

Ecology

Plants, Environment and Ecological Adaptations

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Environmental factors

Environment may be defined as the surrounding of a living organism. With the realization of a direct interference of man with environment and vice versa, environment also encompasses the social and cultural forces of human society. Environmental factors are external forces either living or non-living that affect the life of the organisms. The non-living environment can further be classified into atmosphere, lithosphere and hydrosphere, whereas biotic environment is called biosphere. Environmental factors are substances (soil, rock, water, air), conditions (light, temperature, humidity, rainfall), forces (wind, gravity), and organisms (plants, animals, microorganisms, human being). Broadly the environmental factors are classified as:

1. Climatic factors: These factors denote the long term average weather conditions of a place for examples temperature, precipitation, wind, humidity, fog, cloud cover and atmosphere gases.
2. Physiographic factors: These include the factors of physical geography of earth such as latitude, longitude, altitude, terrain, angle of slope and aspects.
3. Edaphic factors: These include processes related to the formation of soil and physical, chemical and biological characteristics of soil.
4. Biotic factors: These factors denote all kinds of influences caused by living organisms including man.

Environmental factors do not act individually, but many factors interact to influence the existence and success of an organism, known as interaction of environmental factors. The intensity, importance and time scale of factors, however, vary with organisms and ecosystem types

Climatic Factors

Climate is a product of weather, which is day-to-day condition of light, temperature, precipitation, humidity, and wind and air pressure. Climatic factors are mainly concerned with aerial environment of organisms. Following are important climatic factors.

Solar radiation

The sun makes all life on earth possible. It provides habitable temperature, otherwise the average temperature of the planet would approach -33°C when all water would be frozen. Sun's energy is utilized by photosynthetic organisms to convert in food molecules required by almost all forms of life. The amount of solar radiation that reaches a point just out side the earth's atmosphere (at a height of 83 km) measured perpendicular to the sun's rays is known as **solar constant**. Solar constant is estimated as $1.98 \text{ langley min}^{-1}$ or $1.94 \text{ cal cm}^{-2} \text{ min}^{-1}$. Earth reflects

back a percentage of the solar radiation, called **albedo**. Global albedo varies from 50 to 60% at polar regions and to 20 to 30% in equatorial region. Water surface has a low albedo, whereas for snow and ice, albedo may be as high as 45 to 90%. The atmosphere reduces solar radiation at extra terrestrial level of about $1.94 \text{ cal cm}^{-2} \text{ min}^{-1}$ to about $1.3 \text{ cal cm}^{-2} \text{ min}^{-1}$ at sea level on a clear summer day.

The earth surface receives approximately $1 \text{ langley min}^{-1}$ in the form of short wave radiation. If solar radiation reaching the atmosphere is considered 100 per cent, 25% is reflected by atmosphere (clouds) and 5% by earth's surface back to space (Figure 1). Another 25% is absorbed by dust, water vapour and carbon dioxide in the atmosphere. Thus reflection and absorption remove 55% of the solar radiation reaching the earth surface. Earth absorbs remaining short wave radiation, which is radiated back as long wave radiation and is absorbed by the atmosphere. Again there is escape of 12% energy to outer space and the remaining 33% is absorbed by water vapour and carbon dioxide in the atmosphere. This heat, radiated back to earth, maintains warmer surface temperatures. Nearly all the ultraviolet radiation is absorbed by the upper atmosphere. This scatter of shorter wavelength gives bluish colour to the sky.

The energy of solar radiation can be measured by **pyranometers**, which can measure direct and diffuse sunlight. Plant leaves absorb relatively high radiation at wavelengths shorter than 700 nm i.e. of visible and ultraviolet wavelengths. Chlorophylls, carotenoids and xanthophylls absorb highly in visible range. Chlorophylls reflect green light and absorb much of violet, blue and red, while carotene and xanthophylls reflect yellow to orange and absorb heavily in the blue to green range.

Sun's rays hit the earth vertically near the equator making energy more concentrated and producing higher temperatures. In contrast sunrays are inclined near poles and pass through deeper envelope of air resulting in high level of scattering and reflection of sun's energy leading to lowering of temperature near poles. The inclination of earth's axis and the distance of the earth cause seasonal variations in solar energy reaching the earth surface. Differences in temperature caused by variations in the amount of solar energy reaching the earth at surface drive the circulation of the air.

The radiation travels in form of energy packets called **photons**. The energy contained in one photon is inversely proportional to the associated wavelength, the shorter the wavelength, more the energy content. Gamma rays, X-rays, UV-C (<280nm) are highly energetic and harmful, but do not reach ground level as absorbed by atmospheric gases. The ultraviolet radiation is of high intensity short wavelength of 100 to 400 nm. UV radiation is of three types i.e. UV-A (320 – 400nm), UV-B (280-320nm) and UV-C (100-280nm). Visible radiation contains less

specific energy, but has the highest total energy content due to large number of photons. Maximum energy is radiated in the visible band around 500 nm. As the path length increases with latitude, the amount of radiation decreases. Equator receives high intensity than poles, but longer hours of sunlight compensate loss of intensity at high latitudes.

Figure1. Radiational heat balance of the earth. The incoming solar radiation reaching the top of the atmosphere is taken as 100 units (After Smith, R.L. 1996).

