FSC 101 PRINCIPLES OF SILVICULTURE (2+1)

Theory

Forestry – Definition, scope, intensive and multiple use forestry – Geographical distribution and classification of world forests – History – Forest distribution in India – The general problems of forest development in the developed and developing countries – Reasons for diminishing forest cover in India – Deforestation, population, development projects, conversion of forestry for non-forestry pourposes – Recent trends in forestry development in the world – International forestry organization – Role of forests.

Silviculture – Definition, scope and objectives – Its relation with forestry – Factors of locality – Site factors – Climatic factors – Topographic factors – Edaphic factors – Site quality – Biotic factors – Bioclimate and micro climate – Pneumatophore – Lignotubers – Tree form – Classification of forest – Forest types.

Practical

Visit to a forests and near by forests – Study of world forests and Indian forests – Visit to dry deciduous forests and moist deciduous forests of the Nilgiris – Visit to thorn forests and shola grassland ecosystem – Study of wet temperate forests – Visit to a pure and mixed forests – Visit to tropical semi evergreen forests and wet evergreen forests – Study of littoral and swamp forests – Visit to ICFRE / State Forest Institute – Study of various organization in India – Visit to a range.

Lecture Schedule

1. Forestry – Definition – Scope of forestry – Intensive and multiple use forestry
2. Geographical distribution of world forests - Classification of world forests
3. History of forests and forestry in India
4. Forest distribution in India
5. The general problems of forest development in the developed and developing countries
6. Reasons for diminishing forest cover in India – Deforestation, population, development projects, conversion of forestry for non-forestry purposes
7. Recent trends in forestry development in the world
8. International Forestry Organization - its objectives
9. Role of forests - productive and protective roles
10. Definition and scope of Silviculture - objectives – Its relation with forestry
11. Factors of locality - Site factors - climatic factors - solar radiation – light
12. Climatic factors – temperature– frost - snow
13. Climatic factors - moisture and wind
14. Topographic factors – configuration – altitude – slope - aspect
15. Edaphic factors - soil formation - classification of soil - physical and chemical properties of soil
16. Edaphic factors - soil structure - soil water relations - soil organic matter - soil minerals
17. Mid Semester Examination

18. Site quality - classification of site quality
19. Biotic factors – plants – insects – wild animals – man
20. Interaction of locality factors - Bioclimate and micro-climate
21. Tree parts above the ground - crown and stem
22. Tree parts below the ground – root – adventitious roots – stilt roots – Pneumatophore – Lignotubers – root nodules
23. Growth and development of trees – height growth
24. Diameter growth and growth in volume - Tree form - form of crown and branching
25. Form of bole - epicormic branches - stool coppice - seedling coppice
26. Classification of Forests – Basis for classification – regeneration – age – composition – objects – ownership – growing stock
27. Forest types - definition - basis of classification - system of classification of forest types
28. Revised classification of forest types in India - Tropical wet evergreen forest - Tropical Semi-ever green forests
29. Tropical moist deciduous forests - littoral and swamp forests
30. Tropical dry deciduous forests
31. Tropical thorn forests - Tropical dry evergreen forests – subtropical broad leaved hill forests
32. Subtropical pine forests - subtropical dry evergreen forests
33. Montane wet temperate forests - Himalayan moist temperate forests
34. Himalayan dry temperate forests – sub-alpine forests - moist alpine scrub - dry alpine scrub.

Practical Schedule

1. Visit to a forests – study of the beneficial role of forests productive and environmental benefit
2. Visit to a nearby forests – Study of tree structure and form
3. Visit to a forests – study of tree components above ground characters (stem, crown) and below ground characters (root)
4. Study of World Forests– distribution pattern of tropical and temperate forests – forests distribution of the developed and developing countries
5. Study of Indian Forests – distribution pattern – classification of Indian Forests – role of FSI and remote sensing agencies
6. Visit to dry deciduous forests of the Nilgiris – study of factors governing the locality– species composition
7. Visit to moist deciduous forests of the Nilgiris – study of factors of locality – forest sub types – species composition
8. Visit to thorn forests – study of factors of locality – species composition
9. Visit to Shola grass land ecosystem – study of succession –– types of succession
10. Study of wet temperate forests – study of factors of locality – species distribution and composition
11. Visit to a pure and mixed forests – study of factors responsible for pure stands formation – comparison of pure and mixed stands
12. Visit to tropical semi evergreen forests – study of species composition – factors of locality

13. Study of littoral and swamp forests – species composition – factors of locality – significance
14. Visit to a wet evergreen forests – study of species composition – factors of locality
15. Visit to ICFRE / State Forest Institute – Study of various organization in India – Their role in Indian Forestry
16. Visit to a Range – study of range activities – forest types – territorial classifications
17. Final Practical Examination

Assignment

1. Inventory of species distribution in dry deciduous forest of western ghats
2. Inventory of species distribution in thorn forest of western ghats

References

Ahlywalia, S.K. 1992. Indian Forestry Scene. International Book Distributors, Dehra Dun. 198 p.

Champion, H.G. Griffith, A.L. 1989. Manual of general silviculture of India. EBD Educational Pvt. Ltd., Dehra Dun. 284 p.

Champion, H.G. and S.K. Seth. 1968. A revised survey of the forest types of India. Manager of Publication, Delhi.

Haig, I.T., M.A. Huberman and U. Aung Din. 1986. Tropical Silviculture. Periodical Experts Book Agency, New Delhi. Vol. 1, p. 190.

Khanna, L.S. 1981. Principles and practices of silviculture. Khanan Bhandhu Publishers, Dehra Dun. 163 p.

Rawat, A.S. 1991. History of Forestry in India. Indus Publishing Co., New Delhi. 337 p.

INTRODUCTION

Silviculture has been defined variously authors. According to Toumey and Korstian, 'silviculture is that branch of forestry which deals with the establishment, development, care and reproduction of stands of timber'. Indian Forest and Forest Products Terminology, published by the Forest Research Institute and Colleges, Dehra Dun, defines silviculture as, 'the art and science of cultivating forest crops'. According to Champion and Seth, 'the term silviculture in English commonly refers only to certain aspects of theory and practice of raising forest crops'.

Though from the above definitions, there appears to be some diversity in views about the scope of silviculture, yet, in a broad sense, silviculture may be taken to include both silvics and its practical application. According to Indian Forest and Forest Products Terminology, silvics is 'the study of life history and general characteristics of forest trees and crops with particular reference to environmental factors, as the basis for the practice of silviculture'. Thus silvics implies the study of trees and forests as biological units, the laws of their growth and development and the effect of environment on them. It explains the natural laws of their growth and development and their behaviour in a given set of environmental conditions. Though a lost of information on silvics has been collected by experiments, observations and experience of earlier foresters, a lot more information is yet to be collected to explain the unsolved complexities in the lives of trees and crops and the natural laws governing their reproduction, growth and development.

The knowledge gathered in silvics is applied to the production and care of forest crops. Thus the practice of silviculture is applied silvics. It deals with the procedure of obtaining natural regeneration under the various silvicultural systems, artificial regeneration of various species, and methods of tending young crops, whether natural or artificial to help them to grow into forests of quality timbers and great economic value.

Silviculture is not a purely biological science which has no relation with economics. The foresters raise the forests and tend them for the service of the people, but this is not to be done at a prohibitive cost. If forests are to be grown for the public good, the methods of raising and tending them, developed on the basis of knowledge of silvics, will have to be modified in practice by economic considerations.

Silviculture has been rightly described as an art and in this art intuition plays an important part. In our own country as well as in the European countries, there have been foresters who have advocated that, in case of doubt, the trees should be approached for answer. Even today, the local flora is regarded to be the best guide about the suitability of a species for a particular site. This is so because in nature there are so many complex factors at play that it is only the vegetation that can give an indication of the possible solution. But in order to understand the indication of the vegetation or answer of the trees, it is necessary for the forester to be conversant with their language and proficiency in this art comes by close continuous observation and experience.

Objects of Study of Silviculture

The forests are as old as the universe; naturally they must have been growing and renewing themselves. It is a well known fact that forest preceded civilization in every part of the world. Management of the forests by the Forest Departments is a very recent phenomenon. Even today, there are virgin forests in many parts of our country. The question naturally arises as to what use is the study and practice of silviculture and why should a forester take upon himself the work that the nature had been doing all these years. The answer to this question is purely economic. The object study and practice of silviculture is to produce more useful and valuable forests to meet our multifarious requirements, than nature would do and that too, in a shorter time. The objective with which nature produces vegetation are not identical with that of man. The former produces a 'jungle', the latter a forest. The study of silviculture helps in:

1) Production of species of economic value – In the virgin forests, many of the species are generally neither very valuable nor useful. Therefore, the production of timber of species of economic value per unit area is low. If the forests have to produce timber of industrial and economic importance, it is necessary to study and practice silviculture so that we can produce only the desired species.

2) Production of larger volume per unit area – In the virgin forests, the crop is generally either very dense or very open. Both these extremes are unsuitable for quantitative production. If the crop is very dense, the growth of the individual trees is adversely affected resulting in lesser timber volume production per unit area. On the other hand, if the crop is very open, the number of trees, and consequently volume, per unit area would be less. Besides this, a large number of trees die out as a result of competition before reaching maturity. In the unmanaged forest, they are not utilized and that volume of timber is lost. The study and practice of silviculture helps in raising sufficient trees per units area right from the beginning to fully utilize the soil and as they grow up, gradually reduce their number so that the requirement of light and food of the remaining trees is met. In this way, while by raising sufficient number of trees, the volume production per unit area is increased, the utilization of the excess trees as the crop grows in age, prevents the loss and consequently further increases that volume.

3) Production of quality timber – In the unmanaged forests, because of intense competition, a large number of trees become crooked, malformed, diseased and defective. This results in the deterioration of the quality of timber produced. If the production of quality timber is to be ensured, knowledge of silviculture will be essential so that the trees can be grown in disease free condition without adverse competition.

4) Reduction of rotation – In the virgin forests because of intense competition in the dense parts, the rate of growth of the individual tree is retarded with the result that it takes longer time to reach the size at which it can be exploited. This increases the cost of production of timber. With the knowledge and practical application of silviculture, the density of the crop can be properly regulated and consequently the rate of growth increased and rotation reduced.

5) Raising forests in blank areas – In nature, a large number of areas, potentially suitable for tree growth, occasionally remain blank due to certain adverse factors inhibiting growth of trees. Silvicultural skills and techniques help in raising forest in such areas.

6) Creation of manmade forests in place of natural forests – There may be areas in natural forests which may not regenerate or reproduce themselves naturally or where natural regeneration may be extremely slow and uncertain. In such areas, it becomes necessary for the forester to take up the work of nature in his hand and raise manmade forests in such areas. Success in this endeavour can be achieved only when he has a good knowledge of the science and art of raising forest crops artificially.

7) Introduction of exotics – The indigenous species may not be able to meet the commercial and/or industrial demands. In such areas, efforts are made to introduce exotics which can grown in that particular locality and can supply the timber required by

industries, etc., in time. For example, the demand of paper is increasing very fast. There is no indigenous species which may grow in a variety of sites easily and very fast so that the demand of the paper pulp industry may be met. Therefore, a last growing exotic, Eucalyptus hybrid, had to be introduced. This is possible only when the forester is conversant with the silviculture of the exotics as well as climatic and soil conditions of the localities in which they can be introduced.

