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An Introduction to the Ecology of Desert Systems

Shubhi Kulshrestha
M.E. (Control System) from Electrical Engineering Department,
M.B.M. Engineering College, Jodhpur and is presently working in
Arid Forest Research Institute, Jodhpur, India

Abstract:- This paper summarizes the ecology of the Desert systems. An ecosystem is defined as the interaction of all living organisms amongst themselves and with the environment. This concept of ecosystem has no delineated boundaries but simply it could be considered as the tussock of grasses along with its root structure, soil characteristics, soil organisms and the atmosphere around the aboveground parts. Deserts are a part of terrestrial ecosystems defined on the basis of the climatic criteria i.e. bioclimatic aridity. The desert characteristics and their features along with the people livelihood are discussed in this paper. The biome of the desert comprises of a variety of complex ecosystems with diverse and fragile groupings of plants, animals and fungi. Their management strategies should primarily focus on the best and the most judicious use of available water, either from groundwater aquifers or from rainfall.

Keywords:- *Ecosystems, Deserts, Drylands, Aridity Index, Desert Ecosystem.*

I. INTRODUCTION

A. Desert Ecosystem

A.G. Tansleyan English botanist and a pioneer in the science of ecology first coined the term “ecosystem” in 1935. Ecosystem is defined as a functional and self-sustaining unit of nature encompassing interaction between its abiotic (non-living) and biotic (living) components. These ecosystems help in determining the health of the entire earth system. Every organism in an ecosystem has an important niche or role to play. The ecosystems are divided into two major categoriesviz; terrestrial and aquatic, where Deserts falls under the terrestrial ecosystem category. Desert Ecosystems are characterized by an imbalance between precipitation and evapo-transpiration thus leading to the arid environment. Drought isa very common phenomenon observed indeserts due to lack of moisture, thus inhibiting the growth of plants and survival of animals. This situation is exacerbated by low atmospheric humidity, variability in the timing of rainfall, high daytime temperatures, and winds.The measurement or prediction of the prevailing climatic elements of evapo-transpirationis quite difficult. These measurements are based upon timely and widespread occurrence of monsoon, physical properties of soil, and physiology of plant cover (Chouhan and Shama, 2009).

These lands are characterized by irratic rainfall patterns thus limiting the productivity of these lands and making cropping unfeasible. The climatic conditions of the deserts is attributed to the lack of rainfall at most 50 centimeters (20 inches) in a year. These poses a severe threat to the agriculture practices in desertic areas. The desert biome plays acrucial role in the growth of plants. The type of desert determines the type of soil layerviz; sandy, gravelly, or stony.The detailed study of interrelationship between plants and climate along with the judicious use of available water helps in the crop or pasture production during the monsoon season(Wallace and Romney 1972; Walter and Breckle,1986). Desertic areas consists of either xerophytes plants or short-lived annuals vegetation.The sparse vegetation cover is contributed due to limited availability of water and adverse climatic conditions. Only those plants which have adapted themselves to cope up with the adverse living conditions of deserts becomes the most compatible ones in the desert environment. Inspite of the dry climatic conditions of the deserts they are home to a wide variety of flora and fauna.

Deserts and their adjacent semi-desertic regions are exhibiting severe changes in their environmental design because of the anthropogenic activities. Some of these examples are thethe Negev and Sinai,Thar in India, the Namib, the Kyzylkum and Aralkum, the Atacama and Altiplano, the Sahara, Central Australia, the Mohave in Southwestern USA and the Kawir in Iran and the Afghan deserts etc. The fluvial and aeolian soil erosion, pollution by pesticides and other toxics, enhanced salinity by waterlogging, the loss of productive areas, are some of the severe effects of inadequate use by man. Desert degradation takes place by the anthropogenic activities in ecotopic areas due to changes in environmental factors (S.W. Breckle et al., 2001).

The vulnerability of an ecosystem to desertification and magnitude of degradation are the two measures which help in assessing the desertification status.The main causes for desertification are a low and irregular rainfall, over-grazing and over-cultivation, wildfires and un-responsible tree cutting and fuel wood consumption. Overpopulation is a major anthropogenic cause of desertification thus increasing the global social crisis as feedback.This leads to global climate change as a cause and a consequence of the desertification problem. The production of plants is affected by the drought conditions prevailing in the deserts thus decreasing carbon sequestration and further enhancing climate change.Thus in totality all the factors are inter-related thus making the problem more complex (Chouhan and Shama, 2009).

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II. DESERTS AND DESERTIFICATION

According to Webster's dictionary the word 'desert' originated from Latin word 'desertum meaning a desert, abandon, an uninhabited tract of land, a region in its natural state, wilderness, a dry barren region, largely treeless and sandy.The 'arid' or 'semiarid' region represent areas on the earth surface where rainfall is nil or inadequate resultingin non-existent or sparse vegetation.Desertsare lands which produce insufficient vegetation to support human population.The deficiency in the amount of precipitation received, relative to water loss by evaporation leads to the formation of true deserts(Logan, 1968).

Deserts are natural laboratories containing valuable mineral deposits formed in the arid environment. They are fragile environments and form the ideal place for preservation of human artifacts and fossils(A.S. Walker, 2014).

Dry lands is a more comprehensive term used to describe land areas with relatively low amount of precipitation. According to the Aridity Index (AI) given by the United Nations Environment Programme (UNEP), the drylands are defined as the ratio between average annual precipitation and potential evapo-transpiration based on Thornthwaite method (1948). The land areas falling between 0.05 and 0.65 are broadly defined asDrylands (Millennium Ecosystem Assessment, 2005). The further classification of AI based on the aridity index is as follows: hyper-arid lands (AI < 0.05), arid lands (AI = 0.05-0.2), semi-arid (AI = 0.2-0.5) lands and dry sub-humid lands (AI = 0.5-0.65). Hyper-arid, arid, semi-arid and dry sub-humid areas are distinguished based on the climatic or non-climatic criteria.They constitute 41 percent of the global land areaand are found in most of the world's biomes and climatic zones (UNEP-WCMC (2007)).

Lavauden (1927) first gave the term "Desertification" defined as "land degradation in arid, semi-arid, and dry sub-humid areasdue to various climatic and anthropogenic factors (UNEP, 1992). Desertification is defined as a slow process of land degradation which eventually exacerbates the quality of land, leading to decline in the land productivity and thus impacting the people livelihood dependent on them. Desert areas are completely desertified areas. The problem of desertification gets intensified because of the factors like accelerated soil erosion by wind and water, a reduction in species diversity and plant biomass, increasing salinization of soils and near-surface ground water and a reduction in the overall productivity of dryland ecosystems. The loss of fertile soil by water and or wind erosion leads to the formation of land degradation areas(Gamo M. et al., 2013).

According tothe United Nations Convention to Combat Desertification (UNCCD) hyper-arid lands are excluded from the definition of drylands and are termed as deserts. They forma part of a wider class of regions termed asdrylands. Deserts exist under a "moisture deficit" condition where they loose more moisture through evaporation than they receive from annual precipitation. Deserts are commonly defined by factor such as aridity, the temporal and/or spatial scarceness of water. Aridity serves as a basis for delineating deserts from other biomes.UNESCO defines the arid and semiarid regions based on indices of bioclimatic aridity (UNESCO, 1977).

The permanent imbalance in the water availability with high temporal and spatial variability results in overall low moisture and low carrying capacity of the ecosystems. This naurally produced phenomenon is known as aridity (Kepner W.G. et. al.,2003).This condition is enhanced as water gained by rainfall falls far below that potentially lost by evaporation and transpiration. In order to delimit zones of varying degrees of aridity UNESCOMAB(Man and The Biosphere) group generated the UNESCO (1977) map of arid and semiarid zones of the world according to the P/ET(mean annual precipitation/mean annual evapo-transpiration) ratio because of several reasonsviz; itgives the same value for all climates where the potential water loss is proportionally the same in relation to rainfall, it is biologically accurate in climates with highly concentrated seasons, and it was used by the FAO (Food and Agriculture Organization) in its study of desertification risk. The UNESCO's 'World Map of Arid Regions' defines the bioclimatic aridity into 4 classes taking into consideration P/ET ratios. These zones are:

- *Hyperarid zon*e (P/ET < 0.03): areas with very low irregular seasonal rainfall; perennial vegetation limited to shrubs in riverbeds.
- A*rid zone* (P/ET > 0.03 and <0.20), perennial vegetation is woody succulent, thorny or leafless shrubs, annual rainfall between 80 mm and as much as 350 mm; yearlongrainfall variability is 50%-100%.
- S*emiarid zone* (P/ET > 0.2 and < 0.5): steppes, some savannas and tropical scrub; meanannual rainfall is between 300 and 700-800 mm in summer rainfall regimes and between 200 and 500 mm in winter rainfall at Mediterranean and tropical latitudes. Among yearrainfall variability is 25%-50%.
- *Subhumid zone* (P/ET > 0.5 and < 0.75): primarily tropical savannahs, and Chaparral and steppes on chernozem soils. The UNESCO (1977) group included this zone in their map because of the susceptibility to soil and vegetation degradation during droughts.

Another common way of delineating deserts is based on their vegetation pattern and optional land use. Extreme arid zones typically show contracted vegetation restricted to favorable sites or lack vegetation altogether. Arid zones are characterized by diffuse vegetation. Semiarid zones mostly are characterized by continuous vegetation cover (if edaphic conditions allow for it) and only very locally dry-land farming (without irrigation) is possible. Farming without irrigation becomes a reliable option at larger scale in non-arid zones only. (Holzapfel C.,2008)

III. CAUSES OF DESERT FORMATION AND DESERT REGIONS

Earth's climate refers to the meteorological conditions existing at a specific location thus making it variable at different regions of earth. The air circulation pattern within the atmosphere leads to the areas of low and high precipitation thus at certain locations there is a regular pattern of rainfall, while other areas represent a lack ofrainfall defined as arid areas. The tilting of earth at 23.5 degrees adds the effect of thegeneral pattern of circulation within the belt between23.5° north and 23.5° south of theequator, directly following themovement of the overhead sun, orwhat is referred to as the 'thermalequator'. The extreme limits ofthis movement are marked by thetropics of Cancer and Capricorn. This tropical belt containsat its northern and southernboundaries areas of extreme aridity.These areas are defined by extreme aridity and areclassified as deserts.

General circulation of air within theatmosphere centers upon the threerecognized cells of air which operatewithin both the northern andsouthern hemispheres. These are theHadley cell, the Ferrel cell and thePolar cell, and this is referred to as the tri-cellular model (Figure 1).

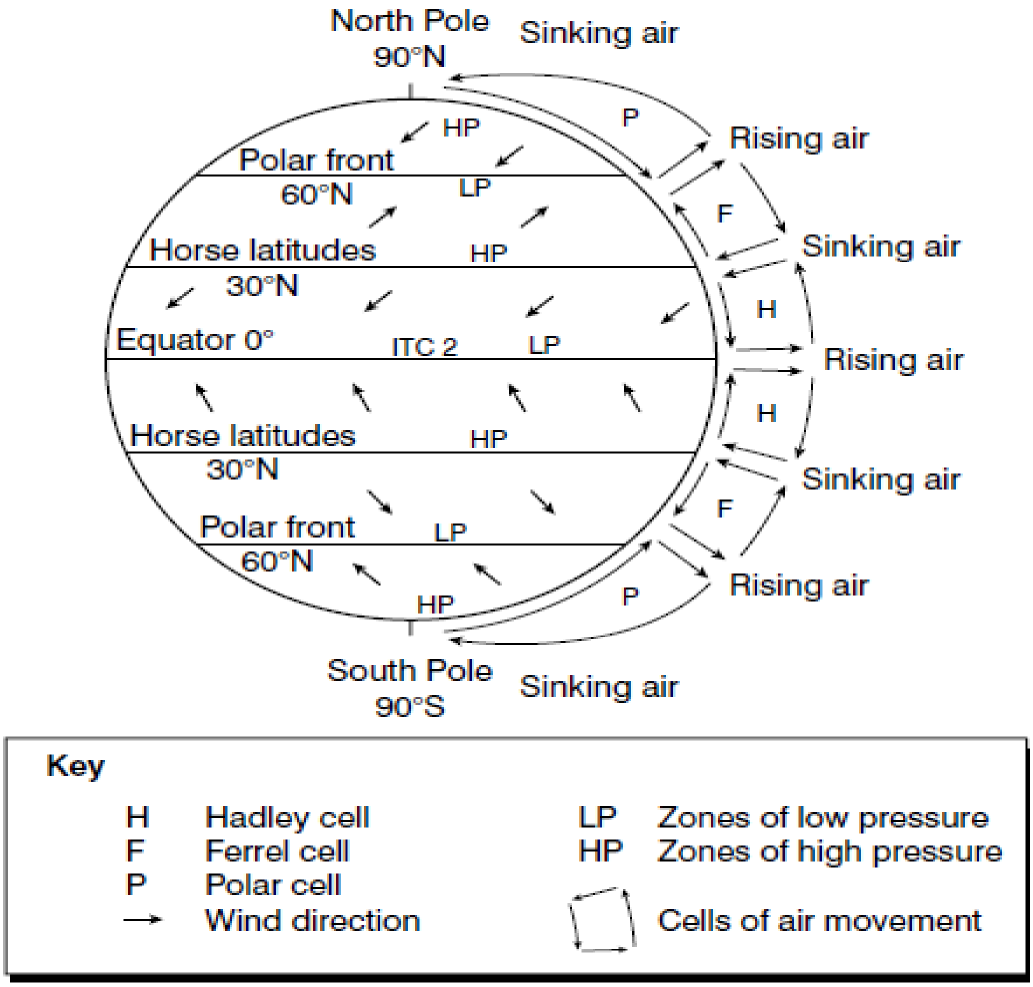

Fig. 1: Air circulation tri-cellular model

Hadley cell are the atmospheric high pressure zones where the circulation occurs at a global scale from tropical atmospheric circulation in which air rising near the equator flows toward the poles at 10–15 km above the surface. The descending air masses from Hadley cell circulation leads to the formation of the world's deserts located in subtropical latitudes (around 30 degrees).The air circulation in the Hadley cell follows the sun's zenith i.e. highest point of elevation, rises at the equator or wherever within the tropical belt the sun's rays are directly overhead, and flows either northwards or southwards away from the Hadley cells and towards the Ferrel cells of the northern and southern hemisphere. Depending upon the time of year, between 15°and approximately 30° north and south of the equator, this air has cooled sufficiently to sink back to the earth. The rising of the air at the equator due to heating from the sun is called convection. This area of low atmospheric pressure consists of unstable air. As air rises, it becomes cool, it condenses, and precipitates. Oceans cover most of the equator thus having moist equatorial air. The high equatorial surface temperature also leads to the evaporation of large amount of water. Thus tropics re developed near the equator having warm and moist air. The further travelling of the air at altitude away from the equator either to the north or south directions makes the air drier and as it later descends it meets the air from the Ferrel cell. As the air

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descends in both the northern and southern hemispheres at about 30 degree latitudes it becomes compressed; it gets heated up and exhibits increased ability of holding water vapour before the formation of precipitation (Horse latitudes) (Fig. 1).Thus the air becomes more stable and an anti cyclonic air mass dominates making the skies in this area as cloudless because of loss of moisture through precipitation. This leads to the formation of the belt of aridity at approximately 15–30° north and south of the equator which encircle the globe at these latitudes (Fig. 2) (Sheppard P., 2010). The Sahara and the Arabian Deserts are the examples of the subtropical deserts resulting primarily from descending dry air. This process of ascending of air to the north and south of the desert latitudes producing moisture for the land and descending over the poles (Polar front) lads to the formation of deserts. Desert formation in these particular latitudes is primarily due to complex global air-circulation patterns caused by the rotation of the earth on its axis (earth moves at great speed near the equator and slowly near the poles), the seasonal tilting of the earth in relation to the sun, and other factors.