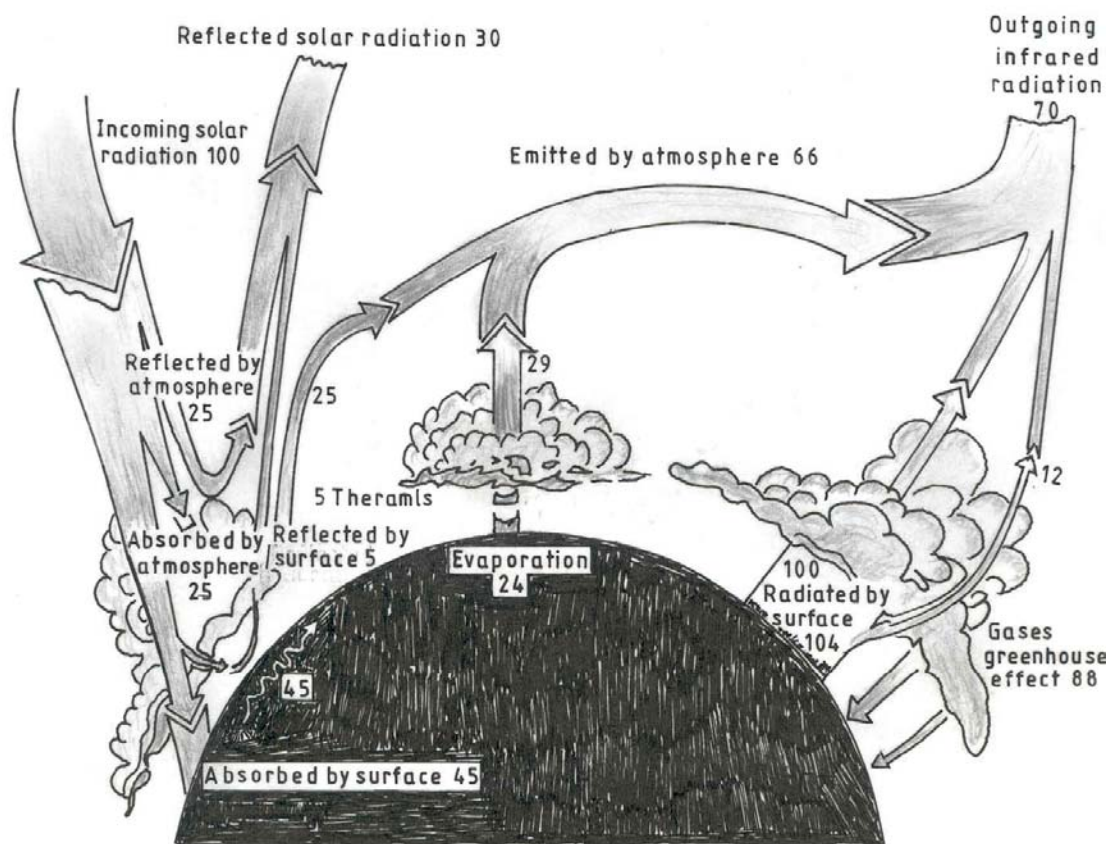


Figure 1

Photosynthetically active radiation (PAR): Solar radiation reaching vegetation has two components (i) irradiance of direct sunlight, and (2) diffuse irradiance from clouds and clear sky. The wavelengths absorbed by photosynthetic pigments are between 400 to 700 nm. This band of light is called photosynthetically active radiation (PAR). About one third of direct solar beam is photosynthetically active radiation and two third in diffuse radiation. Typical instantaneous values of PAR at vegetation surfaces under clear sky conditions vary from 500-1000 W m^{-2} and from 50-200 W m^{-2} under cloudy conditions. PAR is also referred as photosynthetic photon flux density (PPFD), which is photon flux per unit area in the same wave band and expressed as $\mu \text{mol m}^{-2} \text{s}^{-1}$. The intensity of PPFD would be about 2000 $\mu \text{mol m}^{-2} \text{s}^{-1}$ near mid day on a clear sky.

Atmospheric Constituents

The envelope of air surrounding the earth is atmosphere, which helps in maintaining temperature on earth surface tolerable for living organisms filters out high energetic harmful radiations of sun and provides life support gases to the organisms. Atmosphere is composed of a mixture of gases (Table 1). Nitrogen and oxygen contribute 99% of the atmospheric gases. The rest 1% comprises many inert and other chemically active gases. In addition water vapours, oxides of nitrogen, sulphur dioxide and chlorofluorocarbons also add to the composition of the atmosphere. Aerosols, which are very small sized suspended particles of dust are also part of the atmosphere. Aerosols absorb and scatter radiation and thus form a very important component of the atmosphere. O_3 absorbs harmful UV-B radiation of sun thus protecting the life on earth. Hydroxyl ions (OH) help in removing polluting gases from the atmosphere, by oxidizing them in liquid or aerosol forms.

Water vapour content is variable in atmosphere depending on location, time of day and season. Water vapours act as an independent gas, which has weight and exerts pressure. The amount of pressure water vapours exert independent of dry air is **vapour pressure**. The pressure that water vapour exerts when air is saturated is **saturation vapour pressure**, a characteristic, which is a function of temperature. At higher temperature of earth, moisture content may be as high as 4 to 5% leading to reduction in proportion of major gases N_2 and O_2 . Water vapours are the carrier of heat energy from the oceans to higher altitudes. The difference between actual vapour pressure and saturation vapour pressure at any given temperature represents the **vapour pressure deficit**. The rate of movement of moisture is proportional to vapour pressure differences.

The amount of water vapour a given volume or weight of air holds is expressed in terms of absolute humidity (g m^{-3}). Moisture content, expressed as a ratio of the actual moisture content and that required to saturate the air at

the same temperature is called **relative humidity (RH)**. For example if the actual amount of water vapour in the air is only 40 per cent of the amount it could hold if saturated, the relative humidity is 40 per cent. The atmosphere receives water vapours through the process of evaporation from oceans and other water bodies and through transpiration from vegetation. Warm moist air rises upwards, but due to decrease in pressure upward, the ascending moist air cools below the saturation point and results in condensation on suspended dust or other hygroscopic particles to form **clouds**. With more and more condensation, cloud droplets grow bigger and heavier and ultimately result in rainfall.

O₂ is a good absorber of UV radiation upto 180 nm. The wavelengths between 200 to 280 nm are completely absorbed by O₃ while 280-315 nm (UV-B) are partially absorbed based on O₃ density in the stratosphere. UV-A (315-400 nm) and visible radiations reach the ground level without much attenuation. The gases such as CO₂, CH₄, N₂O, H₂O and O₃ naturally present in the atmosphere have high absorption at long wavelengths so these allow the solar radiation of shorter wavelengths to penetrate the atmosphere, but disallow the radiation of longer wavelength to escape from the atmosphere. This enables the earth to maintain a global mean temperature of 15 °C, this is referred as **green house effect** causing natural atmospheric warming. The atmospheric gases causing this effect are called **green house gases** or **radiative gases**.

Water

Water is one of the most important environmental factors regulating the existence of life on earth. Water shortage has been the main concern of human race at present. Oceans cover 71% of the earth surface with a mean depth of 3.8 km. Oceans hold 97% of the all earth's waters. Fresh water resources represent only 3 per cent of earth's water supply. Out of the total fresh water on earth, 75 per cent is locked up in glaciers and ice sheets. This constitutes more than 2 per cent of fresh water and leaves less than 1 per cent of available fresh water in liquid form. Ground water accounts for 25 per cent of fresh water. Renewable and cyclic ground water is roughly estimated at 7×10^6 km³. Some of this ground water is inherited in aquifers of desert regions for more than thousands of years. A portion of the ground water lying below 1000 m is known as fossil water. This is often saline and does not participate in the hydrological cycle. Lakes contain 0.3 per cent and on average rivers and streams contain only 0.005 per cent. Soil moisture accounts for approximately 0.3 per cent. Another small portion is tied up in living organisms. The atmosphere contains 0.035 per cent fresh water in form of water vapours and clouds.

Fresh water resources are either **lentic** having standing water bodies such as lakes and ponds or **lotic**, running water bodies such as rivers and streams. Water is constantly being recycled in all its states between atmosphere,

land and oceans. This cycling is called **hydrological cycle** or **water cycle** (Figure 2). The major processes drawing the hydrological cycle are evaporation, evapotranspiration, precipitation and runoff. The water cycle starts with evaporation of water from oceans, lakes, rivers and through plant leaves. This loss of water from surface of land and plant leaves then forms water vapours in the atmosphere where it condenses at cool temperature and form clouds. The atmospheric water falls in form of precipitation or rain on land and oceans and distributed to fresh water bodies. Some infiltrates to the permanent water table and some remains in the top soil layer to be used by plants. Extra water moves in surface channels as **surface runoff** into rivers, streams, lakes and finally to oceans.

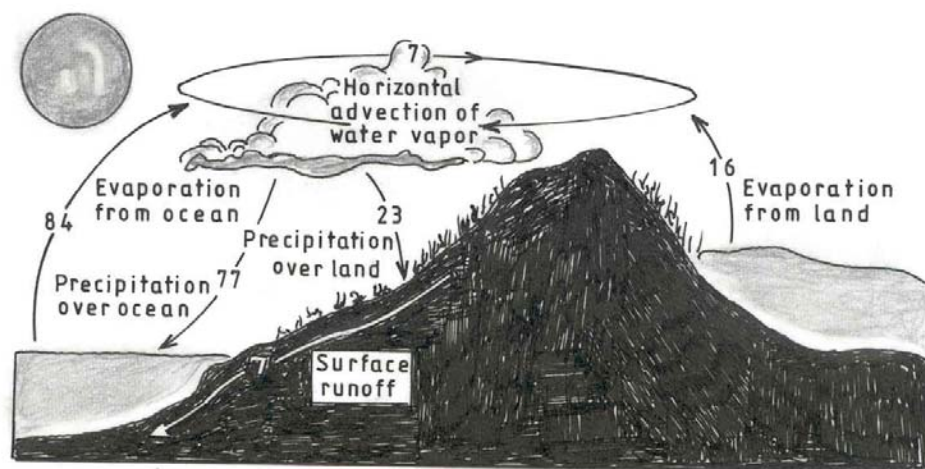


Figure 2

Figure 2. Global water budget. The mean annual global precipitation is taken as 100 units (After Smith, R.L. 1996).

