from soil forming regimes.

...emerging

## Soil Classification

There are several systems of soil classification. On the basis of the **mode of formation,** especially the nature of origin of mineral matter, soils are classified as (*i*) residual soils and (*ii*) transported soils.

(*i*) **Residual soils**—Residual soils are those in which the soil formation *i.e.* weathering and pedogenesis occurs at the same place.

(*ii*) **Transported soils**—Transported soils are those where the weathered material is taken away at other places by several agents. Depending on the nature of the transporting agents, the transported soils may be: (a) colluvial (by gravity), (b) alluvial (by running water), (c) glacial and (d) eolian (by wind).

Soils rich in lime are called *pedocals*. Those characterized by a relatively high iron and alumina content are called *pedalfers*. Pedalfers generally tend towards acidity, whereas pedocals give alkaline reactions. The mature soils in arid and semi arid areas are generally rich in lime, but in areas of abundant rainfall they are deficient. Pedalfers are also known as "forest soils" and pedocals as "grassland soils". The presence of lime in the soil is often an indication of fertility. If time is present in fair quantity, other soluble minerals essential for plant growth, such as phosphates, nitrates and potash are also available abundantly. The presence of such minerals is conducive to a stable soil structure.

The soils of the world have been classifed in a variety of ways on different bases. Russian pedologist **Dokuchayev** was the pioneer in this direction who in the early twentieth century related the development of soil to the climate and vegetation in a region. **Marbut** (1938), a U.S. scientist presented a scheme of *Comprehensive system of Soil Classification* which is recognized as the *USDA* (United States Department of Agriculture)*System.* He classified the soils of the world into three orders *i.e.* (*i*) Zonal soils, (*ii*) Intra Zonal soils and (*iii*) Azonal soils. The American pedologists presented a new system of soil classification named as *Comprehensive Soil Classification System* (*CSCS*) in 1960. This system was initially named as the *Seventh Approximation* because it was seventh in the series of revisions of the system of soil classification since 1950. The classification system of the *CSCS* is also called *Soil Taxonomy.* The other significant soil classifications at global level includes the schemes of *American Soil Taconomy* presented by the Soil Survey Staff in 1975; *Soil type* based on bioclimatic zones as presented by **Bridges** (1978), *Soil orders* presented by **Foth** (1978), Soil Classifications based on Diagnostic Horizons developed by FAO (Food and Agricultural Organization) etc.

The United States Department of Agricultures (USDA) Seventh Approximation soil classification recognizes eleven orders of soil as follows: (*i*) Oxisols, (*ii*) Aridisols, (*iii*) Mollisols, (*iv*) Alfisols, (*v*) Ultisols, (*vi*) Spodosols, (*vii*) Entisols, (*viii*) Inceptisols, (*ix*) Andisols, (*x*) Vertisols, (*xi*) Histosols.

Fig. 3.9 shows the soil orders loosely arranged by latitude, beginning along the equator. A brief description of the various orders is given below:

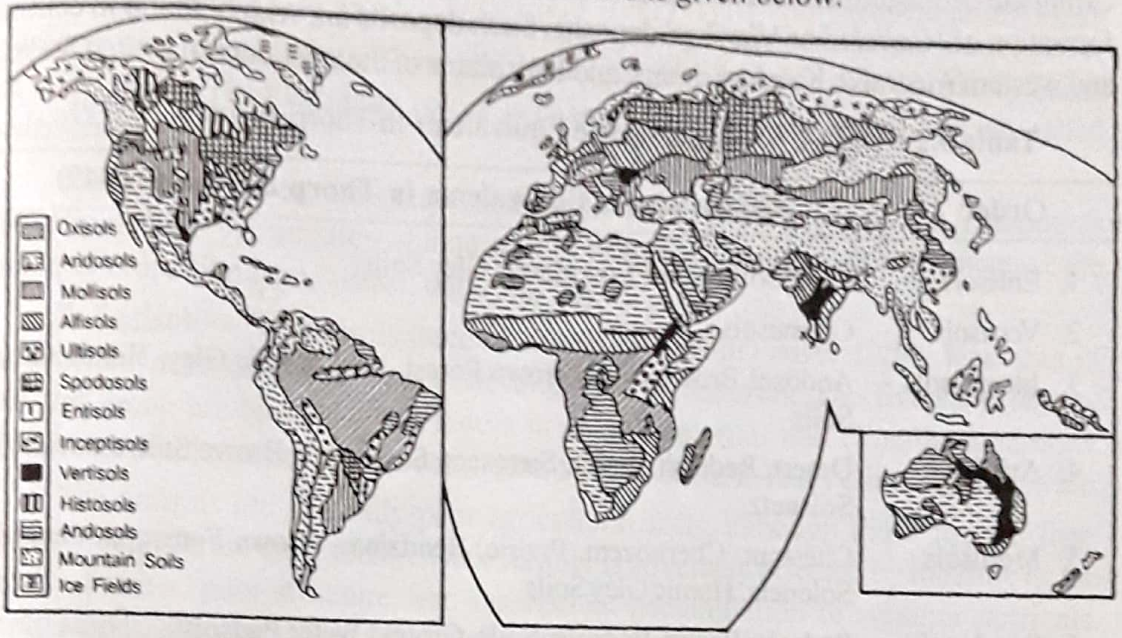


*Fig. 3.9 : Major soil types in the World according to USDA's Seventh Approximation soil classification (1960)*

**1. Oxisols**—These tropical soils covering 9.2% world's land area are characterized by remarkable moisture and temperature intensity and uniform day length which greatly affect soils. These are very old and highly weathered soils. These soils are highly acidic with a high concentration of iron and aluminium and a limited A-horizon. Although easily worked, low humus content and poor cation-exchange capacity of these soils limit fertility.

Early 'slash and burn' shifting cultivation practice were adapted to these soil conditions and formed a unique style of crop-rotation. Later on, plantation system was introduced here, putting enormous pressure on the remaining tracts of forest that proved disastrous. The disturbed oxisols suffered a heavy soil loss besides an increased rate of extinction of plant and animal species.

**2. Aridisols**—These are the most extensive soils covering 19.2% of the world's land area. These sandy soils, usually of pale light colour, are formed in arid and semi-arid regions. Low humus content (due to sparse vegetation), high mineral salts, and lack of water usually make them unsuitable for agriculture. Salinization complicates farming in aridisols. Careful introduction of irrigation and fertilizers increases the agricultural potential of aridisols. In the Nile and Indus river valleys, the aridisols are intensively farmed.

**3. Mollisols**—Mollisols (or grassland soils) cover more than 9% land area of the world. These are soft, dark soils, usually formed under temperate grasslands in semi-arid climates. High humus content and workable texture make them ideal for agriculture.

Soils of the Prairies and Steppes belong to this soil group. Agriculture ranges from large-scale commercial grain farming to grazing along the drier portions of the soil order. With fertilization, high crop yields are common in these soils known as the Chernozems in the Steppes.

The process of calcification (involving the illuviated accumulation of calcium carbonate or magnesium carbonate in the B and C-horizons) in these soils causes the formation of '*Caliche*' or '*Kankar*' deposits. Such deposits are widely found in central and western Australia, Kalahari desert, and high plains of the west-central United States.

**Table 3.2 :** USDA 7th Approximate Equivalents in Thorp & Smith (1949)

| Order | Approximates Equivalents in Thorp & Smith (1949) |
|---|---|
| 1. Entisols | Zonal soils, Some Low Humic Gley Soils |
| 2. Vertisols | Grumusols |
| 3. Inceptisols | Andosol Brown Acid, Brown Forest, Low Humic Gley, Humic Gley Soils |
| 4. Aridisols | Desert, Reddish Desert, Sierosem, Solonchak, Brown Soil, associated Solanetz |
| 5. Mollisols | Chestnut, Chernozem, Prairie, Rendzinas, Brown Forest, associated Solonetz, Humic Gley Soils |
| 6. Spodosols | Podsols, Brown Podsolic Soils, Ground Water Podsols |
| 7. Alfisols | Grey Brown Podsolic, Grey Wooded Soils, Non-Calcic Brown Soils, Degraded Chernozem, associated Planosols, Half-Bog Soils |
| 8. Ultisols | Red Yellow Podsolic Soils, Reddish Brown Lateritic Soils, associated Planosols and Half-Bog Soils |
| 9. Oxisols | Laterite Soils, Latosols |
| 10. Histosols | Bog Soils |

**4. Alfisols**—Alfisols are widely occurring soils, covering about 15% of the world's land area. These are moderately weathered forest soils extending in five sub-orders from near the equator to high latitudes. Most alfisols have a greyish brown to reddish ochric colour. Alfisols are moderately acidic soils, formed under forests and mixed trees and grasses in humid, mild climates. Moderate fertility and good moisture supply make them favourable for agriculture, particularly grains, hay, and dairy products in humid continental/hot summer climates. In moist winter/dry summer climates of the Mediterranean region, these productive soils are intensively farmed for fruits, nuts and special crops like grapes, citrus, almonds, figs, *etc*.