Forestry, its Scope and Classification

Forestry is defined as the theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization of their resources. It is an applied science which is concerned with not only the raising or cultivation of forest crops but their protection, perpetuation, mensuration, management, valuation and finance as well utilization of the forest products for the service of the nation. In favourable localities, this science is applied to get maximum return and so it is called intensive forestry which is defined as the practice of forestry with the object of obtaining the maximum in volume and quality of products per unit are through the application of the best techniques of silviculture and management. When forestry is practiced to achieve more than one purpose, it is called multiple-use forestry which is defined as the practice of forestry for the simultaneous use of a forest are for two or more purposes, often in some measure conflicting, e.g., the production of wood with forest grazing and/or wildlife conservation.

Based on the objectives, forestry is classified as under:

a) Protection forestry – Protection forestry is the practice of forestry with the primary object of (1) protecting lands whether those upon which the forest is situated or those at a distance from it, against wind and water erosion, (2) conserving water supplies for human consumption, fish culture, etc., (3) reducing hazards from flood damage to human life and property and (4) amelioration of adverse climatic effects.

b) Commercial forestry – Commercial forestry is the practice of forestry with the object of producing timber and other forest products as a business enterprise. A specialized aspect of commercial forestry is to meet the requirement of a particular industry and in that case it is called industrial forestry which is defined as the practice of forestry to sustain a given industrial enterprise, such as a saw mill, pulp mill, chemical plant or a combination of these.

c) Social forestry – Social forestry is the practice of forestry on lands outside the conventional forest area for the benefit of the rural and urban communities. Supply of fuel wood to divert cow dung from village hearths to village fields, small timber for rural housing and agricultural implements, fodder for the cattle of the rural population living far away from the forest areas, protection of agriculture by creation of diverse ecosystem and arresting wind and water erosion and creation of recreational forests for the benefit of the rural as well as urban population are the basic economic and cultural needs of the community without which there can be no improvement in the conditions of their living. The application of forestry technology to achieve this social objective is known as social forestry. This is new dimension recently added to the concept of forestry and includes within its scope the following:

1) Farm forestry – Farm forestry is the practice of forestry on farms in the form of raising rows of trees on bunds or boundaries of field and individual trees in private agriculture land as well as creation of wind breaks, which are protective vegetal screens created round a farm or an orchard by raising one at two lines of trees fairly close with shrubs in between.

2) Extension forestry – Extension forestry is the practice of forestry in areas devoid of tree growth and other vegetation and situated in places away from the conventional forest areas with the object of increasing the area under tree growth. It includes within its scope the following:

i) Mixed forestry – Mixed forestry is practice of forestry for raising fodder grass with scattered fodder trees, fruit trees and fuelwood trees on suitable wastelands, panchayat land and village commons.

ii) Shelterbelts – Shelterbelt is defined as a belt of trees and/or shrubs maintained for the purpose of shelter from wind, sun, snow drift, etc. They are generally more extensive than the wind breaks covering areas larger than a single farm and sometimes whole regions on a planned pattern.

iii) Linear strip plantations – These are plantations of fast growing species on linear strips of land on the sides of public roads, canals and railway lines.

3) Reforestation of degraded forests

4) Recreational forestry – Recreational forestry is the practice of forestry with the object of raising flowering trees and shrubs mainly to serve as recreation forests for the urban and rural population. The main object is not to produce timber, grass or leaf fodder but to raise ornamental trees and shrubs in some area to meet the recreational needs of the people. This type of forestry is also known as aesthetic forestry which is defined as the practice of forestry with the object of developing or maintaining a forest of high scenic value.

RELATION OF SILVICULTURE WITH FORESTRY AND ITS BRANCHES

Silviculture and Forest Protection

Forest protection is defined as that branch of forestry which is concerned with the activities directed towards the prevention and control of damage to forests by man, animals, fire, insects, disease or other injurious and destructive agencies. A knowledge of the injuries caused to forests by the local human and animal population, both domestic and wild, insects, fungi and other adverse climatic factors and the preventive and remedial measures to counteract them, is essential for effective protection of the forests. Thus while silviculture is concerned with the raising of forest crop, forest protection is concerned with its protection against various sources of damage.

Silviculture and Forest Mensuration

Forest mensuration is defined as that branch of forestry which deals with the determination of dimensions, form, volume, age and increment of logs, single trees, stands or whole woods. Thus while silviculture deals with raising of forest crop, forest mensuration deals with measurement of diameter and heights of crop so produced, calculation of its volume, age, etc., for sale and research to decide the best treatment to be given to the crop while it is being raised.

Silviculture and Forest Utilization

Forest utilization is defined as the branch of forestry concerned with the harvesting, conversion, disposal and use of the forest produce. Thus while silviculture is concerned with the cultivation of forest crops, forest utilization is concerned with the harvesting and disposal of crops so produced.

Silviculture and Forest Economics

Forest economics is defined as those aspects of forestry that deal with the forest as a productive asset, subject to economic laws. Thus while silviculture is concerned with the cultivation of forest crop, forest economics works out the cost of production including rental of land and compound interest on capital spent in raising the crop, and compares it with the sale proceeds to decide whether raising of the crop is economically profitable or not. It is also the function of the forest economist to compare the cost of production of a particular crop by different methods and then decide the most profitable method of raising that crop.

Silviculture and Forest Management

Forest management has been defined as the practical application of the scientific, technical and economic principles of forestry. Thus while silviculture deals with the cultivation of forest crop, forest management manages that crop according to the dictates of the forest policy. Silviculture deals with the techniques and operations which result in the development of a forest. Forest management prescribes the time and place where the silvicultural techniques and operations should be carried out so that the objects of management are achieved.

The various branches of forestry are so closely related that the considerations of one branch influence the techniques of the other branches. For example, silvicultural techniques and operations are governed by the consideration of cost and modified to suit the requirement of protection. Similarly, even the most profitable method of exploitation or harvestings has to be given up if it is not compatible with silvicultural techniques or the protective considerations.

Silviculture and Forestry

From the definition of forestry given earlier, it is clear that forestry has a very wide scope and silviculture is only one of its branches. It has the same relation with forestry as agronomy has with agriculture. While agronomy and silviculture deal with cultivation of crops, agriculture and forestry deal not only with the cultivation of crops but also with their protection, management, mensuration, marketing, etc. In short, forestry is an applied science which has many branches. It may be compared to a wheel. Silviculture is the hub of the wheel; it is neither the whole wheel nor is it the only essential part. But, just as a cart wheel composed of several sections is supported on its hub, similarly forestry and its other branches are supported on silviculture without which there would be neither forestry nor its branches.

THE TREE AND THE FOREST

THE TREE

Tree is essentially a plant. Plants may be classified into the following three categories:

i) Herb, ii) Shrub and iii) Tree

i) Herb is defined as plant whose stem is always green and tender and height is usually not more than one metre. According to the span of life, it is called annual, biennia or perennial.

ii) Shrub is defined as a woody perennial plant differing from a perennial herb in its persistent and woody stem and less definitely from a tree in its low stature and its habit of branching from the bare. A shrub is usually not more than 6 metres in height.

Both these categories of plants supply, if at all, economic minor forest products only. As they are very small in size, they do not produce timber but shrubs are used as firewood.

iii) Tree is defined as a large woody perennial plant having a single well defined stem (bole or trunk) and a more or less definite crown. A tree is usually more than 6 metres in height which can, according to species, be upto 127 metres. For example, height of a Pseudosuga taxifolia tree in British Columbia has been measured to be 127.1 m and that of a Sequoia sempervirens tree in California has been found to be 112.1 m. In India, the maximum height so far recorded is not more than 75 m. A scrutiny of the record of heights of trees reveals that the conifers are taller than the broad leaved trees. For example, while the maximum height of deodar has so far been recorded to be 73.2 m, those of teak and sal have been found to be only 58.5 m and 51.2 m respectively. From the point of view of girth also, the Sequoia of California and the Eucalyptus of Australia are the biggest because they have attained girths of 3574 cm and 2438 cm respectively. In India the maximum girth so far recorded is 1646 cm, of a deodar in kulu (Himachal Pradesh). The maximum girths of teak and sal are even less; these have been recorded to be only 625 cm and 782 cm respectively.

Even from the point of view of age, tree has very much more longevity than the shrubs and the herbs. For example, age of a Sequoia sempervirens of California has been estimated to be more than 4000 years. In India, the age of a deodar tree, whose section is preserved in the F.R.I. was found to be 704 years. Of the other Indian species, maximum ages of teak and Dalbergia latifolia have been estimated to be 500 years and 600 years respectively. All trees provide timber from their stem and thick branches while the thinner branches and hollow portions of stem are used a firewood.

The tree can be divided into three parts:

TREE

Above the ground	Below the ground
i) The crown	iii) The root
ii) The stem	

THE CROWN

The crown is defined as the upper branchy part of a tree above the bole. It is formed by the foliage of the branches springing from the bole.

Shape and size – The shape and size of the crowns of trees vary with species and the conditions in which they grow. Phoenix, Cocos and Borassus have crowns of large leaves at the tops of cylindrical unbranched stems. This characteristic distinguishes them from other forest trees which are generally much branched. In chir, deodar and some other conifers, the lower branches are longer while the upper branches are gradually shorter, giving the crown a conical shape. On the other hand, the crowns of Mangifera indica, Azadirachta indica, Tamarindus indica, Madhuca indica, etc., are spherical in shape. In Albizzia stipulata the crown is broad and flat topped while in Abies pindrow it is more or less cylindrical. Except the palms, the crowns of other trees are affected by the situation in which they grow. Normally, the trees growing in the open have large branches and big crowns, while those growing in dense forests have smaller branches and smaller crowns, because the branches on the lower part of the bole die out gradually due to shade and the crowns are limited to the upper part of the bole of the tree. The size of the crown depends upon crown development which is defined as the expansion of crown measured as crown length and crown width.

Mode of branching – The mode of branching varies with species and sometimes, it is characteristic of the genus or the family. In most of the species, it is absolutely unsystematic. In species with opposite leaves, the branches are also in opposite pairs, though sometimes, this is visible only in the upper branches. Some species, e.g., Bombax ceiba and Pinus wallichiana, with alternate leaves sometimes develop branches in whorls.

The angle that the branches make with the stem, is also a specific character. Though in most cases, the branches make an angle of 60^o to 70^o with the stem, yet in some species, e.g., Populus nigra, Cupressus sempervirens, they make angles upto 20^o to 30^o. In quite a few species, e.g., old deodar and Dalbergia sonneratioides, the branches are almost horizontal and form terraces of foliage, while in some other, e.g., Anogeissus pendula, Terminalia myriocarpa, leading shoot of young deodar and branchlets and twigs of spruce, they are drooping downwards.

The size and the number of branches also varies with species. While in some species branches are thin and twiggy in others they are thick. Some species have large number of branches while others have only a few. The larger the number of branches and thicker the branches, the more the wood is knotty; this is considered as a defect in timber for several purposes.

Leaf colour, size and texture – Normally the mature leaves are green. The shade of colour of the two surfaces of leaf is often different, the lower being often paler than the upper. In addition to the difference in shade, the lower surface of the leaf is sometimes covered with while (e.g., in Quercus incana) or rusty brown tomentum (e.g., in Quercus semicarpifolia). Some species have characteristic attractive colour in their young leaves. For example, young leaves of Quercus incana are pinkish or purplish, those of Acer caesium, Schleichera oleosa bright red, those of mango brown and those of Cassia fistula dark red brown. In some species, leaves undergo a striking change in colour before falling from the tree; such colours are called autumn tints and help the forester in recognizing the species from a distance. For example, before falling the leaves of Lannea coromandelica turn yellow, those of Anogeissus latifolia dark red or bronze, and Sapium sebiferum beautiful red, purpose and orange. But quite a few species, e.g., Elaeocarpus, Bischoffia are characterized by the presence of a few conspicuous red leaves in almost all seasons.

