious damage to agricultural lands, rendering fertile soil unproductive and turning groundwater brackish in the States of West Bengal, Tamil Nadu, Orissa, Maharashtra, Kerala, Karnataka, Gujarat and Andhra Pradesh as well as Union Territories of Pondicherry and Goa, Daman and Diu.
- Floods and Droughts: In India, among the major and medium rivers of both Himalayas and non-Himalayas categories, 18 are flood prone which drain an area of 150 M-ha. In recent years, flash floods have caused extensive damage even in the desert areas of Rajasthan and Gujarat.

Importance of Soil Conservation

In India, out of the total geographical area of 329 M-ha, an area of about 150 M-ha is subjected to either water or wind erosion. A net area of about 140 M-ha is cropped at present. An area of 40 M-ha is considered to be flood prone. Area lost through ravines and gullies is estimated to be about 4 M-ha. As a whole, it is estimated that about 175 M-ha i.e., 53.3% of the total geographical area of the country is subjected to various soil and land degradation problems like saline-alkali soils, waterlogged areas, ravine and gullied lands, area under shifting cultivation, and desertification. By the year 2100 A.D, the projected population of the country is expected to be two billion, whereas the food grain production is almost stagnant at 211 million tons for the last 5 years. The per capita cropped area is shrinking every day; in the year 1950, it was 0.33 ha/capita, 0.2 ha in 1980 and it was 0.15 ha by 2000. This clearly shows that the limited land resource has to be managed very carefully by adopting total conservation measures for the survival of the huge population. A few suggestions to conserve soil and water resources in Indian context are discussed below.

- To prevent erosion of bare soil, it is important to maintain a vegetation cover, especially in the most vulnerable areas e.g. those with steep slopes, in a dry season or periods of very heavy rainfall. For this purpose, only partial harvesting forests (e.g. alternate trees) and use of seasonally dry or wet areas for pasture rather than arable agricultural land should be permitted.
- Where intensive cultivation takes place, farmers should follow crop rotation in order to prevent the soil becoming exhausted of organic matters and other soil building agents. Where soils are ploughed in vulnerable areas, contour ploughing (i.e. round the hillside rather than down the hillside) should be used. Careful management of irrigation, to prevent the application of too much or too little water will be helpful to reduce the problem of soil salinity development. Livestock grazing must be carefully managed to prevent overgrazing.
- Construction of highways and urbanization should be restricted to areas of lower agricultural potential. With extractive industries, a pledge must be secured to restore the land to its former condition before permission for quarries or mines is granted.

History of Soil Erosion and Soil Conservation Programs in India

To meet the demand for food, fibre, fuel wood and fodder owing to increasing population pressures, the forest areas have been indiscriminately cleared resulting in enormous soil loss in many parts of the country. The human activities such as urbanization, road construction, mining etc. have further aggravated the problem. In the early years, the problem was more localized but now it has become more serious due to over exploitation of natural resources. However, various governmental plans have been implemented in the field of conservation of land, water and plant resources since pre-independence days.

(1) The Pre-Independence Era

In 1882, Sir Dietrich Brands, the Inspector General of Forests, commented on the possibility of soil erosion taking place and the need to counter it in the denuded slopes of the Nilgiri District of Madras Province of pre-independence India. He suggested planting of belts of trees in the midst of cultivation on hill slopes. Protection of land from the menace of 'Cho' (mountain torrents) also received early attention and one of the first enactments for prevention of soil deterioration was passed in Punjab in 1900 as Land Preservation Act. It provided for such measures as Wat Bandi (ridge formation), contour trenching, gully plugging, terracing, tree planting etc. for preventing the havoc caused by Chos. Soil conservation research in India was initiated during 1933-35 when the then Imperial (now Indian) Council of Agricultural Research decided to establish its regional centres for research in dry farming at Sholapur (Maharashtra), Bijapur, Raichur, Bellary (Karnataka) and Rohtak (Haryana). Holding rain water by construction of bunds, green manuring, cultivation of kharif crops on shallow soils and fallowing in deep black soils were important measures recommended by the research stations.

A real push to soil conservation was given when a separate Soil Conservation Wing in Agricultural Department was established in Maharashtra during 1940's and massive contour bunding programme was taken up following scientific guidelines and specifications. Field bunding was also practiced as part of famine relief programmes in the Deccan plateau during 1930's and 40's. Soil conservation was not confined to contour bunding alone but also included nala bunding (check dams of loose stones) and percolation dams for water harvesting.

A commission was appointed by the Gwalior State as far back as 1919 to consider ways and means of arresting further extension of ravines and suggest methods for improving production of economic plants in these areas. In the 1930's, ravine reclamation practices were applied in the Chambal ravines of the erstwhile state of Gwalior. In 1953, Board of Agriculture made a proposal for a systematic reconnaissance survey of Indian soils to assess the damage caused by erosion. The Bombay Land Improvement Act of 1942 provided for setting up in each division a Land Improvement Board for conservation, improvement and regulation of agriculture, forest and pasture lands.

In 1945, the Central Government obtained the services of Dr. Donald V. Shuhart of Soil Conservation Service, USDA to report on soil erosion problems in India and suggest remedial measures. A high powered seven member team visited United States in May, 1947 for exhaustive study of soil conservation practices and submitted a report to Government of India taking due cognizance of the conditions peculiar to the Indian Agriculture. The team suggested that the unit of planning should be a village or a group of villages or a watershed. The report also emphasized that there should be a close cooperation between the Department of Forest, Agriculture and Irrigation at the centre and in the provinces in initiating and developing different phases of the conservation programme.

(2) Post-Independence Period

A conference of state Ministers in-charge of agriculture and cooperation was held in New Delhi in September, 1953. The conference considered that at the state level, existing organizations and state development committees should be entrusted with the task of formulating soil conservation programmes. It also suggested that any state problem with regard to soil conservation should be concern of the Central Soil Conservation Board. The central Government in the Ministry of Food and Agriculture set up a Central Soil Conservation Board in 1953. Maharashtra state did pioneering work on problems of soil erosion and conservation measures in cultivated lands. It was realized that ultimate aim of soil conservation was not only to control erosion but also to maintain the productivity of soil.

(3) First Five Year Plan (1951-56)

During the First Five Year Plan (1951-56), considerable attention was given to soil and moisture conservation. With a view to develop a research base for soil conservation, a Soil Conservation Branch and a Desert Afforestation Research Station at Jodhpur were established under the control of Forest Research Institute, Dehra Dun. Consequently, the Central Soil Conservation Board established a chain of nine Soil Conservation Research, Demonstration and Training Centers at Dehra Dun, Chandigarh, Bellary, Ootacamund (now Udhagamandalam), Kota, Vasad, Agra, Chatra (Nepal) and Jodhpur during the late First Five Year Plan and early Second Five Year Plan.

(4) Second Five Year Plan (1956-61)

In this plan, the Desert Afforestation and Soil Conservation Centre at Jodhpur were developed into the Central Arid Zone Research Institute (CAZRI) in 1959 with collaboration of UNESCO.

A Centre was set up at Chatra in Nepal to take-up research on soil conservation problems of Kosi River Valley Project. The All India Soil & Land Use Survey Organization was established at central level.

(5) Third Five Year Plan (1961-66)

A centre at Ibrahimpatnam (Hyderabad) in the semi-arid red soil region was established in the third five year plan in 1962. The Government of India reorganized the Soil Conservation Division in the Ministry of Agriculture and redesignated the Senior Director as Advisor and entrusted him with the responsibility of coordinating the soil and water conservation development. After the reorganization of Agricultural Research and Education in India, all the Soil Conservation Research, Demonstration and Training Centres of the Government of India except Chatra (Nepal) were transferred to the Indian Council of Agricultural Research (ICAR) on the 1st October, 1967.

(6) Fourth Five Year Plan (1969-74)

Under this plan, All India Soil & Land Use Survey prepared a detailed analysis of different watersheds of the country. The concept of Integrated Watershed Management was successfully introduced at field level in different parts of the country.

(7) Fifth Five Year Plan (1974-79)

In this plan, the Government of India introduced many centrally sponsored programmers, viz; Drought Prone Area Programme (DPAP), Flood Prone Area Programme (FPAP), Rural Development Programme (RDP), and Desert Development Programme (DDP). In DPAP and DDP, the focus was on planting of trees on degraded lands and to drill tube wells to extract groundwater.

(8) Sixth Five Year Plan (1980-85)

In this plan period, more emphasis was given on the treatment of small watersheds varying in size up to 2000 hectare. An intensive programme for integrated management of about 200 sub-watersheds of 8 flood prone catchments of Ganga river basin was undertaken during this plan.

(9) Seventh Five Year Plan (1985-90)

In this plan, DDP in hot and cold desert areas took a major establishment and aforestation practices were adopted on a large scale following integrated watershed management approach.

On the basis of the experience gained in various schemes, National Watershed Development Programme for Rainfed Areas (NWDPRA) was launched in the 7th Plan in 99 selected districts in the country. NWDPRA was implemented in about 2550 watersheds in 357 districts of 25 states and two Union Territories, viz; Andaman and Nicobar Islands and Dadra and Nagar Haveli. The watershed approach has the advantage of serving the twin objectives of restoration of ecological balance and socio-economic welfare of watershed community.

(10) Eighth Five Year Plan (1990-95)

During this period, Ministry of Agriculture, Department of Agriculture and Cooperation, New Delhi formulated the guidelines for the implementation of NWDPRA and published it in the form of a document commonly known as WARASA (Watershed Areas Rainfed Agriculture System Approach). The Ministry of Rural Development also brought out common guidelines for the implementation of DPAP, DDP and Integrated Wasteland Development Programme (IWDP) in the country so as to maintain uniformity in objectives, strategies and expenditure norms for various watershed development projects.