**5. Ultisols**—Ultisols are highly weathered forest soils with five sub-orders. An alfisol might degenerate into an ultisol due to increased weathering under moist conditions. These soils extend over 8.5% of the world's land area. Their reddish brown colour is due to residual iron and aluminium oxides in the A-horizon. Heavy leaching of nutrients results in low fertility. Fertility is further reduced by certain cultural practices and soil damaging crops such as cotton and tobacco, which deplete nitrogen and expose soil to erosion. However, these soils respond well if subjected to good management like crop rotation that restores fixed nitrogen and cultivation practices that prevent sheet wash and soil erosion.

**6. Spodosols**—The spodosols (northern coniferous forest soils) and their four sub-orders occur generally to the north and east of the alfisols. These soils cover about 5.4% world's land area. These soils are found in cold and forested moist regimes in the northern hemisphere only. These soils form from sandy. Parent materials, shaded under evergreen coniferous forests: These soils lack humus and clay in the A-horizon. These are acidic soils. Their ash gray colour is characteristic of a formation process called podzolization.

Cultivation of these soils requires an addition of nitrogen, phosphate, and potash and crop rotation. An addition of limestone to these soils can significantly increase the yields of crops like corn, wheat, oats, and hay.

**7. Entisols**—The entisols (recent, undeveloped soils) cover 12.5% land area of the world. These soils lack vertical development of horizons. The five suborders of this soil group are based on differences in parent materials and climatic conditions. However, entisols are not climate dependent, for they occur in many climates worldwide.

The entisols are generally poor agricultural soils, although those formed from river silt deposits are quite fertile. Their fertility is adversely affected by too little or too much of water, poor structure, and insufficient accumulation of weather nutrients. Steep slopes, alluvium-filled flood plains, poorly drained tundra, tidal mud-flats, dune sands, and ergs (sandy) deserts and glacial out-wash plains are characteristic regions of entisols.

**8. Inceptisols**—Inceptisols (weakly developed soils) and their six sub-orders are inherently infertile. These soils cover nearly 16% of the world's land area. These soils include a wide variety of soils, exhibiting a lack of maturity and an evidence of weathering. Inceptisols are associated with moist soil regimes. These soils include the soils of the Arctic tundra, glacially derived till and out-wash materials, and alluvium of the flood-plains. Their productivity varies from excellent to poor.

**9. Andisols**—Andisols (volcanic parent materials) with seven sub-orders occur in areas of volcanic activity. Until 1990, these soils were included in the categories of inceptisols and entisols. In these soils weathering and mineral transformations are very important. Andisols possess a high water holding capacity and develop a moderate fertility, but lack in phosphorus. The fertile fields of Hawaii produce cane sugar and pine apple. Andisols are limited in their distribution, but highly useful, locally.

**10. Vertisols**—Vertisols (expendable clay soils) are heavy clay soils, located in regions of highly variable soil moisture balances through the seasons. These soils occur in sub-humid to semi-arid moisture conditions, and under moderate to high temperature patterns. They frequently form under savanna and grassland vegetation in tropical and sub-tropical climate.

Vertisol clays are black when wet and range to brown and dark gray. These deep clays swell when moistened and shrinked when dried. Repeated swelling and shrinking causes vertical cracks in these soils. Vertisols are high in bases and nutrients and are good for farming. The soils of Deccan region of India are exceptionally good for cotton cultivation. Elsewhere, they are planted with grains, sorghum, and corn, *etc.*

**11. Histosols**—Histosols (organic soils) with four sub-orders are formed from accumulations of thick organic matter. These soils were formed in the former lakes in the mid-latitudes. Bog and Marsh are a few examples. Histosols also form in poorly drained depressions and produce ideal condtions for peat formation.