Size of leaf depends upon rainfall and the species. As a rule, the leaves in low rainfall areas are small while they are generally bigger in heavy rainfall areas. In some species, e.g., teak, Dillenia, the leaves are bigger than the usual size of most leaves. Leaves of most conifers are needle shaped and that is why they are called needles.

While the texture of leaves of some species is soft and membranous, it is hard and coriaceous in others. The membranous and soft leaves of species, e.g., Grewia, Ougeinia, Anogeissus, etc., on falling not only decompose rapidly and get mixed up with the soil but hasten the decomposition of the hard and coriaceous leaves of species, e.g., sal and conifers which otherwise, decompose very slowly and create problem for natural regeneration.

Leaf shedding – All trees shed their old leaves regularly and produce new leaves. The new leaves may be produced while the old leaves are still present on the tree or after they have fallen. On the basis of the presence or absence of old green leaves at the time when the new leaves are produced, the trees and other plants are classified into deciduous and evergreen. A tree is called deciduous if it normally remains leafless for sometime during the year. In other words, it produces new flush of leaves after all the old leaves have been shed and it has remained leafless for sometime. The leafless period varies with species and situation. For example, sal is leafless for about a weak or ten day while Hymenodictyon excelsum remains leafless for about six months. Even in the same species different trees remain leafless for different periods due to their situation. For example, in areas with abundant and well-distributed rainfall, teak becomes nearly evergreen while in drier areas, it remains leafless for about six months. Santalum album is exception to the above general rules; it becomes deciduous or evergreen according to the habit of its host plant.

An evergreen is defined as perennial plant which is never entirely without green foliage, the old leaves persisting until a new set has appeared. The persistence of the old green leaves after the new leaves have been produced, depends upon species and in the same species upon the environment. For example, in chir, the old leaves persist from one year five months to two or three years but in deodar, they persist for five or six years. On lower altitudes, due to higher temperature, chir, which is normally evergreen, become deciduous.

The following are some examples of deciduous and evergreen trees:

Deciduous – Acacia catechu, Adina cordifolia, Ailanthus excelsa, Bombax ceiba, Garuga pinnata, Holoptelia integrifolia, Lannea coromandelica, Melia azaderach, Schleichera oleosa, Terminalia tomentosa.

Evergreen – Abies pindrow, Cedrus deodara, Cupressus torulosa, Hopea parviflora, Mallotus philippinensis, Mangifera indica, Michelia champaca, Picea smithiana, Pinus wallichiana, Pterospermum acerifolium.

THE STEM

The stem is defined as ‘the principal axis of plant from which buds and shoots are developed; in trees, stem, bole and trunk are synonymous’ but bole is ‘some times used to refer to only lower part of the stem upto a point where the main branches are given off, i.e., as a synonymous for clear or clean bole which is defined as the part of the bole that is free of branches.

The shape and length of the stem varies with species and the situation in which the tree grows. Some species have long and straight stem with relatively few branches, while others have stem which are crooked and/or much branched. Normally the stem is thicker at the base and thinner in the upper portion of the tree. The decrease in diameter of the stem of a tree or of a log from the base upwards, is known as taper. This is due to the pressure of wind which is centred in the lower one third of the crown and is conveyed to the lower parts of the stem, increasing with increasing length. To counteract this pressure, which may snap the tree at the base, the tree reinforces itself towards the base.

The situation in which the tree grows affects the shape and length of the stem. The trees growing in the open in plains and or ridges in hills have generally shorter and conspicuously tapering stem as a result of wind pressure. On the other hand, the trees growing in dense forest have relatively longer and more or less cylindrical stem. The production of a long cylindrical bole is a desirable quality in trees because that increases their timber volume.

In the earlier stages, thin branches generally cover almost the entire stem of a tree but as the saplings grow into poles and trees, the lower branches fall off resulting in a clean bole. But even in later life, sometimes, due to some adverse factors the clean bole again develops small branches known as epicormic branches which are defined as 'branches originating in clusters from dormant or adventitious buds on the trunk of a tree or on older branch when exposed to adverse influence such as excessive light, fire or suppression'. They are also caused by drought and that is why they are generally found on stag-headed trees.

Normally trees have one stem but sometimes they are forked and have more than one leader. From the point of view of timber production, this is not a desirable quality because the portion below the point of forking is either wasted or produces small sized timber and there is always a danger of one of the leaders being broken down in wind storms.

In some species, e.g., Acrocarpus fraxinifolius, Bombax ceiba, Pterocarpus dalbergiodes, Terminalia myriocarpa, etc., buttresses are formed in the basal portion of the stem. They are out growths formed usually vertically above the lateral roots and thus connect the base of the stem with roots. They are generally associated with the absence of long taproot due to either shallow soil resulting from the presence of rock a little below the surface or badly aerated and infertile subsoil. Buttress formation, sometimes, extends upto 5 m and therefore the lower portion of the stem becomes useless, unless the buttresses are very small. The felling of buttressed trees present great difficulties as the felling has to be done above buttress formation.

In some other species e.g., teak, the lower portion of the stem is characterized by fluting which is defined as 'irregular involutions and swellings on the bole just above the basal swell'. As fluting decreases the basal volume considerably, it is considered to be a serious defect. It is attributed to epicormic branches, insect attack, unsuitable site or faulty thinnings; no definite reason is so far known.

THE ROOT

The root is that portion of the plant which develops inside the soil and away from light. Unlike stem it does not produce leaves, flowers or fruits. The roots of trees support them firmly to the ground, absorb soil moisture containing mineral salts and send it to stem for onward transmission to the leaves. They, generally, comprise of two kinds of roots, viz., the taproot and the lateral roots.

The tap roots is the primary descending root formed by direct prolongation of the radicle of the embryo. In trees, it is the main axis of the large root system and descends vertically below the stem. It is conical in shape, develops towards the permanent moisture in the soil and sometimes, attains considerably length.

The lateral roots are the roots that arise from the taproot and spread laterally to support the tree. As the taproot grows, it develops lateral roots which are branched and re-branched and ultimately form rootlets. The ends of the rootlets are covered with fine hairs, called the root hairs. These root hairs spread in the soil particles, and absorb soil moisture to translocate it to stem and leaves where the food is manufactured. The taproot and the lateral roots including their branches upto root hairs, form the root system of the tree. The lateral roots are generally confined to the area covered by the crowns of trees but sometimes they go far beyond. For example, the lateral roots of trees growing on the edge of a forest go far into the cultivated fields and adversely affect the agricultural crops. Even in the forest, they sometimes go beyond the area of the crowns of trees and may form root grafts with the roots of other trees in dense forest.

The roots of the seedlings develop very fast and sometimes reach one metre depth in one season in favourable localities. As the roots develop much faster than the shoot in early stages, it is not possible to estimate the length of the root from that of the shoot. Early development of taproot to such a depth where the moisture in the soil is more or less permanent protects the plants against post monsoon and summer drought.

The roots, generally, require a well aerated soil for their development. Therefore, the roots of may species, e.g. sal, are killed by rise in the water table, though those of some species may adjust themselves according to the changed conditions. Similarly, when a layer of silt is deposited on top of the soil, some trees die but some others develop roots from the covered portion of the stem and are not killed.

On the basis of the depth of the root system the trees are classified into shallow-rooted and deep rooted trees. Shallow rooted trees are those whose root system does not extend far enough into the soil to save them from relatively easy wind throw. The deep rooted trees, on the other hand, are those whose roots go very deep in the soil. The trees, which develop a long taproot and large lateral roots are not easily uprooted by wind and are called wind firm.

Adventitious Roots

Adventitious roots are the roots produced from parts of the plants other than the radicle or its subdivision. In bamboos, the roots are produced from the underground stem called rhizome and are therefore adventitious. These roots are thin and usually undivided. They do not show secondary thickening and are replaced by new roots when the older ones die. The following kinds of adventitious roots are commonly found in trees:

1) Prop-roots – Ficus bengalensis produces from its branches adventitious roots which remain suspended in the air till they reach the ground. On reaching the

ground, they enter it and get fixed up in the soil. As they support thick branches of the tree, they are called prop-roots.

2) Stilt roots – Stilt roots are adventitious roots which emerge from the butt of a tree above ground level, so that the tree appears as if supported on flying buttresses, e.g., mangroves of the genus Rhizophora.

3) Pneumatophore – Pneumatophore is a knee shaped or spike like projection of the roots of swamp tree, e.g., Heretiera, Bruguiera, enabling the submerged roots to obtain oxygen.

Mycorrhiza

In certain, species, the fine extremities of rootlets behind the root cap, instead of being covered with root hairs are found to be invaded by specific non-pathogenic soil fungi. The invasion results in the formation of composite structures which are neither roots nor fungi. This composite structure or invaded rootlet is called mycorrhiza (plural mycorrhizae). Thus mycorrhiza may be defined as a structure produced from the combination of the modified rootlet with fungal tissue.

Types of mycorrhizae – Mycorrhizae are broadly classified as ectotrophic, endotrophic and ectendotrophic. In the ectotrophic type, fungi usually belong to Basidiomycetes. They form a mantle over the rootlets and the hyphae usually radiate from the mantle. The fungi enter the cortex, thus permitting the hyphae to grow in the intercellular space. In the endotrophic type, the fungi usually belong to Phycomycetes. They are present in the form of individual hyphae on the root surface and penetrate the cells of the cortex. Roots, sometimes, become beaded. In the ectendotrophic type, both kinds of above mentioned infections are combined, i.e., a condition where typical ectotrophic condition is accompanied by intracellular penetration of the hyphae.

Occurrence – Mycorrhiza is found in Pinus, Picea, Abies, Cedrus, Cupressus, Taxus, Populus, Aurocaria, Salix, Podocarpus and Eucalyptus, etc.

Importance of mycorrhiza in forestry – Though the exact role of mycorrhiza is still not understood, it is believed to perform the following functions:

i) Absorbs soil moisture by increasing the area of absorbing surface

ii) Helps in the absorption of minerals, e.g., phosphorus, copper, iron, which are in short supply and can not be absorbed by non-mycorrhizal roots and

iii) Fixes nitrogen from raw humus

Because of these functions, mycorrhiza is very beneficial to tree growth and is considered essential for the growth and survival of several species, especially the exotics. A large number of plantations in many countries have failed due to failure to introduce mycorrhiza. With the large scale introduction of exotics in India, it is likely to plant a dominant role in their establishment.

Introduction of Mycorrhiza – Though, sometimes, mycorrhiza develops itself in new soils without being introduced by foresters as seen in the successful Eucalyptus plantations in India and chir pine plantations in sal forests of M.P., yet it is advisable to introduce it before planting any exotic. Mycorrhiza may be introduced by the following ways:

i) Mixing soil brought from the natural good quality forests of the species. The soil should be neither dry nor very moist but should contain adequate moisture as well as mycorrhizal roots. It should be brought in sealed polythene bags and applied to the site as early as possible, but not later than 10 days after collection to ensure viability of mycorrhiza.

ii) Interplanting imported seedlings with mycorrhizae in nursery beds

Lignotubers

Lignotubers are underground swellings found on most species of Eucalyptus. They are actually modified stems developed from double accessory buds in the axils of cotyledons. They serve the purpose of food storage and regeneration because they bear numerous buds, which become active and produce shoot, if the tree is injured, cut down or burnt.