(11) Ninth Five Year Plan (1997-02)

The centrally sponsored scheme for reclamation of alkali soils was launched during the Seventh Five Year Plan in the states of Haryana, Punjab and Uttar Pradesh. It continued during the Eighth Five Year Plan and was extended to the states of Gujarat, Madhya Pradesh and Rajasthan. During 2000-01, it was extended to all other states where alkali soil problem exists. The scheme aimed at improving physical conditions and productivity status of alkali soils for restoring optimum crop production. The major components were assured irrigation water, on-farm development works like land leveling, bunding and ploughing, community drainage system, application of soil amendments, organic manures etc. During IX Plan, an area of 0.97 lakh ha, mostly occurring in isolated patches, was reclaimed at a cost of Rs. 14.99 crores (Govt. of India share).

Up to IX plan (1997-02), an area of 426 lakh ha had been covered under Priority Delineation Survey (PDS) and about 13.1 lakh ha under Detailed Soil Survey (DSS) by the All India Soil and Land Use Survey.

(12) Tenth Five Year Plan (2002-07)

The Tenth Five Year Plan (2002-2007) has put emphasis on natural resource management through rainwater harvesting, groundwater recharging measures and controlling groundwater exploitation, watershed development, treatment of waterlogged areas. The Government of India fully funded the Western Ghats Development Programme (WGDP), area affected due to erosion and water problem. In this programme, the State Governments were directed to adopt Integrated Watershed Approach in implementing the activities such as soil conservation, agriculture, horticulture, afforestation, fuel and fodder development, minor irrigation, animal husbandry etc. various soil conservation measures (engineering and agricultural) like construction of check dams, gully plugging, plantation of mixed species and contour trenching etc were taken up in sensitive Western Ghats areas of Sattari, Canacona and Sanguem talukas.

(13) Eleventh Five Year Plan (2007-12)

Watershed development projects, for the purpose of conserving soil and water, were funded through various schemes including National Watershed Development Projects in Rainfed Areas (NWDPRA), River Valley Projects (RVP), and Integrated Wasteland Development Programme (IWDP). Emphasis has been given to increase the water resources availability and their efficient use. Responsibility for ensuring adequate availability of water for agricultural use was divided between the Ministry of Water Resources (MoWR), which was responsible for major, medium, and minor irrigation, the Department of Land Resources, which was responsible for watershed management, the Department of Rural Development, which was responsible for the Mahatma Gandhi Rural Employment Guarantee Act (MGNREGA) and strongly oriented to deal with water conservation issues, and the Department of Agriculture, which deals with water use efficiency.

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Topic: **Soil Erosion and Its types**

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2. Soil Erosion and its Types

2.1 Introduction

Soil erosion is the process by which soil is removed from the Earth's surface by exogenetic processes such as wind or water flow, and then transported and deposited in other locations. In general, soil erosion implies the physical removal of topsoil by various agents, including rain, water flowing over and through the soil profile, wind, glaciers or gravitational pull. Land and water are the most precious natural resources that support and sustain the anthropogenic activities. In India particularly, about 65% of the population depend on agriculture, the only sector which generates half of the employment and maintain ecological balance.

Soil erosion in India is amongst the leading areas of concern as it affects cultivation and farming in the country in adverse and unfavourable ways. Soil erosion leads to deprivation of physical characteristics of soils and damages plant and crops. In India almost 130 million hectares of land, i.e., 45 % of total geographical surface area, is affected by serious soil erosion through gorge and gully, shifting cultivation, cultivated wastelands, sandy areas, deserts and water logging. Soil erosion by rain and transportation of soil particles through rivulets that takes place in hilly areas causes severe landslides and floods. The anthropogenic activities including cutting trees for agricultural implements, firewood and timber; grazing by a large number of livestock over and above the carrying capacity of grass lands, traditional agricultural practices, construction of roads, indiscriminate quarrying and other activities, have all led to the opening of top surfaces to extreme soil erosion. In Indian condition, the control of soil erosion is a challenging task in the sense that the onset of monsoon often coincides with the kharif sowing and transplanting. In this stage of kharif crop when canopy cover is minimal, major part of the land is exposed to the rainfall let the land prone to soil erosion. It is prudent to check soil erosion from agricultural lands since it affects majority of people.

2.2 Types of Soil Erosion

Broadly, soil erosion can be divided into three categories depending on the eroding agents namely water erosion, wind erosion and chemical or geological erosion. Soil erosion due to the agents like water and wind is mostly prevalent and tangible. The erosion caused through chemical and geological agents is a slow process and continues to years and often it is non-tangible. Water erosion is further subdivided into classes depending on the effect of water erosion. These include sheet erosion, rill erosion, gully erosion, land slide or slip erosion and stream bank erosion.

2.2.1 Geologic Erosion

Geologic erosion sometimes referred to as natural or normal erosion; represent erosion under the cover of vegetation. It includes soil as well as soil eroding processes that maintain the soil in favourable balance, suitable for the growth of most plants. The rate of erosion is so slow that the loss of soil is compensated by the formation of new soil under natural weathering processes. The various topographical features such as existing of streams, valleys, etc. are the results of geologic erosion.

2.2.2 Wind Erosion

Wind erosion is the detachment, transportation and redeposition of soil particles by wind. A sparse or absent vegetative cover, a loose, dry and smooth soil surface, large fields and strong winds all increase the risk of wind erosion. Air movement must attain a certain velocity (with enough speed to generate visible movement of particles at the soil level) before it can generate deflation and transport of particles. Winds with velocities of less than 12-19 km/hr seldom impart sufficient energy at the soil surface to dislodge and put into motion sand-sized particles. Drifting of highly erosive soil usually starts when the wind attains a forward velocity of 25-30 km/hr. Wind erosion tends to occur mostly in low rainfall areas when soil moisture content is at wilting point or below, but all drought-stricken soils are at risk. Often the only evidence of wind erosion is an atmospheric haze of dust comprising fine mineral and organic soil particles that contain most of the soil nutrients. Actions to minimize wind erosion include improving soil structure so wind cannot lift the heavier soil aggregates; retaining vegetative cover to reduce wind speed at the ground surface; and planting windbreaks to reduce wind speed. Also, be ready for severe wind erosion seasons which tend to be the summers following dry autumns and winters. The most familiar result of wind erosion is the loss of topsoil and nutrients, which reduces the soil's ability to produce crops. Topsoil loss can be seen as rocky or gravelly knolls, thin soils mixed with lighter coloured subsoil, or the presence of calcium carbonate in surface soils.

Soil productivity is affected by wind erosion in various ways. Areas of erosion and deposition within a field increase the variation in soil characteristics, requiring more costly and less efficient soil management practices. Wind removes the smaller clay particles and organic matter from the soil while coarser materials are left behind. The continued loss of fine particles reduces soil quality. In shallow soils and soils with a hardpan layer, wind erosion also results in decreased root zone depth and water-holding capacity. Such changes may occur slowly and go unnoticed for many years especially if mixing by tillage masks the effects of wind erosion.

2.2.2.1 Process of Wind Erosion

The process of wind erosion comprises of three basic stages namely saltation, suspension and surface creep. Fig. 1.1 describes the process.

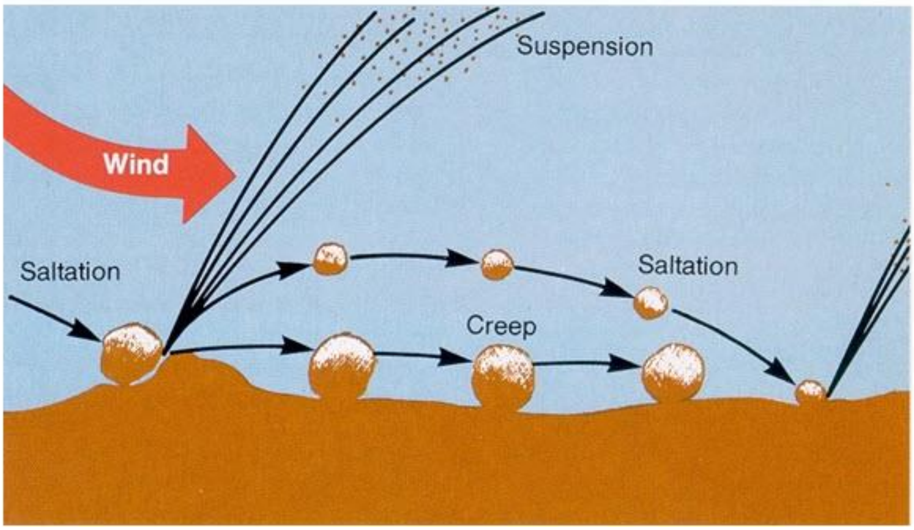

Fig.2.1 Process of wind erosion
(Source:http://www.weru.ksu.edu/new_weru/images/CreepSaltSusp.jpg)

(i) Saltation: Saltation occurs when the wind lifts larger particles off the ground for short distances, leading to sand drifts. Fine and medium sand-sized particles are lifted a short distance into the air, dislodging more soil as they fall back to the ground.

(ii) Suspension: Suspension occurs when the wind lifts finer particles into the air leading to dust storms. Very fine soil particles are lifted from the surface by the impact of saltation and carried high into the air, remaining suspended in air for long distances.

(iii) Surface Creep: The movement of large soil particles along the surface of the soil after being loosened by the impact of saltating particles.