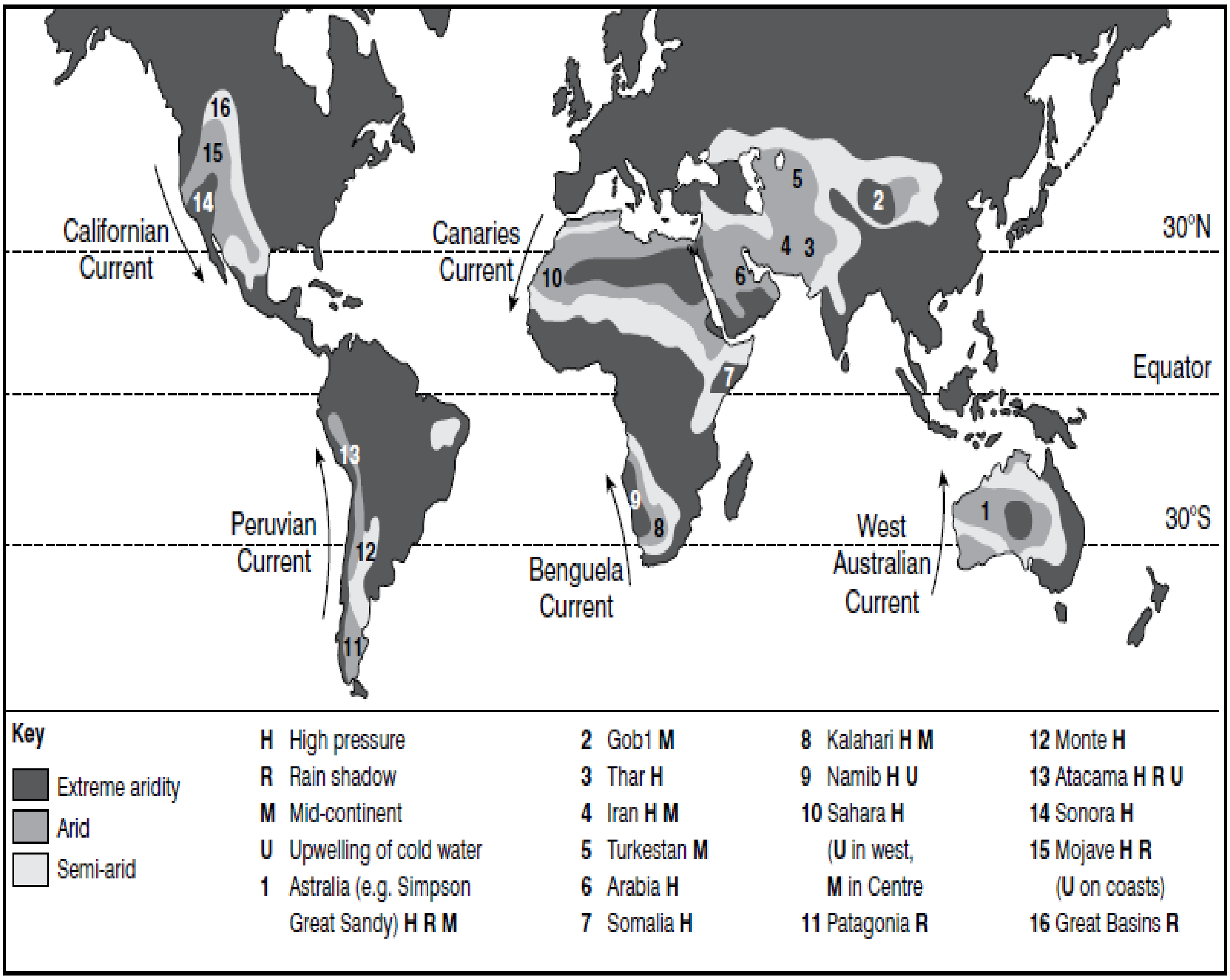

Fig. 2: Arid regions of the world and cold ocean currents

Source: adapted from D. Waugh, Geography: an Integrated Approach, 3rd edn, p 179

Distance from the oceans is also responsible for creation of water deficient areas. A major portion of water from sea is evaporated which eventually precipitates on land.Thus lands closer to the sea generally receivelarger amount of moisture.The movement of air inland makes it moisture depleted and precipitation also drops.Some of the Asian deserts for example the Gobi and Takla-Makan Deserts becomes desertic because air currents reaching them have already traversed vast land distances and have already lost the moisture they once carried.

Once over the summit, the air descends the lee side of the range, warming as it does so, and hence increasing its evaporative power.The windward side of a range may support a heavy well-watered forest, while the leeward side and the area far below it, robbed of moisture, and is occupied by a desert or steppe plant community.

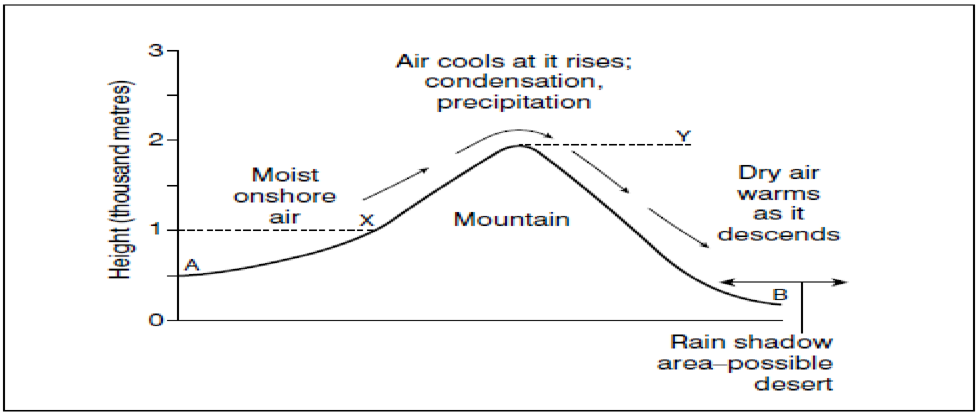

Fig. 3: Cause of Rain Shadow Desert formation

Rain-shadow effect includes adiabatic heating followed by cooling.Most of the arid region of continents are clustered around 30 degrees north and south latitude.Some of the arid regions at higher latitudes are primarily formed by the rain shadow effects of mountain ranges or simply because of large distances from the oceans.The lee of the mountains produces rain-shadow effect thus creating arid regions. This moisture-laden air on encountering mountains moves upward where it is cooled and releases moisture on the windward side of the range.Air gets warm on descending down the leeward side of mountains and this warm air has more capacity for holding moisture than cold air. Thus the descending air mass has insufficient water content for precipitation (Fig. 3). The desert at higher latitudes with limited amount of precipitation in the winter season forms the rain shadow deserts like the Great Basin Desert between the Sierra Nevada Mountains and the Rocky Mountains. Other rain shadow deserts in North America include the Mojave and Sonoran Deserts of the United States and Mexico.South American rain shadow deserts are located in Argentina in the rain shadow of the Andes Mountains: the Monte Desert and Patagonian Desert. The continent of Australia has the largest rain shadow arid region in the world. The Thar Desert of India is in the rain shadow of the Aravalli mountain range to the south-east, the Himalayas to the north-east and the Kirthar andSulaiman mountains to the west (Fig. 2).

IV. DESERT CHARACTERISTICS

A. Climate

Deserts or arid zonesform the important components of the Earth's environment. They are fragile ecosystem where vegetation is absent or scarce as moisture is insufficient to support it. Arid regions are characterized by various climatic elements viz; humidity, precipitation, wind, temperature, sunshine, etc.and the range of their spatial and temporal changes. The scarce or very low vegetation in desert is exposed to the sun’s rays thus resulting in high air temperatures and large diurnal ranges.Climatologically, deserts are considered to be the most hottest places in the world due to large absorption of heat from the Sun as compared to other lands in humid climates. The presence of clouds in the sky obstructs the falling of Sun’s rays onto the ground during day time thus slowing the rate of heating of the air near the surface. During night the clouds and water vapour absorbs earth's radiations composed of infrared rays thus slowing the rate of cooling. Winter season is colder in middle latitude semiarid regions and deserts.

Aridity characteristically defines the hot deserts. Koppen-Geiger defines deserts as regions with an annual precipitation of less than 250 mm (Peel et al., 2007). However, annual precipitation can often be a misleading term because water loss is an important component of the water budget. Thus, the definition given by the United Nations Environmental Programme under normal climatic conditions defines the potential evapo-transpiration (PET) to be five times higher than actual precipitation for deserts (Middleton and Thomas, 1997). The lack of cloud cover in arid regions leads to high PET thus allowing more solar radiations to fall on the ground.Two systems of desert climatic characterization are usually followed after Koppen and Thornthwaite (Sikka D.R., 1997).

- The Koppen'ssystem characterizes desert or arid climate regions as the ones where mean annual precipitation is low (< 250 mm) and Surface air temperature is high. According to thissystem Desert or arid climate is characterized by very low precipitation, ranging between 25 mm and 200 mm annually. Arid regions generally described as deserts receive <25 cm of rainfall annually. Deserts are dry, have high rates of evaporation, poorly developed soils, and are mostly or completely devoid of vegetation. (Marshak, 2002).
- The Thornthwaite'ssystem is based on water balance or hydrological approach and compares the mean annual rainfall against mean annual potential evapo-transpiration (PET).Deserts can be classified into two types based on their level of aridity as hyper arid deserts having an aridity index (P/PET) of<0.05 and arid deserts having P/PET between 0.05 and 0.2. As such, deserts are distinguished from semi-arid drylands (P/PET 0.2-0.5) and dry sub-humid drylands (P/PET 0.5-0.65). The diurnal temperature variation in deserts is very pronounced, with high day time and low night time temperatures (Woodward, 2003). Due to the high surface temperature and temperature differences most deserts are also high wind energy environments (Parsons and Abrahams, 2009).

B. Temperature

Desertic regions experiences temperature extremes. These areas have very hot day temperatures often increasing the risk of dehydration in the people whilethe nights are very colddue to the lack of insulation provided by humidity and clouds. Temperatures can drop to 4°C (40°F) or lower at night time. Deserts are renowned for their largediurnal temperature fluctuations; scarce vegetation within deserts exposes the surface of earth to the solar energythus heating up the area quickly while at nightheat radiates rapidly away. There exists a large variation in the day and night temperatures of these regions. The winter nights in hot deserts mayfall below 0°C while the daytime air temperaturesmay be as high as 40°C. The highest airtemperature ever recorded was 57°C in theLibyan part of the Sahara. However, thetemperature on the soil surface can be considerably higher than the air temperature; ashigh as 75-80°C (Ward. 2009;Rewald B. et. al.,2012).

C. Rainfall

Rainfall is a determining factor in deserts and is very scanty in all desertic areas. Inspite of these deserts are not barren waste lands. There are some characteristics that are common to all deserts i.e.,irregular rainfall of less than 250 mm per year, very high evaporation rates often 20 times the annual precipitation, and low relative humidity and cloud cover. Most of the deserts receive less than 200 mm rainfall per year. However, the amount of rainfall may vary greatly from year to year. A desert may not receive any rain for several years and in some cases about 250mm of rain might fall within a few hours. The mean annual aridity indices are different for different land deserts of the world and the aridity is highest for the core Saharan and Peruvian deserts, followed by the Saudi Arabian, East African and Gobi, Australian and South African deserts. It is low for India's Thar desert and the North American deserts of California and Mexico. It is observed that there are regions in the Saharan, the Australian and the Namibian deserts where the annual rainfall is almost negligible <50 mm. Compared to that most of the Thar desert in India receives considerable rainfall (100–300 mm)(Sikka D.R., 1997).

Deserts have dry air devoid of water vapour where light rains often get evaporatedin this dry air before reaching the ground. Rainstorms sometimes come as violent cloudbursts. A cloudburst may bring as much as 25 centimeters (10 inches) of rain in a single hour, the only rain the desert gets all year.Humidity in deserts is quitelow such that not enough water vapour exists to form the clouds. Due to the absebce of clouds the sun’s rays directly bakes the land. The air in contact with the ground gets heatedup so much that air rises in shimmering waves which confuse our eye, causing travellers to see distorted images called mirages.

The primary forces acting either singly or in combination produces arid lands. These climatic, desert-producing factors aremountain-produced rain shadows, descending, drying air currents, cold ocean currents and distance from oceanic moisture sources.