Root Nodules

The roots of a large number of plants and trees have small nodules. They contain bacterial (Rhizobium) in large numbers. The bacteria present in the soil, enters the root through the root hairs in the form of bacterial filament. After entering the root, the filament branches rapidly and reaches inner cortex where it causes active cell division resulting in the formation of nodules. These nodules vary greatly in shape and size. The bacteria living in the root nodule (and not those in the soil) help in fixation of free nitrogen from the air in the form of nitrates. The plants utilize the nitrates and in return, provide the bacteria with carbohydrates. Thus a mutually beneficial relationship, called symbiosis, is established.

Root nodules are found in about 65 species of about 8 families, the commonest being Leguminosae in which they are found in Dalbergia, Bauhinia, Acacia, Albizzia, Erythrina, Tephrosia, Crotolaria, Indigofera and Leucaena. They are, however, not found in Cassia tora. Besides Rhizobium there are some other nitrogen fixing and root nodule forming bacteria also.

Growth and Development of Trees

The tree starts its life as a small seedling which grows by increase in length and diameter of its shoot and root. As the shoot grows upwards, it develops branches and foliage. The root grows downward and develops lateral roots and its branches. Thus the seedlings grows not only by increase in the size of its shoot and root but also by the formation of new organs. The increase in size is commonly referred to as growth or increment and the formation of new organs is referred to as development. Thus both growth and development are responsible for the change that takes place in a small seedling growing into a tree.

Various stages of growth and development of a plant are designated as follows:

i) Seedling – Seedling is a plant grown from seed till it attains a height of about one metre, i.e., before it reaches the sapling stage.

ii) Sapling – Sapling is defined as a young tree from the time when it reaches about one metre (3 feet) in height till the lower branches begin to fall. A sapling is characterized by the absence of dead bark and its vigorous height growth.

iii) Pole – Pole is defined as a young tree from the time when the lower branches begin to fall off to the time when the rate of height growth begins to slow down and crown expansion becomes marked.

iv) Tree – Tree is the stage of growth beyond the pole stage when the rate of height growth begins to slow down and crown expansion becomes marked.

As the plant grows, certain changes occur in its morphology. The plant sheds its leaves and produces new leaves every year. It produces flowers and seeds after a certain age and sheds or disperses them on ripening. These changes are important events in the life of plant and in order to know the silviculture of a particular species, it is necessary to study such changes in the members of that species. The science that deals with the study of these changes in plants is known as phenology; it is defined as the science that deals with the time of appearance of characteristic periodic events such as leaf shedding, etc., in the life cycle of organisms in nature especially as those events are influenced by environmental factors.

These events do not occur on the same date every year. The variation in time of these periodic events every year can, in most cases, be correlated with changes in the climatic factors but it also depends upon the species. For example, if the weather has unusually warmed up a little before leaf fall or at the time of fruiting, leaf fall is hastened and fruit ripening is quickened. But if that occurs before the normal time of leafing or flowering, these events are delayed. Heavier rainfall in Albizzia procera and sal, but they appear to delay new leafing and flowering. Fruit ripening in Dalbergia sissoo and Mangifera indica does not appear to be affected by the changes in climatic factors.

In addition to these morphological changes, some anatomical changes also take place in the plants annually and these results in the growth. The growth in trees is confined only in certain regions, called the growing points. These consist of meristematic cells which have the capacity to divide and give rise to new cells. The meristematic cells found in the apices of shoot and root are called apical meristems and they are responsible for the growth in height of shoot and length of root. Besides these apical meristems, the trees have primary lateral meristem in the form of cylindrical sheath which is responsible for diameter growth of shoot and root and secondary lateral meristem responsible for the growth of bark.

As the plant grows, its physiological activity increases and this requires division of labour; to achieve this, a growing plant develops various kinds of tissues which perform diverse functions.

The growth in plants is not uniform throughout the year. Generally, the periods of rapid growth are preceded and followed by periods of slow growth, thereby creating difference between the wood formed during the two periods. This results in the formation of distinct annual rings in some species. The number of annual rings counted on stump, when added with the number of years the tree took to grow to stump height gives the age of the tree at the time of felling. The width of the rings indicates the rate of growth, fast growth being indicated by rings wider than 5 mm. Width of growth rings has considerably effect on the strength properties of wood.

A forester is interested in height and diameter growth of trees as both these affect the volume growth. In addition, he is interested in quality of timber. Therefore, they need a more detailed description.

Height Growth

Height growth in trees varies with age, species and in the same species with the quality of site on which they grow. Thus the forester has very little control over the height growth of trees. In terms of age, three distinct stages are usually distinguished, viz., the juvenile or the seedling stage the sapling and pole stages of young ages, and finally the tree stage past the middle age of the tree. During the juvenile stage, the growth varies from very slow to fast according to species. For example, height growth of Abies pindrow seedlings is very slow. Even in nursery condition, they attain a height of only about 30 cm in 4 years. Deodar seedlings grow slightly faster as they attain this height in about 2½ years. Amongst the Western Himalayan conifers, kail seedlings are faster grown. In the tropical zone sal seedlings are slow fastest grown. In the tropical zone sal seedlings are slow grown and continue to die back for several years. Teak on the other hand, is faster grown in juvenile stages. The rate of growth in juvenile stage is a very important factor in the survival of the seedlings. After the juvenile stage, most of the trees grow fast and attain maximum height for that species and site by the time they reach the middle age; after that the rate of growth falls again and a time comes after which there is no height growth.

Diameter Growth

Diameter growth of trees is of great importance as it affects the volume of wood produced. It has an added importance for the forester because while he can not influence the height growth of trees, he can influence its diameter growth by silvicultural treatment.

The tree grows in diameter right from the juvenile stage of its life; but the growth in diameter upto pole stage is rather slow as the tree concentrates mainly on height growth upto this stage. It is only when the tree has reached the maximum height that it starts increase in diameter with speed. This continues till the tree reaches maturity, when the rate of diameter growth also starts falling.

The diameter growth in trees is affected by a variety of factors such as:

i) Size of the tree – The smaller the tree, the lesser the diameter increment.

ii) Climate – The trees on the warmer sites put on faster diameter increment than those of the same species on colder sites. Rainfall also affects the diameter growth. A warmer season results in higher diameter increment only when there is adequate moisture.

iii) Soil – The diameter growth is influenced by soil quality, soil moisture and nutrient content.

iv) Production of seed – The growth in diameter is retarded in years of heavy seed production because the entire food material is used up in seed production.

v) Injuries – Defoliation by insects, insect attacks and fires have an adverse effect on diameter growth.

vi) Density – In dense forests, the growth in diameter of individual trees is retarded. As soon as the crop is opened up, the diameter growth becomes faster.

As already mentioned, the growth in diameter of the tree is not uniform throughout its height; it is maximum near the base and least at the tip. In the crown portion, the diameter growth is maximum at its base and decreases rapidly towards the tip to give it a conical shape. In the stem portion, the decrease from the base to the top is very gradual with the result that the diameter at the top of the stem is generally about half the diameter at the base.

The taper of the tree is characteristic of each species and in the some species it varies with age, density of the stand and site. It is described by the term form. The typical form of a tree can be seen in the open on the best quality sites. Age has a great effect on form; the taper is greatest in young age and reduces gradually towards the old age or maturity. The denser the stand, the greater the tree bole approaches the cylindrical form.

Growth in Volume

The growth in volume is a function of height, diameter and the form of the tree. Therefore, greater the height and diameter and lesser the taper, the greater the volume of the tree.

Growth of Trees in Quality

The object of silviculture is not served just by producing trees of large dimensions; if the timber contained in them is not of good quality, it would not only result in lesser merchantable timber but also lesser economic return. Therefore, the aim of silviculture regarding producing trees containing large volume of timber is modified to produce large quantity of timber of high quality. Thus the growth of tree in quality is as great a concern of the forester as the production of larger volume.

The quality of timber in trees depends upon size, straightness, taper, knots, other defects and strength. The larger the size of timber, the lesser the wastage and greater the volume. If the tree is straight and not crooked, longer sized timber can be produced with minimum of wastage. The quality of straightness should not be confined to the bole but also to fibres inside, because if the fibres are twisted, the timber would be useless. Taper also affects the quality of timber as it increases wastage. Knots seriously affect the quality of timber. The greater the number of knots, the lower the quality of timber. If the knots are loose, they usually come out on drying leaving a hole in the wood. Similarly, insect and fungus attacks reduce the quality of timber. Fire also affects the quality of timber. Strength of timber depends upon the rate as well as the uniformity of growth. Very fast rate of growth impairs the strength of timber and reduces the quality. If the rate of growth is sometimes fast and sometimes slow, the timber will not be of uniform quality. The more uniform the growth, the better the quality.

Reproduction

After attaining maturity or old age, tree dies. Therefore, in order to maintain continuity of its own species and also to multiply its numbers, it has to reproduce itself. Thus reproduction is that vital process by which tree species perpetuate themselves by reproducing new independent members of their own species by some method. Reproduction in nature can be sexual or asexual or vegetative but in trees, only sexual and vegetative reproduction takes place.

Sexual Reproduction

Sexual reproduction consists in the fusion of two dissimilar sexual units called gametes. In trees, this is achieved by the production of flowers, their pollination, and finally by fertilization resulting in development of seeds.

Flowering

All trees produce flowers. The age at which the trees start flowering varies with species and their situation. Generally trees produce flowers when the height growth has nearly been completed but there are exceptions also. For example, sissu usually starts flowering at the age of 3 or 4 years and teak occasionally flowers at the age of one or two years. Situation also affects the age of flowering; many trees in open flower at a much earlier age than they do in dense forest.

Flowering of trees is affected by internal and external factors. The internal factors relate to certain conditions in the tree itself, e.g., the development of special hormones or florigins and the presence of high concentration of carbohydrates. The external factors relate to environmental factors, the most important of which are temperature and light. Favourable temperature and light conditions accelerate photosynthesis and increase carbohydrate production, resulting in increased flowering. Observations made on teak indicate that flowering is inhibited on the shaded portion of the crown.

In case of trees raised by vegetative methods, flowering is reported to be stimulated by pruning the roots, planting at an angle of 45^{o} or so, strangulation by wire or metal hand and training of branches in horizontal position. As a general rule, however, it may be said that treatment which inhibits growth and prevents or even obstructs the translocation of food material downward promotes early flowering. But this does not appear to apply to trees raised by seed. Sickly trees likely to die soon, sometimes, produce large quantity of flowers and seeds as a last effort to perpetuate their species.

Time of Flowering

Though most of the trees flower every year, some flower at an interval of years. The time of flowering varies with species and climatic conditions. The time of flowering of some of the important species mentioned below is given in brackets after them:

Acacia catechu (June to September), Ailanthus excelsa (February to March), Azadirachta indica (March to May), Bombax ceiba (January to March), Dalbergia sissoo (March, April), Shorea robusta (February to April), Tectona grandis (June to August or September), Quercus dilatata (April, May).

Trees have mostly bisexual flowers but many species have unisexual flowers also. Trees with unisexual flowers may be monoecious, i.e., the male and female flowers may be found on the same individual, or dioecious, i.e., the male and female flowers may be on different individuals. Some species are also polygamous, i.e., they have both unisexual and bisexual flowers.