2.2.2.2 Extent of Wind Erosion

Several factors, other than the wind velocity itself, contribute to wind erosion. These fall into two main groups of closely interrelated elements: those inherent in the properties of the soil per se and those associated with soil cover. A rough soil structure, especially at the surface, effectively reduces the movement of soil particles. Arid regions, however, are dominated by smooth, pulverized and structure less top soils. Soil texture also influences soil erodibility; soils of fine texture are, for example, particularly susceptible to wind erosion.

Measurements of dust in the air up to three metres above the soil surface at Jodhpur, India, showed that on a stormy day the amount of dust blowing varied between 50 and 420 kg/ha. In the Jaisalmer region of India, where wind speeds generally are higher, average soil loss of 511 kg/ha was recorded.

According to Global Assessment of Human-induced Soil Degradation (GLASOD), 21.6 Mha area of Indian soil is affected by wind erosion, which account for 6% of total geographical area. However, area varied from 12.9 to 38.7 Mha from various sources. The GLASOD assessment of extent of area under wind erosion is presented in Table 1.1

Table 2.1. GLASOD assessment: areas affected by wind erosion (Unit: 1000 ha) – South Asian Countries

Country	Light	Moderate	Strong	Total	Total as percent of land
Afghanistan	1 873	0	209	2 082	5%
Bangladesh	0	0	0	0	0%
Bhutan	0	0	0	0	0%
India	0	1 754	9 042	10 796	6%
Iran	6 559	25 730	3 085	35 374	60%
Nepal	0	0	0	0	0%
Pakistan	3 998	6 742	0	10 740	42%
Sri Lanka	0		0	0	0%
India, dry region	0	1 754	9 042	10 796	-
India humid region	0	0	0	0	-
Dry zone	12 430	34 225	12 337	58 992	39%
Humid zone	0	0	0	0	0%
Region	12 430	34 225	12 337	58 992	18%

2.2.3 Water Erosion

The soil erosion caused by water as an agent is called water erosion. In water erosion, the water acts as an agent to dislodge and transport the eroded soil particle from one location to another (Fig. 1.2).

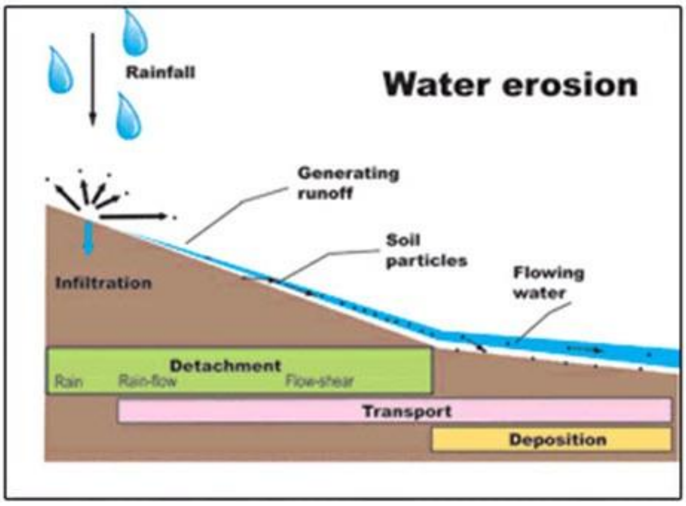

Fig. 2.2 Process of water erosion

2.2.3.1 Extent of Water Erosion

The extent of water erosion in Indian subcontinent are presented in Table 1.2. In India, 32.8 Mha area in India is affected by water erosion which accounts for 18% of the land. However, the water erosion extent estimated by different sources varies from 87 to 111 Mha in India.

Table 1.2.GLASOD assessment: areas affected by water erosion (Unit: 1000 ha) – South Asian region

Region	Light	Moderate	Strong	Total	Total as percent of land
Afghanistan	8 560	2 597	0	11 156	29%
Bangladesh	0	1 504	0	1 504	15%
Bhutan	36	0	4	40	10%
India	2 936	17 217	12 620	32 773	18%
Iran	14 504	11 896	0	26 400	45%
Nepal	520	1 072	0	1 592	34%
Pakistan	6 080	1 124	0	7 204	28%
Sri Lanka	72	157	845	1 074	46%
India, dry region	1 177	0	1676	2 853	-
India, humid region	1 759	17 217	10 944	29 920	-
Dry zone	30 320	15 617	1 676	47 613	32%
Humid zone	2 387	19 951	11 791	34 130	20%
Region	32 707	35 568	13 468	81 743	25%

The state wise extent of soil erosion from wind as well water is presented in Table 1.3. The Fig.s are adopted from National Bureau of Soil Survey & Land Use Planning(NBSS&LUP 2005). The NBSS&LUP estimates are higher in case of water erosion and lower in case of wind erosion when compared to GLASOD.

Table 2.3. Extent of erosion in India unit- (1000 ha)

S. No.	Name of the States	Water Erosion	Wind Erosion
1	Andhra Pradesh	11518	0
2	Arunachal Pradesh	2372	0
3	Assam	688	0
4	Bihar+ Jharkhand	3024	0
5	Goa	60	0
6	Gujarat	5207	443
7	Haryana	315	536
8	Himachal Pradesh	2718	0
9	Jammu & Kashmir	5460	1360
10	Karnataka	5810	0
11	Kerala	76	0
12	Madhya Pradesh + Chhattisgarh	17883	0
13	Maharastra	11179	0
14	Manipur	133	0
15	Mizoram	137	0
16	Meghalaya	137	0
17	Nagaland	390	0
18	Orissa	5028	0
19	Punjab	372	282
20	Rajasthan	3137	6650
21	Sikkim	158	0
22	Tamil Nadu	4926	0
23	Tripura	121	0
24	Uttar Pradesh + Uttarakhand	11392	212
25	West Bengal	1197	0
26	Delhi	55	0
27	Union Territories	187	0
	Grand Total	**93680**	**9483**
	Grand Total(Million ha)	**93.68**	**9.48**

(Source: NBSS&LUP, 2005)

2.2.3.2 Types of Water Erosion

The different types of water erosion are described in the following section.

2.2.3.2.1 Splash Erosion

This type of soil erosion is because of the action of raindrop. The kinetic energy of falling raindrop dislodges the soil particle and the resultant runoff transports soil particles. Splash erosion (Fig. 1.3) is the first stage of soil erosion by water. It occurs when raindrops hit bare soil. The explosive impact breaks up soil aggregates so that individual soil particles are 'splashed' onto the soil surface. The splashed particles can rise as high 0.60 meter above the ground and move up to 1.5 meter from the point of impact. The particles block the spaces between soil aggregates, so that the soil forms a crust that reduces infiltration and increases runoff.

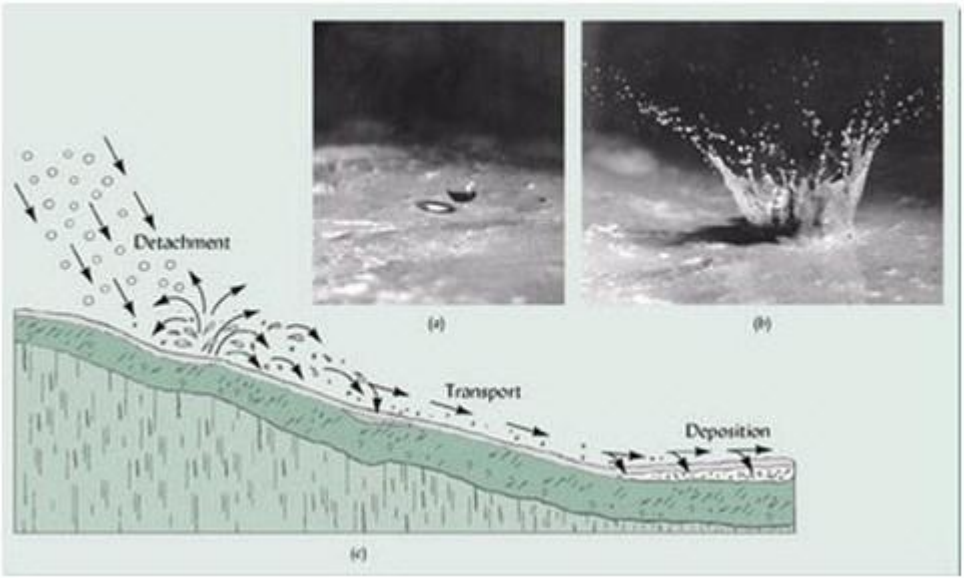

Fig. 2.3 Picture describing Splash erosion of the soil

(Source: http://restoringutopia.blogspot.in/2010/07/like-hollow-point-bullets-from-sky.html

2.2.3.2.2 Sheet Erosion

Sheet erosion (Fig. 1.4) is the removal of soil in thin layers by raindrop impact and shallow surface flow. This action called skimming and is prevalent in the agricultural land. It results in loss of the finest soil particles that contain most of the available nutrients and organic matter in the soil. Soil loss is so gradual that the erosion usually goes unnoticed, but the cumulative impact accounts for large soil losses. This type of soil erosion is mainly responsible for loss of soil productivities. Soils most vulnerable to sheet erosion are overgrazed and cultivated soils where there is little vegetation to protect and hold the soil. Early signs of sheet erosion include bare areas, water puddling as soon as rain falls, visible grass roots, exposed tree roots, and exposed subsoil or stony soils. Soil deposits on the high side of obstructions such as fences may indicate active sheet erosion.

Vegetation cover is vital to prevent sheet erosion because it protects the soil, impedes water flow and encourages water to infiltrate into the soil. The surface water flows that cause sheet erosion rarely flow for more than a few meters before concentrating into rills.