V. DESERT FEATURES

A. Topography

Playas, alluvial plains, Pediments, inselbergs, mesas, buttes and badlands are the typical desert topographies. The evaporation of water from lakebeds ranging from few hours to sevral months leads to the formation of dry lake beds known as Playas. Theyare characterized by formation of salt pans formed from the mud cracks and precipitated salt crystals. The origin of salt lakes or depressions indicates that brine of salt lakes was surface deposit as a result of desiccation of sea in the late tertiary period. There is possibility that salts are carried by winds from the Rann of Kachchh as particles or sprays of sea water and deposited over land, subsequently washed by rains and deposited in lakes. Structure, relief and morphogenesis of these playas are varying and they are important gathering ground of natural evaporates and ground water (Chouhan and Shama, 2009). Saline depressions or lakes are scattered throughout desert region important among them being Sambharlake, Pachpadra, Loonkaransar and Didwana. There are small playa lakes near Khatu, Pokaran, Sujangarh and Kuchaman. In the hilly and sandydune tracts, there are enclosed basins and local runoffs possessing clayey soils withevaporate deposits like sodium chloride gypsum, gypsite, nitrate etc when dried duringsummer. Like the saline lands of West Australia, there are some relics of the onceextensive river system. Rann of Sanwarla, Pachpadra salt basin and other minordepressions in the northern part of central Luni basin are ‘wet playas’. Centripetaldrainage system was not conspicuous at all and channels connected from headwaterbranched after dryland conditions were set in. The highly saline surface limits crop production. Stream which originates from high lands of Shergarh- Kailana-Jodhpurdrains into this basin is underground surface drainage enriched by high dunes. In theLuni basin or in alignment with it, most of these salt lakes occur while others are alongthe periphery of Barmer Bikaner dune free country located at Pokaran, Phalodi, Bap and Lunkaransar.

Heavy textured saline soils occur in some localized depressions which are clay loam,shallow to moderately deep loamy sand overly strong clay loam in upper reaches wheresheets occur. The extent of sand cover ranges from 10 to 80 cm, the upper sandcover is calcareous and non-saline sometimes supporting crop in 30 cm deep conditions.Deep to moderately deep, medium to coarse textured soils, slightly affected by salts at alower depth also occur in the low-lying locations.

The deposition of sediments down the slope of the land as aprons at the mouth of canyons or as a piedmont plainis known as Alluvial fans (Fig. 4). They are quite common in many deserts, especially the Basin and Range. The sediment laden streams deposit their load onto the flat desert floor leading to the formation of alluvial fans. Theyare formed at the outlet of mountain valleys. The concentric contours of alluvial fans are formed from alluvia deposited as stream, velocity rapidly decreases when released from the confines of the valley walls. Since only part of an alluvial fan receives sediment at any time, the surface is made up of sectors of differing age.

The broad aprons of sediment deposition at the foot of steep mountain fronts by coalescing and overlapping alluvial fans are called Bajadas(Fig. 4). Bajadas and large alluvial fans are sources of groundwater. Alluvial fans coalesce to form a bajada, a broad alluvial apron with an undulating surface. Slope profiles are determined by the slopes of the fans that coalesced thereby forming an undulating surface that gradually grades into slopes of finer alluvia in basin areas that may form ephemeral lakes. Most alluvial fans and bajadas are not formed by simple depositional gradients. Because of a complex geological history, episodes of deposition and erosion result in complex surface deposits on what appear to be simple alluvial fans. Each depositional episode may build a different segment of the fan from sediments of different origins and particle sizes (Mabbutt, 1977;Whitfordand Duval,2020).

Piedmonts are graded slopes of alluvial materials extending outward from the base of mountains, mesas, or hills (Fig. 4). Piedmont gradients appear to be the result of interactions of coarseness of surface debris, nature of sediment load, magnitude and frequency of run-off across the surface, rate of stream channel cutting, and density of perennial vegetation. These same factors plus the chemical nature of the parent rock largely determine the soils developed along piedmont gradients. The characteristic morphologies of drainages that develop on pediments tend to be dendritic moving from rills to small channels into larger channels. (Whitfordand Duval ,2020)

Inselberg a German word which means island mountains are oftensteep sided, isolated erosional remnants of bedrock which are characterized by greater resistance to weathering than surrounding mountains(Chernicoff& Whitney, 2002) (Fig. 4). Generally carbonate pan is concealed under alluvial or blown sand deposit but sometimes exposed at the surface due to removal of soil by erosion. It is not encountered in inselberg zone, while in piedmont plains, it is found at about 45 cm depth, which gradually increases in depth towards the lower plains it is found at a depth range 65-100 cm. In alluvial plains it lies at 45-100 depth and at 120 cm depth in shallow saline depressions of internal drainage. In appearance it neither resembles rock nor alluvium or sand. These are very hard and impervious and penetration of roots is difficult. In piedmont zone, layers of pan are found where soil deposits are also observed. Rock fragments washed away from highlands are deposited in bands and become cemented with lime. Development of pan is very much related with dry climate with rainfall varying 100-150 mm, high temperature and prolonged droughts. Glaciations in the Himalayas have considerably influenced climatic conditions of this tropical belt. It is surmised that glaciations of different intensities have resulted in climate declining towards more drylands (Chouhan and Shama, 2009).

The broad, flat-topped erosional remnants bounded on all sides by steep slopesare called Mesas which are capped by horizontal and more resistant rock layer formed by easily weathered sedimentary rocks. The continued weathering and erosion of Mesas leads to the formation of Buttes which are pillar-like erosional remnants. Both mesas and buttes consist of easily weathered sedimentary rocks capped by more resistant rock (Marshak, 2002). Badlands are areas of closely spaced ravines with sparse vegetation.Pediments areerosional bedrocksurfaces of low reliefthat slope gentlyaway from mountainbases.Most pediments arecovered by a thinlayer of debris,alluvial fans, and/orbajadas (Fig. 4).

The desert experiences another kind of erosional mechanism by the wind known as abrasion which is basically a kind of "sand blasting" process. The process of blasting will remove the particles on the exposed surfaces by the impact of wind.This process also influences the size of the particles being moved limiting to the height of 1 meter or 2 meters maximum.It creates its own kind of landforms likeventifacts and yardangs. Ventifacts are land surfaces containing pebbles, cobbles or boulders that have been eroded on one or more sides by wind abrasion. Yardangs are ridges which run parallel to dominant wind direction, believed to be formed by abrasion. They also create a pillar-likestructure which is undercut by abrasion.

Yardangs are elongated, streamlined ridges that look like the hull of an overturned ship. They are often found in clusters aligned parallel to the prevailing wind direction. Yardangs are larger than ventifacts and formed by differential wind erosion and abrasion (Wicander and Monroe, 2002).

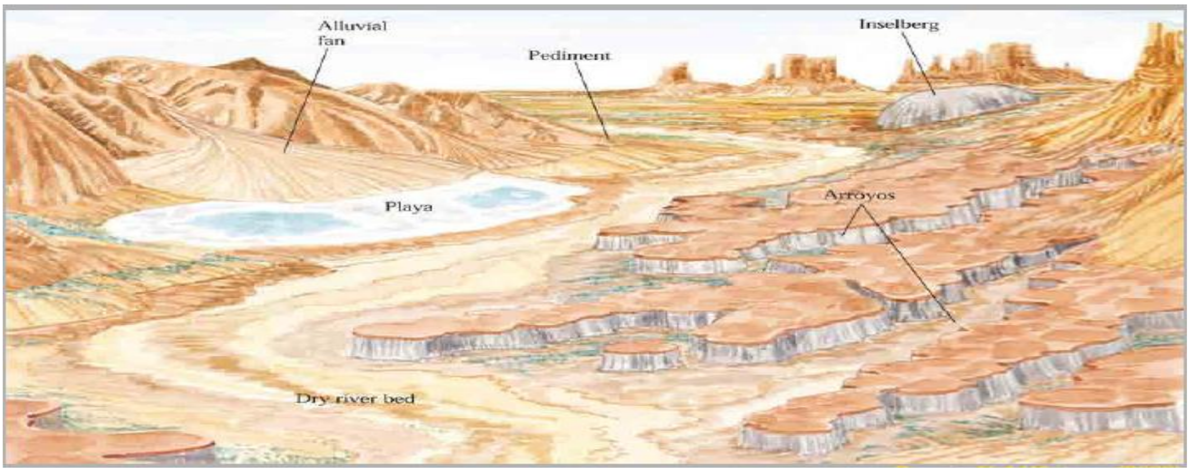

Fig. 4: Desert landforms produced by water

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B. Sand dunes

Sand Dunes are a characteristic feature of deserts formed as large piles of wind-borne sands reaching a maximum height of 250 metres above the surface of earth. The shapes and patterns of dunes changes continuously due tothe highly active winds. They have two-sided slopes one along the windward direction and the other along the leeward direction.

Sand of dunes indistinguishable from seashore seems to have been transported to a great measure by monsoon winds. The fine grained sand seems to have been transported by drainage systems from the Aravallis which seems a major reason of variation. Orientation and distribution of sand dunes depend upon the source of sand and size of grains, since coarser grains drop at a short distance while fine grains continue their flight down the wind at varying distance depending on the velocity of the summit wind and violence of eddies in leeward side of dunes. In barchan dunes, the average size of sand grains increases with the size of the dune. Bigger sand grains contribute to more weight and pressure, require more wind energy to be carried vertically as well as horizontally (Fig. 5). Near the Rann of Kachchh and in Barmer the density of dunes is comparatively high and gradually decreases in the north-east. (Chouhan and Shama, 2009)

Wind-deposited materials hold clues to past as well as to present wind directions and intensities. These features help us understand the present climate and the forces that molded it. Wind deposited sand bodies occur as sand sheets, ripples, and dunes. Sand sheets are flat, gently undulating sandy plots of sand surfaced by grains that may be too large for saltation. They form approximately 40 percent of eolian depositional surfaces. The Selima Sand Sheet, which occupies 60,000 square kilometers in southern Egypt and northern Sudan, is one of the Earth's largest sand sheets. The Selima is absolutely flat in some places; in others, active dunes move over its surface. Wind blowing on a sand surface ripples the surface into crests and troughs whose long axes are perpendicular to the wind direction. The average length of jumps during saltation corresponds to the wavelength, or distance between adjacent crests, of the ripples. In ripples, the coarsest materials collect at the crests. This distinguishes small ripples from dunes, where the coarsest materials are generally in the troughs. Accumulations of sediment blown by the wind into a mound or ridge, dunes have gentle upwind slopes on the wind-facing side. The downwind portion of the dune, the lee slope, is commonly a steep avalanche slope referred to as a *slipface.* Dunes may have more than one slipface. The minimum height of a slipface is about 30 centimeters. Sand grains move up the dune's gentle upwind slope by saltation and creep. When particles at the brink of the dune exceed the angle of repose, they spill over in a tiny landslide or avalanche that reforms the slipface. As the avalanching continues, the dune moves in the direction of the wind.

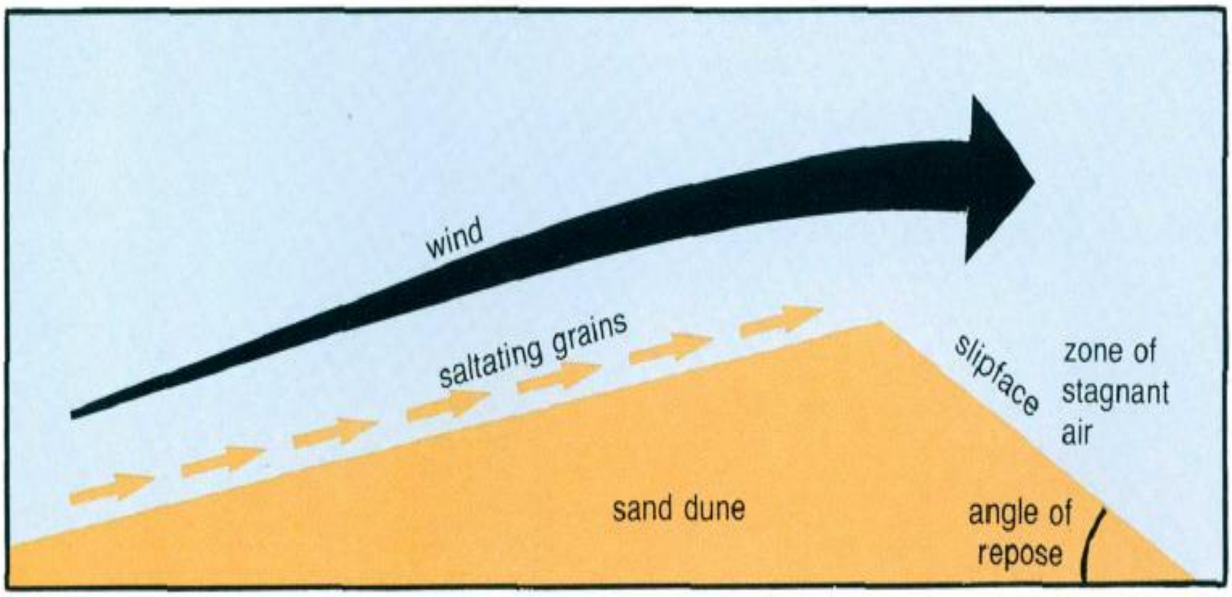


Fig. 5: Wind-blown sand moves up the gentle upwind side of the dune by saltation or creep. Sand accumulates at the brink, the top of the slipface. When the buildup of sand at the brink exceeds the angle of repose, a small avalanche of grains slides down the slipface. Grain by grain, the dune moves downwind

Most dunes have asymmetric profiles and began formation where wind blows over or around an obstruction. Sand grains move up the gentle windward slope by saltation and accumulate in inclined layers on the steep leeward slope. Dunes slowly grow and migrate in the direction of the prevailing wind (Wicander and Monroe 2002).