Some of the water reaches the ground directly, and some is intercepted by vegetation, litter on the ground, and structures. A forest in full leafing condition may intercept a significant portion of a light rain. Water exceeding

the storage capacity of canopy either drips off the leaves as **through fall** or runs down the stem and trunk as **stemflow**. In urban areas, a larger proportion of precipitation on roofs and streets runs down to drains and to the rivers without being intercepted by soil. The precipitation reaches the ground through soil by infiltration, which is governed by the factors such as soil types, vegetation, terrain and amount of rain fall. Water moves through the soil by the action of capillary attraction and gravity. Vegetation tends to roughen the soil surface and allows the water to move into the soil, whereas in urban areas because of low infiltration, surface run off may reach 85 per cent of total precipitation. Water losses from soil also take place through plants by the process of transpiration. The loss continues till moisture is available in the soil, roots are capable of removing water and amount of energy is available to supply the necessary latent heat of evaporation. The total flux of water evaporating from surface of the ground and vegetation is called evapotranspiration. If the total water on the earth is considered in terms of 100 units, then the average 84 units are lost from the oceans by evaporation, while 77 units are returned through precipitation to the oceans. Land areas lose 16 units by evaporation and gain 23 units by precipitation. Run off from land to oceans makes up 7 units, which balances the evaporative deficit of the ocean. The remaining 7 units circulate as atmospheric moisture. About 0.005 per cent water is all the time moving. The mean annual rainfall on a global basis is 85.7 cm out of which land receives 23% and oceans, 77%. Through evaporation and transpiration oceans and plants supply 84 and 16% water vapours, respectively.

Wind

Wind is an important environmental factor as it governs transpirational water loss from vegetation, dispersal and dissemination of seeds and pollination in plants. Wind velocity varies at different geographical situation and along vegetation types. Wind plays more important role at sea shores and at high altitude mountains. Air heated at the equatorial regions rises until it reaches the stratosphere, where it is blocked from any upward movement. These air masses are forced to move north and south towards the poles. Above poles, they cool become heavier, and sink. The pattern of rising and descending air forms circulation cells near equator, mid latitudes and polar region called **Hadley cells**, **Ferrel cells** and **polar cells**, respectively. The interaction of wind and heating produces high pressure cells known as subtropical highs in the Atlantic and Pacific oceans. Winds and cooling interaction produce low pressure cells such as the Aleutian and Icelandic lows. Seasonal winds are also important because dry winds blow from continental interiors to the oceans during early summer and winds heavy with moisture blow from oceans to the continent in rainy or winter, bringing heavy rains. Major air circulations are responsible for the changing cloud pattern on the earth.

Physiographic Factors

Earth surface is not even. Latitude, altitude, inclination of earth's axis at an angle, revolution of earth, location of region within the continental land masses, nearby bodies of water and geographical features such as mountains influence the environment indirectly through their effects on weather and climate. Mountains influence regional climate in two ways; by modifying the pattern of precipitation and by creating climatic differences with altitude. When an air mass is intercepted by a mountain range, it ascends, cools, reaches to its condensation point and falls in the form of rains or snow on the windward side. The dry air then descends on the leeward side, warms and picks up moisture from the land. Such pattern results in more moisture in windward side and a drier condition in the **rain shadow** leeward side. Mountain areas show wide variations in climate along an altitudinal gradient similar to that experienced by going to higher latitudes. Temperature drops to about 1.5 to 3⁰ C for every 300 m rise in elevation.

Heat, moisture, air movement and light vary from hill to mountains slope, valleys, and surface of the ground and beneath vegetation, thus creating a range of climate. South facing slopes in the northern hemisphere receives more solar energy as compared to north facing slopes. This has marked effect on moisture and heat budget of the two aspects. The evaporation rate is often doubled, the average temperature higher and the soil moisture is lower at south facing than north facing slopes. Thus warm and xeric conditions prevail on south facing slopes as compared to cool and moist north facing slopes. Steepness of the slope is also important on top of the south facing side because of high speed air movement and poor soil drainage and at the valleys in north facing slopes due to water logging. Vegetation occupying two different sides of slope is also different, which further influence mineral recycling, physico-chemical characteristics of soil and nature of ground cover.

Edaphic Factors

Soil is the weathered outer layer of earth's crust, which ranges from a thin film to thick layers composed of weathered rock materials and organic matter interspersed with pores filled with air and water, and which supports plant life. Soil not only provides water and mineral nutrients to the plant for manufacture of various organic compounds, but minerals to the soil through the process of decomposition and mineralization. Soil is home to many types of animals.

Soil formation

The soil formation is a complex process resulting from solid rock, or from mineral material deposited by a glacier, wind or water. The process of soil formation initiated with weathering process is called **pedogenesis**. Weathering

may be mechanical, chemical or biological. **Mechanical weathering** results from cracking of big rocks into little ones by the wedging action of water freezing in a crack, expansion of tree trunk, root penetration and forces created by the beating of rain splashes. **Chemical weathering** is caused due to reaction of mineral matter with water through processes of oxidation, reduction, hydrolysis and carbonation. **Biological weathering** is caused by chemical substances produced by plants, which break down to weather rocks. The lower plants produce CO_2 in rock crevices and surfaces, which dissolves in water to produce carbonic acid causing weathering of rocks.

Any vertical cut through a body of soil is called soil profile. The apparent layers of soil are called **horizons**. Each horizon has characteristic set of features related to colour, thickness, structure, consistency, porosity, chemistry and composition.

In general soils have five major horizons: O, an organic layer, and A, E, B and C, the mineral layers (Figure 3). Below these layers, non soil horizon R lies. The O horizon is composed of fresh or partially decomposed organic matter not mixed into mineral soil. The horizon O is further subdivided into an O_i , the litter layer and O_a , the humus layer. The A (earlier called A_1) horizon is the upper layer of mineral soil with high content of organic matter. O and A horizons constitute the zone of maximum biological activity. The E (earlier called A_2) horizon is the zone of maximum leaching (eluviation denoting E). The downward movement of suspended and dissolved material through leaching alters soil and structure. The B horizon is the zone of illuviation, the collection of leached material like silicates, clay, iron, aluminum, etc from E horizon. It has a characteristic physical structure with blocky, columnar or prismatic shapes. C horizon refers to the layer where active weathering occurs from the unweathered material in horizon R below. Horizon R is consolidated bedrock.

Properties of soils: Soils vary in their physical and chemical properties.

Physical properties: These include **colour**, texture, structure, depth and moisture. Brownish black and dark brown colours in the A horizon indicate high organic matter. Very pale brown to reddish colours of B horizon are characteristics of well drained soil, whereas dark brown to blackish colours of B horizon indicate poor drainage. Red soils derive their colour from presence of iron oxides. The bright colours indicate good drainage and aeration. Red and yellow colours increase from temperate to the equator. Grayish colour denotes permanently saturated soils in which iron is in ferrous form. The colours of soils are determined by the use of standardized colour charts known as **Munsell colour charts**.