Fig. 2.4 Picture describing sheet erosion of the soil

(Source: http://soer.justice.tas.gov.au/2003/image/101/index.php)

2.2.3.2.3 Rill Erosion

Rills formation is the intermittent process of transforming to gully erosion. The advance form of the rill is initial stage of gully formation. The rills are shallow drainage lines less than 30cm deep and 50 cm wide. They develop when surface water concentrates in depressions or low points through paddocks and erodes the soil. Rill erosion is common in bare agricultural land, particularly overgrazed land, and in freshly tilled soil where the soil structure has been loosened. The rills can usually be removed with farm machinery. Rill erosion is mostly occurs in alluvial soil and is quite frequent in Chambal river valley in India. The typical rill formation is presented in Fig. 1.5.

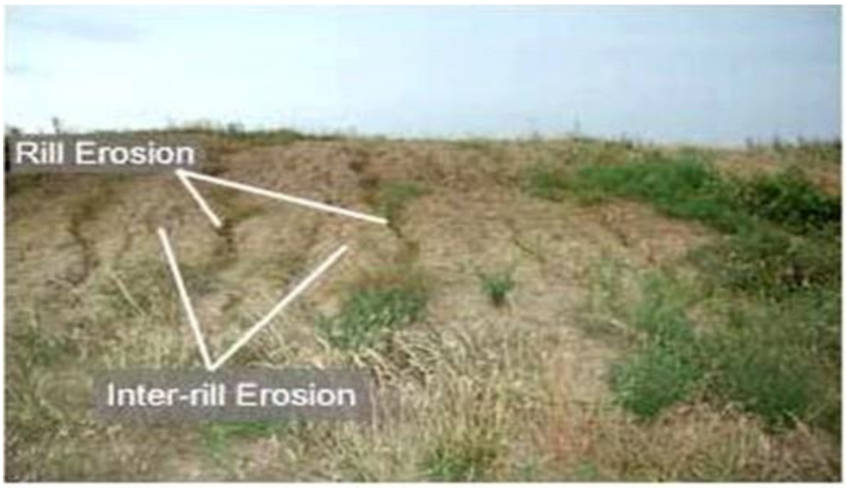

Fig.2.5 Rill Erosion

(Source: http://passel.unl.edu/UserFiles/Image/siteImages/Rillerosion-LGjpg.jpg

2.2.3.2.4 Gully Erosion

The advance stage of rills is transformed into initial stage of gully. Gully formation are initiated when the depth and width of the rill is more than 50 cm. Gullies (Fig. 1.6) are deeper channels that cannot be removed by normal cultivation. Hillsides are more prone to gullying when they cleared of vegetation, through deforestation, over-grazing or other means. The eroded soil is easily carried by the flowing water after being dislodged from the ground, normally when rainfall falls during short, intense storms. Depending upon the depth and width, the gullies further divided into 4 classes namely G1, G2, G3 and G4 (Table 1.4). Gullies reduce the productivity of farmland where they incise into the land, and produce sediment that may clog downstream water bodies. Because of this, much effort are required to invested into the study of gullies within the scope of geomorphology, in the prevention of gully erosion, and in restoration of gullied landscapes. The total soil loss from gully formation and subsequent downstream river sedimentation can be sizable.

Fig. 2.6 Gully Erosion

(Source: CSWCRTI, Dehradun)

Table 1.4. Classification of Gully

Particulars	Description of symbols of Gully			
	G1	**G2**	**G3**	**G4**
Depth (m)	Up to 1.0	1.0-3.0	3.0-9.0	>9.0
Width (m)	<18.0	<18.0	18	>18.0
Side slope (%)	<6.0	<6.0	6.0-12.0	>12.0

2.2.3.2.5 Tunnel Erosion

Tunnel erosion (Fig. 1.7) occurs when surface water moves into and through dispersive sub soils. Dispersive soils are poorly structured so they erode easily when wet. The tunnel starts when surface water moves into the soil along cracks or channels or through rabbit burrows and old tree root cavities. Dispersive clays are the first to be removed by the water flow. As the space enlarges, more water can pour in and further erode the soil. As the tunnel expands, parts of the tunnel roof collapse leading to potholes and gullies. Indications of tunnel erosion include water seepage at the foot of a slope and fine sediment fans downhill of a tunnel outlet. This type of erosion is more frequent in foothills where elevation is between 500-750 meter.

Fig.2.7 Tunnel Erosion

(Source: http://www.ccma.vic.gov.au/soilhealth/photos.htm)

2.2.3.2.6 Stream Bank Erosion

Stream bank erosion (Fig. 1.8) occurs where streams begin cutting deeper and wider channels as a consequence of increased peak flows or the removal of local protective vegetation. Stream bank erosion is common along rivers, streams and drains where banks have been eroded, sloughed or undercut. This is quite prevalent in alluvial river and streams. Generally, stream bank erosion becomes a problem where development has limited the meandering nature of streams, where streams have been channelized, or where stream bank structures (like bridges, culverts, etc.) are located in places where they can actually cause damage to downstream areas. Stabilizing these areas can help protect watercourses from continued sedimentation, damage to adjacent land uses, control unwanted meander, and improvement of habitat for fish and wildlife.

(a) (b)

Fig. 2.8 Stream Bank Erosion

(**Source: http://www.flickr.com/photos/sarfrazh/3849502770/**)

2.2.3.2.7 Coastal erosion

The waves, geology and geomorphology are the three major factors that affect the coastal erosion. Waves are the cause of coastal erosion. Wave energy is the result the speed of the wind blowing over the surface of the sea, the length of fetch and the wind blowing time. The **geology** of the coastline also affects the rate of erosion. If the coast is made of a more resistant type of rock (say, granite), the erosion rate will be lower than if the coast is made of a less resistant type of rock (say, boulder clay). The **geomorphology** (or shape) of the coastline further affects the rate of erosion. Headlands cause wave refraction, making waves converge and combining their energy. Wider, shallower bays, meanwhile, allow waves to diverge, losing energy due to friction with the sea bed. A wider beach cause more wave energy to be lost due to friction before the waves can break. A narrower beach will mean that the breaking point of the waves is closer to the coastline, and less energy will have been lost due to friction before they break. Similarly, shingle and pebbles will allow more water to infiltrate and cause more wave energy to be lost due to friction, while sandy beaches allow less infiltration and cause less friction and so allow for a higher rate of erosion. If the beach gradient is steep, this will encourage steeper, higher-energy waves. Paradoxically, though, because shingle and pebble beaches leave less energy for backwash, material tends to be moved upwards, making the beach steeper. The coastal erosion is a major concern for India as about 40% of the Indian coasts are subjected to severe erosion that has the potential to change the coast line. The typical coastal erosion is presented in Fig. 1.9.

Fig.2.9 A view of eroded Goa beach

(Source: http://www.concierge.com/ideas/beachisland/tours/)

2.3 Effects of Soil Erosion

The soil erosion adversely affects the livelihood of the people in one way or other. The major losses and problem occurs due to the soil erosion from various agents are listed below.

- Siltation of rivers.
- Siltation of irrigation channels and reservoirs.
- Problems in crop irrigation and consequent need of conserving the water.
- Damage to sea coast and formation of sand dunes.
- Disease and public health hazards.
- Soils eroded by water get deposited on river beds, thus increasing their level and causing floods. These floods sometime have various extreme effects, such as killing human and animals and damaging various buildings.
- Soil erosion decreases the moisture supply by soil to the plants for their growth. It also affects the activity of soil micro-organisms thus deteriorating the crop yield.
- Top layer of soil contains most of the organic matter and nutrients, loss of this soil reducing soil fertility and affecting its structure badly.
- Wind erosion is very selective, carrying the finest particles - particularly organic matter, clay and loam for many kilometres. There the wind erosion causes losses of fertile soils from highly productive farming areas.
- The most spectacular forms are dunes - mounds of more or less sterile sand - which move as the wind takes them, even burying oases and ancient cities.
- Sheets of sand travelling close to the ground (30 to 50 metres) can degrade crops.
- Wind erosion reduces the capacity of the soil to store nutrients and water, thus making the environment drier.

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Subject: **Soil and Water Conservation Engineering**

Class: **First Year, II Semester**

Topic: **Soil Conservation and Its Importance**

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4. Soil Conservation and Its Importance

4.1 Introduction

Soil conservation is an on-field activity to address the problem of soil erosion of any type, which has been discussed in previous lecture. In broader sense soil conservation activities control soil erosion through adaptation of different methods. The ultimate objective of soil conservation is to check the further soil erosion and sustain the agricultural productivity. The integrated nutrient management is also associated with soil conservation, and this employs the measures such as correction of soil defects, application of manures and fertilizers, proper crop rotations, irrigation, drainage etc., which aim at maintaining the higher level productivity in soils. However, soil conservation mainly deals with improvement of land use and reclamation of eroded land to utilize the unusable land resources under cultivation as well as protecting the land resources from further degradation. In other words, soil conservation is by itself the proper land husbandry, which would preserve the land and its fertility on a sustained basis and at the same time promote better agriculture, increase yields and achieve maximum benefits from such land. Such land husbandry should be based on proper classification of land utilization and balance allotment of lands for the different purposes, for which various local conditions are suitable.

4.2 Need for Soil Conservation

The basic needs of soil conservation remain to enhance and sustain the agricultural productivity in tandem with the prevailing agro-socio-economic practices in the respective region. However, specific objectives of soil conservation are as follows:

1. To sustain the production from natural resources to meet the basic requirements of food, shelter and clothing of growing population.