## Soil Classification with Reference to Agriculture

During ancient times in India, two broad types of soils were distinguished. *Urvara* and *Anurvara* or (*usar*). In the sixteenth century, agricultural land was classified into four types on the basis of suitability of crops as determined by sources of irrigation. These four types were:*Barani, Nehri, Sailabi* and *Abi*. In the nineteenth century, some states of India were divided into assessment circles, on the basis of soil texture and availability of water and sources of irrigation, which collectively determine soil productivity and agricultural patterns. On the basis of such information arable land was classified into *Barani, Nehri, Khadar, Bangar, Chhachhra, Naili, Rohi, Rangoi, Bagar, Tibba, Tal, Bet* etc. The classification of soils on scientific lines was undertaken only when the Geological Survey of India was founded. **Voelkar** (1893) and **Leather** (1898) recognized five major groups of soils related to broad regional complexes of climate and regolith. These five major types are: alluvial soils, sandy soils, black soils, laterite soils and red soils.

Since crop growth and production are the main functions of the soils under cultivation, the criteria of soil classification should be agronomic (based on texture). Classification of soils for planning purposes should be based more on their agricultural capability rather than on their genetic characteristics. Accordingly, the agronomic and generalized classification of soils of India exhibit six major categories : (*i*) alluvial soils, (*ii*) sandy soils, (*iii*) black soils, (*iv*) red soils, (*v*) laterite soils and (*vi*) other soils

**1. Alluvial soils**—These soils comprise 23.4% of the total soil cover. These soils are highly fertile, contributing the largest share of agricultural wealth of the country. These soils are very suitable for the cultivation of wheat, rice, sugarcane etc. and at some places gram, barley, maize are also raised on these soils.

**2. Sandy soils (desert soils and grey brown soils)**—These soils comprise about 8.46% of the total soil cover. These are suitable for high salt toterant crops, *e.g.* barley, rapeseed, mustard, cotton and also medium salt tolerant crops such as wheat, maize, millets and pulses.

**3. Black soils**—These soils are found on a variety of rocks such as basalt, gneiss and schists. On the basis of fertility these soils are further classified into deep black, medium black, shallow black and poor mixed red and black soils. This soil group comprises 24.12% of the total soil cover of the country. These soils are most suitable for cotton, wheat and sorghum (jowar). With irrigation facilities rice and sugarcane are also grown.

**4. Red soils**—These soils include red loamy soils, red gravelly sandy soils and red yellow loamy soils. Together they comprise 29.08% of the total soil cover. They are generally deficient in nitrogen, phosphorus and humus and also differ in depth and fertility. Their agricultural value depends on the extent of their irrigation and manuring. A large variety of crops such as rice, sorghum, millet (ragi) and cotton are grown under irrigation, while millets, pulses and gram are raised under rainfed conditions.

**5. Laterite soils**—These soils are formed from weathering of several types of residual rocks, laterite in particular, under an inter mittently hot, moist climate. These soils are highly leached and washed out of plant nutrients due to chemical weathering. They comprise 4.03% of the total soil cover. Tea, coffee, rubber and coconut plantations are raised on these soils, when manured and irrigated. Rice is grown in river valleys.