Texture: Soil texture is determined by the relative proportion of mineral particles classified as gravel, sand, silt and clay. Gravel consists of particles larger than 2.0 mm size. Sand ranges from 0.5 to 2.0 mm and upon touch feels gritty. Silt consists of particles from 0.002 to 0.5 mm and is not visible by naked eye and feels like flour. Clay particles are less than 0.002 mm and decide the plasticity of the soil and exchange of ions between soil particles and soil solution. Based on percentages of sand, silt and clay, soils are classified into different textural classes. Texture decides pore space and therefore the movement of water and air and penetration of roots. Coarse textured soils possess large pore spaces that favour rapid water filtration and rapid drainage. Fine textured soils have high proportion of clay and are poorly aerated.

Soil particles are held together in clusters or shapes of various sizes called **aggregates** or **peds**. The arrangement of these aggregates is called **soil structure**. Soil aggregates are classified as granular, crumb like, plantlike, blocky, prismatic and columnar.

Depth: The layers of soil vary in depth depending on slope, weathering parent material and vegetation. Soils are several meters deep under native grasslands but relatively shallow under forest.

Moisture: Water in soil can be **gravitational water**, **capillary water** and **hygroscopic water**. The maximum amount of water the soil will hold following the drainage of gravitational water is called **field capacity**. It consists of capillary water plus hygroscopic water. The metric tension of soil at field capacity varies between 0.1 and 0.3 bar. Capillary water is retained by capillary action against the pull of gravity in smaller pores of soil and is the main source of water to the plants. Hygroscopic water is adsorbed on the surface of soil particles. Permanent wilting percentage is the amount of water in a soil when plants growing in it are irreversibly wilted. At a soil metric tension value of about 15 bars, majority of plant except xerophytes wilt permanently. The amount of organic matter also increases water retention capacity of soil.

Chemical properties: Chemical elements in the soil are dissolved in soil solution, part of organic matter and are adsorbed on the soil particles. Positively charged minerals called cations are stored on the surface of the particles, whereas anions are dissolved in soil water. Plant roots absorb cations by replacing them with hydrogen ions. The total number of negatively charged exchange sites on clay and humus particles that attract positive charged cations is called **cation exchange capacity** (CEC). The negative charges enable the soil to prevent the leaching of cations. Exchange sites are occupied by calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), sodium (Na^+) and hydrogen (H^+). The percentage of sites occupied by ions other than hydrogen is called the **per cent base saturation**. Acidity

of soil is one of the most important chemical characteristics. Typical soil ranges from a pH of 3 (strongly acidic) to pH of 9 (strongly alkaline).

Biological properties: A variety of organisms are part of soil. Dominant organisms are bacteria, fungi, protozoans and nematodes. Spaces within the surface litter, cavities in soil aggregates, pore spaces within individual soil particles, root channels are habitat for soil organisms, which obtain food from roots of living plants and organic matter within the pore spaces. The most abundant soil animals are mites. Among the larger fauna are the earthworms. Feeding on the surface litter are millipedes, causing mechanical breakdown of litter, making it more vulnerable to fungal decomposition. Millipedes live on fungi in the litter. Snails and slugs also accompany millipedes and help in hydrolyzing cellulose and even highly indigestible lignins. Termites and some dipteran are larger inhabitants causing breakdown of cellulose of wood. Termites dominate the tropical soil fauna.

Soil organic matter, which originates from biological activities during decomposition strongly influences the development of O and A horizons. The fraction of organic matter that remains after decomposition is called **humus**, which is dark colour, chemically complex organic material with characteristic constituents like fulvic acid and humic acid. Two types of humus formation occur due to interaction of physical, chemical and biological mechanisms; **Mor:** It has a well defined, unincorporated compact organic deposit resting on mineral soil. There is a sharp distinction between horizons O and A. The main decomposing agents are fungi, which depress soil animal activity and produce acid. **Mull:** It possesses only a thin layer of litter on surface and mineral soil has high organic matter. Animal activity is very high. There is no sharp break between the O and A horizons. Bacteria are the main decomposers in this soil.

Soil development

Soil continues to develop over time due to climate, vegetation and other factors. Major processes in soil development are podsolization, laterization, calcification, gleyization and salinization.

Podsolization denotes the ash colour of the soil due to depletion of bases from surface layers to the B horizon. The organic horizon is a mor with a layer of fermented litter on top of a layer of humus unmixed with mineral soil. Such soils are highly acidic and develop under coniferous forests in cool humid regions.

Laterization is common in humid sub tropical and tropical forested regions, where rainfall is heavy and temperature is high. Weathering is entirely chemical brought by water and its dissolved substances. Bases, silica, Al, hydrated aluminosilicates and iron oxides become soluble and carried down ward. The weathered end product

is composed of silicate, hydrous oxides, clays deficient in bases and low in plant nutrients. The large amount of residual Fe and Al hydroxides gives bright reddish colour in upper part of E horizon, which may be especially deep.

Calcification: The sub humid to arid and temperate to tropical regions supporting grassland vegetation show calcification. Vegetative material above ground and part of root system turned back to soil as organic matter every year and thus developing soil is high in organic matter. Rainfall is generally not sufficient to remove calcium and magnesium carbonates and grasses help in maintaining of soil a high calcium content of soil by redepositing during decomposition. In this process of soil development A horizon is distinct and CaCO_3 and leaches to the B horizon where calcium nodules are formed, which are called kanker.

Gleyization: Under poor drainage condition of cold wet situation and where water table is high upto B and C horizons, compact structureless horizons develop and this process is called gleyization. Organic matter is high due to reduced rate of humification and soil has dull gray to bluish colour. Iron stays in reduced ferrous compound most of the time.

Salinization: In arid and semi arid regions with sparse vegetation and scant precipitation, slightly weathered and slightly leached soils are formed. The horizons are very thin and soils contain very high amounts of soluble salts. Due to high rate of evaporation a more or less cemented horizon of Na, Ca and Mg salts is formed below surface. This horizon is called **caliche**. Soils are low in humus and high in base content.

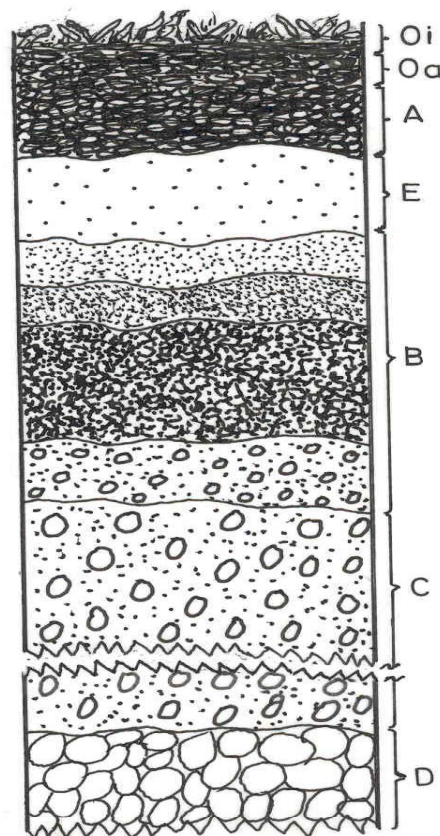


Figure 3

Figure 3. A generalized profile of the soil (After Smith, R.L. 1996)

Adaptations to Environmental Factors

Any environmental factor that inhibits the growth of plant either through its deficiency or excess is said to be a limiting factor. For example cold temperature restricts plant growth at higher elevations and water availability in desert. Limiting factors for terrestrial plants are light, moisture and temperature. **Liebig's Law of minimum** states that growth of plants is dependent on the amount of nutrient present in minimum quantity. Shelford's **Law of tolerance** suggests an ecological minimum and an ecological maximum and the range between these two

conditions represents the tolerance range of plants. The plants with narrow range of tolerance to temperature are called **stenothermal** and those with wide range of tolerance are called **eurythermal**.