2. To preserve topsoil to reduce deterioration in soil fertility and the water holding capacity, thus sustaining productivity.

3. To check the formation of rills and gullies due to soil erosion in the field, which adversely affect the productivity.

4. To increase the groundwater recharge, by sustaining the soil moisture retention capacity of the soil.

5. To maintain the land productivity and prevent shrinkage of arable area.

6. To reduce the dredging work due to sedimentation in creeks, rivers, lakes and reservoirs.

7. To protect water bodies from non-point source pollution.

8. To minimize the flooding risk that affects the sustainability and livelihoods of humans, animals and plants.

9. To control the deterioration of ecosystem due to soil loss, which leads to interruption of nutrient cycle, loss of soil fertility, extinction of flora and fauna and soil erosion etc. ultimately resulting in biological impoverishment and human sufferings.

10. To facilitate environmental system that affects the plant growth and rejuvenation of forests.

4.3 Soil Conservation Programmes

Various watershed development programmes are being implemented by mainly three ministries, namely, Ministry of Agriculture, Ministry of Rural Development & Ministry of Environment & Forests for development of degraded lands.

These programmes are listed below,

1. National Watershed Development Project for Rainfed Area (NWDPRA)

2. River Valley Project & Flood Prone River (RVP & FPR)

3. Watershed Development Project for Shifting Cultivation Area (WDPSCA)

4. Reclamation & Development of Alkali and Acid Soil (RADAS)
5. Watershed Development Fund (WDF)
6. Drought Prone Area Programme (DPAP)
7. Desert Development Programme (DDP)
8. Integrated Wasteland Development Project (IWDP)
9. National Afforestation and Eco-Development Project (NAEP)

4.3.1 National Watershed Development Project for Rainfed Area (NWDPRA)

Rainfed areas constitute about 57% of the total 140.30 million hectares cultivated in the country. Rainfed agriculture is characterized by low levels of productivity and low input usage. Variability in rainfall results in wide variation and instability in yields. The bulk of the rural poor live in the rainfed regions, therefore, Government of India accords highest priority to the holistic and sustainable development of rainfed areas through watershed development approach. The scheme of National Watershed Development Project for Rainfed Areas (NWDPRA) was launched in 1990-91 in 25 States and 2 Union Territories based on twin concepts of integrated watershed management and sustainable farming systems.

During IX Plan, the scheme was extended to three newly formed States of Uttarakhand, Jharkhand and Chhattisgarh. The scheme of NWDPRA has been subsumed under the Scheme for Macro Management of Agriculture (MMA) from 2000-2001. At present, this scheme is being implemented as a programme of Centrally Sponsored Scheme of Macro Management of Agriculture in 28 States and 2 UTs. Funds are released to the States based on Approved Annual Work Plan. The scheme is presently being implemented on the basis of Common Guidelines for watershed development projects developed by National Rainfed Area Authority (NRAA).

4.3.2 River Valley Project and Flood Prone River (RVP & FPR)

Natural resources conservation, development and their scientific utilization are very crucial for sustained agricultural production. Land and water constitute the important natural resource base for meeting the essential requirement of the society such as food, fodder, fiber, fuel and timber. Land degradation poses a severe challenge to useful life of reservoirs and agricultural productivity. The Centrally Sponsored Scheme of Soil Conservation in the catchments of River

Valley Project (RVP) was launched during the Third Five Year Plan for mounting a concerted effort at prevention of catchment deterioration.

Floods are annual features in the Indo-Gangetic Plains & in the Brahmaputra basin. Five States, namely, Uttar Pradesh, Bihar, West Bengal, Assam and Orissa account for nearly 80% of the total flood area and about 75% of the damages caused. Several Expert bodies have highlighted the need for proper catchment management for moderating peak floods and improvement of land resources and moisture regime in the catchments and reduction of silt load in the channel flow affecting river beds. In order to achieve these objectives a Centrally Sponsored Scheme of Integrated Watershed Management in the Catchments of Flood Prone River (FPR) in the Gangetic Plains was launched in Sixth Five Year Plan.

4.3.3 Watershed Development Project for Shifting Cultivation Area (WDPSCA)

Shifting cultivation known as *Jhum* cultivation in the North Eastern States is a traditional form of crop production, practiced on hill slopes. Shifting cultivation involves clearance of forest on sloppy land (usually before December), drying and burning the debris (Mid-February to Mid-March before the onset of the monsoon) and cropping. The plot remains fallow and vegetative regeneration takes place till the plot is reused for the same purpose in a cycle. Population pressure compels the shifting cultivators to reduce the earlier fallow period of 20-25 years to 2-5 years in the present days hence reducing the cycle. This form of cultivation is therefore, highly resource depleting and environmentally degrading.

The Scheme of Watershed Development in Shifting Cultivation Areas (WDPSCA) was launched in 1994-95 by the Ministry of Agriculture and Cooperation, Government of India in the seven North Eastern States. The scheme is aimed at overall development of *jhum* areas on watershed basis, reclaiming the land affected by shifting cultivation and socioeconomic up gradation of *jhumia*families living in these areas so as to encourage them to go in for settled agriculture.

4.3.4 Reclamation & Development of Alkali and Acid Soil (RADAS)

The main objectives of this programme are to:-

- Reclamation and development of the lands affected by alkalinity and acidity
- Improvement of soil fertility by under taking appropriate on-farm measures.

- Development and application of soil amendments for growing suitable field crops and horticulture crops
- Plantation of suitable fuel wood and fodder trees as per local demand and suiting to soil capability
- Improving capacity of extension personnel and beneficiaries in various aspects of alkali and acid soils reclamation technology and
- Generate employment opportunities & thereby reduce rural urban migration.

4.3.5 Watershed Development Fund (WDF)

A Watershed Development Fund (WDF) has been established at NABARD with the objective of integrated watershed development in 100 priority districts of 18 States through participatory approach. Under WDF, two-thirds of amount is given for loan based project and one-third of amount is given for grant based project in the State. A number of externally aided projects are also under implementation on watershed approach, which covers an area of about 1.5 lakh hectares annually.

4.3.6 Drought Prone Area Programme (DPAP)

The basic objective of the programme is to minimize the adverse effects of drought on production of crops and livestock and productivity of land, water and human resources ultimately leading to drought proofing of the affected areas. The programme also aims to promote overall economic development and improving the socio-economic conditions of the resource poor and disadvantaged sections inhabiting the program areas.

4.3.7 Desert Development Programme (DDP)

The basic objective of the program is to minimize the adverse effect of drought and control desertification through rejuvenation of natural resource base of the identified desert areas. The program strives to achieve ecological balance in the long run. The program also aims at promoting overall economic development and improving the socio-economic conditions of the resource poor and disadvantaged sections inhabiting the program areas.

4.3.8 Integrated Wasteland Development Project (IWDP)

Agriculture is the mainstay of India's economy. Land and water therefore, are of critical importance. Vast tracts of the land are, however, degraded but can be brought under plough with some effort. Such lands are known as wastelands. The productivity of these lands is very low and people owning these lands are poor and are therefore forced to earn a living from wage employment. Redressing these lands is regarded as a powerful tool of attacking the issues of poverty and backwardness. Government of India has therefore, launched the Integrated Wastelands Development Program (IWDP) throughout the country so as to improve the productivity of these lands and there by improve the living standards of the rural poor who own these lands. The IWDP is a 100% centrally sponsored scheme. The development of wastelands is taken up on watershed basis. The objective of the program is to arrest rainwater runoff and conserve it in situ where it falls. This would in turn lead to control of soil erosion which is usually caused by rainwater –runoff. Soil and water conservation also leads to improved green cover in the project areas leading to improved productivity of land. Under this program, Wastelands are sought to be developed in an integrated manner based on village micro watershed plans. These plans are prepared after taking into consideration the land capability and site conditions and in consultation with the local people in regard to their needs. The watershed projects are executed by the local people using locally available low cost technologies.

4.3.9 National Afforestation and Eco-Development Project (NAEP)

The National Afforestation and Eco-Development Board (NAEB), set up in August 1992, is responsible for promoting afforestation, tree plantation, ecological restoration and eco-development activities in the country, with special attention to the degraded forest areas and lands adjoining the forest areas, national parks, sanctuaries and other protected areas as well as the ecologically fragile areas like the Western Himalayas, Aravallis, Western Ghats, etc. The detailed role and functions of the NAEB are given below.

- Evolve mechanisms for ecological restoration of degraded forest areas and adjoining lands through systematic planning and implementation, in a cost effective manner.
- Restore the forest cover in the country for ecological security and to meet the fuel wood, fodder and other needs of the rural communities.

- Sponsor research and extension activities to disseminate new and proper technologies for the regeneration and development of degraded forest areas and adjoining lands.
- Create general awareness and help foster people's movement for promoting afforestation and eco-development with the assistance of voluntary agencies, non-government organisations, Panchayati Raj institutions and others
- Coordinate and monitor the action plans for afforestation, tree plantation, ecological restoration and eco-development
- Undertake all other measures necessary for promoting afforestation, tree plantation, ecological restoration and eco-development activities in the country.

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Subject: **Soil and Water Conservation Engineering**

Class: **First Year, II Semester**

Topic: **Principles of Soil Erosion**

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4. Principles of Soil Erosion

4.1 Causes of Soil Erosion

No single unique cause can be held responsible for soil erosion or assumed as the main cause for this problem. There are many underlying factors responsible for this process, some induced by nature and others by human being. The main causes of soil erosion can be enumerated as:

(1) Destruction of Natural Protective Cover by

(i) Indiscriminate cutting of trees,

(ii) Overgrazing of the vegetative cover and

(iii) Forest fires.