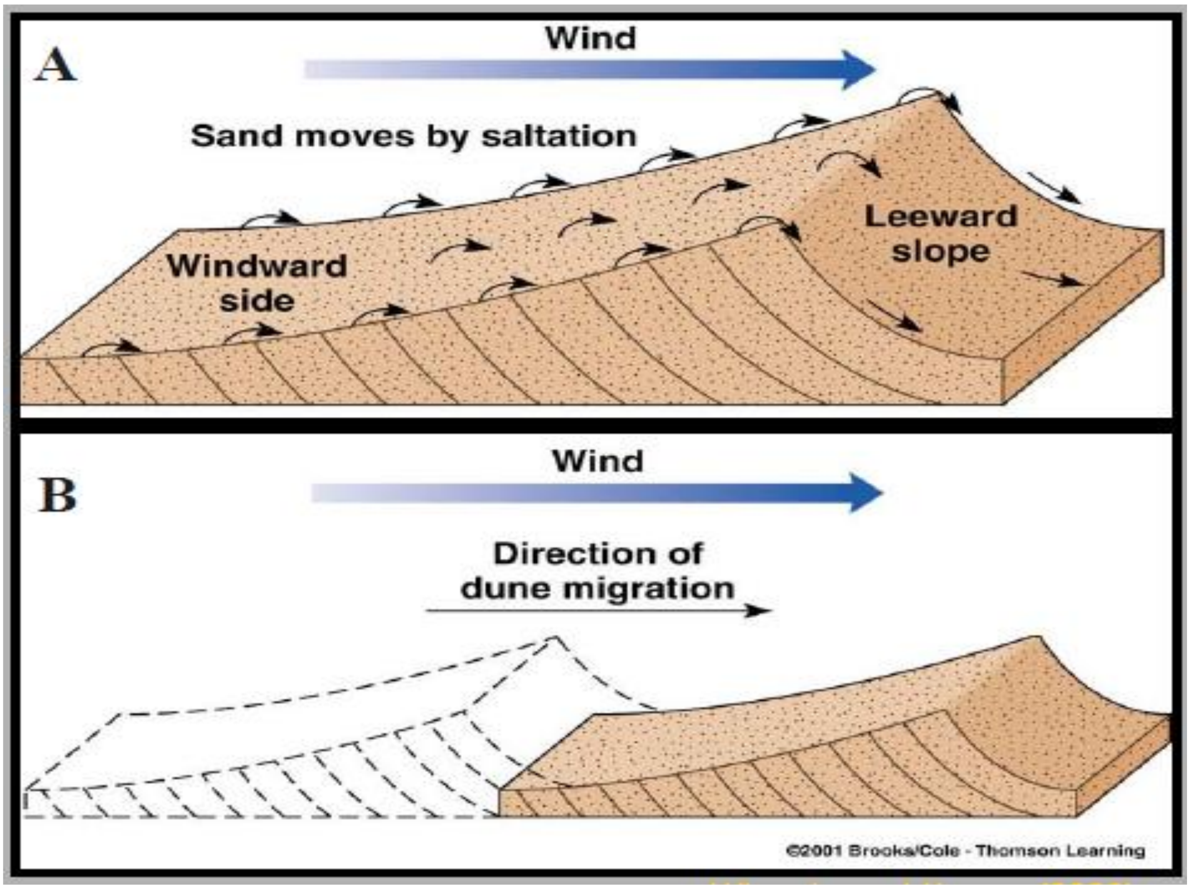
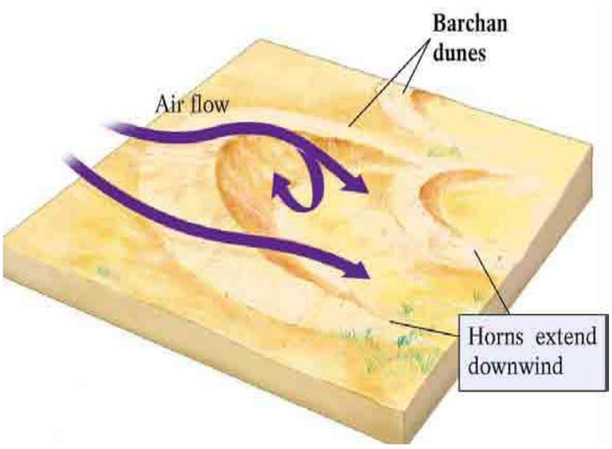


Fig. 6: Dune Migration due to wind

The phenomenon of sand movement is intimately connected with the velocity of surface wind, force exerted on sand grains and resistance offered by grains to passage of wind. Wind velocity falls nearer to the surface level, pebbles, grass blades or other surface irregularities. From this level upward it increases quite rapidly at first, becomes slow at significant height. Smaller clay or dust particles do not react unless stirred by flying sand grains. Hard rough surface remains stationary and not affected with blown wind (Fig. 6). Wind speed ranges between 30 and 62 km per hour during the summer months of April to June in India. (Chouhan and Shama, 2009)

- *Dune Types*

Barchan dunes are crescent-shaped with tips that point downwind.Barchans are small, seldom more than 30m in height. They are the mostmobile of dunes and can migrate at rates exceeding 10m/year.Barchan dunes form on flat, dry surfaces with little vegetation and alimited supply of sand. Formation of barchan dunes requires a nearlyconstant wind direction (Fig. 7).



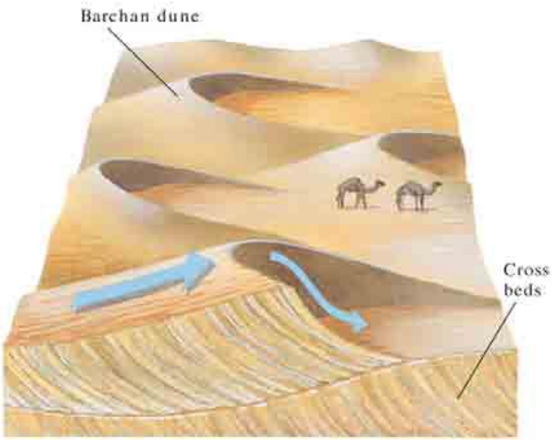


Fig. 6: Formation of Barchan Dunes

Longitudinal dunes are long, parallel ridges aligned with the prevailingwind direction. They are from 3 to 100 m in height and can be morethan 100 km in length. They form where winds converge to producethe prevailing wind.Longitudinal dunes are especially common in central Australia andcover one-fourth of the continent.Transverse dunes form long ridges perpendicular to the prevailingwind direction. They form in areas where abundant sand isavailable and little or no vegetation exists. Crests of transversedunes can reach 200m in height. The dunes can be up to 3 km inwidth. Due to their wave-like appearance, transverse dunes aresometimes called sand seas.Parabolic dunes have acrescent shape likebarchan dunes, but theirtips point upwind. These dunes arecommon in coastalareas with abundantsand, strong onshorewinds, and a partialcover of vegetation. Star dunes resemble a multipointedstar. Thesepyramidal hills of sand canreach in excess of 100 m inheight. The arms of thestars are formed by radiatingridges of sand.Star dunes can remainstationary for centuries andserved as landmarks fordesert nomads (Fig. 7).

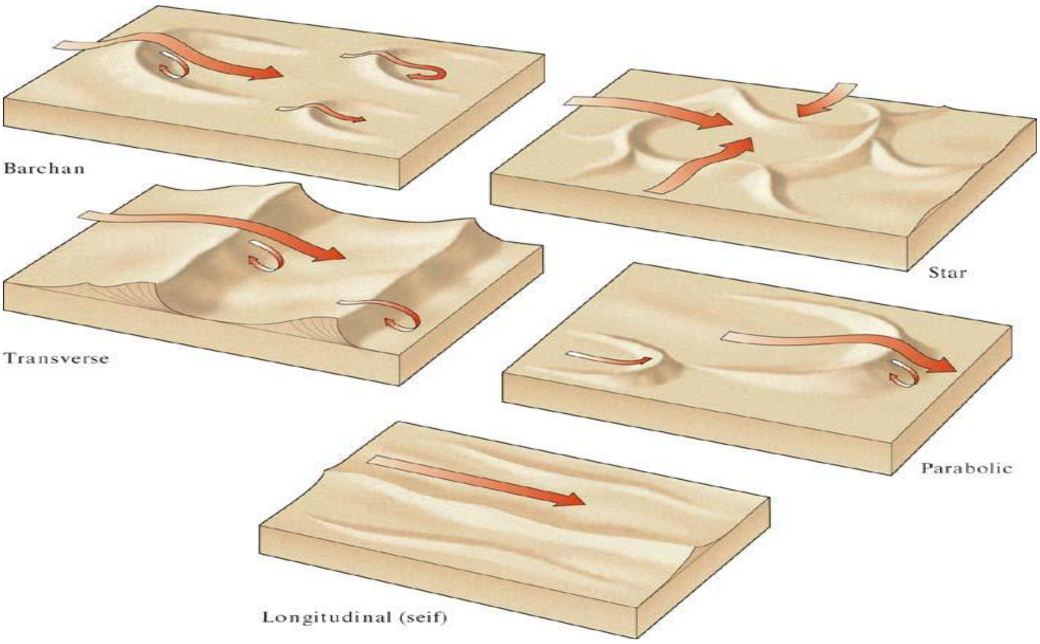


Fig. 7: Types of Dunes

VI. MAJOR KINDS OF DESERTS

Symmetrical clusters of deserts are found around the Tropic of Cancer and the Tropic of Capricorn - the two latitudes that define the area where the sun's angle at solar noon is closest to ninety degrees overhead at the Equinox. Deserts are classified by their geographical location and dominant weather pattern as trade wind, mid latitude, rain shadow, coastal, monsoon, or polar deserts. Deserts are most notable for their dry climates; usually a result from their surrounding geography. For example, rain-blocking mountain ranges, and distance from oceans are two geographic features that contribute to desert aridity. Rain-blocking mountain ranges create Rain Shadows. As air rises and cools, its relative humidity increases and some or most moisture rains out, leaving little to no water vapor to form precipitation on the other side of the mountain range.

A. Monsoon deserts

"Monsoon," derived from an Arabic word for "season," refers to a wind system with pronounced seasonal reversal. Monsoons develop in response to temperature variations between continents and oceans. The southeast trade winds of the Indian Ocean, for example, provide heavy summer rains in India as they move onshore. As the monsoon crosses India, it loses moisture on the eastern slopes of the Aravalli Range. The Rajasthan Desert of India and the Thar Desert of Pakistan are parts of a monsoon desert region west of the range (Fig. 8a).

B. Trade wind deserts

The trade winds in two belts on the equatorial sides of the Horse Latitudes heat up as they move toward the Equator. These dry winds dissipate cloud cover, allowing more sunlight to heat the land. Most of the major deserts of the world lie in areas crossed by the trade winds. The world's largest desert, the Sahara of North Africa, which has experienced temperatures as high as 57° G, is a trade wind desert (Fig. 8b).

C. Mid-latitude deserts

Mid-latitude deserts occur between 30° and 50° N. and S., poleward of the subtropical high-pressure zones. These deserts are in interior drainage basins far from oceans and have a wide range of annual temperatures. The Sonoran Desert of southwestern North America- is a typical mid-latitude desert (Fig. 8c).

D. Rain shadow deserts

Rain shadow deserts are formed because tall mountain ranges prevent moisture-rich clouds from reaching areas on the lee, or protected side, of the range. As air rises over the mountain, water is precipitated and the air loses its moisture content. When moisture-laden air hits a mountain range, it is forced to rise. The air then cools and forms clouds that drop moisture on the windward (wind-facing) slopes. When the air moves over the mountaintop and begins to descend the leeward slopes, there is little moisture left. The descending air warms up, making it difficult for clouds to form.A desert is formed in the leeside "shadow" of the range. Leeward slopes face away from prevailing winds. Death Valley, in the U.S. states of California and Nevada, is a rain shadow desert. Death Valley, the lowest and driest place in North

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America, is in the rain shadow of the Sierra Nevada mountains.

E. Coastal deserts

Coastal deserts generally are found on the western edges of continents near the Tropics of Cancer and Capricorn. They are affected by cold ocean currents that parallel the coast. Because local wind systems dominate the trade winds, these deserts are less stable than other deserts. Winter fogs, produced by upwelling cold currents, frequently blanket coastal deserts and block solar radiation. Coastal deserts are relatively complex because they are at the juncture of terrestrial, oceanic, and atmospheric systems. They are cooler than hot and semiarid deserts, with average summer temperatures ranging between 13 and 24 °C. A coastal desert may be almost totally rainless, yet damp with fog.A coastal desert, the Atacama of South America, is the Earth's driest desert (Fig. 8d). In the Atacama, measurable rainfall 1 millimeter or more of rain may occur as infrequently as once every 5-20 years. But the region can go decades without rainfall. In fact, the Atacama Desert is the driest place on Earth. Some weather stations in the Atacama have never recorded a drop of rain.

F. Polar deserts

Polar deserts are areas with annual precipitation less than 250 millimeters and a mean temperature during the warmest month of less than 10° C. Polar deserts on the Earth cover nearly 5 million square kilometers and are mostly bedrock or gravel plains. Sand dunes are not prominent features in these deserts, but snow dunes occur commonly in areas where precipitation is locally more abundant. Temperature changes in polar deserts frequently cross the freezing point of water. This "freeze thaw" alternation forms patterned textures on the ground, as much as 5 meters in diameter.Parts of the Arctic and the Antarctic are classified as deserts (Fig. 9e). These polar deserts contain great quantities of water, but most of it is locked in glaciers and ice sheets year-round. So, despite the presence of millions of litres of water, there is actually little available for plants and animals. The largest desert in the world is also the coldest. Almost the entire continent of Antarctica is a polar desert, experiencing little precipitation. Few organisms can withstand the freezing, dry climate of Antarctica.

Fig. 8(a):The Thar Desert, India (Monsoon Desert)

Fig. 8(b): The Sahara Desert, Africa
(Trade wind, Arid desert)

Fig. 8(c): The Sonoran Desert near Tucson, Arizona
(Mid Latitude, Semiarid Desert)

Fig. 8(d): Atacama Desert of Chile in South America is an example of a coastal desert

Fig. 8(e): Antarctic is an example of a cold desert

VII. INDIAN DESERTS

Cold desert region is limited to Ladakh in Himalayan Mountain while hot desert areas are spread over a large part, situated on north-western part of country. The cold desert region of Ladakh is a unique feature of cold snow covered area but this can be termed as a fringe area with characteristics different from other parts of Jammu & Kashmir state. The cold desert is limited to one district of Jammu & Kashmir state but situated in a large part of more than 70 thousand sq km of area. The remaining 36 districts are hot deserts of which 28 districts are part of the Thar Desert. Andhra Pradesh and Karnataka desert regions are shadow deserts of coastal range. The total Indian desert is spread over in 442 289 sq km situated in 37 districts wholly or partly belonging to seven states of the Indian Union. In area terms total area covered by these 37 districts is 512 503 sq km and desert regions constitute 86.30 percent of their geographical area which is evident from the concentration of deserts in interlinked zones. However the total desert land is 13.52 percent of the country's geographical area. The Great Indian Desert spreads across the state of Rajasthan and parts of Gujarat in western India covers about 200000 km2, the desert is interspersed with hillocks, gravel, salt marshes and some lakes. About 61% of the Indian Desert is in Rajasthan covering 12 districts (Singh G. et. al., 2012). The natural vegetation of this dry area is classed as Northern Tropical Thorn Forest (Champion and Seth, 1968) occurring in small clumps scattered more or less openly and composed of tree, shrubs and herbs.