A plant does not do equally well throughout its whole range of distribution. There is a range of environmental condition, where it does better and this is referred as the **range of the optimum**. When some important feature of environmental condition changes, the plant changes in response. These changes keep certain important aspects of the plant's internal environment constant despite of changing external environment. This tendency is known as **homeostasis**. When the environmental factor changes beyond a certain level, plants try to adapt. **Adaptation** is any morphological, anatomical, physiological or behavioral feature, which favour results from some environmental pressure to increase the ability of an organism under changing environment and favour the success of an organism in a given environmental condition. The populations showing non-heritable differences in morphology due to varied natural environment are called **ecophenes** or **ecads**. The differential success or fitness of populations comes through process of natural selection. A given population shows different levels of tolerance to a given limiting factor over its geographic distribution. Such locally adapted populations are called ecotypes, which may have developed due to genetic changes resulting in different responses to varying environment. The genetic responses of individuals under a particular set of conditions are expressed in **phenotypes**. The phenotypic responses may be morphological (physical characteristics), physiological (functional characteristics) or phenological (timing of growth, flowering and other life history changes). The ranges of adaptiveness influence distribution of plants and their population. The plants possessing a wide range of tolerance to many environmental factors will be most widely distributed.

Adaptations to light variations

Light plays many important ecological roles but the two most important aspects of light are relative light requirements and photoperiodism. Ecologically plants are classified on the basis of their relative light requirement for overall vegetative development as heliophytes and sciophytes. Heliophytes require full sunlight for best growth. Sciophytes grow best at lower light intensities. Some heliophytes can also grow fairly well under shade and are called **facultative sciophytes**. On the other hand some sciophytes can also grow well under full sunlight and are called **facultative heliophytes**.

Heliophytes grow best in open sites and establish rapidly on disturbed sites, tolerate extremes of dryness and wetness and have a high rate of photosynthesis as well as respiration. Shade tolerant plants have lower rate of photosynthesis and more importantly a lower rate of respiration. Sciophytes carry on photosynthesis at low light intensities. Leaves of heliophytes are smaller, thicker and more deeply lobed than sciophytes, with well developed support and conduction systems. Shade leaves are thinner, weakly lobed, have large surface area per unit weight, fewer stomata and less support and conduction tissues. These adaptations increase efficiency of light utilization, increase area for light interception and reduce reflection. Sciophytes have a lower dark respiration and therefore a

lower light compensation point allowing maintaining a positive carbon balance even at very low gross photosynthesis rate. When shade plants are exposed to full light, they lose an excessive amount of moisture and experience light damage to the chloroplasts. Many forest herbaceous plants are shade tolerant. Heliophytes if forced to grow in the shade will respond by growing rapidly in height in an attempt to emerge from the shade. The leaves will be thinner and more widely spaced, making them susceptible to drought and fungal infections. To avoid bright light, plants develop some characteristics such as vertical orientation of leaf blades, thicker stem, well developed conducting elements and mechanical tissues, thick palisade layer, longer root, shorter internodes, more branching, higher root/shoot ratio, lower chlorophyll content, higher respiration rate, higher osmotic pressure due to high concentration of salts and sugars, more resistance to temperature, drought and pest injury. Most shade tolerant trees have low growth rates, but their growth was not reduced as much by low light.

C₄ plants have higher light saturation levels than C₃ species. PAR is frequently limiting to desert plants with CAM photosynthesis. Cacti tend to grow oriented in a way that maximizes light inception during the season when other environmental factors are optimal for photosynthesis.

In marine environment, the pattern of distribution of different algae is explained by different absorptive spectra of the photosynthetic pigments. Red algae found in deepest water have phycobilin pigments, which can absorb green wavelengths common at those depths. Green algae with chlorophyll a and b are inhabitants of shallow water, whereas brown algae with chlorophyll a and c and special carotenoid pigment fucoxanthin are common at intermediate depths.

Photoperiodism: Light has both direct and indirect effects. It affects metabolism directly through photosynthesis, growth and development and indirectly as a consequence of the immediate metabolic responses and its control of morphogenesis. Spectral distribution of radiation has impact on germination, stem extension rates and apical dominance. Light responses are mediated by three main receptor systems. Chlorophyll for photosynthesis, phytochrome absorbing in two interchangeable form at 660 and 730 nm for many photomorphogenetic responses and flavins absorbing at 450 nm for tropisms and high energy photomorphogenesis. Temporal variations in irradiance and its relative duration day/night vary with latitude. This is the basis of photoperiodism. All temperate zone plants exhibit photoperiodic responses for flower initiation, seed germination, bud break, stem elongation, leaf fall and other processes. This is of less value in equatorial region as day length shows little seasonal variation, compared to that in temperate region. The photoperiodic response enables the plant to time the vegetative and floral growth to fit seasonal changes in the environment.

The activities of plants are geared to the changing seasonal rhythms of day and night. The signal for these responses is **critical day length**. It varies somewhere between 10 and 14 hours. On the basis of photoperiod, plants may be classified as (I) **short day plants**, which develop and reproduce normally only when photoperiod is less than a **critical maximum** (12-14 hrs), such as *Cannabis sativa*, *Andropogon virginicus* and *Datura stramonium*, (II) **Long day plants** are those whose growth and reproduction are stimulated by day lengths larger than the critical day length such as *Brassica rapa* and *Sorghum vulgar*. Some plants are indifferent to photoperiod and are called (III) **day neutral plants**, such as *Cucumis sativus*, *Poa annua* and *Nicotiana tabacum*, which in different to the length of photoperiod

Adaptations to temperature variations

Temperature affects metabolic processes of plants by influencing the kinetics of biochemical reactions and the effectiveness of enzymes. The thermal environment of plants varies a lot from one part to another. Roots are generally buffered from temperature extremes by the soil, while the above ground structures are exposed to a wide range of temperatures. Temperature of leaves, twigs and buds exposed to sunny side is higher than the shaded side. Plants maintain heat balance by reradiation, convection and transpiration.

During each part of the life cycle, plants may have a different set of **optimum temperature**. The temperature required to stimulate germination may be lower than that favouring flower development. Optimal temperatures vary among species, ecotypes within species, and among individuals in a population.

Heat stress: In response to heat stress, net photosynthesis drops and respiration becomes dominant. In heat tolerant species, rapid rise in temperature leads to shut down of normal protein synthesis coupled with initiation of a set of heat shock proteins that help in short term survival. If the heat persists, it disrupts the protein structure of the plant. Many species of cacti acclimate to high temperatures because they have high levels of bound water and high cytoplasmic viscosity. Many plants have very small leaves or no leaves at all and carry on photosynthesis through stems. Such plants are called phylloclades for example *Ophuntia* and *Muehlenbeckia*. Short term tolerance to heat stress involves a response by some behavioral means. Under heat stress plants hang their leaves parallel rather than horizontal to the sun's rays. Heat tolerance varies with developmental stages as germinating and young plants and growing organs are more sensitive to heat stress than adult organs.

C₄ plants have ability to carry on positive photosynthesis at higher temperature than C₃ plants and therefore usually tolerate warmer temperatures compared to C₃ plants. This disadvantage of C₃ plants is mainly ascribed to high rate of photorespiration at warmer temperature. The C₃ plants may have higher amount of CO₂ absorbed per unit of light, but will lose that advantage due to greater photorespiration at higher temperature. CAM photosynthesis is also regulated by temperature because night time CO₂ uptake is dependent upon low temperature. In desert plants, stomatal resistance increases several fold when leaf temperature increases.