(2) Improper Use of the Land

(i) Keeping the land barren subjecting it to the action of rain and wind,

(ii) Growing of crops that accelerate soil erosion,

(iii) Removal of organic matter and plant nutrients by injudicious cropping patterns,

(iv) Cultivation along the land slope, and

(v) Faulty methods of irrigation.

2.2 Types of Soil Erosion

2.2.1 According to Origin: Soil erosion can broadly be categorized into two types i.e. geologic erosion and accelerated erosion.

4.2.2 Geological Erosion: Under natural undisturbed conditions an equilibrium is established between the climate of a place and the vegetative cover that protects the soil layer. Vegetative covers like trees and forests retard the transportation of soil material and act as a check against excessive erosion. A certain amount of erosion, however, does take place even under the natural cover. This erosion, called geologic erosion, is a slow process and is compensated by the formation of soil under the natural weathering process. Its effect are not of much consequence so far as agricultural lands are concerned.

4.2.3 Accelerated Erosion: When land is put under cultivation, the natural balance existing between the soil, its vegetation cover and climate is disturbed. Under such condition, the removal of surface soil due to natural agencies takes places at faster rate than it can be built by the soil formation process. Erosion occurring under these condition is referred to as accelerated erosion. Its rates are higher than geological erosion. Accelerated erosion depletes soil fertility in agricultural land.

4.2.4 According to Erosion Agents: Soil erosion is broadly categorized into different types depending on the agent which triggers the erosion activity. Mentioned below are the four main types of soil erosion.

(1) Water Erosion: Water erosion is seen in many parts of the world. In fact, running water is the most common agent of soil erosion. This includes rivers which erode the river basin, rainwater which erodes various landforms, and the sea waves which erode the coastal areas. Water erodes and transports soil particles from higher altitude and deposits them in low lying areas. Water erosion may further be classified, based on different actions of water responsible for erosion, as : (i) raindrop erosion, (ii) sheet erosion, (iii) rill erosion, (iv) gully erosion, (v) stream bank erosion, and (vi) slip erosion.

(2) Wind Erosion: Wind erosion is most often witnessed in dry areas wherein strong winds brush against various landforms, cutting through them and loosening the soil particles, which are lifted and transported towards the direction in which the wind blows. The best example of wind erosion are sand dunes and mushroom rocks structures, typically found in deserts.

(3) Glacial Erosion: Glacial erosion, also referred to as ice erosion, is common in cold regions at high altitudes. When soil comes in contact with large moving glaciers, it sticks to the base of these glaciers. This is eventually transported with the glaciers, and as they start melting it is deposited in the course of the moving chunks of ice.

(4) Gravitational Erosion: Although gravitational erosion is not as common a phenomenon as water erosion, it can cause huge damage to natural, as well as man-made structures. It is basically the mass movement of soil due to gravitational force. The best examples of this are landslides and slumps. While landslides and slumps happen within seconds, phenomena such as soil creep take a longer period for occurrence.

4.3 Agents of Soil Erosion

Soil erosion is the detachment of soil from its original location and transportation to a new location. Mainly water is responsible for this erosion although in many locations wind, glaciers are also the agents causing soil erosion. Water in the form of rain, flood and runoff badly affects the soil. Soil is in fact a composite of sand, silt and clay. When the rain falls along the mountains and bare soil, the water detaches the soil particles, and takes away the silt and clay particles along with the flowing water. Similarly, when wind blows in the form of storms, its speed becomes too high to lift off the entire soil upper layer and causes soil erosion.

Other factors responsible for soil erosion are human and animal activities. Vegetation is the natural cover of soil. When the animals continuously graze in the pastures, the vegetation is removed due to their walking and grazing. Bare lands left behind are easily affected by soil erosion. Activities of human like forest cutting, increased agriculture, and clearing of land for different purposes are the other agents that cause erosion of the soil. The soil erosion agent can be classified and summarized as shown in Fig. 2.1.

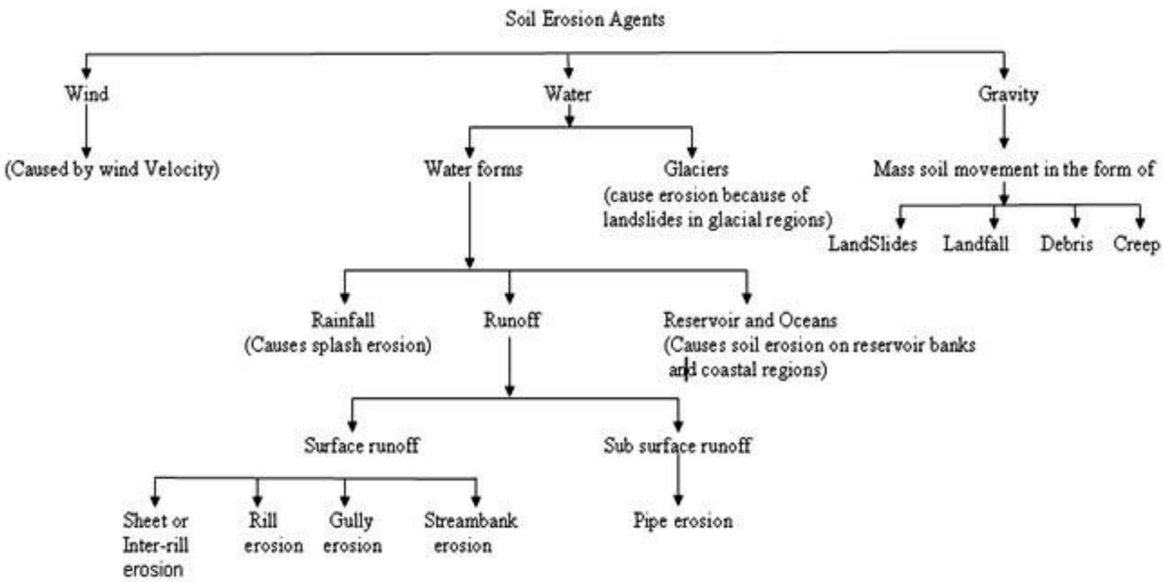

Fig.2.1 Soil erosion agents, processes and effects. (Sources: Das, 2000)

4.4 Factors Affecting Soil Erosion

Soil erosion includes the processes of detachment of soil particles from the soil mass and subsequent transport and deposition of those soil/sediment particles. The main factors responsible for soil erosion, in India, are excessive deforestation, overgrazing and faulty agricultural practices. Soil erosion is a very complicated problem as many complex factors affect the rate of erosion and therefore it is difficult to solve. These factors include:

1. Climatic Factor: The climatic factors that influence erosion are rainfall amount, intensity, and frequency. During the periods of frequent or continuous rainfall, high soil moisture or saturated field conditions are developed, a greater percentage of the rainfall is converted into runoff. This in turn results in soil detachment and transport causing erosion at high rate.

2. Temperature: While frozen soil is highly resistant to erosion, rapid thawing of the soil surface brought about by warm rains can lead to serious erosion. Temperature also influences the type of precipitation. Although falling snow does not cause erosion, heavy snow melts in spring can cause considerable runoff damage. Temperature also influences the amount of organic matter that get collected on the ground surface and get incorporated with the topsoil layer. Areas with warmer climates have thinner organic cover on the soil. Organic matter cover on the surface protects the soil by shielding it from the impact of falling rain and helping in the infiltration of rainfall that would otherwise cause more runoff. Organic matter inside the soil increases permeability of the soil to cause more percolation and reduce runoff.

3. Topographical Factors: Among the topographical factors, slope length, steepness and roughness affect erodibility. Generally, longer slope increases the potential for erosion. The greatest erosion potential is at the base of the slope, where runoff velocity is the greatest and runoff concentrates. Slope steepness, along with surface roughness, and the amount and intensity of rainfall control the speed at which runoff flows down a slope. The steeper the slope, the faster the water will flow. The faster it flows, the more likely it will cause erosion and increase sedimentation. Slope accelerates erosion as it increases the velocity of flowing water. Small differences in slope make big difference in damage. According to the laws of hydraulics, four times increase in slope doubles the velocity of flowing water. This doubled velocity can increase the erosive power four times and the carrying (sediment) capacity by 32 times.

4. Soil: Physical characteristics of soil have a bearing on erodibility. Soil properties influencing erodibility include texture, structure and cohesion. Texture refers to the size or combination of sizes of the individual soil particles. Three broad size classifications, ranging from small to large are clay, silt, and sand. Soil having a large amount of silt-sized particles is most susceptible to erosion from both wind and water. Soil with clay or sand-sized particles is less prone to erosion.

Structure refers to the degree to which soil particles are clumped together, forming larger clumps and pore spaces. Structure influences both the ability of the soil to absorb water and its physical resistance to erosion. Another property is the cohesion which refers to the binding force between the soil particles and it influences the structure. When moist, the individual soil particles in a cohesive soil cling together to form a doughy consistency. Clay soils are very cohesive, while sand soils are the least cohesive.

5. Vegetation: Vegetation is probably the most important physical factor influencing soil erosion. A good cover of vegetation shields the soil from the impact of raindrops. It also binds the soil together, making it more resistant to runoff. A vegetative cover provides organic matter, slows down runoff, and filters sediment. On a graded slope, the condition of vegetative cover will determine whether erosion will be stopped or only slightly halted. A dense, robust cover of vegetation is one of the best protections against soil erosion.