Rajasthan is a single largest state having 47.20 percent of its total desert area spread over 2 districts. Three districts of Andhra Pradesh and five districts of Karnataka represent fringe deserts representing 6.22 and 5.26 percent of the total country's desert. Ladakh is a single largest district having total geographical area of 82 665 sq. km of area of which 70 300 sq. km desert containing 37 555 sq. km. The second largest desert district is Kachchh in Gujarat with 45 652 sq km and Jaisalmer ranks third with 38,401 sq km of area.

Rajasthan, Gujarat, Punjab and Haryana are part of the Great Indian Desert- Thar and possess very difficult conditions for survival of people, livestock and vegetation. Indian desert is most densely populated among the world's desert regions, which is due high density of the country's population and people inhabiting in the desert regions have no alternative except to survive in adverse climatic conditions (Chouhan and Sharma, 2009).

A. The Thar Desert

The Thar desert of Sind Province of Pakistan and Western Rajasthan region of India is a meteorologically homogeneous region where physiographic and anthropogenicconditions are somewhat comparable to the contiguous Saharan region to its West. The Aravallis range in Rajasthan defines the eastern limit of the Thar. Most spectacular amongst the land forms in West Rajasthan are the sand dunes which contribute about 40% of area of the region. The dunes are not contiguous and dune-free corridors exist. Some of the dunes are stabilized whereas others are less stable and wind erosion is a common feature from dunes to dune-free areas. The Thar region is under the influence of the Indian South-west monsoon (or summer monsoon) during July and August and occasionally rain-producing weather disturbances like 'depressions and 'lows' penetrate up to parts of Rajasthan triggering rain events in the Thar. The precious rain events in Thardesert support a large population with above average growth rate than the average growth rate of India(Sikka D.R., 1997).

Fig. 9: TheThar Desert in Rajasthan, India

The Thar Desert is one of the smallest deserts in the world, but it exhibits a wide varietyof habitats and biodiversity (Fig. 9). It is the most thickly populated deserts in the world with anaverage density of 83 persons per sq. km, whereas, in other deserts, the average is onlyseven persons per sq. km (Baqri and Kankane 2001). It is considered an important desertin terms of its location where Palaearctic, Oriental and Saharan elements of biodiversityare found. Despite its comparatively small area, the Thar Desert has a high avian diversity, from its location on the crossroads of the Palaearctic and Oriental biogeographic regions. As theThar desert is not isolated, avian endemicity is very low and most species of birds of the Tharare widely distributed.Between 250 to 300 species have been reported from the Thar desert. This variation ismainly due to the fact that some authors include Kutch, parts of Saurashtra and thewestern side of the Aravalli mountains in the Thar desert while others have more arestrictive definition of the desert that includes only nine districts of western Rajasthanand Kutch in Gujarat. Tremendous changes in the avifaunal structure of theThar desert are taking place due to the Indira Gandhi Nahar Project (IGNP) and speciesnever seen earlier are now regularly found near the canal. Due to easy availability of water everywhere, unsustainablelivestock grazing is taking place and the famous Sewan grasslands which have survivedfor hundreds of years with low grazing pressure is now under tremendous pressure. Thesegrasslands are the major habitat of the highly endangered Great Indian Bustard *Ardeotisnigriceps*, and the winter migrant Houbara or the Macqueen's Bustard *Chlamydotismacqueeni*.Other important desert species are the Cream-coloured Courser *Cursorius cursor*, GreaterHoopoe-Lark *Alaemonalaudipes*, various species of sandgrouse, raptors, wheatears,larks, pipits and munias. In the Rann of Kutch of Gujarat, both Greater *Phoenicopterusroseus*and Lesser *P. minor* flamingoes breed are seen when conditions are favorable (Chouhan and Sharma, 2009).

B. Cold Desert of the Indian Trans-Himalayas

The Indian Trans-Himalayas, also known as the Indian cold desert, support very sparse vegetation. Based on the physiognomy, three categories of natural vegetation are clearly discernible namely, Alpine Arid Scrub (AAS) or Steppe formations, Alpine Arid Pastures (AAP), and Marsh Meadows (MM). The AAS vegetation is dominated by the *Artemisia-Caragana, Hippophae- Myricaria,* and *Ephedra gerardiana* communities. The AAPs are largely dominated by graminoids while the MMs have a preponderance of sedges. The plant community structure and composition are strongly influenced by the micro topography and soil moisture. Accordingly, various habitats such as moist slopes, riverine areas, sandy plains, field borders, valley bottoms, rubble slopes, scree slopes, and marsh meadows exhibit distinct formations and communities. The characteristic species in the Trans-Himalayas are the species of *Saussurea*, *Potentilla*, *Corydalis*, *Astragalus*and *Oxytropis*. In general, the Indian Trans-Himalayas is poorer in floral diversity as compared to the moist alpine meadows of the Greater Himalayas. A small portion of the Indian Trans-Himalayas is represented in the Central Himalayas (Sikkim) which is relatively higher in terms of species diversity compared to the northwestern region. This region is characterized by low primary productivity, harsh climatic conditions, and specialized growth forms (Kachroo*et al*. 1977). The Trans-Himalayas (4,500 to 6,000 m) consisting of Ladakh in Jammu and Kashmir, Lahul-Spiti in Himachal Pradesh, and a small area of Sikkim is a part of a much larger Tibetan plateau of Tibet and China, consisting of about 2.6 million sq. km. It has high mountains, deep valleys and flat, arid plains. Many major rivers, for example, theBrahmaputra, Sutlej and Indus start from this region but much of this has internal drainage system where the rivers end in vast lakes. Such lakes and marshes, mostly saline, are important as breeding grounds for birds such as the Black-necked Crane *Grusnigricollis*, Bar-headed Goose *Anserindicus*, Great Crested Grebe *Podicepscristatus*, and others. While the flat plains provide habitat to the Tibetan Sand grouse *Syrrhaptestibetanus*, Horned Lark *Eremophilaalpestris*and various species of wheatears *Oenanthe*. The Tibetan Snowcock*Tetraogallustibetanus*and the Himalayan Snowcock *Tetraogallushimalayensis*can be seen on the treeless mountains, sometimes both the species occurring in the same area. There is no truly endemic or restricted-range bird species in this region. The Tibetan Eared Pheasant *Crossoptilonharmani*, often considered to be a subspecies of the White Eared Pheasant *Crossoptiloncrossoptilon*, is found at the edges of mixed broadleaf-coniferous forests, rhododendron, juniper and deciduous scrubs and grasslands, between 3,000 to 5,000 m. It is listed as Near Threatened (Bird Life International 2001). It is locally common and has adapted to disturbed habitats (Ali and Ripley 1987, Grimmett*et al*. 1998). Recent surveys have indicated that its population must be greater than 10,000 individuals (McGowan and Garson 1995). Where unmolested, it becomes exceedingly tame, coming to monastries in the remoteareas to be fed by Buddhist lamas, and even eating out of their hand (Ali and Ripley 1987). In India, it is found in parts of the Lohit, Siang and Subansiri districts of Arunachal Pradesh.

VIII. BIOTIC AND ABIOTIC COMPONENT OFDESERTS

A. Abiotic Component of Deserts

The non-living physical factors of the ecosystem like temperature, light, soil and water and chemical factors consisting of inorganic and organic compoundsare called as Abiotic. They also include the nutrients present in the soil and the aerial environment. The characteristic feature of the abiotic component is lack of organic matter in the soil and scarcity of water. On a smaller scale, the geomorphology with the main processes of weathering, erosion and accumulation of substrate material leads to a typical landscape pattern, where also desert types can be distinguished. One of the striking features in deserts is the salt factor (Waisel 1972; Chapman 1974).Salinization in endorrheic basins is a natural factor. Salt in small quantities is transported by rainwater and thus accumulates in arid basins. Evolution of halophytes has taken place in several arid regions, the Chenopodiaceae have one of their evolutionary centers in the Caspian and Aral Sea area. Water is a very important factor of desert. Deserts experiences scanty rainfall and also the sandy soils have very little ability to hold water. This leads to the loss of soil moisture and water may only exist in some depressions. Moreover the hot climatic conditions and prevailing winds lead to quick evaporation of the soil moisture. The dried streams builds up the drainage system called arroyo which is filled by rainfall. Arroyo travels down the mountains cutting the land and carrying deposits of rock, sand and gravel to the bottom. A wet and fertile land in a desert with vegetation is called Oasis. Water that occurs within an oasis has been drawn through groundwater base flow from distant catchments like mountains or hills. Oases supports farming practices and settlement are expected to be more because of the presence of water. Some oases may be small and can support only a few people, but others are large enough to support millions of people (Balasubramanium A, 2013).

➢ *Geomorphology of Deserts*

Deserts are mostly composed of 10-20% of sandy soils and the rest of the land is composed of boulders, gravels and mountains.The wind erosion leads to the creation of various landscapes.Mesas and buttes a common feature in deserts is created by the wind erosion. Sand drifts, Crescentic Dunes or Barchans, Loess and Longitudinal dunes and sand sheets are the notable wind-borne geomorphic features. One of the most remarkable features of desert dunes is their power of collecting all the sand from their neighborhood. For the past thousand years, Indian deserts remained unique human ecosystems as all life-forms human, animal and vegetation survived by evolving delicate and precarious relationship with the fragile ecosystems with symbolic relationship between man and environment. Most marvelous inheritance of this desert civilization is its great physio-cultural institutions andbiotechnological capacities to sustain variety of life forms (Chouhan and Sharma, 2009).

Physiography of India desert regions is quite varied in landscape, soil structure,precipitation, temperature, humidity and evaporation. This is also relevant thatformation of desert regions have distinguished conditions, which resulted into desert.There is no common factor of aridity in desert regions and even there are inter-regionalvariations in the total desert regions. Landforms with associated characteristics aregiven in Table 1. These formations are based on ecological features of landscape, soiltypes, slopes, availability of water and natural vegetation etc.

S. No.	Landform	Major Shaping Force	Soils	Dominant plant	Adaptive character
1.	Mountains and Hills	Chemical and physical	Exposed bed rock	Anogeissumlatifolia, Acacia Senegal, CompiphoraWightii	Regions with rainfall less than 25 cm
2.	Upper piedmont zone	Water erosion	Sandy loam	Salvadoraoleoides, Capparisdeciduas, Acacia Senegal (sparse)	Evergreen shrubs with low diffuse roots
3.	Lower piedmont merging with plains	Water erosion	Sandy loam to loamy sand	Acacia Arabica, Prosopiscpicigera, Salvadoraoleoides, Acacia Senegal, Capparisdeciduas (rainfall less than 25 cm)	Evergreen with deep tap root. Evergreen tree and shrub.
4.	Depression (saline)	Water deposition	Clay loam	Salvadorapersica, Tamarixdioica, Halophytic succulents	No vegetation when salinity is high.
5.	Water courses	Water erosion	Coarse sand	Acacia Arabica, Salvadoraoleoides	Deep Tap root.
6.	Depression (non-saline)	Water deposition	Clay loam	Acacia Arabica	Deep Tap root.
7.	Sandy plains	Wind erosion and deposition	Wind deposited sand	Prosopis cineraria, Capparis decidua.	Deep Tap root.
8.	Sand Dunes	Wind deposition	Fine sand	Calligonumpolygonoides.	Deep Tap and shallow side roots.
9.	Inter Dunes	Water deposition	Clay loam covered with sand	CapparisHaloxylon	Deep Tap root.
10.	Flood plains (old)	Water deposition	Clay loam	Saloxylonsalicornicum and H. recurvum	Deep Tap root.

Table 1: Landforms with associated characteristics

Source: Indian Desert: Resources and Potential Development (1994).

➢ *Soils in Deserts*

Stand structure is known to interact with growth, survival, density, and spatial patterns to influence competition and demographic changes in a population (Huston and DeAngelis, 1987; Weiner and Damgaard, 2006). To a certain extent, stand structure determines habitat and species diversity and can be quantified to assess habitat quality for conservation purposes (Pommerening, 2002; Skov and Svenning, 2003). Thus, to understand plant communities, one needs to study the dynamic aspects of their stand structures (Harper, 1977; Mcintire and Fajardo, 2009), and these have rarely been documented for desert plants. Spatial patterns of plants also are important characteristics of vegetation, and can play a significant role in ecological processes including competitive coexistence and transmission of mortality, and can have impacts that scale up to ecosystem–level processes (Alekseev and Zherebtsov, 1995; Arévalo and Fernández-Palacio, 2003). However, many factors play important roles in determining the spatial patterns of tree species distribution in a plant community. In general, biotic and abiotic factors may influence the distribution of species, and potentially control their abundance and promote coexistence (Zhang et al., 2010). Thus, some ecologists worked intensively to looking for the particular adaptations of each species to abiotic factors or for the complexity of species interactions (Hardy and Sonké, 2004), and has also successfully demonstrated that each species is restricted to a more or less wide range of habitats (Zhang et al., 2010). Furthermore, many species also exhibited ecological habitat preferences, although species numbers and associations are different among sites (Bazzaz, 1991). In addition, theoretical models also confirmed the coexistence of plant species based on habitat heterogeneity (Wang M. et. al. 2016).

Soil biodiversity has an important influence on soil properties andprocesses thataffect plant productivityand environment regulatorv functions (Sctala 1990). Soil organisms, in close interaction with each other and their environment, are responsible for decomposition of organic matter andsometimes act as biological regulators in nutrient cvcling(Anderson et.al.1985).Soil faunal affect soil physical properties through mixing,ingestingand soil turnover (Lavelle et al. 1992), chemical properties through mineralization and microbial activity (Abbadic&Lepage, 1987) and biological properties throughorganic matter dynamics and turnover of biomass carbon(Woomer& Swift,1994).