Cold stress: Plants of cold climate develop tolerance to cold temperature and even when temperature drops below minimum for growth, photosynthesis and respiration may continue slowly. Plants of tropical and subtropical regions may suffer lethal damage at temperatures just above freezing i.e. close to 0 °C. Damage due to chilling and frost depends upon the magnitude and duration of drop in temperature. Sensitive plants experience damage to cell membrane and lose electrolytes rapidly. If freezing occurs slowly, ice crystals are formed outside the cells drawing water from the cells thus causing dehydration. In case of temperature falling rapidly, ice crystals are formed within cells thus damaging cell structure. When the tissues thaw, the cellular contents spill out producing the watery appearance of frozen plants. Chilling and frost damage is avoided by increasing the sugars and alcohols, which help in lowering the freezing points of cytoplasm. This can allow supercooling of cell sap without injury for short period.

Winter dormancy is common in plants of cold climates to tolerate frost. Plants harden themselves by producing organic compounds, such as sugars, amino acids and nontoxic substances, which act as antifreeze. This acquired tolerance is retained until growth starts with favorable conditions. Among the plant parts, roots, bulbs and

rhizomes are most sensitive to freezing stress. Terminal buds of trees are less resistant to cold than lateral buds, which in turn are more sensitive than basal buds on twigs. Woody stems are more resistant than leaves. Insulation is another way to resist chilling and frost damage. The cushion type and rosette plants of arctic and alpine and temperate regions may keep the temperature 10-20°C higher than the surrounding air.

Thermoperiodism: Many plants require a day night temperature difference for optimal growth. A positive response to a thermoperiod, which is a diurnal difference, is termed thermoperiodism. A thermoperiod requirement is adaptive in the pines and firs because of great diurnal temperature fluctuations in their areas of abundance. Some species show positive response to temperature depression during the dark period.

Dormancy: The dormancy of apical buds of many woody species of temperate climate is initiated by short days interacting with cold temperature. The environmental stimulus that enables the plant to perceive the passage of winter is cold temperature. Most plants growing at higher latitudes possess seeds that require cold temperatures for germination. Such seeds are dormant prior to exposure to cold temperature.

Vernalization: The flowering of cereal plants is influenced by exposure to cold temperature during the time of germination. This cold exposure response is called vernalization.

Sumorization: Heat cracking is essential for the rupturing of the seed coat of some fire adapted plants. Heat pretreatment also promotes germination of desert annuals. This treatment is called sumorization.

Life Forms of Plants

Danish ecologist Raunkiaer (1934) has proposed life form system of categorizing plants primarily based on methods by which they survive the coldest season. The life form system relates plant morphology and life history to the climate. The categories are based on the location of bud from which the growth sprouts during favourable condition. The categories are:

Therophytes: Annual plants that survive the cold temperature or dry season as seeds, which are typically much more resistant to temperature stress than growing plants.

Hydrophytes: Rooted water plants where buds are insulated under water during winter, e.g., Water lily.

Geophytes: Buds are buried in soil and thus well insulated. This category includes plants with underground stems such as bulb, e.g., Tulips.

Hemicryptophytes: Buds are located close to surface of the ground and are insulated by litter, e.g., biennials and perennial grasses.

Chamaephytes: Buds are located above the ground (not more than 25 – 30 cm). The buds may sometimes be insulated by snow cover by snow and are not exposed to strong winds, e.g., Trailing and creeping shrubs and succulents.

Phanerophytes: Mainly trees and shrubs whose buds are located on shoots more than 25 – 50 cm above the ground. Lianas are also phanerophytes.

Relative proportion of different life forms in an area represents the **biological spectrum** of the area. Deserts have high proportion of therophytes. Arctic and alpine areas will have high proportion of chamaephytes, whereas grasslands have a dominance of hemicryptophytes. Phanerophytes dominate in tropical rain forests.

Adaptations to Water Variations

Less than 1% of water taken up by the roots is used in photosynthesis, the rest is transpired. The upward movement of water brings required mineral nutrients to the plants and also causes a cooling effect on plants.

Availability of water is a major selective force in the evolution of the plants ability to respond to moisture stress. Mosses, algae, fungi and lichens have no protective mechanism against water loss because their internal water status tends to match atmospheric moisture conditions. At the condition of water scarcity, their cells sink without disturbing the fine protoplasmic structures and the vital processes are suppressed. With the improvement of moisture condition, they imbibe water and cells resume normal functioning. Such organisms are called **poikilohydric** as they restrict their growth to moist periods. Other plants such as ferns and seed plants are able to maintain stable water balance within limits independent of fluctuations of atmospheric moisture levels and are called **homohydric**. The ability is supported by vacuoles that store water within the cell, a protective cuticle slowing down evaporation, stomata to regulate transpiration, a combination of osmotic pressure and turgor pressure of water within the cells and the extensive root system.

Responses to water deficits

Leaves respond to water stress by an inward curling or show wilted appearance caused by a lack of turgor in the leaves. A significant response to water deficit is closure of stomata that reduces transpirational water loss, but raises the internal temperature of leaf causing heat stress. Stomatal closure reduces CO₂ diffusion ultimately reducing plant growth. Prolonged drought inhibits chlorophyll production causing the leaves to turn yellow. Deciduous trees may prematurely shed their leaves leading to dieback of twigs and branches. Reduction in soil water increases soil temperature, reduces root growth and alters mineral uptake from the soil. Such changes make the plants more susceptible to pest attack.

Adaptations to drought

Plants of semi arid and arid regions have evolved many adaptive mechanisms to survive and reproduce in dry environment. Such plants are called **xerophytes** meaning growing where it is dry (xeric). There are several types of xerophytes adapted in its own way in a dry environment. **Xerophytes** may be drought resistant perennials usually shrubs such as sage bush having small and hard leaves to reduce water loss and during periods of extreme drought leaves are dropped altogether and new leaves are developed with onset of rain. Such response results in decreased photosynthesis, but some plants maintain a proportion of it by increasing photosynthetic activity in stem. Plants reorient the angle of leaves parallel to sun's rays at the time of water limitation reducing the leaf temperature as well as transpirational water loss. With adequate water, plants orient leaves perpendicular to the sun's rays.

Succulents are another kind of xerophytes. Cacti are examples. These plants store and retain water within the plant's fleshy tissues, which it is available for later use. Many succulents have uncoupled the light and dark reactions of photosynthesis in such a way that can keep their stomata closed in the day time and open them taking CO₂ during night to form organic acids and stored in cell vacuoles. In the day light CO₂ yielded by the organic acids is processed in standard C₃ photosynthetic fixation. This arrangement is known as crassulacean acid metabolism (CAM) after the family crassulaceae, which includes many succulent plants.

Some plants adapt an **ephemeral life cycle** in which the population survives the dry period as dormant seeds and germinate, grow, flower, set seeds and die in a short period when conditions are fairly moist. The seeds may remain dormant for a number of years, waiting for adequate moisture.

Another category of xerophytes is **phreatophytes** (derived from Greek word meaning well). Some woody plants such as mesquite have deep roots in constant contact with a fringe of capillary water above the ground water table. Mesquite (*Prosopis* spp.) has a root system reaching down 175 ft.

Trees established on perennially dry sites rarely grow tall, but are long lived. They grow slowly with just enough photosynthetic production to achieve microscopic annual growth. By producing little biomass, they reduce drought stress and avoid senescence and death. *Pinus aristata* is known to live for 6000 years or longer on Rocky Mountains of USA.

Adaptations to leaves, which reduce water stress are thickening of cell wall, smaller size of stomata, dense vascular system and highly developed palisade tissue. These structural features increase the ratio of the exposed surface to the external surface of the leaves. Some leaves are covered by hairs that scatter incoming solar radiation and cool the air close to the leaf surface. Leaves may also be coated with waxes and resins, which reflect the light and reduce the leaf temperature.