6. Biological Factors of Soil Erosion: Biological factors that influence the soil erosion are the activities like faulty cultivation practices, overgrazing by animals etc. These factors may be broadly classified into following three groups:(i) Energy factors, (ii) Resistance factors, and (iii) protection factors.

(i) Energy Factors: They include such factors which influence the potential ability of rainfall, runoff and wind to cause erosion. This ability is termed as erosivity. The other factors which directly reduce the power of erosive agents are reduction in length/degree of slope through the construction of terraces and bunds in case of water eroded areas and creation of wind breaks or shelter belts in case of wind eroded areas.

(ii) Resistance Factors: They are also called erodibility factors which depend upon the mechanical and chemical properties of the soil. Those factors which enhance the infiltration of water into the soil reduce runoff and decrease erodibility, while any activity that pulverizes the soil increases erodibility. Thus, cultivation may decrease the erodibility of clay soils but increases that of sandy soil.

(iii) Protection Factors: This primarily focuses on the factors related to plant cover. Plant cover protects the soil from erosion by intercepting the rainfall and reducing the velocity of runoff and wind. Degree of protection provided by different plant covers varies considerably. Therefore, it is essential to know the rate of soil erosion under different land uses, degrees of length and slope, and vegetative covers so that appropriate land use can be selected for each piece of land to control the rate of soil erosion. The quantity of soil moved past a point is called soil loss. It is usually expressed in unit of mass or volume per unit time per unit area.

4.5 Mechanics of Soil Erosion

Soil erosion is initiated by detachment of soil particles due to action of rain. The detached particles are transported by erosion agents from one place to another and finally get settled at some place leading to soil erosion process. Different soil erosion processes are shown in Fig. 2.2.

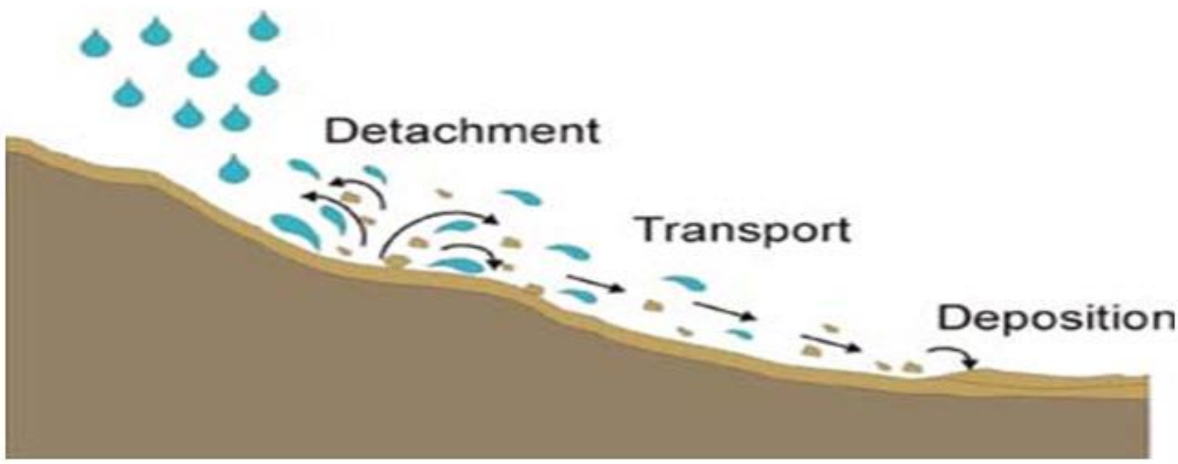

Fig. 2.2. Process of water erosion by the impact of raindrops.

(Source: www.landfood.ubc.ca)

Mechanics of soil erosion due to water and wind is discussed below.

4.5.1 Mechanics of Water Erosion

There are three steps for accelerated erosion by water:

i) Detachment or loosening of soil particles caused by flowing water, freezing and thawing of the top soil, and/or the impact of falling raindrops,

ii) Transportation of soil particles by floating, rolling, dragging, and/or splashing and

iii) Deposition of transported particles at some places of lower elevation.

Rain enhances the translocation of soil through the process of splashing as shown in Fig.2.2. Individual raindrops detach soil aggregates and redeposit them as particles. The dispersed particles may then plug soil pores, reducing water intake (infiltration). Once the soil dries, these particles develop into a crust at the soil surface and runoff is further increased.

4.5.2 Mechanics of Wind Erosion

Wind erosion occurs where soil is exposed to the dislodging force of wind. The intensity of wind erosion varies with surface roughness, slope and types of cover on the soil surface and wind velocity, duration and angle of incidence. Fine soil particles can be carried to great heights and for (may be) hundreds of kilometers. The overall occurrence of wind erosion could be described in three different phases. These are initiation of movement, transportation and deposition.

1. Initiation of Movement: The initiation of the movement of soil particles is caused by several factors acting separately in combination. In the course of collision of grains rolling and bumping on the surface, some particles may be bounced up. It occurs when the wind force or the impact of moving particles is strong enough to dislodge stationary soil particles.

2. Transportation: The transportation of the particles once they are dislodged take place in three ways:

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) Surface Creep – Saltation also encourages surface creep (rolling or sliding) along the surface of the 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.

3. Deposition: Deposition of the particles occurs when the gravitational force is greater than the forces holding the particles in air. Deposition could occur when the wind velocity is decreased due to surface obstructions or other natural causes.

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Subject: **Soil and Water Conservation Engineering**

Class: **First Year, II Semester**

Topic: **Erosion due to Water**

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5. Erosion Due to Water

Erosion of soil by water is caused by its two forms: liquid as the flowing water, and solid as the glaciers.

5.1 Forms of Water Erosion

The impact of rainfall causes splash erosion. Runoff water causes scraping and transport of soil particles leading to sheet, rill and gully erosion. Water waves cause erosion of bank sides of reservoirs, lakes and oceans. The subsurface runoff causes soil erosion in the form of pipe erosion, which is also called tunnel erosion. The glacial erosion causes heavy landsides. In India, glacial erosions are mainly confined to Himalayan regions. The various forms of water erosion are given below.

5.1.1 Hydraulic Action: The hydraulic action takes place when water runs over the soil surface compressing the soil, as a result of which the air present in the voids exerts a pressure on the soil particles and this leads to the soil detachment. The pressure exerted by the air voids is called hydraulic pressure. The soil particles so detached from their places, are scoured by the running water. The hydraulic action is more effective when the soil is in loose condition.

5.1.2 Abrasion: Soil particles mixed with the running water create an abrasive power in the water which increases the capacity of flowing water to scour more soil particles. Due to this effect, larger soil particles are eroded by the flowing water.

5.1.3 Attrition: This form includes mechanical breakdown of loads running along the moving water due to collision of particles with each other. The broken particles are moved along with the flow velocity, which generate abrasion effect on the bottom and banks of the water course. This effect pronounces the water erosion.

5.1.4 Solution: This form is associated with the chemical action between running water and soil or country rocks. This type condition is observed in areas where existing rocks or soils are easily dissolved in the running water.

5.1.5 Transportation: The process of soil transportation by running water is completed under the following forms:

1) **Saltation:** the water soluble contents present in the water are transported by the water in solution form.

2) **Suspension:** it involves the transportation of finer soil particles, which are present in suspension form in the flowing water.

3) **Surface Creep:** it involves transportation of medium size soil particles that are not able to stand in suspension form, but are mixed in water and flow over the stream bed in the form of mud. The surface creep action is responsible for transporting the coarser soil particles.

5.2 Factors Affecting Water Erosion

Water erosion is due to dispersive and transporting power of the water; as in case of water erosion first soil particles are detached from the soil surface by the raindrop force and then transported with surface runoff. There is a direct relationship between the soil loss and surface runoff volume. The water erosion process is influenced primarily by climate, topography, soils and vegetative cover. The factors influencing the water erosion are discussed below.

5.2.1 Climatic Factors: Climate includes rainfall, temperature and wind. The frequency, intensity and duration of rainfall are the principal aspects of rainfall influencing the volume of runoff, erosion and sediment (potential) from a given area. As the volume and intensity of rainfall increase, the ability of water to detach and transport soil particles increases. When storms are frequent, intense, and of long duration, the potential for erosion of bare soils is high. Temperature has a major influence on soil erosion. Frozen soils are relatively erosion resistant. However, bare soils with high moisture content are subject to uplift or “spew” by freezing action and are usually easily eroded upon thawing. Wind contributes to the drying of soil and increases the need for irrigation for new plantings and for applying wind erosion control practices.

5.2.2 Soil Characteristics: Soil characteristics include texture, structure, organic matter content and permeability. In addition, in many situations, compaction is significant. These characteristics greatly determine the erodibility of soil. Soils containing high percentages of sand and silt are the most susceptible to detachment because they lack inherent cohesive characteristics. However, the high infiltration rates of sands either prevent or delay runoff except where overland flow is concentrated. Clearly, well-graded and well-drained sands are usually the least erodible soils in the context of sheet and rill erosion. Clay and organic matter act as a binder to soil particles, thus reducing erodibility. As the clay and organic matter content of soils increase, the erodibility decreases. However, while clays have a tendency to resist erosion, they are easily transported by water once detached. Soils high in organic matter resist raindrop impact, and the organic matter also increases the binding characteristics of the soil. Sandy and silty soils on slopes are highly susceptible to gully erosion where flow concentrates because they lack inherent cohesiveness. Small clay particles, referred to as colloids, resist the action of gravity and remain in suspension for long periods of time. Colloids are potentially a major contributor to turbidity where they exist.