Examples

Monoecious – Pinus, Abies pindrow

Dioecious – Salix, Mallotus, Taxus, Diospyros, Cedrus deodara, Pistacia

Polygamous – Sterculia, Garuga, Rhus

Pollination

Pollination of flowers of trees may take place by wind, insects and birds. The following are some examples of the different methods of pollination:

By wind (Anemophily) – Conifers, Betula, Alnus, Juglans

By birds (Zoophily) – Bombax, Butea, Erythrina, Anthocephalus, Oroxylum (the last two are pollinated by bats).

By insects (Entomophily) – Sal, Teak, Sissoo

Flowering of Bamboo

Flowering of bamboos varies from species to species. While some species of bamboo flower after long periods with no flowering in between, others flower so irregularly that some flowers can be found practically every year. The periodic flowering occurs on practically all the clumps of the species over a considerable area. Thus, flowering in bamboo is of the following two kinds:

i) Gregarious flowering – It is the general flowering, within one or a few years, and over considerable areas, of all or most of the individuals of certain species that do not flower annually; in some cases followed by the death of the plant.

ii) Sporadic flowering – It is the flowering of one or a few culms in a clump or a few clumps in a locality.

In addition to the above two kinds of flowering, annual flowering is also met with in certain species of bamboos, e.g., Arundinaria wightiana, Bambusa lineata, Ochlandra stridula, etc. It is not followed by the death of bamboo.

Interval between Pollination of Flowers and Ripening of Seed

The interval between pollination of flowers and ripening of seed varies from species to species even in the absence of any adverse factors. The following table shows range of interval in a few species:

Sl.No.	Species	Interval in Months
1.	Ailanthus excelsa	2
2.	Tectona grandis	3
3.	Acacia catechu	4-5
4.	Dalbergia sissoo	6-7
5.	Cedrus deodara	12-13
6.	Pinus roxburghii	24-26

SEED

After fertilization, the ovary grows and develops into a fruit, while its ovules, after a series of changes, develop into seeds. Thus the seeds are enclosed in the fruit. The plants in which the seeds are enclosed in the fruit, belong to a sub-division called angiosperms. In certain other plants, however, the seeds are not enclosed in the fruit but are directly borne on the open carpel. The plants which have such naked (i.e., not enclosed in fruit) seeds belong to a subdivision known as gymnosperms. In the angiosperms, the fruit as a whole, may fall to the ground on ripening but generally the fruits open up and only the seeds fall to the ground where they may germinate and produce the plants.

Vegetative Reproduction

In sexual reproduction, the creation of a new and independent plant is achieved by sowing the seed in the soil. In vegetative production, on the other hand, a new plant is created by some vegetative part of the plant e.g., a portion of the root or shoot (stem or branch), or a combination of both, a bud or even injured roots. Sometimes, however, after a plant has been utilized, its stump produces new plants. There are several methods of vegetative reproduction but in forestry only coppice, root sucker, cuttings (branch, stem or root shoot) and grafting are used.

THE FOREST

Definition

Forest is defined as an area set aside for the production of timber and other forest produce, or maintained under woody vegetation for certain indirect benefits which it provides, e.g., climatic or protective. This is the general definition of the term and lays emphasis on the direct and indirect benefits that the forests provide. But in ecology, it is defined as a plant community predominantly of trees and other woody vegetation, usually with a closed canopy. This definition describes the forest as a kind of vegetation in which trees constitute the predominant part, to distinguish it from vegetation in which grasses or shrubs may be predominant, and are fairly dense so that their crowns touch each other. In legal terminology, forest is defined as an area of land proclaimed to be forest under a forest law. This definition describes the forest not as a biological unit but as property having a owner and with rights or certain people. This definition is useful only in law courts, where cases pertaining to offences committed are tried. From the point of view of silviculture, the first two definitions are more important.

The term forest has generally been used so far in India to denote crops raised by the practice of silviculture. But in recent years, an American term ‘stand’ is also used. American foresters differentiate between ‘stand’ and ‘forest’. According to them, stand is defined as an aggregation of trees occupying a specific area sufficiently uniform in composition (species), age arrangement and condition to be distinguishable from the forest on adjoining areas. Thus the unit of silviculture is a stand. Forest, on the other hand, is a collection of stands administered as an integrated unit to obtain the objective of sustained yield.

Classification of Forests

Forests can be classified on the basis of

i) Method of regeneration

ii) Age

iii) Composition

iv) Objects of management

v) Ownership and legal status and

vi) Growing stock

i) Classification based on method of regeneration – Forests can be regenerated either from seed or from vegetative parts; those which are regenerated from seed are called high forests and those regenerated by some vegetative method are called coppice forests.

ii) Classification based on age – Even in plantation raised in a particular year, all the trees are not of the same year because casualities are replaced in the second and third years. Thus forests having all trees of the same age, are usually not found. Therefore forests are classified on the basis of age into even-aged or regular forest and uneven-aged or irregular forest. Even-aged or regular forest is defined as a forest composed of even-aged woods. The term even-aged used in this definition is applied to a stand consisting of trees of approximately the same age. Differences upto 25% of the rotation age may be allowed in cases where a stand is not harvested for 100 years or more. Uneven-aged or irregular forest is defined as a forest composed of trees of markedly different ages. The term uneven-aged is applied to crops in which individual stems vary widely in age, the range of difference being usually more than 20 years and, in the case of long rotation crops, more than 25% of the rotation. Such a forest is called selection forest when all or nearly all age gradations or age classes are present.

iii) Classification based on composition – A forest may have only one species or more than one species. On the basis of the number of species present, the forest is classified into pure or mixed forest. Pure forest is defined as a forest composed of almost entirely of one species, usually to the extent of not less than 80%. It is also called pure crop or pure stand. Mixed forest, on the other hand, is defined as a forest composed of trees of two or more species intermingled in the same canopy; in practice, and by convention, atleast 20% of the canopy must consist of species other than the principal one. The species composing the mixture may be distinguished as principal, accessory and auxillary. Principal species is defined as the species first in importance in a mixed stand either by frequency, volume or silvicultural value or the species to which the silviculture of a mixed forest is primarily directed. Accessory species is defined as a useful species of less value than the principal species, which assists in the growth of the latter and influence to a smaller degree the method of treatment. Auxillary species is defined as a species of inferior quality or size, of relatively little silvicultural value or importance, associated with the principal species. It is also referred to as secondary species or subsidiary species.

iv) Classification based on objects of management – On the basis of objects of management, forests are classified into production forest, protection forest, farm forest, fuel forest, recreation forest, etc. Production forest is a forest managed primarily for its produce. It is also sometimes referred to as national forest, i.e., a forest which is maintained and managed to meet the needs of the defence, communications, industry, and other general purposes of public importance. Protection forest is defined as an area wholly or partly covered with woody growth, managed primarily to regulate stream flow, prevent erosion, hold shifting sand or to exert any other beneficial influence. Farm forest is a forest raised on farms and its adjoining area either as individual scattered trees or a collection of trees to meet the requirement of fuel and fodder of the farmers and to have a beneficial influence on agriculture. Fuel forest is a forest raised on village wasteland to supply fuel, small timber, fodder, etc., to the village communities living far away from government forest. Recreational forest is a forest which is managed only to meet the recreational needs of the urban and rural population.

v) Classification based on ownership and legal status – On the basis of ownership, forests are classified into state forest, communal forest and panchayat forest. State forest is a forest owned by state. Communal forest is a forest owned and generally managed by a community such as a village, town, tribal authority or local government, the members of which share in the produce or proceeds. Panchayat forest is any forest where management is vested in a village panchayat (i.e., a body of men elected by the villagers from among themselves for specific administrative or other purposes pertaining to the village).

The state forests are further classified into reserved forest, protected forest and village forest on the basis of their legal status. A reserved forest is an area so constituted under the Indian Forest Act or other forest law. A protected forest is an area subject to limited degree of protection under the provisions of Chapter IV of the Indian Forest Act. A village forest is a state forest assigned to a village community under the provisions of the Indian Forest Act.

vi) Classification on the basis of growing stock – On the basis of growing stock, the forests are classified into normal and abnormal forest. Normal forest is defined as a forest which for a given site and given objects of management, is ideally constituted as regards growing stock, age class distribution and increment and from which the annual or periodic removal of produce equal to the increment can be continued indefinitely without endangering future yields. Such a forest by reason of its normalcy in these respects serves as a standard of comparison, for sustained yield management. Abnormal forest is a forest in which, as compared to an acceptable standard, the quantity of material in the growing stock is in deficit or in excess or in which the relative proportions of the age or size classes are defective.

From the point of view of silviculture, only the first three bases of classification are important.

Growth of Forest

A forest starts its life as an aggregation of seedlings. In the beginning, the number of seedlings over a unit of area is very large but as the forest grows, the number of plants keeps on diminishing. Thus, the most important characteristics of growth of forest is the gradual reduction with age and size, of the number of plants per unit area. The growth of one forest differs from that of the other due to species, age, quality of site and biotic factor, etc.

Growth in Even-Aged Forests

Even-aged forest start their life as aggregation of seedlings of nearly the same age as a result of natural or artificial regeneration. While in the seedling crop resulting from natural regeneration, the seedlings are scattered all over the area without any regular spacing, the seedlings of artificially raised crops are generally in lines or rows. In the beginning, the seedlings have ample growing space and in case of conifers, the crowns extend right upto the ground. Before long, due to increase in size, the crowns touch each other. This results in a social struggle or competition for growing space.

Crown differentiation – As a result of competition for light and moisture, the inherently stronger trees grow rapidly and their crowns form the uppermost canopy. The less vigorous remain in the intermediate position while the weakest occupy the lowest position. As the trees grow further, competition becomes more intense and crown differentiation becomes more prominent. Due to difference in vigour of trees, all the trees in the upper canopy do not attain the same height and thus some trees are found to be ahead of the others. Thus even the top canopy consists of crowns reaching the highest level and those slightly below them. The trees in the middle position may continue to be there or get relegated to the lowest class due to being overtopped by the neighbours. Some of the trees, in the lowest position may die for want of light and food. Thus the following crown classes are generally met with in an even-aged forest.

i) Dominant trees – All trees which form the upper most leaf canopy and have their leading shoots free. These may be subdivided according to the position and relative freedom of their crowns into predominants, i.e., the tallest trees determining the general top level of the canopy and the codominants, i.e., the slightly shorter dominants or to be more precise, 5/6 of the predominants.

ii) Dominated – Trees which do not form part of the upper most leaf canopy but the leading shoots of which are not definitely overtopped by the neighbouring trees. Their height is about ¾ of the tallest trees.

iii) Suppressed – Trees which reach only about ½ to 5/8 of the height of predominants, with their leading shoots definitely over-topped by their neighbours or at least shaded on all sides by them.

Crown development – In addition to developing crown classes as a result of varying heights of trees, the social struggle also affects the shape and size of crown of individual trees. In the earlier stages crowns of seedlings cover a greater part of their stem and in conifers, they start from the ground level. As the seedlings grow, their crowns touch each other and the portion below the point of contact gradually dies for want of light. In other words, gradually the length of crown is reduced and it is confined to the upper portion of the tree, making the greater portion of the bole clear of branches. The competition also affects width of the crowns. While the crowns of the vigorous individuals are large, those of the dominated and suppressed trees are relatively smaller and constricted. As the length and width of crowns of individual trees are affected, their crown development is affected. The shape and size of the crown gives a good indication about the growth of the trees, in the past and present as well as the possibilities of the future.