Soils in desert regions are generally fertile but lack soil moisture to encourage plant growth. A discussion of the role of the soil in arid ecosystems is inseparable from a discussion of the ecosystem water balance and its dynamics. The edaphic factors often so prominent in arid zones operate almost always by modification of the regime. The soil acts as: (a) a temporary store for the precipitation input, its use by organisms; (b) a regulator controlling the partition of this input the major outflows: runoff, drainage, evaporation, and uptake transpiration, the latter (biologically active) flow between different organisms. Some aspects of these flows relevant in deserts are considered in order of time lag after a rain event. Most of the water input (rain + runon) at any point either infiltrates the soil or runs off the surface within minutes to hours. Interception by plants causes only minor evaporative losses in arid zones (due to low cover), but may, in conjunction with stemflow, create marked patterns of soil wetting under and around shrubs and trees (Qashu H.K,1972;Slatyer, R.O., 1967). Surface storage for more than a few hours occurs in deserts only in low sites receiving runon, with low-permeability soils. Runoff from sandy and stony surfaces is usually lower than from clayey and silty ones, particularly if the latter are crust-forming (Evenari et. al., 1971). Cover of dead and living vegetation usually increases infiltration in arid zones (Tadmor and Shanan, 1969) by reducing rain impact and probably some physical or chemical modifications of the surface catchment. Even in a rain event producing no channel flow, runoff from some areas (sources) may become runon to others (sinks) and infiltrate there. The infiltration input at any point may be much lower or higher than precipitation, depending on position in the landscape, surface properties, and vegetation. The ensuing spatial variation in soil moisture has significant effects on diversity and production in arid zone. Therefore, in coarse-textured soils more water is generally lost by drainage (deep percolation) beyond the root zone. However, it is characteristic of the water balance in arid zones that the depth of wetting by prevalent rains is normally not greater than maximal rooting depth. Hence all soil moisture is evaporated or transpired, and layers beyond that depth are permanently dry (Walter H., 1964;Hillel and Tadmor, 1962). Substantial drainage and groundwater recharge flows occur mostly in runon areas and channels and in unvegetated deep-wetting soils (e.g. dunes).

- *Wind movement in deserts*

Wind can transport silt and clay size grains as suspended load. Sand and larger grains are transported as bedload. Larger grains slide or roll, but sand grains generally move by saltation, intermittent bouncing or hopping. Saltating grains seldom rise more than a meter above the surface (Chernicoff& Whitney 2002) .Wind is turbulent fluid and transports sediment in much the same way as running water. Particles are transported by winds through suspension, saltation, and creep. Small particles may be held in the atmosphere in suspension. Upward currents of air support the weight of suspended particles and hold them indefinitely in the surrounding air. Typical winds near the Earth's surface suspend particles less than 0.2 millimeters in diameter and scatter them aloft as dust or haze (Fig. 10).

Saltation is downwind movement of particles in a series of jumps or skips. Saltation normally lifts sand-size particles no more than one centimeter above the ground, and proceeds at one-half to one-third the speed of the wind.

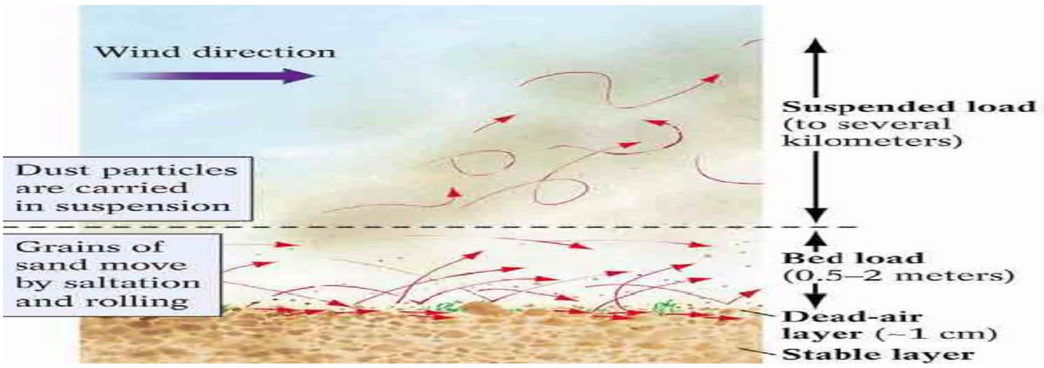

Fig. 10: Wind Transport

A saltating grain may hit other grains that jump up to continue the saltation. The gram may also hit larger grains that are too heavy to hop, but that slowly creep forward as they are pushed by saltating grains (Fig. 11). Surface creep accounts for as much as 25 percent of grain movement in a desert. Eolian turbidity currents are better known as dust storms. Air over deserts is cooled significantly when rain passes through it. This cooler and denser air sinks toward the desert surface. When it reaches the ground, the air is deflected forward and sweeps up surface debris in its turbulence as a dust storm Most of the dust carried by dust storms is in the form of silt-size particles. Deposits of this windblown silt are known as loess. The thickest known deposit of loess, 335 meters, is on the Loess Plateau in China. In Europe and in the Americas, accumulations of loess are generally from 20 to 30 meters thick. Small whirlwinds, called dust devils, are common in arid lands and are thought to be related to very intense local heating of the air that results in instabilities of the air mass. Dust devils may be as much as one kilometer high. (A.S. Walker, 1992).

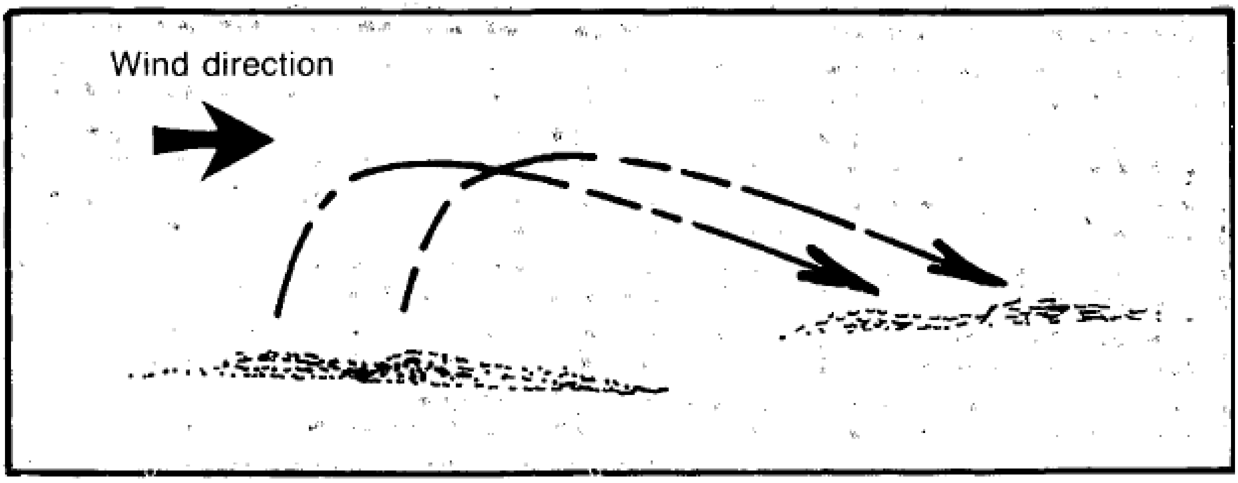

Fig. 11: Saltation moves small particles in the direction of the wind in a series of short hops or skips

The movement of wind in deserts erode, transport and deposit the sand particles. Deflation a kind of Wind Erosion is a process by which loose sediments are removed by the action of wind. The sand and silt sized material will be moved first. The larger sized materialis generally left behind. Deflation creates its own types of landforms. The deflation landforms are Blowouts, these are shallow depressions formed by removal of sediment. Their diameters range from a few meters to 1000 meters.

B. Desert Biota (Flora and Fauna)

The desert biome comprises a variety of complex ecosystems with diverse and fragile groupings of sometimes bizarre plants, animals and fungi and little studied members of the Protista and Monera. The biomes may be influenced by their positions in coastal, inland or rain shadow deserts (Ezcurra 2006). Key characteristics of the biota are their adaptations to aridity, climate variability, scant summer and winter rainfall patterns and, most importantly, unpredictable rainfall pulses. Some elements of the desert biota escape from the desert environment while others tolerate it (Louw and Seely 1982). The most important factors that affect life in the desert biomes include radiation, heat and temperature, wind, water and nutrition. The radiant environment to which organisms in the desert environment are exposed is complex including, inter alia, direct solar radiation, diffuse radiation from clouds and the atmosphere, and considerable short wave radiation reflected from the soil's surface and other objects. The heat to which a desert organism is exposed comes not only from solar radiation but includes metabolic heat production, radiant heat transfer, conduction, convection and evaporative heat exchange, all of which are exacerbated in the desert environment. Wind and the role of limited water in the water balance of the organisms are also important influencing factors, together with nutritional stress. Those plants and animals which survive in the harsh and unpredictable conditions in desert environments require an array of adaptations responding to the complex habitats in which they live. The adaptations fostering tolerance may take the form of morphological, physiological or behavioural adaptations but most commonly some combination of the three. Most plants and animals survive in the desert because they have adapted their life to avoid the most extreme of desert conditions. The general conception about desert, being uninhabited wasteland is not true. Despite such harsh living conditions, desert ecosystem exhibits a spectacular biological diversity. A large number of plant and animal species thrive in the deserts due to their morphological, anatomical, physiological and behavioral adaptations. This ecosystem which covers 14 percent of earths land surface is actually reservoir of rich and diverse flora and fauna.

➢ *Adaptations of Flora in Desert Ecosystems:*

Low soil water avaibility is often one of the main factors limiting plant productivity (Honeysett et al., 1992). Lack of soil nutrient elements particularly nitrogen (N) and phosphorous (P), is another constraint affecting plant productivity in dry areas (Gutierrez Boem& Thomas, 1999, Singh and Bhati, 2004). Plants have evolved many adaptions for surviving the rigors of the desert. Ephemerality and micro-climate exploitation are found in many desert plants. There are three life-forms of plants that are adapted to desert ecosystem: a) ephemeral annuals, b) succulents, and c) desert shrubs.

- **Ephemeral annuals** are also called as 'drought evaders' or 'drought escapers'. They germinate, grow, flower, and release seeds within the brief period (6-8 weeks) when water is available and temperatures are warm. The seeds remain dormant, resisting drought and heat, until the following spring. Seeds wait out adverse environmental conditions, sometimes for decades, and will germinate and grow only when specific requirements are met. With their small size and large shoots in relation to roots, they are well adapted to dry habitats. They escape dryness in both external and internal environments. Desert sunflower and desert marigold complete their life cycles during brief rainy seasons.
- **The succulent plants** suffer from dryness in only external environment. Their succulent, fleshy stems, leaves and roots serve as water storage organs (water storage region is present in these organs) which accumulate large amount of water during brief rainy seasons. Opuntia, Aloe, Euphorbia, Yucca and Agave have mastered the art of enduring in the desert ecosystem by economizing in their expenditures of moisture.

They rely on their waxy coatings, spongy stem and/or leaf tissues, root structures and their night time stomata openings to carefully regulate their water use. At night the temperatures are lower and humidity higher than during the day, so less water is lost through transpiration. Such plants are sometimes called "drought endures". In *Opuntia spp.* (Cactus), the stem modified into a thick, fleshy, green, life-like structure called phylloclade which manufacture food by photosynthesis and conserve water. Their leaves modified into spines which retard transpiration, promote dew formation at their tips, protect from insolation and from thirsty animals. The bulk of the tissue consists of large, round, pitted, parenchymatous water-storing cells. The cell sap is mucilaginous which helps in checking evaporation of water. The extensive shallow root systems are usually radial, allowing for the quick acquisition of large quantities of water during the rainy period.

The leaves are fleshy in *Aloe spp.* with marginal spines and a large water-storing tissue. The succulent *Euphorbia spp.* has succulent stem which store large quantities of water during rainy season. It contains toxic milky latex that irritates skin and eyes. The stipules become modified into spines. The toxic substances and spines prevent them from predator animals. The Century plant (*Agave spp.*) has saw-toothed leaves with waxy coatings that render them nearly waterproof and so prevents loss of water.

The leaves of these plants channel rain water to the plant's base. It also contains toxic chemicals like oxalate crystals and irritating substances that can irritate the skin and mucous membranes and can cause digestive problems in their predator animals. The Joshua tree (*Yucca spp.*) is a very tough plant. The leaves are stiff and very pointed. The roots become fleshy to store water in *Asparagus spp.*

- **The shrub in desert** ecosystem or non-succulent perennials suffers from dryness both in their internal as well as external environments. Their morphological and physiological features include rapid elongation and extensive root system, high osmotic pressure and endurance of desiccation, ability to reduce transpiration and reduction in size of leaf blade. Root system is very extensive i.e. more than 30 m long (*Alfalfa spp*.) to siphon deep groundwater supplies.

There is waxy coating and sunken type of stomata on leaves, which reduces loss of water during transpiration. Desert grasses have rolled and folded leaves so that the sunken stomata become hidden to minimize the rates of transpiration. In desert ecosystem, individual plants are scattered thinly with large bare areas in between. These spacing reduces competition for a scarce resource; otherwise intense competition for water might result in the death or stunting of all of the plants.

The grasses (bunchgrass) in desert ecosystem also grow in isolated tufts. During extremely hot and dry period, the parts of the plants that are above the land may wither and die, but the root systems remain alive. Desert mariposa and desert lily have bulbs that may remain dormant for several years until a deep soaking rain awakens them. The extensive bare ground in desert ecosystem is not necessarily free of plants. Mosses, algae, and lichens may be present which form a stabilizing crust on sands and soils (Goudie and Seely, 2011).

- *Adaptations of Fauna in Desert Ecosystems*

Animals of desert ecosystem are much more affected by extremes of temperature than desert plants because the biological processes of animal tissue function properly within a relatively narrow temperature range. Thus, most of the animals in desert ecosystem rely on their behavioural, physiological and structural adaptations to avoid the desert heat and dryness. Deserts have relatively high diversity with respect to reptiles and invertebrates and sometimes to succulent plants. Scorpions and camel spiders (solpugids) are more species-rich in deserts than in other habitats and along with spiders and acarines (mites and ticks) are particularly successful in deserts. Depending on the definition of the desert area, the degree of endemism of invertebrates, reptiles and some plants can be high. In most desert areas the invertebrates are not well known and their degree of endemicity may be higher than estimated. Protection of seemingly barren desert areas for their undiscovered endemic plants and animals could be expected to yield valuable results.Animal adaptations to life in deserts are as varied as those of plants and often act in concert. Mobile animals may move out of the desert completely during dry times while others may take refuge in burrows or simply beneath the sand. Side-winding behaviour has evolved in several deserts as a way to traverse warm surfaces. Animals with four legs may raise themselves above the hot ground and bipedalism allows rapid traverses at greater distances from the surface. Tails, ears, feathers or different coloured pelage may be deliberately used to warm or cool by different animals at different times of their daily cycle. The adaptations to maintain water balance range from ability to drink large quantities of water at one time to absorbing water through the skin or rectal pads as found in some insects. Taking up water from food, reducing water loss, tolerating dehydration, facultative hypothermia, and dormancy are all used individually or in combination as part of the diverse array of adaptations to maintain water balance.