Many xerophytes are C_4 plants, which are able to fix CO_2 at very low concentration. This is an advantage to a xerophyte as the plant can continue photosynthesis even when its stomata are nearly closed and have small amount of CO_2 available in the air spaces. In contrast C_3 plants have to keep their stomata open to continue photosynthesis.

Adaptations to water abundance

The plants growing under wet (hydric) condition are called **hydrophytes**. The concentration of oxygen is lower in water than air. Some sites are wet for a part of the year. The length of time that the soil is saturated is called **hydroperiod**. On the sites with short hydroperiods of days or weeks, species of mesophytes dominate. As hydroperiod lengthen, specialized hydrophytes can only do well. Excess water around the roots stimulates the plant to resist the movement of water through the roots to the shoots by wilting. Adventitious roots grow horizontally along the oxygenated zone. Shallow root systems make these plants susceptible to wind throw.

Hydrophytes are subdivided into following categories;

1. Free floating hydrophytes: They float freely in water bodies on surface with constant contact of water and air. For example *Wolffia*, *Azolla*, *Lemna*, *Salvinia* and *Eichhornia*.
2. Rooted hydrophytes with floating leaves: The leaves with long petioles are floating on the water surface with roots fixed in the muds. For example *Nymphaea*, *Nelumbo* and *Trapa*.
3. Submerged floating hydrophytes: They are completely submerged in water with long stems and no roots. For example *Ceratophyllum* and *Utricularia*.
4. Rooted submerged hydrophytes. They are completely submerged in water and rooted in soil. For example *Hydrilla*, *Potamogeton* and *Vallisneria*.
5. Rooted emergent hydrophytes. They grow in shallow water and shoots are partially or completely exposed to air. Root system is well developed and fixed in soil. For example *Sagittaria*, *Ranunculus* and *Scirpus*.

Anatomical features of root and shoot show absence of cuticle, thin walled parenchymatous epidermis, well developed cortex with thin walled parenchyma occupied by well developed air cavities called **aerenchyma**, absence of mechanical tissues and poorly developed vascular tissues. Stems are long, slender and flexible in most

of the plants. Vegetative propagation is common. Leaves are thin, long and ribbon shaped or linear or finely dissected in submerged forms. Floating leaves are large, flat with upper surfaces coated with wax. Petioles are long, flexible and mucilaginous. Emergent forms show heterophylly. Leaves of hydrophytes that grow submerged or floating tend to have big internal open spaces (lacunae) where the CO_2 given off during respiration and O_2 given off during photosynthesis can accumulate and recycled. Cuticle is absent in submerged leaves, but thin and poorly developed in floating and emergent species. Stomata are absent in submerged species, but present on upper side of floating species and both the sides of emergent species. Mesophyll is undifferentiated in submerged leaves, but differentiated into palisade and spongy parenchyma with well developed lacunae in floating and emergent species. There is little water conducting tissues. In floating leaved and emergent hydrophytes, air cavities continue in stem and roots allowing the transport of air from the leaves to the underground or submerged parts.

Under flooded condition, plants are asphyxiated due to low O_2 levels. Without sufficient O_2 the roots cannot respire aerobically and are shifted to anaerobic metabolism. Under this circumstance, uptake and transport of ions are inhibited leading to reduction in the concentration of nitrogen, phosphorus and potassium in the shoot. Plants accumulate ethylene, which is highly insoluble in water. Under flooded conditions both ethylene diffusion from the roots and O_2 diffusion into the roots is inhibited. This stimulates adjacent cortical cells of the cortex to lyse and form interconnected gas filled chambers called aerenchyma, which allow some exchange of gases between submerged and aerated portions.

Halophytes

High concentrations of salts like sodium chloride, magnesium chloride and magnesium sulphate in soils make it difficult for ordinary plants to obtain sufficient water. Saline soils, which include the soil of semi-arid and arid regions, tidal marshes, coastal dunes and mangrove swamps, are occupied by plants called **halophytes** or **salt plants**. Halophytes grow in soil with more than 0.2 per cent salt content. Halophytes extract water from soil with a higher osmotic pressure than normal water. Halophytes have several structural features found in xerophytes, several are **succulents**. Halophytes have high concentrations of salts in roots and are able to absorb water by osmosis. Halophytes are salt resistant and can carry on metabolic functions in the presence of excess salt within limits. Increased salt tolerance in cells may also involve other solutes such as malate.

Succulent species are able to store water in the cells of leaves and stem and thus dilute the ionic concentration. Even though halophytes tolerate higher salt concentration in their cell sap than non halophytes, they also have ways of getting rid of excess. Several mangroves (*Rhizophora* spp. and *Sonneratia* spp.) have salt glands that excrete salts to the surface of the leaves. Some accumulate ions in tissues away from metabolic sites and shed the leaves and their accumulated salts.

Halophytes tend to make their growth after heavy rains, when the salt concentration is lowest and this is also the most favorable time for germination of seeds. Some halophytes are obligates, requiring a saline habitat, while halophytes of coastal marshes and swamps (salt marsh grass, mangroves) grow best at low salinity. Glassworts (*Salicornia*) grow best at moderate salinity.

Most of the mangrove halophytes produce negatively geotropic roots that come out of the soil to take O_2 directly. Such roots are called **pneumatophores**, which possess pores for gaseous exchange. In some halophytes, seeds germinate before shedding from parent plants. This characteristic is called **vivipary**.

Ecological Adaptations to Biotic Factors

Organisms living together in natural conditions may influence the vital processes of other organisms in the community. Such interactions may involve peculiar ecological and physiological effects, which have profound evolutionary implications. For most of the plants, responses shown towards environmental factors are a complex interaction that results from the acquisition of same resources by competing plants, fungi, and other microbes and modification of other environmental parameters by co-inhibiting species. Interactions not only occur between different species (inter-specific) of plants, but also between individuals of same species (intra-specific).

Organisms may influence other organisms in following ways:

1. Direct influence on the supply of resources.
2. Indirect effects by altering the physical or chemical environment.
3. Dispersal

The influences of organisms on plants can be:

Competition for resources

Competition represents the situation where the supply of resource is less than the joint requirements of two organisms, and as a result the performance of one or both is impaired. The competition may be for PAR, water or nutrients. Competition is an important factor structuring ecological communities. The features that confer competitive superiority are leaf canopy architecture and height, rates of transpiration, root morphology and distribution, nutrient uptake capacity and nutrient uptake kinetics and portioning of biomass. Competitive superiority for PAR resides in the ability to place leaves in illuminated rather than shaded positions and is characterized by foliage height and the rate at which height is attained. In an annual crop and weeds competition the critical factors are seed size, relative growth rate and elongation rate. The large seeds have larger cotyledons producing a positive feedback to capture more light and so grow faster. The critical parameters for water and ion uptake are water flux, plant demand, root density and diffusion coefficients of the soil plant system that control uptake in competition. Under competition for exploiting a resource, the survival depends either on partitioning of the resource thereby avoiding competition or on the establishment of competitive superiority. **Intraspecific** competition is an important regulator of density of a population, whereas **interspecific** competition may lead to elimination one or both species.

Predation and Parasitism

There are hundred thousand species of phytophagous insects, several thousand species of parasitic fungi apart from herds of grazing mammals to consume the plants. Plants discourage potential pathogens and herbivores from causing excessive damage through following ways.