Reduction of number of trees with age – The increasing space required by the trees as they grow in age can only be obtained by reduction in number of trees in the forest per unit area. Thus in nature, as the forest grows, there is a gradual reduction in number of trees so that the rest of the trees may have enough space inside and outside the ground for their optimum and healthy growth. As natural reduction in number affects the growth of the survivors in the social struggle, the foresters reduce the number of trees as the forest grows in age so that the growth of the crop is not adversely affected by excessive competition for food and light.

Crop height and top height – With the increase in height of individual trees with age, the height of the forest also increases. The terms, crop height and top height, are used to describe it. Crop height is the average height of a regular crop as determined by Lorey's formula. The crop height is not of great significance as it varies for the same age and site quality with the intensity of thinning.

Top height, on the other hand, is the average height of the dominant trees in a stand. As used in sample plot work and yield tables in India, it refers to the height corresponding to the mean diameter (calculated from basal area) of the 250 biggest diameters per hectare as read from height/diameter curve. The top height at it varies with age is generally the basis for determining the site quality of any area.

Crop diameter – With the increase in diameter of the individual trees constituting a forest crop, the diameter of the crop also increases. The diameter of the forest crop is described by the term, crop diameter which is defined as the diameter corresponding to the mean basal area of a uniform, generally pure crop.

Crop volume – The sum of the volumes of the individual trees forming a forest crop is the volume of that crop. Yield tables for various species given data for volume per acre of a fully-stocked, regularly thinned, even-aged crops at different ages for different site qualities. The crop volume is given for the main crop (i.e., the crop left after thinning), final yield (i.e., the main crop and the volume of thinning at that age) and the total yield (i.e., the final yield plus the accumulated yield of thinning at the previous age).

Crop density – The volume per unit area of a forest has to be compared with the volume given in the yield table for that site quality and age to determine whether the volume in the forest question, is equal to, more or less than the volume given in the yield table. This is described by the term crop density which is defined as the relative completeness of the stocking expressed as a decimal coefficient, taking normal number of trees, basal area or volume as unity. The terms over-stocked, full or complete, and incomplete are used to describe crop density, according as it exceeds, equals or is less than 1.0.

FACTORS OF LOCALITY

Definition

Even a causal observation reveals that the forests occurring in various localities differ from each other in composition and density. The forests found in the Himalayan region are not similar to those found in South India. Even in the former, different types of forests are found in different places. The difference is not confined to species of the dominant trees, their size, and their mixture with other species but it is also found in the composition of the middle storey, undergrowth and ground flora. This, is due to the fact that the trees and other vegetation constituting a forest, are a living entity. They grow in the soil and derive food from it. Local temperature and wind affect their growth. Rain water provides them with moisture and, therefore, its quantity affects their luxuriance. All living beings, i.e., man, animals, birds, insects, etc., living in or around the forest, have greater influence on its development. Thus, from the time of germination to the time of felling or death, the trees and other vegetation forming the forest, are influenced by the climate, soil, topography and living beings of that place. In other words, the type of forest occurring naturally in a place is not an accidental aggregation of various plants out is the result of the complex influence of the climatic, edaphic, topographic and biotic factors of the locality. Thus the factors of locality may be defined as the effective climatic, edaphic, topographic and biotic conditions of a site, which influence the vegetation of the locality.

These factors are also referred to as environment which is defined as all the biotic and abiotic factors of a site. As environment of forest is also referred to as site by foresters or habitat by ecologists, the factors of locality are also sometimes, referred to as site or habitat factors.

Classification

Factors of locality are classified into following four broad categories:

1) Climatic factors, 2) Topographic factors, 3) Edaphic factors and 4) Biotic factors

CLIMATIC FACTORS

The seeds require moisture, temperature, and air definitely and light to some extent for germination. These elements, which form part of climate of a place, are also required by plants for their growth. Thus climate exerts a great influence on the vegetation of a locality. In our large country, just as there is a great diversity in languages, customs, dresses, similarly there is a great diversity in climate as well. This is reflected in the large number of species and multiplicity of forest types found in our country. Our forests range from the dry thorn scrub of Rajasthan in the west to the wet evergreen forests of Assam and Meghalaya in the east, and from the tropical dry deciduous forests of the south to the alpine forests and scrub of Himalayas in the north.

Climate is defined as the average weather conditions prevalent in any locality. Though it is dependent on various meteorological and weather conditions, the most important are solar radiation which gives light and heat both, moisture and wind.

Therefore, climatic factors are defined as light, atmospheric temperature, pressure, and humidity, wind and other features of climate – regional, local and seasonal – that influence vegetation. Thus the climatic factors may be classified as under:

1) Solar radiation – a) Light, b) Heat and Temperature, 2) Moisture and 3) Wind

SOLAR RADIATION

The energy which is responsible for the growth of vegetation and all life depending on it, on this earth comes directly or indirectly from the sun. Thus, the nature and amount of solar radiation received on the surface of the earth is a factor of great importance. The energy radiated by sun reaches the earth in the form of electromagnetic waves of varying length, ranging nearly from 290 m μ to 5300 m μ (millimicrons) but the portion of the radiant energy by which objects are made visible due to stimulation of the retina of the eye and therefore, in common parlance, called light, ranges in wavelength from 400 mμ to 720 mμ. Energy composed of wavelengths shorter than 400 mμ is known as ultra violet and that longer than 720 mμ is known as infrared.

The total energy received from the sun may be classified on percentage basis as under:

Ultra violet	-	about 1%
Visible spectrum	-	about 39%
Infrared	-	about 60%

The maximum energy of solar radiation occurs in the green and yellow regions of the visible spectrum (400 mμ to 720 mμ). Since the heat produced by the radiation is independent, in its effect, of the wavelength, the intensity of the radiation is generally measured by the heat generated by it.

The full solar radiation that should reach the earth, does not actually reach it. The atmosphere surrounding the earth partly reflects it back and partly absorbs it also. Similarly the clouds, other solid particles in the atmosphere, and the vegetation absorb as well as reflect back part of it. Even on reaching the earth part of it is absorbed while some part of it is reflected back. It has been estimated that 42% of the incoming radiation is reflected, and this is known as albedo. The solar radiation reaching the earth is further affected by latitude, altitude, season of the year and time of the day. As latitude increases, the intensity of solar radiation decreases. With increase in altitude, the turbid layer of the atmosphere, through which the radiation has to pass, decreases and, therefore, the radiation increases.

The most important effect of solar radiation is that it provides both light and heat (temperature); as both are very important, they are being described separately.

LIGHT

Importance of Light

Light is a very important factor of locality because of its following effects on plants and other vegetation:

1. Chlorophyll formation – Light is one of the important and essential factors responsible for chlorophyll formation in plants. Though lower plants, such as, algae, mosses and ferns and some coniferous seedlings can develop it even in darkness, yet the quantity of chlorophyll so formed is less than that formed in light. In the angiosperms, however, light is essential. Light of any wavelength or low intensity is sufficient to form chlorophyll. Without light, plants become pale yellow and have long thin internodes, a condition known as etiolation. Chlorophyll decomposes in bright

sunlight, thus formation and decomposition both go on simultaneously when the plant is exposed to light.

2. Functioning of stomata – Light is an important factor influencing the daily opening and closing of stomata which, in turn, affects respiration and photosynthesis.

3. Photosynthesis – Light is the most important factor of locality for photosynthesis as it can not take place in darkness. Out of the seven colours in the visible part of the spectrum, only red and blue are effective in photosynthesis.

The light actually used in photosynthesis is a small fraction of the total light that falls on a leaf. There are two main factors responsible for it. The thickness of the leaf and its chlorophyll content allow only a portion of the light to be absorbed. The rest is either reflected back or transmitted through it. Most of the light energy absorbed is used up in raising the temperature of the leaf and is lost as heat or consumed in transpiration. It has been estimated that light used in photosynthesis is less than 2% of the light energy incident on well-illuminated leaves. As the light actually required for photosynthesis is so low, there is usually sufficient light even in dense forest for this important physiological activity. In very dense forests, however, light intensity may be so low that the photosynthetic gains may not be able to balance the loss due to respiration.

4. Growth – Light influences the growth of plants and trees through its effect on photosynthesis. The influence of light varies with its quality, duration and intensity.

Quality of light refers to the wavelength of the light spectrum or, in other words, refers to colors. Plants grown in blue light are small but otherwise show normal growth. Red light, on the other hand, results in elongation of cells, giving the appearance of etiolated plants. Violet and ultra violet light bring about dwarfing effect. For example, preponderance of ultra-violet radiation combined with slow absorption of water due to low temperature and desiccating winds is responsible for limiting the heights of plants in alpine region.

Duration of light or the length of exposure to day light also affects the growth of plants. The duration of light or, more correctly, the relative length of day and night to which the plant is exposed is called photoperiod and the response of the plants to photoperiod is called photoperiodism which is defined as reponse in the ontogeny of an organism to relative duration of day and night. Photoperiod varies with altitude and latidue. In higher latitudes, where seasonal differences are marked, photoperiod is particularly important. It affects the growth, breaking of dormancy, germination, leaf fall and flowering. In many species, the duration of growth is related to the length of the day; quite a few species can be grown continuously throughout the year in artificially created conditions of long days. Dormancy of trees can be broken by lengthening the day artificially under favourable temperature conditions. Photo periodism varies with species, e.g., short days may cause dormancy in Populus but not in Juniperus.

5. Form and quality of trees – The elongation of the growing axes of trees in the forest occurs mainly between sunset and sunrise because the low intensities of light and infrared radiation tend to stimulate height growth. Height growth is retarded in intense light conditions. Trees growing in shade are usually taller than those of the same age growing in open provided other factors of growth are not restricted.

Even the form of trees growing in shade is very dissimilar to that of trees growing in the open. Deficiency of light due to shading effect of upper branches is responsible for the death of lower branches on the stem of trees growing in congested crops, resulting in their having long clear boles. The continued restriction of the crown in the upper part of the tree results in formation of much more cylindrical stem than would otherwise be formed. Thus regulation of light gives forester a powerful weapon to regulate the form of trees and quality of timber produced in the forest.

6. Species stratification and size and structure of leaves – The intensity of light in the forest varies from place to place and from time to time between wide limits. While the top canopy has full light, the canopies lower down receive only that much light which escapes the top canopy. Thus the light reaching the forest floor is considerably less. It also depends upon the locality and the density of crop. This results in the stratification of species in different canopies according to the requirement of light. In natural undisturbed conditions, the vegetation itself gives an indication of light conditions in the forest. For example, Ardesia solanacea is indicative of damp shady places in sal forest.

TEMPERATURE

Factors Affecting Temperature

As already mentioned, the source of all heat is solar radiation. While the energy received is constant, the temperature of various places on the earth is different because it is affected by the following factors:

i) Latitude – Latitude is defined as the distance of a place, north or south of equator, measured as an angle whose apex is at the center of the earth. The ray of the sun strike the earth vertically at the equator and therefore the temperature is highest at equator. As we move to the north or south from the equator, the temperature decreases because the sun's rays become oblique. Thus as the latitude increases, the temperature decreases. In the Indogangetic plain, the normal fall in the mean temperature is estimated to be roughly 0.55^{o}C for increase of each degree in latitude. The effect of latitude on temperature is, however, modified by other factors, e.g., altitude, distance from the sea, wind, etc.

ii) Altitude – The altitude of place also affects the temperature. It has been observed that there is a fall of 1^{o}C in mean temperature in the hills for every 270 m rise in altitude upto about 1500 m, after which the fall is more rapid. The marked difference in the mean temperatures of Nainital and Muzaffarnagar in U.P. and Simla (H.P.) and Jullundur (Punjab) situated on the same latitudes, is only due to their varying altitudes.

iii) Distance from the sea – Sea has a moderating effect on temperature; the farther a place is from the sea, the greater are the diurnal and seasonal ranges of temperatures.

iv) Winds – The winds affect the temperature, and if they are from the sea side, their effect is still more marked. In our country, south west monsoon brings rain and reduces the temperature to a great extent.

v) Mountains – The direction of the mountain ranges affects temperature through its effect on winds and rainfall. As the windward slopes bear the brunt of the winds and rainfall from monsoonic winds, they have lower temperature than that on the leeward side. The slopes of the mountain on which sun's rays strike vertically are warmer than those on which they strike obliquely. That is why southern slopes of mountains in northern hemisphere are hotter than the northern slopes.

vi) Cloudiness – As clouds screen off the sun, their presence of affects temperature.

vii) Presence or absence of forest vegetation – The rays of the sun strike bare sites directly; such place are, therefore, hotter than the places covered with forest vegetation. The crowns of trees obstruct the rays of the sun before they can reach the ground and thus reduce the temperature of the place.