Darkling beetle is the common name of the large family of beetles. Tenebrionid beetles occupy ecological niches in mainly deserts and forests as plant scavengers. Most species are generalistic omnivores, and feed on decaying leaves, rotting wood, fresh plant matter, dead insects, and fungi as larvae and adults. Several genera, including Bolitotherus, are specialized fungivores which feed on polypores. Many of the larger species are flightless, and those that are capable, such as T. molitor, only do so when necessary, such as when dispersing or malnourished(Bouchard P. at. Al., 2005).Solifugae is an order of animals in the class Arachnida known variously as camel spiders(also known as a "Joel Burke"), wind scorpions, sun spiders, or solifuges. Solifugae are moderately small to large arachnids (a few millimeters to several centimeters in body length), with the larger species reaching 12–15 cm (5–6 in) in length, including legs. Acantho proct us diad ematus posses three proximal tarsal pads (euplantulae) having a nubby surface, whereas the most distal euplantula is rather smooth with a hexagonal ground pattern resembling. A. diadematus attaches its nubby euplantulae less often, compared to situations in which the animal is hanging upright or head down on a vertical plate.Chameleons possess a host of physical adaptations which help them survive. Their hooded heads help them collect water in the form of dew and to also impress mates. Swiveling eyes help them pinpoint fast-moving prey. Color-changing skin helps them blend in, stand out to potential mates and intimidate rivals. Their horizontal feet help them grip branches to keep from falling and to hold fast against predators that may try to carry them off.

The drought evader animals adopt either a short annual life cycle that revolve around the scanty rains or undergo aestivation (e.g. ground squirrel). During aestivation, the breathing, heartbeat and other body activities slowdown, this in turn decreases the need of water. Many lay eggs that survive until the next rains when they hatch in the transient puddles. On the onset of rains, a variety of animal like grasshoppers, butterflies, bees, beetles, and spider's and more may be seen in the desert ecosystem. Amphibians like spade foot toad dig burrow with the help of its spade-like feet and goes to sleep till the rains arrive. It can undergo aestivation for 8-10 months. The birds make nest and reproduce during the rainy season when there is abundant food.

The drought resistant animals are active and carry their normal function throughout the year. They circumvent aridity and heat through morphological and physiological adaptations or by modifying their feeding and activity patterns. They remain in cool, humid underground burrows during the day time and search for food only at night when temperatures are lower.

Some xerocole rodents of desert ecosystem, that are active in the day periodically seek burrows and passively lose heat through conduction by pressing their bodies against the burrow walls. The desert toad uses a survival strategy similar to that employed by succulent plants. It stores water in its urinary bladder. The reptiles and some insects are pre-adapted to the hot desert ecosystem. They excrete a dry metabolic waste product in the form of uric acid and guanine so that water loss is minimal. They have thick waterproof skin that also minimizes water loss.

Desert spiders, mites and insects secrete a waxy layer over their cuticles. Wax is impermeable to water thus prevents loss of water from their bodies. Mammals as a group are not well adapted to desert life because they excrete urea, which involves the loss of much water.

Most of the mammals of desert ecosystem, like kangaroo rat, the pocket mouse and the jerboa have adapted nocturnal habitat. They seal their burrows by day to keep their chamber moist, and can live throughout year without drinking water. They feed on dry seeds and dry plants even when succulent green plants are available. They remain in burrows during the day, and conserve water by excreting very concentrated urine and by hygroscopic water in their food. Thus, adaptation to the desert ecosystem by these rodents is as much behavioural as physiological. Other desert ecosystem mammals like mule, deer and elk avoid the extreme temperatures of the day by limiting activity hours to dawn and dusk. The wood rats survive in parts of the desert by eating dry food as well as succulent cacti or other plants that store water. Jackrabbits and kit fox have large ears that reduce the need of water evaporation to regulate the body temperature. Their ears release heat during their resting periods in a cool, shady place.

The camel in the desert ecosystem can go for long periods without water because their body tissues can tolerate elevation in body temperature and a degree of dehydration. However, it uses water for temperature regulation. The body temperature of camel drops to 33.8ºC over night and rising to 40.6ºC by day when the animal begins to sweat.

Opposed to popular belief, camels do not store water in their hump. Their hump stores fat which yields water after its metabolic oxidation. The kangaroo rat and jerboa have long legs, which help them in jumping and swift running as well as in lifting the body above the ground and thus reducing direct contact with the hot sand.

Desert Gerbils have hairy soles on their feet which allow them excellent traction on sand. The sand rat feeds on plants that have very salty sap which can be toxic in large quantities. Thus, rats simply retain the water and excrete urine that is about four times as salty as sea water. The desert birds utilize a salt gland to help in the maintenance of water balance. They occasionally drink water from dew or other sources.

Thus, these unique natural habitats (desert) with their incredibly diverse flora and fauna have been home to some of the world's oldest civilizations. Besides, we should always remember that the desert is easily damaged and is very, very slow to recover. Thus, fragile beauty and unique heritage of world's deserts deserve protection.

IX. PEOPLE LIVELIHOOD IN DESERTS

People have lived in and around deserts sincetime immemorial where their activities and use ofnatural resources have been, and are, governed bythe basic parameters defining all deserts. Rainfall,essential for growth and reproduction of plantsand animals, for grazing and for agriculture, is acentral factor. High temperatures and strong windsalso influence people's use of deserts. Adaptationsof people to these elements are different, mainlyin degree but not in kind, from those of otheranimals and of plants. People have relatively fewmorphological and physiological adaptations with apredominance of behavioural, cultural andtechnological adaptations. People have used a variety of approaches to live in deserts andcontinue unusual innovations.Humans, unlike manylarge mammals, do not pant in response to heat.Instead, humans sweat profusely and no otheranimal sweats as efficiently to support evaporativecooling.Surprisingly,many people under hot conditions undergoconsiderable dehydration before drinking to replacelost body fluids. Heat stress, from increased bodytemperatures exacerbated by dehydration, mayrange

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from temporary loss of consciousness tostoppage of sweating, circulatory failure and death.Overall, key factors supporting humans in desertsare an adequate supply of water and shelter fromthe sun's direct rays.

Meagre physiological adaptations of people todeserts are more than adequately augmentedby behavioural, cultural and technologicaladaptations. People are able to thrive in desertsimply by modifying their micro-environment. Thesemodifications range from using natural shelters, forexample caves or shade trees, to using appropriateclothing, to construction of dwellings and use of airconditioning. Behavioural, cultural and technological adaptations have evolved to ensure adequate food,water and shelter. The result of these adaptationshas led to three major inter-related livelihoods: hunting and gathering, domestic livestock herding, and irrigated agriculture. While all these lifestyles arebeing practiced today, most have been extensivelyaltered by modern technology.Diet presents another aspect for consideration inhot deserts although basic requirements for highqualityprotein, vitamins, minerals and sufficientenergy naturally apply (Louw and Seely 1982).

Adequate water intake is of primary importanceand, contrary to popular opinion, the normal amountof salt used for flavouring meals is sufficient. Veryhigh protein intakes are undesirable. If present insufficient quantities, the traditional diet of West Asia,based on low-protein cereal grains and protein-richleguminous seeds and featuring tea and coffee whileexcluding alcohol, fulfils most theoretical criteria foran appropriate diet in deserts.Heat and aridity also are important in terms ofhousing. The physical principles governing the designof permanent desert dwellings are well-known.Thick walls and small windows protect from theday's heat but do not allow for cool air circulation inthe often still night hours. In many areas, this leadsto people sleeping outdoors or on the roof.

A. Desert Dwellers: Resource Use and Management

The early inhabitants of deserts used desert resources in an injudiciousway by excessive hunting and gathering. In deserts itwould have meant having the essential knowledge and being well attuned to variable rainfall andthe resultant growth patterns and behaviour ofplants and animals, as well as to replenish ephemeral water sources. Certainly as far backas when *Homo erectus* occupied dry areas, it isthought that they used deserts on an intermittentbasis when productivity was high (Shackley 1980).Desert suggests that resource use is anequilibrial or density-dependent system making useof key resource locations with reliable water duringthe dry season, within a wider area of ephemeralresources, would provide a better explanation.A key resource essential for most groups of huntergatherersliving in deserts is the presence of at leastone tree-borne fruit that serves as a staple and iscapable of long storage. This wouldbe combined with grains, beans, roots and fruits,supplemented by small amounts of animal protein.Hunting and gathering may have been the onlyway of life known to people when they firstoccupied deserts, even intermittently. With the slowevolution of use of domestic crops and animals,the livelihoods of hunter-gatherers took on aspectsof herding and agriculture in varying proportions. In the rapidly developing world of the 21st century,hunter-gatherers necessarily undertake mixedstrategies of resource use while trying not to losetheir rich resource base.Population constraints within deserts, imposed bychanging climates and agricultural developments,have caused wide fluctuations in the numbersof desert inhabitants (Reader 1997). With theexpansion of technologies supporting people tolive in deserts, the degree of fluctuation may bereduced. Nevertheless, institutions focused onresource management, as required for successfulhunting and gathering, nomadism, transhumanceand oasis agriculture, will undoubtedly play a large,although altered, role in future desert development(Seely M., 2004).

B. Occupation

- *Pastoralists*

Pastoralism refers to a livelihood approachthat makes use of domesticated animalsfor example, sheep, goats, cattle, camelsto provide a variety of products such as milk,skins, cash and occasionally, meat.Pastoralism evolved predominantly in Asian andAfrican arid lands where most livestock weredomesticated. Domestication is thought to havebeen undertaken by sedentary farmers rather thanhunters, as they would have had the capacityto corral animals for extended periods (Channell, 1999). Camels, the only livestock domesticatedin hyper-arid deserts, are physiologically ableto withstand desert conditions as they tolerateelevated body temperatures, are able to minimisewater loss and reduce heat gain from theenvironment. They areable to tolerate water loss of more than 25 percent of their body weight and can replace thiswithin three minutes.Other domestic animals are less well-adaptedto deserts physiologically, but are neverthelessimportant for desert pastoralists. Sheep and goatsrepresent the smaller, more tradable and expendableanimals in southern African deserts, while cattlehave greater associated prestige. Cattle (zebu intheir humps), camels (in their humps) and sheep (intheir tails) have concentrated fat deposits that storeenergy to carry them through times of limited pasture,but which do not hinder temperature regulation.Mobility is a key to successful pastoralism indeserts as much as it is important for huntergatherers.Early herders followed rainfall and thevariable grasslands that would appear in someareas in some years (Henschel J.R. et. Al., 2005). In some instances early herdersharvested and ground natural grass grains aspart of their resource base.While hunter-gatherers used reliable waterholes asperiodic dry season gathering points, pastoralistswith their herds spent dry periods in smalldispersed camps. After good rains, pastoralistsand their herds would aggregate wherever patchyrain provided good grazing (Kinahan 2005).Today, pastoralists do not necessarily live in desertsbut continue to herd their animals there to providevaluable products for urban consumption. Camelsare being replaced by cattle with their bettermarket value, and four-wheel drive vehicles providetransport (Smith 1994).

➢ *Irrigated Agriculture*

Agriculture has been important to people in desertssince domestication of crops began. Rain-fedagriculture is less important in deserts than inhigher rainfall areas because of the scarcity andunpredictability of rain; alternative systems began as attempts to reduce risks imposed by rainfallvariation. Irrigated agriculture has evolved indifferent ways in different places based on differentsituations and crops available. Small-scale rainfall harvesting in deserts hasbeen adapted to specific types of terrain, climateconditions and choice of crop (Lövenstein 1994).None of these approaches lend themselves to largescale, mechanised farming, but have providedabundant agricultural products for desert people.The terrace system was probably one of theearliest irrigation systems involving a series of stonewalls across a water course. With rain, the terracedfields would fill up and excess water cascadedonto fields below.

"Oasis" has become a metaphor for refuge, and many oases in the desert are just this: welcome shade and security in ablisteringly hot and dangerous environment.Some of the ancient hydraulic systems that harvest wateronto oases still astonish. The *qanat*, *foggara*, *karez*or*falaj*system leads water, from deep in an alluvial fan in a mountainbasin, down a gently sloping tunnel to an oasis. The wateris found with a well, sometimes hundreds of meters deep,and the tunnel from it is marked on the surface by a lineof maybe hundreds of other wells for ventilating the welldiggers and getting rid of their spoil. Other oases are fed by springs or mountain streams which are led into channels; some hackedout of the sides of gorges, others taken over small aqueducts.Oases produce many types of crop, the most common being dates, other tree-crops like mangoes, vegetables, cereals like wheat and themore salt-tolerant barley, and fodder crops like alfalfa. Many local varieties of all these crops havebeen developed to suit local conditions (Moore K.M. et. al., 1994).

Hunting and gathering, pastoralism and irrigatedagriculture all advanced, at different rates anddifferent times, with different innovations. Basketsand pottery for transporting food and other goodsallowed people to gather and carry more food andother materials. Deserts have always been a part ofthe global environment with desert peoples tradingwithin deserts and with neighbouring cultures(Seely M., 2004).

X. MINING ACTIVITIES IN DESERTS

Continuous expansion of mining activities are creating herculean problems of disposal of large volume of debris coming out after working in the mine areas and creating various ecological hazards with varying magnitude in vertical dumpings. No doubt, mining of these minerals are important not only for the local and national economy but also for the development of industry as well but extraction of these minerals is bringing about superimposition of natural fertile soil by inactive and infertile materials (Taberima et al., 2010). Although, the land under mining operations occupies a very small area in comparison to the total geographical area of the country, but hazardous activities start right from clear felling of vegetation for mining and allied activities which accentuate as the operations increase in intensity. The impact of physical disturbances to the top soil during stripping, stockpilling and reinstatements results in soil degradation by reduced soil structure, accelerated soil erosion, excessive leaching, compaction, reduction in soil pH, accumulation of heavy metals in the soils depending upon mining types, depletion of soil organic matter, reduction in soil available nutrients, decrease in cation exchange capacity, lowering of microbial activities and corresponding decrease in soil fertility and productivity (Hu et al., 2012; Mensah, 2015).