- (i) Nutrient inadequacy: Most plants have relatively low protein content varying from 1% in wood to over 30% in many seeds. Insect herbivores are specialist feeders on more nutritious parts. Other nutritional factors are levels of sterols, amino acids tryptophan and methionine, many plant proteins and even of sodium. For herbivores, quantity of food is not that critical as quality. To breakdown the plant cellulose and convert to animal flesh, high quality forage rich in N is required.
- (ii) Physical barriers: Many plant organs have external coverings of scales, hairs or glandular structures. There are thick cuticles, thick epidermal cell walls, bands of collenchyma or sclerenchyma or deposition of substances such as silica (in grasses) or resins (in conifers), which pose problems for predators in their

attempt to penetrate plant tissues. Many seeds have thick hard seed coats that provide protection from seed eating animals.

- (iii) **Toxins:** Toxins are most dramatic chemical defenses either constitutive or induced by attack. These chemicals include alkaloids, tannins, cyanogens, and a wide range of phenolic compounds. Chemicals make the food hardly digestible, unpalatable or even toxic.

There are two types of classes of plant feeding organisms based on type of material removed. Some organisms obtain essential metabolites by removing whole cells and are called **tissue feeders**. Others specifically remove cell contents and termed **metabolic feeders** such as stem mining beetle aphids and leaf mining beetles. Metabolite feeders feed on xylem contents, phloem contents and parenchymatous or other cell contents either by mechanical insertion of a probe to withdraw material or systemic infection. Metabolic feeders rarely cause dramatic damage to plants, but tissue feeders especially leaf feeders can destroy large proportion of plant's assimilatory tissue, leading in some cases to total defoliation. Tissue feeders may be insects, molluscs and mammals. Tissue feeders have biting or tearing mouth parts, but more subtly cope with cellulose based diet.

Predation on plants by herbivores leads to defoliation and consumption of fruits and seeds. Defoliation is the destruction of plant tissue. Continued grazing may kill the plant, but if it ceases, the plant may regenerate. Grazing reduces the plant biomass, plant's competitive position in community and its fitness. Productivity is severely limited by grazing of photosynthetic tissues or by pathogen damage. Plants compensate it physiologically by an increase in photosynthetic rate in surviving leaves or morphologically by new leaf growth. Roots become the carbon sources for new leaves. If the plants are severely damaged and neither adequate reserves nor sufficient surviving leaf area to resynthesize carbohydrates are available, break down of protein and other non storage substrates takes place. The morphological problem with regrowth is loss of meristems. A dicot leaf cannot regenerate the lost tissues, but the grasses have continuously active **basal meristem** to produce a new tissue from the base. This is why grasses make good lawns. Seed predation has different impact. Predation on one side reduces the rate of increase of plants, but on the other hand can be advantageous if consumption of seeds is mechanism for seed dispersal.

Parasites are mostly microorganism. In case of systemic attack, the resistance to parasitic fungi often involves the phenomenon of hypersensitivity, where cells around the point of infection die. Chemicals capable of inhibiting fungal growth (phytoalexins) accumulate in the dying cells. Phytoalexins are a form of inducible chemical defense in response to a predictable attack.

In parasitism, one organism either lives in or on other organism, or comes in contact for a short duration during life cycle. Parasite plants may be either **holoparasite**, which can not perform photosynthesis and attain all of their reduced carbon from host plant or **hemiparasite**, which perform photosynthesis at a reduced rate but still receive a portion of reduced carbon from the host. Parasitic vascular plant *Cuscuta* sp (stem parasite) is a holoparasite and *Aceuthobium* sp. is hemiparasite. Parasites grow on other plants with the help of adventitious roots penetrating the conducting elements of host stem through **haustoria**. Complete root parasites such as *Orabanche*, *Epifagus*, etc are found on roots of higher plants. *Santalum album* is partial root parasite. There are about 4000 parasitic angiosperms distributed in 22 different families. Parasites may be **specialist** attaching to only one host species such as *Epifagus virginiana* on *Ficus grandifolia* or **generalist** having a host range of several species such as *Cuscuta* sp. **Epiparasite** are connected to their host through a secondary organism, usually mycorrhizae.

Allelopathy

Allelopathy is the production of substances by one plant injurious to another plant. Allelopathic chemicals may be simple organic acids, polyacetylenes, unsaturated lactones, coumarins, tannins, flavonoids, derivatives of cinnamic acid, steroids, terpenoids, amino acids, glucosides, etc. These chemicals are liberated during following processes:

Withering: During decomposition of plant material, allelopathic compound are released.

Exudation: Below ground parts of plants release these compounds.

Production: Volatile toxic substance are produced, which inhibit sprouting, growth and establishment of other plants.

Leaching: Allelopathic compound leach from living or dead plant cells.

Allelopathic compounds act by interfering with membrane function, cell division and thus interfering with uptake of nutrient. Allelopathy is found to be useful also by discouraging predators and pathogens and directly affecting competitors. **Autotoxicity** can also be caused by allelopathic compounds with specific effects on their own seedlings representing a form of intraspecific competition. Allelopathy is tolerated by variety of mechanisms. Plants either avoid the chemical, tolerate the toxicity or neutralize the toxicity of allelochemicals. Avoidance is accomplished by dormancy, which regulates germination at lowest concentration of chemicals. Seedlings avoid toxicity by deep rooting. Tolerance to allelochemicals is achieved by excluding toxins at root surface, compartmentalizing toxins in apoplast, in non-sensitive cytoplasm or into vacuole, and localizing toxins in glandular trichomes. Toxins can be incorporated into cell wall constituent such as ferulic acid, a precursor for lignin synthesis. Toxins can also be detoxified by conjugating with sugars and amino acids or by excretion. There are other biotic adaptations developed for the benefit of either the species or both the species. These adaptations are:

Mutualism

In case of mutual benefits of organisms, the interaction is said to be positive. In such associations a close and obligatory contact of the organisms are essential for mutual benefits as well as survival. Mutualism may be:

Pollinator interaction: Pollinators derive food from plants and in return help in reproduction of plants.

Dispersal: Animals eat fruits and seeds of plants and help in dispersal of the population.

Symbiosis: When two different species associate to mutual benefit of each other, the association is called **symbiotic association** and the participating species are termed **symbionts**. Phycobiont and mycobiont association in lichen, rhizobium association in root nodules, mycorrhizal association in different species are examples of symbiotic associations. Symbiosis may be **ectosymbiosis** as in mycorrhizal association where both the organisms reside external to each other, or **endosymbiosis** when one organism lives inside the other such as algal cells within the fungal matrix in lichens and rhizobium bacteria in root nodules of plants.

Commensalism: When two different species associate in such a way that one species is benefited and the other neither benefited nor harmed, the association is said to be **commensalism** and participating species are **commensals**. **Epiphytism** is an important example where plants grow on other plants without taking any nourishment. In tropical forests, epiphytes grow on trees with specialized roots having **velamen** to absorb water from atmosphere. The **lianas** are vascular plants rooted in ground but to get their light requirement for manufacturing food, take support of large trees. Such associations are very common in forests. The microorganisms in soil get continuous supply of nutrition from living roots as well as leaves of higher plants. This is also an example of commensalisms.

Table 1. Average composition of the dry atmosphere measured upto 25 km.

<i>Composition</i>	<i>Volume</i>
Nitrogen (N ₂)	78.084%
Oxygen (O ₂)	20.946%
Argon (Ar)	0.934%
*Carbon dioxide (CO ₂)	350 ppm
Neon (Ne)	18 ppm
Krypton (Kr)	11 ppm
Helium (He)	5 ppm
*Methane (CH ₄)	1.7 ppm
Xenon (Xe)	90 ppb
Hydrogen (H)	50 ppb
*Ozone (O ₃)	40 ppb
* Nitrous oxide	30 ppb

* Variable gases

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