Importance of Temperature

The solar radiation warms up the atmosphere and the soil, thereby raising their temperatures. The temperature of the atmosphere affects the activities of shoots of plants while soil temperature influences those of their roots. Through its effect on plants, temperature has a profound influence on forest vegetation.

Air temperature – Air temperature influences the plants in the following ways:

i) The solar radiation directly as well as through its influence on air temperature, provides heat to the plant body and helps in satisfactory initiation and continuation of various physiological activities, e.g., transpiration, photosynthesis and respiration. High temperature increases transpiration while low temperature decreases it. Though photosynthesis takes place under a wide range of temperatures varying with species and locality, increases in temperature upto 25^{o}C increases photosynthesis, after which it deceases sharply. The rate of respiration increases as temperature rises from 0^{o}C to 40^{o}C but it decreases in temperature lower than 0^{o}C and higher than 40^{o}C. Thus temperature exerts a greater influence on the vital physiological activities of trees.

ii) Air temperature increases microbiological activity on soil surface resulting in decomposition of organic matter and release of nutrients to be available to trees.

iii) Air temperature affects activities of enzymes, which are practically stopped at temperatures above 50^{o}C or below 1^{o}C.

iv) Air temperature increases cambial activity in the shoot portion.

v) Through its effect on the vital physiological activities and cambial activity, air temperature affects growth of trees.

vi) Temperature is essential for germination of seeds.

Soil temperature – Soil temperature influences trees in the following ways:

i) Soil temperature has a profound influence on absorption of soil moisture which increases markedly with the rise in temperature upto a certain limit. When soil temperature rises above 35^{o}C, there is a decrease in absorption as the permeability of plasma membrane is adversely affected. On the other hand, if there is a fall in soil temperature below 27^{o}C, water absorption is greatly reduced till at 0^{o}C it becomes insignificant. Cold soils are, therefore, physiologically dry.

ii) Soil temperature also affects cambial activity, particularly in temperate climate. Cambial activity in trees starts earlier in warmer soils than in colder soils. Thus growth starts earlier in warmer soils than in colder soils.

In short, increase in temperature creates conditions in which trees and other vegetation grow well. This means higher temperature is indicate of multiplicity of vegetation while low temperature that of limited vegetation.

FROST

Frost means chilling of air below the freezing point. Depending on the mode of occurrence, it is classified into:

i) Radiation frost

ii) Pool frost and

iii) Advective frost

i) Radiation frost is defined as the frost occurring on nights with a clear sky, produced by loss of heat by radiation. It is defined as freezing confined to ground level, ice crystals forming on the surface objects, soil or ground vegetation.

ii) Pool frost is defined as the accumulation to a considerable depth of heavy cold air flowing down into natural depressions from adjoining areas. This has more deleterious effect on vegetation than ground frost as the freezing effect extends to a considerable height.

iii) Advective frost is defined as a frost produced by cold air brought from elsewhere. Frost pocket, frost hole or frost locality which is defined as an area in which frosts are more frequent and more intense than in the district generally. Frost free season which is defined as the period between the last injurious frost in spring and the first injurious frost in the autumn.

Frost Injuries

The injuries inflicted by frost may be of the following kinds:

i) Killing of young plants or their parts

ii) Death of plants due to damage to cells

iii) Injuries to the crowns of poles and saplings

iv) Frost cracks

v) Formation of canker

Frost Hardy and Frost Tender Species

The species which posses power to withstand frost without being damaged are called frost hardy. Frost hardiness varies from species to species and in the same species with age, because some species are affected by frost in earlier stages but can withstand it later. The species which are killed back by frost are called frost tender. A list of some frost hardy and frost tender species is given below:

Frost hardy – Acacia catechu, Hardwickia binata, Madhuca indica, Toona ciliata, Pinus roxburghii.

Moderately frost-hardy – Adina cordiforlia, Bombax ceiba, Dalbergia latifolia, Gmelina arborea

Frost tender – Acacia arabica, Azadirachta indica, Tectona grandis, Terminalia arjuna

Factors Affecting Frost Resistance

Frost resistance in trees depends on internal (i.e., those relating to the cells in plant body) and external (i.e., those relating to environment) factors described below:

A) Internal Factors

i) Size of cell – Plants with smaller cells are usually more frost hardy than those with larger cells.

ii) Water content – The greater the amount of water, the greater the danger of inter-cellular or intracellular ice formation.

iii) Osmotic concentration – The greater the osmotic concentration within the cells, the greater the resistance to frost because, as freezing point of the cell sap would be lower, there would be lesser likelihood of internal ice formation.

iv) Permeability to water – The higher the permeability of the protoplasm to water, the greater is the frost resistance.

v) Water binding colloids – The greater the water binding colloids in cells, the greater the frost resistance because their presence results in (a) reducing the amount of free water that can be frozen, (b) making internal ice formation less likely and (c) reducing the amount of water that can be removed on external ice formation.

B) External Factors

i) Temperature – A rapid fall in temperature is much more injurious than its gradual fall even for partially hardy plants because rapid fall increases danger of internal ice formation. Continued freezing for many days causes greater damage with the result that even plants resistant to start with are affected. Frost resistance varies with seasons; plants which can withstand extremely cold conditions during winter, may be killed by slight frost during spring. Increase in temperature even for a short period during winter, decreases frost hardiness. On the other hand, frost hardiness increases if the plants are gradually exposed to increasingly low temperature before the advent of winter.

ii) Light – The lesser the duration of light, the greater the frost hardiness as reduced photoperiod and low temperature result in cessation of growth. Consequently the reserve carbohydrate are converted into sugar resulting in increased frost resistance.

iii) Mineral nutrition – Nitrogen stimulates vegetative growth and therefore reduces frost hardiness. On the other hand, application of potassium and phosphorus generally increases it.

Hardening Off

Hardening off is the natural process by which plants become adapted to drought, cold or heat. For preparing seedlings in a nursery for planting out by gradually reducing watering, shade and/or shelter resulting in hardening of plant.

SNOW

At higher altitudes, the decrease in temperature results in precipitation taking the form of snow. The amount of snowfall and the period during which it remains on the round depends upon temperature and the amount of winter precipitation. Snow occasionally falls down to 1200 m in north western and central Himalayas but it stays only above 2000 m. In the eastern Himalayas and the south, the altitude to which snow falls, is higher.

Beneficial Effects of Snow

i) Snow influences the distribution of deodar, fir and spruce and their best forests are found in places of heavy snowfall. Heavy water snowfall is essential for satisfactory natural regeneration of deodar.

ii) Snow is the source of water in streams and rivers. All perennial rivers and streams have their origin from snow glaciers.

iii) Snow acts as a blanket, prevents further drop in temperature and thus protects seedlings and other vegetation from the damaging effect of excessive cold and frost.

Injurious Effects of Snow

i) Snowfall results in the mechanical bending of stems of trees. Snow gets accumulated on the uphill side of the young saplings and poles and causes them to bend outward at the base. This curve is maintained even when the poles develop into trees and can be seen on all mature trees. The bend makes this portion of the tree unfit for utilization. As this portion of the stem has maximum diameter, there is a great loss in volume.

ii) Accumulation of snow on the crowns of trees results in breaking of branches and tops of trees. Kail is most susceptible to snow break and deodar comes next.

iii) Sliding snow not only causes erosion but also uproots trees. Often snow slides wipe out strips of forests along their course. The folds of the hills, in which snow slides regularly, are devoid of vegetation and thus a fair amount of area is without tree growth.

iv) Snow shortens the period of vegetative growth

v) Snow is reported to favour the growth of certain fungi, e.g. Fomes, Trametes

Effect of Excessively High Temperature

i) Excessively high temperature is injurious to plant life. There is an optimum and maximum temperature for growth and other physiological activities. Above this optimum temperature, growth is adversely affected but after the maximum is crossed, the life processes may cease and the plant may die. The highest temperature that can be withstood by plants varies from species to species but for most higher plants, the range of lethal temperature lies between 45^oC to 55^oC, though they may also be killed by continuous exposure to temperatures above 40^oC. The death resulting from excessively high temperature usually occurs due to coagulation of protoplasmic proteins.

ii) Even if temperature between 35^oC to 40^oC may not kill the plant, it disturbs the balance between respiration and photosynthesis. The optimum temperature for photosynthesis is lower than that for respiration. When the optimum temperature for photosynthesis is exceeded, the synthesis of food deceases but its breakdown in respiration continues at a high rate. This causes depletion of food resulting in greater susceptibility to attacks of fungi and bacteria.

iii) Excessively high temperature results in deficiency of moisture. Silver fir seedlings are reported to start wilting as soon as temperature reaches 38^oC. Sometimes, seedlings die due to heating of soil surface, resulting from excessively high temperature. The sandy soils get heated excessively and this is a common cause of death of seedlings in such soil.

iv) Excessively high temperature results in excessive transpiration and this may result in desiccation of plant tissues. Increased transpiration combined with deficiency of moisture in the soil results in death of plants.

v) Excessive heat, sometimes, results in developing cracks in stem due to excessive shrinking of the outer tissues. This happens particularly in species having thin bark.

MOISTURE

Moisture is one of the most important factors influencing vegetation, because water is essential for various physiological activities of plants as well as for soil formation processes.

A) Importance in Physiological Activities

1. Water forms about 90 to 95% constituent part of the cell wall and 80% part of the protoplasm which is the physical basis of all life.
2. Water occurs in all the cell vacuoles as cell sap and on it depends the turgidity of the cells, which in turn, governs the growth of plants.
3. It is the only medium for absorption of soil minerals and gases in the plants
4. It is one of the raw materials required for photosynthesis
5. It is required for translocation of manufactured food as well as for all chemical reactions taking place in plant body
6. It is essential for respiration which cannot take place in its absence

7. It is also necessary for transpiration which prevents excessive heating of the plant
8. It is responsible for various movements of plants
9. It is essential for germination and viability of seeds

B) Importance in Soil Formation Processes

Water is required for physical as well as chemical weathering, which are the most important soil forming processes. It is also required for translocation of the products of weathering and is, thus, an important factor in soil formation.

C) Influence on Vegetation

Because of its great importance in the vital processes of plant life as well as in soil formation, water exerts a profound influence on vegetation. It determines the nature of vegetation that would survive in a particular area. In other words, it determines the species that would grow, their number per unit area, height, diameter and volume growth of trees and other vegetation. It is therefore used as basis for classifying vegetation in broad temperature zones.