XI. BENEFITS AND USES OF DESERTS

Deserts have not only supported and continueto support a variety of livelihoods; they havecontributedextensively to global culture, traditionaland modern. In a different sphere, camping, hiking, fishingand hunting are all popular in deserts amongthose seeking sunshine, warm weather, unusuallandscapes and interesting plants and animals.For the same reasons, however, and encouragedby sparse vegetation cover, off-road vehicle use isalso very popular in deserts (Lacher 1999). Use ofdune buggies, dirt bikes, quad bikes and ordinaryvehicles produces noise, disturbs wildlife anddestroys the soil surface and vegetation. Disruptionof soil surface can lead to increased wind andwater erosion, loss of organic material andcompaction of soil which reduces water infiltration.Archaeological sites are particularly prone todestruction. On the gypsum plains of the coastalNamib desert, the rich lichen cover is eliminated bya single passage of an off-road vehicle and tracksremain visible for decades if not centuries (Seely2004).The conservation of desert areas has had achequered history and faces an unsure future.Deserts are often viewed as wastelands,uninteresting and useful for little more than perhapsprospecting and mining or military testing.Meanwhile, diamond,uranium and copper mines together with extensiveprospecting and army activity left their indeliblemark on the desert landscape.Conservation of deserts has gone hand-in-handwith desert tourism. Desert movies, desert booksand other awareness-raising media have contributedto the tourism drive. However, desert tourism canbe seen on a continuum with desert recreation andthe mix is not always a happy one. Nevertheless,tourism is growing and expected to be the mainmeans of generating income in many desert areas ofthe world.Thepotential for tourism growth, in terms of quality ofexperience and number of attractions and peopleexperiencing these options, is huge.Energy is another abundant key resource essential for moderndevelopment and it is present in deserts,again almost by definition, in great abundance. Till date, developers in deserts have largely ignoredthe abundant solar energy available and relied onincreasingly expensive traditional sources of energy,like water, often brought from great distances, orotherwise on polluting the clear desert atmosphere a mainreason people come to the desertenvironment in the first place. Abundant solarenergy could contribute to development not only ofdeserts but the entire globe (Seely M. et. al., 2004).

XII. MONITORING OF DESERTIFICATION BY REMOTE SENSING

Remote sensing is commonly introduced as the science to collect informationabout objects without coming into physical contact with them; in Earthobservation, the most important medium to transmit this information iselectromagnetic radiation in the optical and microwave region. Remote sensing systems exhibit a large variety of spectral, spatialand temporal parameters (Kramer 1996), and it depends on the user requirements which system is to be used. It is widely agreed that environmental change in arid, semiarid and dry subhumidecosystems is not necessarily driven by climatological variables but triggered byprocesses which result from adverse human impact (Mainguet 1994). Traditionally, albedo and vegetation cover have been considered themost important remotely sensed indicator variables to characterize the state ofecosystems under the threat of global environmental change. More recently,however, the awareness has grown that more specific information on surfaceproperties is required to understand processes on local to regional scales (Hill and Peter 1996). Vegetation attributes are usually described by structure, dynamics andtaxonomic composition, of which taxonomy is the least important of the three.However, since arid or semiarid ecosystems are dominated by sparsevegetation, the key issue is to obtain accurate estimates of vegetation abundancewhich are not biased by the spectral contribution of background components (i.e.litter and substrate). At the same time, the soil surface itself should be as much anobject of attention as is the vegetation. At the desert fringe, which is characterizedthrough an enormous inter-annual variability in rainfall rather than long-termaverages, specific surface properties with implications for water concentration,infiltration and leaching are becoming primary indicators for assessing ecosystemconditions. Soil texture, in particular, is one of the most important factors for thewater balance as it controls infiltration and the capillary rise of water. Infine-textured (i.e. loamy) soils, rainfall can hardly infiltrate and is thereforesubject to rapid and substantial evaporative losses. More coarsely textured soils (e.g. sandy or stony substrates) permit water to rapidly infiltrate into greater depthwhere it is well protected against evaporation after the topsoil layer dries out;additionally, almost all infiltrated water is readily available to plants, and saltconcentrations in the soil remain low due to the higher leaching efficiency.Relationships between climate and environmental conditions, which may be ofprimary importance at a global scale, thus become problematic when local factorssuch as topography, lithology and soil properties determine the redistribution ofwater available for plant growth (Yair 1994, Breckle S. W., Pg. 244).

FAO and UNEP launched a Desertification Assessment and Mapping project in 1979, in association with Unesco, the World Meteorological Organization (WMO) and the International Society of Soil Science (ISSS). The objective was to provide more reliable data on the rate and risk of desertification activities at national and regional levels, as a basis for international action. A provisional methodology was compiled and subsequently tested in nine countries.In cooperation with WMO and UNEP, FAO and Unesco prepared a world map of desertification to delineate deserts and those areas, mainly on the fringes of deserts, which risk desertification. The map, presented to the United Nations Conference on Desertification (1977), provides a preliminary synthesis of the available cartographic information on desertification on a global basis. It locates homogeneous areas and representative sites for monitoring and conservation and development programmes, and serves as a framework for more detailed surveys in selected areas. Data on the extent of desertification, by continent and by bioclimatic zone, are shown in Table2.

Degree of Desertification risk	**South America**		**North and Central**		**Africa**		**Asia**		**Australia**		**Europe**	
	km²	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**
Very high	414195	2.3	163191	0.7	1725165	5.7	790312	1.8	307732	4.0	48957	0.5
High	1261235	7.1	1312524	5.4	4910503	16.2	7253464	16.5	1722056	22.4	-	-
Moderate	1602383	9.0	2854293	11.8	3740966	12.3	5607563	12.8	3712213	48.3	189612	1.8
Extreme desert	200492	1.1	32638	0.16	177956	20.4	1580624	3.6	-	-	-	-

Table 2: Area of regions affected by or in danger of desertification

Source: FAO/Unesco/WMO. World Map of Desertification,1977

XIII. COMBATING DESERTIFICATION

A. Sand dune Stabilization

The consequences of sand movement on the morphodynamics of sand dune and its rehabilitation have long been recognized (Wolle And Nickling, 1993). Sand dune stabilization is based on an understanding of edaphic and climatic characteristics of bare dune and the semi-stabilized dune system. In India,the total area affected bysand drift is estimated at 88,078 km^2(Kaul, 1996). The major causes for such sand drift are overgrazing,faulty agricultural practices and the destruction of natural vegetation on dune and the sandy plains. High human and livestock populations in the desert are leading to the mismanagement of the sandy terrain causing reactivation and land degradation resulting from sand movement (Gupta el al., 1981) and encroachment upon,productiveagricultural fields, human habitation, canal road and railway tracks. Thus, it is necessary to stabilize the moving sand to control the menace of sand drift (Singh and Rathod, 2001).Effective surface vegetation could beachieved through regeneration of existing vegetation or byestablishing suitable vegetation (Fang & Peng 1997).However, dry soil in summer and low temperature in winterare risk factors in seedling survival and revegetation efforts(Myers et al. 2000; Duchesneau et al. 2001). Neighbourspecies can ameliorate the microclimate and can enhance thechances of survival and growth performance of the regeneratedseedlings (Callaway & Walker 1997; Senbeta&Teketay2001) and therefore help to produce better surface vegetationand control sand drift.Therefore, it is importantto determine suitable combinations of adult neighbours andsurface vegetation that facilitate regeneration for effectivecontrol of sand drift in Indian desert.

B. Role of forestry in combating desertification

The loss of productive land to desertification is widespreadand increasing. The arid regions of India are characterized by low rainfall, high evapo-transpiration, high temperature and desiccating wind velocity. Water deficit for most of the year, recurrent drought and deteriorating oil properties result in poor vegetationcover, most of which confined to the rainy season of July-September only. Over-exploitation of existing vegetation further aggravates the problem of landdegradation and supply of fuel and fodder in the arid area. The options to improve the productivityof the areaincludeprotectionofthe natural vegetation and planting oflocallyimportantspecies to control further degradation and fulfill the requirement of fuel and fodder for the rural. Further, low rainfall receivedduring rainy season induces the growth of surface vegetation, which generally competes for the resources and affects the growth and productivity of the planted seedlings under afforestation programmes. (Gupta, 1995, Singh 2003).

C. Soil and Water Conservation in Combating Desertification

Natural resource conservation and rehabilitation are the best options to control and degradation and enhance biomass for fodder and fuelwood. This will provide a basis for environmentalimprovement by way of avoiding desertification, a process increasing rapidly in tropicalcountries. However, inadequate availability of water and nutrients limits the growth of theplantations and natural regeneration in many landscapes (Li et al. 2008). Conservation ofsoil and water may fulfill the needs of water and nutrients of the planted seedling on degraded lands exposed to vegetation exploitation. However, the establishment of vegetation is quite difficult due toinadequate availability of soil moisture (Li et al., 2008) in these dry areas. Low and irregular rainfall is the most critical factorto plant growth (Barron et al., 2003).More than 70% of the rainfall is lost asevaporation, or run-off that causes erosion and flooding downstream(Singh et al., 2007). Thus, both floods and droughts andtheir detrimental consequences are result of this wastage ofvaluable rainwater. Because the water and soil resource is finite,the only option for increasing biomass production is to increase thewater productivity i.e., the water use efficiency (WUE), byproducing more biomass per unit of water (Gregory, 1989).Adoption of improved water conservation and harvesting technologiescontributes to increase in groundwater recharge, soilnutrients and biomass production and supports a higher number ofplants (Gowing et al., 1999; Vohland and Barry, 2009). Theprinciple requirement is the adequate soil and water managementtechniques that guarantee a maximum of infiltration andtranspiration for increased biomass production in intensivelygrazed and degraded dry areas (Venketeswarlu, 1987). Rainwater harvesting (RWH)supports agriculture (Li et al. 2004; Faroda et al. 2007), tree growth (Prinz, 2001) and forage yield (Jia et al. 2006) and improves infiltration and soil nutrients andfacilitates groundwater recharge (Vohland and Barry 2009). However, suitability and eco-hydrologicalfunctioning of micro-catchments depend upon the amount of rainfall (Cohenet al. 1995), vegetation cover and the topographical conditions of the area.Further, water harvesting supports flourishing agriculturein many dry areas (Suleman et al., 1995; Faroda et al., 2007).

XIV. CONCLUSION

A desert ecosystem is defined as the interactions between organisms, climate, and any other non-living influences on the habitat. Deserts ecosystem cover about 14 percent of the earth’s land and occur mainly near 30º north and south latitude where global air currents create belts of descending dry air. The extreme limits ofthis movement are marked by thetropics of Cancer and Capricorn,and this tropical belt containsat its northern and southernboundaries areas of extreme aridity.It is at these locations that themost extensive areas of aridity areexperienced, and these areas areclassified as deserts.These regions are characterized by the lack of rainfall which leads to their classification as arid.

Intense solar radiation, lashing winds, and little moisture i.e. less than 10 inches (25 cm) of rainfall create some of the harshest living condition in the biosphere called hot desert. In hot desert ecosystem generally with cloudless skies, the sun quickly heats the desert by day, producing the highest air temperatures in the biosphere. In contrast, the nights are very cold, as the temperature goes down tremendously due to loss of heat into the atmosphere through radiation. There is little water and temperatures vary widely, one may bake during the day and freeze at night.

Deserts tend to have relatively low biomass of plants and animals simply because of the arid environment although in some deserts the density and biomass of ants, termites, scorpions andisopods may be extraordinary. Efficient functioning of the Earth’s ecosystems is based on the autotrophic plant life, which can make use of the radiation energy of the Sun directly. Organisms exploit favourable micro-climates within the desert ecosystem, no matter how unpredictable. Longer term escape and shorter term retreat describe the adaptations most commonly observed.

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Deserts are considered to be the treasure of soil resources. The deserticsoils are mineral soils often called as aridisols with low organic content. Most desert soil is too dry to support widespread vegetation, but much of it is rich in salt, uranium, and other minerals. They are dry landforms comprising of sand and sediments. They are the cradles of centrifugal eolian forces. Deserts sometimes contain valuable mineral deposits that were formed in the arid environment or that were exposed by erosion. Evaporation in arid regions enriches the mineral accumulation in their lakes. Playas may be sources of mineral deposits formed by evaporation. Water evaporating in closed basins precipitates minerals such as gypsum, salts (including sodium nitrate and sodium chloride), and borates. The minerals formed in these evaporite deposits depend on the composition and temperature of the saline waters at the time of deposition. The natural forces that create deserts have not changed much for thousands of years. However, various human activities have caused desert regions to expand considerably.The major causes of desert expansion include mining, improper farming methods, and destruction of trees. Climate has a major impact on dryland soil, vegetation, water resources, and land use. By virtue of low organic matter contents, aggregate stability and low levels of biological productivity, drylands are vulnerable to desertification.

The management of dry land areas should primarily focus on the best and most economic use of available water, either from rainfall or from groundwater aquifers. This involves surface water management and water harvesting, groundwater exploitation and recharge, efficient irrigation and drainage, and crop adaptation.

Human population in deserts is also equally facing the same issues. Deserts do not support a large number of people as in humid regions. People living in desert regions must adjust to the local and prevailing hot or dry climate. People have lived in deserts for millennia, asdesert dwellers, took up occupations as agriculturalists and pastoralists which are continued till present day to earn their livelihood. Butother people now live in urban developmentssituated in deserts, or enjoy deserts temporarilyfor tourism or recreation. Yet others are extractingprofits from mining or other non renewableresources. Deserts are a large and probablygrowing environment globally and their future willbe best supported if it is based on a thoroughunderstanding of their structure and function, andthe influence of people's activities in the past,present and future. Humans must discuss problems and find new solutions. The use of renewableenergy is of focal interest in the desert areas, where solar energy is plentiful.And even more, a very rational use of water with an optimal waste water use andrecycling is necessary.

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