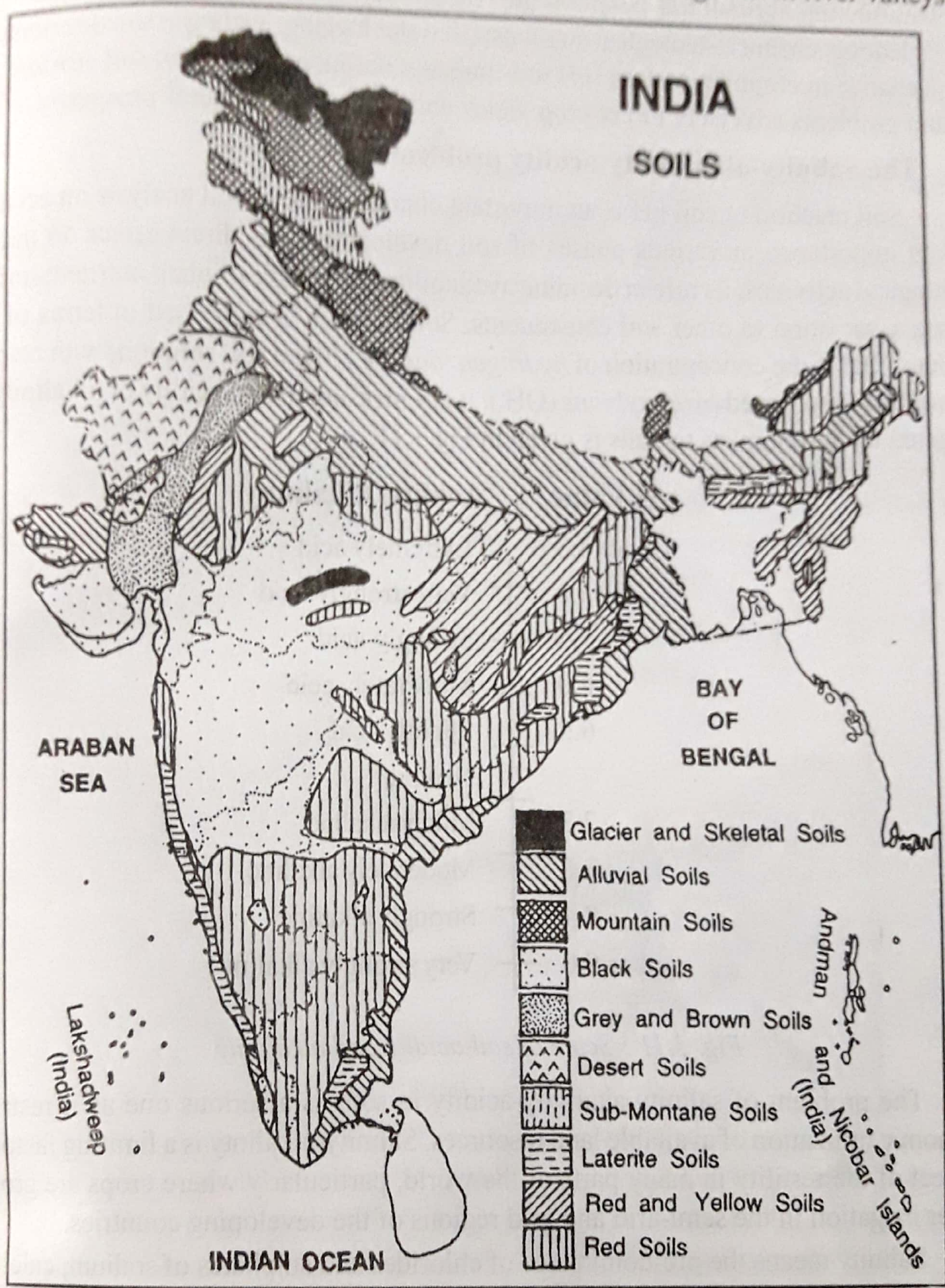


*Fig. 3.10 : Soils of India.*

**6. Other soils**—These soils include hill soils, sub montane soils, mountain meadow soils, *Tarai* soils and skeleted soils. They cover 10.64% of the total soil cover and exhibit a variety of texture, colour, profile and degree of development. They are usually deficient in nitrogen, phosphorous and humus. Forest soils are suitable for orchard crops, forest trees, maize and wheat. They may be used for rice and plantation crops after terracing. Tarai crop management in areas ...

## Soil erosion

The removal of organic matter and plant food from the top layer and its leaching by the agents of denudation is called soil erosion. Soil erosion is caused by running water on sloping lands, by winds over the drier areas and in sandy soils and by waves on lake and ocean shorelines. Soil erosion is influenced by the nature of soil, steepness