5.2.3 Vegetation Cover: Vegetative cover is an extremely important factor in reducing erosion at a site. It absorbs energy of raindrops, binds soil particles, slows down the velocity of runoff water, increases the ability of a soil to absorb water, removes subsurface water between rainfall events through the process of evapotranspiration and reduces off-site fugitive dust. By limiting the amount of vegetation disturbance and the exposure of soils to erosive elements, soil erosion can be greatly reduced. Vegetations create a surface obstruction for direct falling of raindrops on the land surface as well as in the flowing path of surface runoff. A good vegetative cover completely negates the effect of rainfall on soil erosion.

5.2.4 Topographic Effect: The main topographic factors which influence the soil erosion are land slope, length of slope and shape of slope. The land slope or slope inclination affects the erosion predominantly. As the slope increases, the runoff coefficient, kinetic energy and carrying capacity of surface runoff also increase thereby decreasing the soil stability. Critical slope length is the slope length at which the soil erosion begins. It is related to the critical land inclination. Lower the critical inclination larger will be the critical slope length. The slope shapes have greater bearing on erosion potential. The base of a slope is more susceptible to erosion than the top, because runoff has more momentum and is more concentrated as it approaches the base of slope. The slopes may be roughly convex or concave. On convex slope the above phenomena is magnified, whereas on concave slope it is reduced. It is because in convex slope, the steepness increases towards bottom, while it is flattened towards bottom in case of concave slope.

5.3 Types of Water Erosion

Water erosion can be classified as splash erosion, sheet erosion, rill erosion, gully erosion, stream bank erosion, sea-shore erosion and land slide erosion. They are discussed as follows.

5.3.1 Splash Erosion: It is also known as raindrop erosion (Fig. 3.1) because it is caused by the impact of raindrops on exposed soil surface. The process of raindrop erosion can be described as: when raindrop strikes on open soil surface it forms a crater. This is accomplished by forming a blast which bounces the water and soil up and returns back around the crater. The soil may be splashed into the air up to a height of 50 to 75 cm depending upon the size of rain drops. At the same time the soil particles also move horizontally as much as 1.50 m on level land surface. On sloping land, more than half of the splashed particles move down with the runoff.

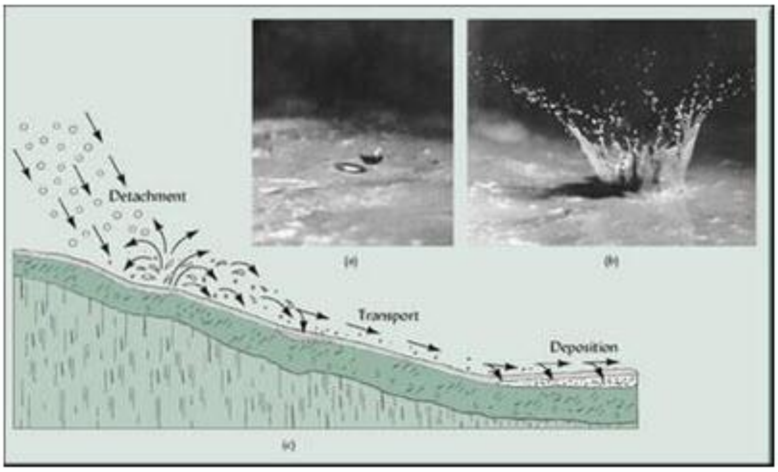

Fig. 3.1. Splash erosion. (Source: www.bierbrauerf.weebly.com)

5.3.2 Sheet Erosion: Sheet erosion may be defined as more or less uniform removal of soil in the form of a thin layer or in “sheet” form by the flowing water form a given width of sloping land (Fig. 3.2). It is an inconspicuous type of soil erosion because the total amount of soil removed during any storm is usually small. In the sheet erosion two basic erosion processes are involved. First process is the one in which soil particles are detached from the soil surface by falling of raindrop and in the second one the detached soil particles are transported away by surface runoff from the original place. The detached process is referred to as the splash erosion and transportation of detached particles by flowing water is considered as the wash erosion. When the rate of rainfall exceeds the infiltration rate of the soil, the excess water tends to flow over the surface of sloping land. This flowing water also detaches soil particles from the land surface and starts flowing in the form of thin layer over the surface. The erosion during these processes is called sheet erosion. The eroding and transporting power of sheet flow depends on the depth and velocity of flowing water for a given size, shape and density of soil particles.

Fig. 3.2. Sheet erosion. (Source: www.soer.justice.tas.gov.au)

5.3.3 Rill Erosion: This type of water erosion is formed in the cultivated fields where the land surface is almost irregular. As the rain starts, the water tends to accumulate in the surface depressions and begins to flow following least resistance path. During movement of water large amount of soil particles are eroded from the sides and bottom of the flow path, which are mixed in the flowing water. This surface flow containing soil particles in suspension form moves ahead and forms micro channels and rills (Fig. 3.3).

Fig. 3.3. Rill erosion. (Source: http://www.kalkaskacounty.net)

5.3.4 Gully Erosion: Rills are small in size and can be leveled by tillage operations. When rills get larger in size and shape due to prolonged occurrence of flow through them and cannot be removed by tillage operation, these are called gullies (Fig. 3.4). Large gullies and their network are called ravines. It is the advanced and last stage of water erosion. In other words it is the advanced stage of rill erosion. If the rills that are formed in the field are overlooked by the farmers, then they tend to increase in their size and shape with the occurrence of further rainfall. Some of the major causes of gully erosion are: steepness of land slope, soil texture, rainfall intensity, land mismanagement, biotic interference with natural vegetation, incorrect agricultural practices, etc. Gully erosion gets initiated where the longitudinal profile of an alluvial land becomes too steep due to sediment deposition. Gullies advance due to the removal of soil by the flowing water at the base of a steep slope, or a cliff at the time of fall of stream. High intensity of flow of the runoff increases the gully dimensions. In the absence of proper control measures, slowly the gullies extend to nearby areas and subsequently engulf the entire region with a network of gullies of various sizes and shapes.

Fig. 3.4. Gully erosion. (Source: www.soilsurvey.com.au)

5.3.5 Stream Bank Erosion: Stream bank erosion is defined as the removal of stream bank soil by water either flowing over the sides of the stream or scouring from there (Fig.3.5). The stream bank erosion due to stream flow in the form of scouring and undercutting of the soil below the water surface caused by wave action is a continuous process in perennial streams. Stream bank erosion is mainly aggravated due to removal of vegetation, over grazing or cultivation on the area close to stream banks. Stream bank erosion is also caused by the occurrence of flood in the stream. Apart from scouring, the sloughing is also a form of stream bank erosion which is caused when the stream water subsides after reaching the peak. Sloughing is mainly due to movement of underground water from side into the stream due to pressure difference.

Fig. 3.5. Stream bank erosion. (Source: www.sswc.org)

3.3.6 Sea-shore Erosion: It is also called coastal erosion. Sea shore erosion is the wearing away of land and the removal of beach or dune sediments by wave action, tidal currents, wave currents, or drainage (Fig. 3.6). Waves, generated by storms, wind or fast moving motor craft, cause coastal erosion which may take the form of long-term losses of sediment and rocks, or merely the temporary redistribution of coastal sediments. It may be caused by hydraulic action, abrasion, impact and corrosion.

Fig. 3.6. Sea-shore/ coastal erosion. (Source: www.climatide.wgbh.org)

3.3.7 Landslide Erosion: When gravity combines with heavy rain or earthquakes, whole slopes can slump, slip or slide (Fig. 3.7). Slips occur when the soil (topsoil and subsoil) on slopes becomes saturated. Unless held by plant roots to the underlying surface, it slides downhill, exposing the underlying material.

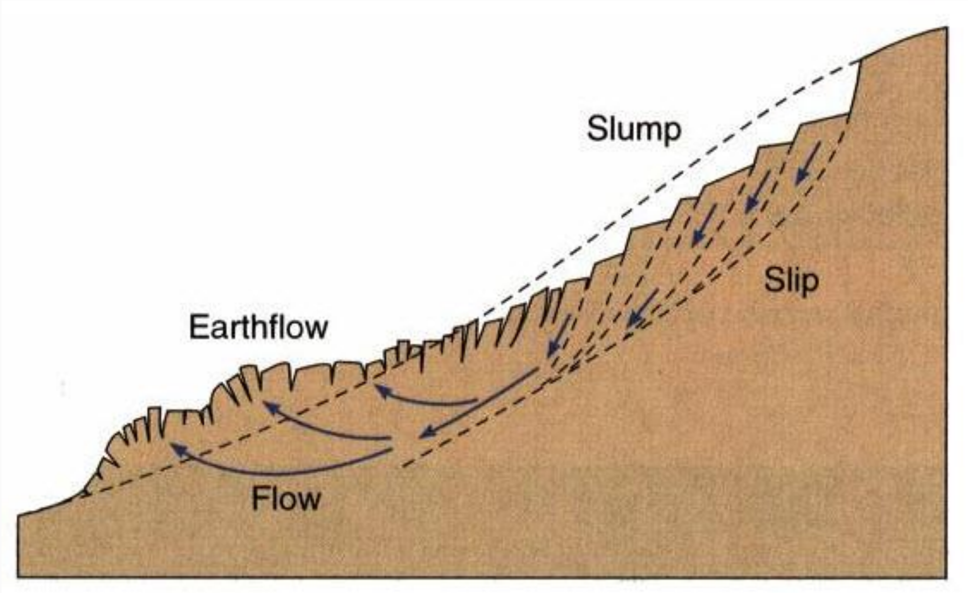

Fig. 3.7. Cross-section of landslide characteristics.

(Source: www.drstoney.wikispaces.com)

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