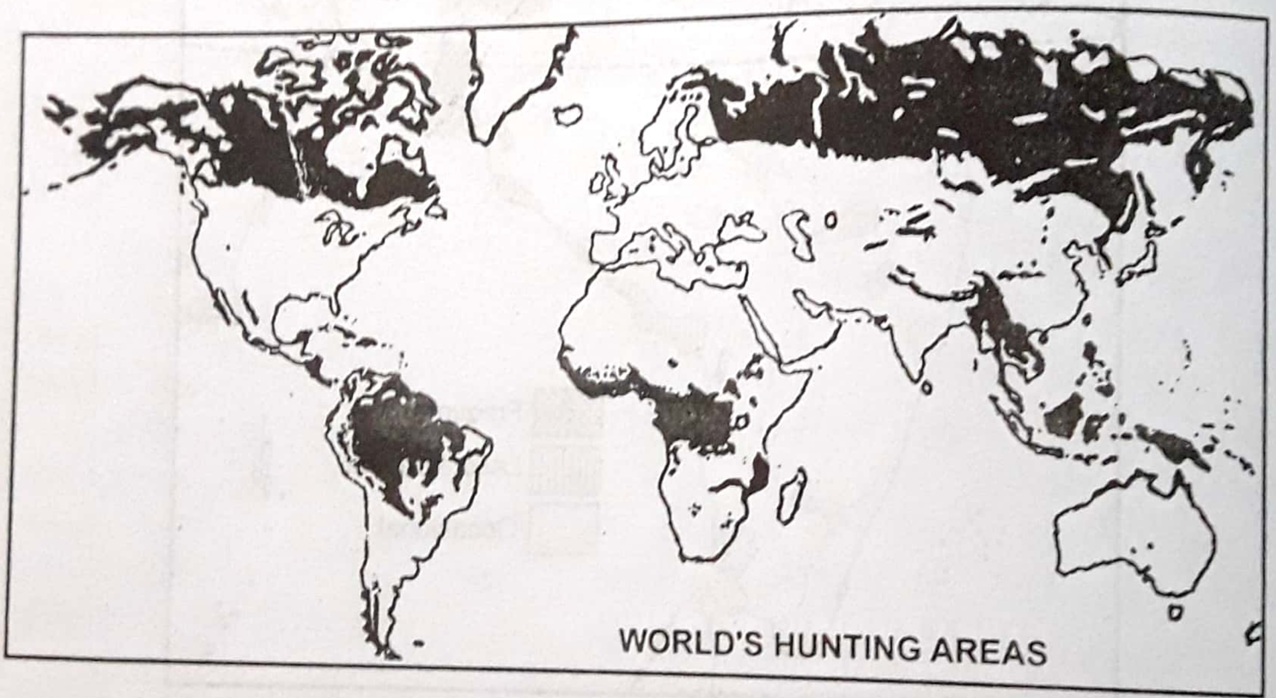


*Fig. 3.13 : Desertification in the World.*

of slopes, climate, especially rainfall and by crops grown. Erosion takes place with an accelerated rate on long and steep slopes.

- Heavy rains cause flash runoff that leads to severe erosion. Agricultural practices and crops grown do have their influence on soil erosion, as the crops grown vary in the degree of exposure of soil. For example, crops like alfalfa, grasses, pastures and small grain crops are soil protecting, while cotton, maize, beans, tobacco, potato and most of the other vegetables are soil exposing crops. Soil exposing crops lead to soil erosion.

- In the semi arid and arid areas, owing to insufficient vegetative cover, wind erosion is quite significant. Overgrazing and devegetation also increase soil erosion. The congregation of livestock causes excessive grazing and trampling of the vegetation. The bare soil is then exposed to wind erosion. Mismanagement of forest and soil resources has increased the process of desertification in the sub tropical and semi-arid temperate regions.

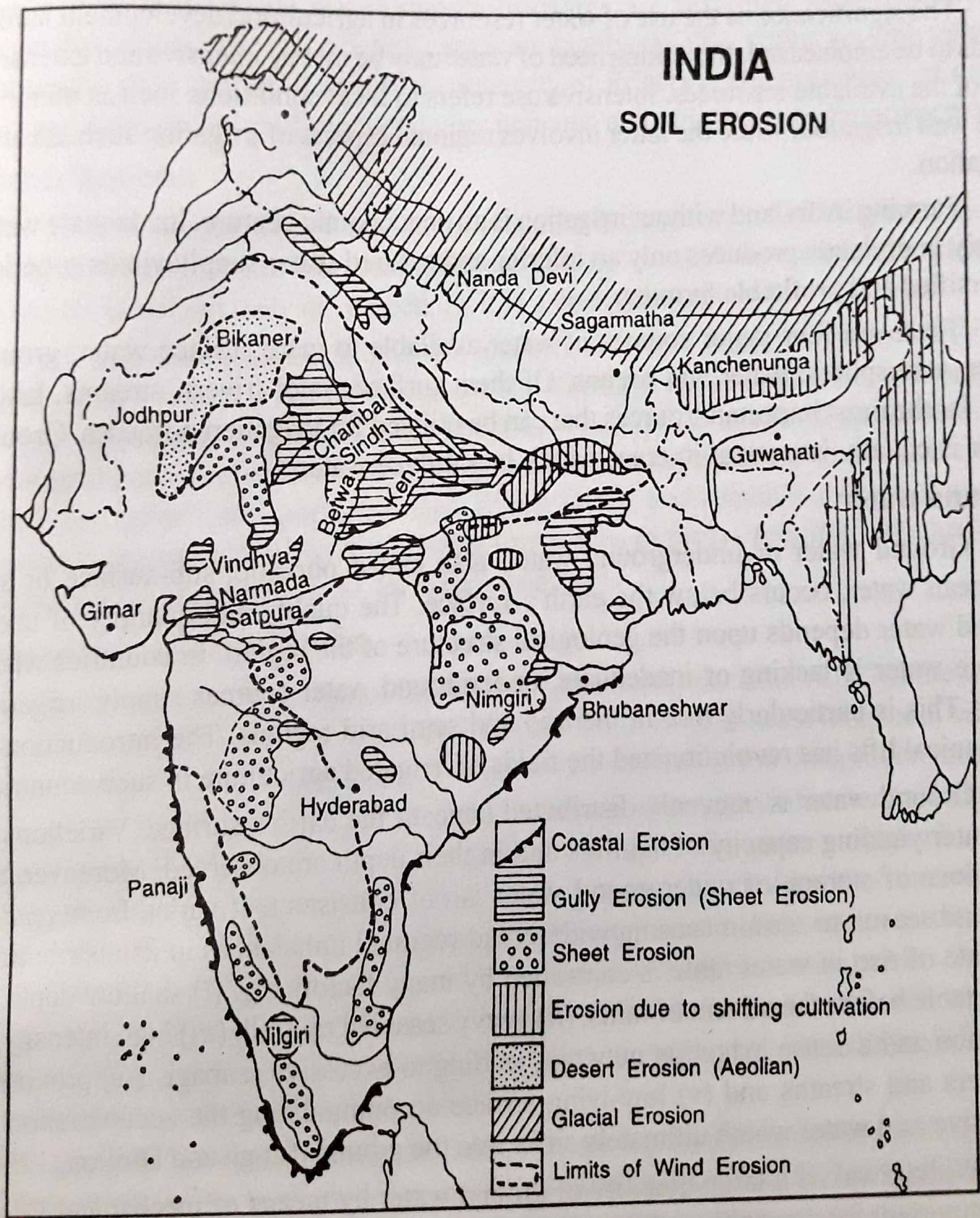


*Fig. 3.14 : Major areas of soil erosion in India*

Soil Erosion :—



Soil erosion is a worldwide problem. Entire life on the Earth's surface depends on the thin (less than 30 cm) layer by top soil. Under natural conditions, soil is constantly being formed by the physical and chemical decomposition of rock material and by the decay of organic matter. Soil erosion is a natural process. Under most natural conditions the rate of soil formation equals or exceeds the rate of soil erosion, so that soil depth and fertility tend to increase with time.

- When land is cleared and planted to crops or when the vegetative cover is broken by overgrazing, deforestation, or other disturbances, the process of soil erosion inevitable **exceeds.** (please check this word) The life-sustaining cover of top soil becomes thinner and eventually disappears, leaving behind only sterile subsoil or barren rock. Thus, the renewable soil resource is converted through human impact into a non-renewable asset. Water and wind denuded plains become non-arable. Many early civilizations were ruined, thus. Any massive destruction of the soil resource could spell the end of the civilization it has supported.

- Farmers have devised ingenious ways to preserve and even improve the soil resource upon which their lives and livelihoods depended. They have practised fallowing, terracing, and crop rotation. Farming skills have not declined in recent years. Rather, pressures on farmlands have increased with population growth. Farming has been forced higher up on steeper slopes, more forestland has been converted to cultivation, grazing and crops have been pushed farther and more intensively into semi-arid areas, and existing fields have had to be worked more intensively. Many traditional agricultural systems and areas that were ecologically stable and secure until 1950, are disintegrating under the pressures of growing population. The evidence of that deterioration is found throughout the world and expresses itself in two ways : (*i*) throug hdecreasing yields of cultivated fields and (*ii*) in increased stream sediment loads and down stream deposition of salt. In Guatemala, nearly 40% of the productive capacity of the land has been lost through erosion. The figure is 50% in El Salvador, 75% in Turkey (54% is severely eroded). Haiti has no high-value soil left at all. In India 25% of the total land has been eroded – some 13 million hectares by wind and nearly 74 million hectares by water. China lost 15% of its arable land due to erosion, between 1960 and 1998. Worldwide, an estimated 6 to 7 million hectares of existing arable land are lost to erosion each year.

- As top soil is progressively removed, decline in yields occurs. The removal of an inch of top soil in the United States has resulted in an average decline of 6% in wheat and crop yields. In Mexico, productivity of land dropped from 3.8 to 0.6 tonnes of corn per hectare as a result of removal of 7 inches of top soil. Fertility of soil is reduced through excessive farming pressures even if soil is not physically lost from the surface.

- Off-farm erosion evidence is provided by siltation loads carried by streams and rivers and by the downstream deposition of lands. All the major rivers of the world carry huge amounts of eroded material (load) and deposit the silt at various sites. In the United States, about 3 billion tonnes of sediments are washed int owaterways each year. This results in reduced reservoir capacity, fish kills, dredging costs *etc.* The world's river about 23 billion tonnes of sediment to the oceans each year, while additional billions of tonnes are deposited along stream valley or in reservoirs.

- Agricultural soil depletion through erosion, salt accumulation, and desertification has been called "the quiet crisis". It is frequently accelerated by practices for increasing crop yields. Few governments have responded meaningfully to the loss of national wealth and food security that erosion threatens. In many cases, land degradation has proceeded so far that reclamation is no longer economically possible.

Soil erosion is a crisis of growing importance and calls for immediate action. The Worldwatch Institute report of the mid 1980s projected a 19% decline in cropland per person between mid 1980s and 2000. This rate of decline has profound significance for food production trends and for economic and political stability in the world.

... and gravity act together.

### Factors Affecting the Rate of Soil Erosion by Water

1. **Rainfall :** The amount of precipitation in a region greatly affects erosion rates. However, even more important factors are rainfall intensity and the seasonal distribution of the rainfall. Intensive rains can cause serious erosion even in areas of low annual rainfall.
2. **Soil erodibility and surface cover :** Soil structure greatly influences a soil's erodibility. The influence of agriculture on soil erosion depends mostly on the amount of surface over and the intensity of tillage operation. A dense cover of vegetation with plant residue on the ground provides excellent protection from erosion.
3. **Topography :** The slope of the terrain greatly affects the intensity of surface runoff and soil erosion. Steep slope greatly increases the velocity of runoff and the rate of erosion.

### Measures for Controlling Soil Erosion by Water (Soil erosion managment)

Some important erosion control practices include : (1) Contour farming, (2) Strip cropping, (3) Terracing, (4) Gully reclamation, (5) Conservation tillage, and (6) Afforestation on hill slopes and along the river banks.

1. **Contour farming :** It may be defined as ploughing, seeding, cultivating, and harvesting at right angles to the direction of the slope.
2. **Strip cropping :** It is the practice of growing crops that require different types of tillage such row and sod in alternate strips along the contours or across the prevailing direction of the wind. A row crop, such as corn, cotton, tobacco, or potatoes, and a cover crop of hay or legumes are alternated along the contours. Strip cropping is frequently combined with crop rotation.
3. **Terracing :** It has been practised by humans for centuries. It was used by the Incas of Peru and

by the ancient Chinese. A variety of terraces are in use around the world today. In the United States, two types of terraces – the ridge terrace and the channel terrace – are constructed.

4. **Gully reclamation :** Gullies are erosion channels too large to be erased by ordinary farm operations. Small gullies can be ploughed. In case of severe gullying, small check dams of manure and straw constructed at 6 meter intervals may be effective. Earth, stone, and even concrete dams may be built at intervals along the gully. Soil may be stabilized by planting rapidly growing shrubs, vines, and trees (especially willows).

5. **Conservation tillage :** It restricts ploughing of the soil to reduce erosion. Conservation tillage systems leave enough of the previous crop residues so that at least 30% of the soil surface as covered when the next crop is planted. Conservation tillage increased from 2% of the harvested croplands in 1962 to about 35% in 1994, and to 50% in the year 2000 in United States.

6. **Afforestation on hill slopes and along river banks :** Trees should be planted on hill slopes and alongside the river banks. In addition, drains should be constructed and concrete or stone pitching *etc.* should be done for checking the caving of river banks.