HUMIDITY

Presence of water vapour makes air humid; humidity refers to that state of air of the atmosphere in which water vapour is present. The amount of water vapour actually present in the atmosphere at a given time at a given temperature is a measure of atmospheric humidity. It is described by the terms absolute humidity, relative humidity and saturation deficit.

Humidity affects evaporation and transpiration and consequently the vegetation. Lower the relative humidity, the greater the evaporation from the soil and higher the transpiration from the plants. As humidity affects the availability of moisture to plants, it is a factor of importance particularly in dry and arid areas where only those species can survive, which have well developed contrivances to resist transpiration.

WIND

Wind has a great influence not only on the form of trees but also on their distribution. It has favourable as well as harmful effects on trees.

Harmful effects – These may be caused both by direct and indirect action of wind.

Direct Harmful Effect

1. Because of the pressure of the wind, the tree in the open in the plains and on the ridges on the hills are short-statured and have pronounced taper in their boles.
2. Trees often get bent if wind blows only in one direction
3. Trees are often uprooted or their stem or branches get damaged. The trees which withstand strong winds without being over thrown or broken are called wind firm. But the trees which are uprooted are referred to as wind fall or wind throw. In case only the stem is snapped from some place or the branches are damaged, it is referred to as wind break
4. The branches on the windward side get, often killed and they remain only on the leeward side. This adversely affects the growth on one side
5. The bole of the tree, often, becomes elliptic with larger diameter in the direction of the prevailing wind
6. As a result of strong winds, timber often gets ruptured

Indirect Harmful Effects

1. Wind fans up forest fire thereby increasing fire damage
2. Wind affects the trees through its influence on humidity. Dry winds lower the amount of atmospheric water vapour by mixing it with dry air and thereby increase transpiration
3. Winds also increase evaporation from the soil
4. In dry areas, wind causes wind erosion. It removes the top fertile soil or deposit sand on fertile fields, thereby deteriorating the soil in both cases
5. Along sea coast wind-brone salt spray, often results in considerable injurious effect on sensitive plants
6. Strong cyclonic winds to immense damage not only to trees but also to other property and agricultural crops

Favourable Effects

1. Wind brings fresh supplies of carbon dioxide to the foliage of trees and thus helps in photosynthesis
2. Wind helps in pollination of anemophilous flowers
3. Wind helps in dispersal of seed of many forest trees, e.g., Holoptelia, Bombax, Hymenodictyon, Toona, etc.

BIOCLIMATE

The various climatic factors influence the vegetation collectively but not individually and separately. Thus the vegetation of a place is the result of various climatic factors acting together. While affecting vegetation collectively, these factors modify the influence of each other to certain extent. Therefore, each climatic factor has to be modified or adjusted in such a way that it may describe the influence of the collective complex climatic factors on plant life. The climate defined by these modified or adjusted climatic factors is called bioclimate. For example, total rainfall of a place will have a certain effect on vegetation. But the effect of total rainfall is modified by the number of rainy days. A certain amount of total rainfall with larger number of rainy days will result in a different vegetation than the same total rainfall and small number of rainy days is further modified by the amount of evaporation taking place in that locality. Therefore, in order to describe the correct effect of rainfall as a climatic factor, the total rainfall will have to be modified by the number of rainy days and evaporation.

Topographic Factors

Topography is the description of the physical features of a place. It describes configuration of the ground, its altitude, slope, aspects, etc. These physical features affect the local climate, soil formation processes, soil moisture, soil nutrients, etc., and since all these have a profound influence on vegetation, topography affects the vegetation indirectly. Thus topographic factors may be defined as factors pertaining to the configuration of land surface viz., altitude, slope, aspect and exposure. These factors have a great influence on vegetation through their influence on climatic and edaphic factors which have a direct bearing on vegetation of a place.

Topographic factors may be classified into:

i) Configuration of land surface, ii) Altitude, iii) Slope and iv) Aspect and exposure.

MICROCLIMATE

Eventhough the climatic factors such as light, temperature, rainfall, humidity and wind define the general climate of a region, certain variations are often met with in localized places due to the effect of the topography, soil climate, or the vegetation itself. The difference in the growing conditions in that particular place affects vegetation locally although the general vegetation type may change or not. Thus, microclimate is defined as the climate of small areas, which for some reason, differs significantly from the general climate of the area, more particularly, the climate outside that cover.

The effect of topography on solar radiation, temperature, rainfall, humidity and wind has already been described. The effect of forest cover on these important factors is described below:

Solar radiation – Forest cover reduces the intensity of solar radiation reaching the forest floor in an inverse proportion with its density, i.e., the denser the cover, the lower the intensity of solar radiation reaching the forest floor. As the amount of light affects temperature, atmospheric humidity, soil moisture regime, it has a great influence on the nature and density of vegetation and regeneration of various species. As the requirement of light of seedlings of various species is different, canopy has to be manipulated to admit sufficient quantity of light to induce regeneration to come up. Chaturvedi found a direct relationship between incident light and the density of bamboo clumps. He found that when over wood was clear felled and maximum light admitted on the forest floor, largest number of new clumps were obtained.

Temperature – Forest cover makes the temperature, both of the air and soil, more equable than it is in the open. This is due to the fact that forest cover acts as a screen and prevents sunrays from heating the air and the soil inside the forest to the same extent as it does in the open. During the night, this screen prevents the loss of heat by radiation. The result is that mean maximum temperature of the air inside the forest is lower and the mean minimum temperature higher. The effect on temperature inside the forest varies with species. For instance, studies in new forest revealed that the temperature under a cover of Casuarina equisetifolia was the lowest during the summer and highest during winter. On the other hand, temperature under cover of Pinus roxburghii was highest during summer and lowest during winter.

Rainfall – Though influence of forest in increasing the total rainfall of a place has been disputed, there is no doubt that forests exercise considerable influence in increasing the number of rainy days over limited regions. Studies made in Nilgiris before and after afforestation have indicated that the presence of forest increases the number of rainy days during that period of the year when monsoon is not active.

Dew – Observations made at new forest have revealed that there is no dewfall immediately below the crowns of trees in a forest, though there is some dewfall in the openings in the canopy.

Humidity – It has been estimated by Seth that a sal forest of 37 years age and containing 778 trees per hectare transpires about 1200 mm of water annually. Thus, forests have a favourable effect of humidity. Warren observed that while humidity of treeless Ranchi plateau dropped to 5 in hot dry summer, humidity of Chaibassa in the neighbourhood of Singhbhum forests never dropped below 50. Forests increase humidity not only of the adjoining areas but also inside themselves.

Evaporation – As forests reduce solar radiation reaching the forest floor and consequently temperature and wind velocity inside, they reduce evaporation of moisture from the forest floor. Reduction in evaporation depends upon the type of forest, its age, density as well as the moisture regime of the soil. However, it has been estimated that evaporation from forest floor may be 10 to 80% of that in the open.

Wind – A strip of trees and shrubs reduces wind velocity considerably. The reduction in wind velocity, the height and distance to which it is affected, is dependent on the height of trees and their density. That is why wind breaks are established around orchards and shelterbelts are raised in areas experiencing wind erosion or desiccating effect of cold winds. In case of a forest, the influence of height of trees and their density on wind velocity is further affected by the length and breadth of the forest. It has been estimated that inside the forest, the reduction of wind velocity may be from 20 to 60% of that in the open. However, the efficiency of forest in decreasing wind velocity on the leeward side of the forest is considerably less as compared to that of a shelterbelt.

Importance of Microclimate

Microclimate is of great importance in the practice of silviculture. If proper attention is not given to this important factor, silvicultural operations, such as natural or artificial regeneration, may fail completely due to the local adverse or limiting factors responsible for the microclimate. The following examples will illustrate the importance of microclimate:

1) As already stated, microclimate of different aspects of hills in the temperate zone of Himalayas is different and that is why on the two sides of a ridge two different species occur towards the upper limit of deodar altitudinal zone. This is due to the fact that northern aspect at that altitude is too cold for deodar. If deodar is planted on the northern aspect at that altitude in utter disregard of the microclimate, the attempt is bound to fail. Even in deodar zone, warmer aspects are occupied largely by kail.

Attempts to replace kail by deodar in such places are never successful as the microclimate of these aspects is not suited to deodar.

2) In the upper reaches of subtropical zone, northern aspects become too cold for chir which is replaced by kail in nature. Sowings of chir in such places are not likely to be successful.

3) In Dehra Dun valley, pool frost is a common occurrence. If, in utter disregard of this factor, clear felling followed by sowing or planting may be done to raise a new crop, it is bound to fail.

4) If, in the introduction of an exotic, climate and microclimate of its natural habitat are not taken into consideration and it is introduced in areas with different climate, it is not likely to succeed.

EDAPHIC FACTORS

Edaphic factors are defined as ecological influences characteristic of the soil brought about by its physical and chemical characteristics. Thus, edaphic factors are factors which relate to the soil in which the trees grow and which, therefore, forms environment of roots.

Definition of Soil

Soil has been defined variously by geologists and pedalogists. The Indian Forest and Forest Products Terminology following pedalogist's view, defined soil as the upper most weathered layer of the earth's crust and recognized the following two sub-divisions:

i) Surface soil - The more or less completely weathered surface layer, rich in soluble material and containing a relatively higher proportion of organic matter and fine earth; also called top soil. The zone of aeration and intense root and micro-biological activity.

ii) Sub-soil – The layer immediately below the surface soil which is incompletely weathered and contains much less of soluble ingredients, organic matter and fine earth.

This definition, though correct, is not comprehensive because forests, sometimes, grow on rocks. The following two definitions are suitable from the point of view of foresters:

i) Forest soil is defined as a portion of earth's surface which serves as a medium for the sustenance of forest vegetation; it consists of minerals and organic matter, permeated by varying amounts of water and air and inhabited by organism; it exhibits peculiar characteristics impressed by the physical and chemical action of tree roots and forest debris – Wilde.

ii) Soil is defined as a dynamic layer of surface material which is constantly changing and developing under processes of adjustment to conditions of climate, parent material, topography and vegetation – Champion and Seth.

SOIL FORMATION

The factors responsible for soil formation and development are climate, biological agencies including vegetation and animals, parent rock, topography and time. The first two of these factors are referred to as active factors because it is through their action that soil formation takes place. As the last three do not take any active part in soil formation, they are referred to as passive factors. Actually, it is only when the active factors, having been modified by topography, act on the parent material for considerable length of time that the soil is formed.

The active factors results in the formation of soil through their effect on a geological process known as weathering which is defined as all physical and chemical changes produced in rocks, at or near the earths surface, by atmospheric agents and which result in more or less complete disintegration and decomposition. The weathering process is of two kinds, viz., physical and chemical weathering.

Physical weathering – Physical weathering is the physical disintegration or breaking up of rocks resulting in exposure of their larger surface for other forces to act. It is mainly the result of climatic factors. Temperature changes result in unequal expansion and contraction and, therefore, in breaking up the rock. As there is a great diurnal variation in temperature in most parts of India, this is a very important factor. In higher hills, water, lying in the crevices of rocks, is frozen at night and therefore expands in volume resulting in disintegration of rocks. Moving water erodes them and ultimately breaks them. Moving glaciers also result in fragmentation of rocks. Strong winds with sand particles in them, keep on sculpturing the rocks.

Physical Properties of Soil

Physical properties of soil have a profound influence on tree growth because of their effect on the supply of moisture, nutrients and air. They affect the supply of moisture directly by affecting its movement, storage and availability and nutrient supply and air through their effect on water. The physical properties of soil relate to its texture, structure, porosity, etc.

1. Soil Texture

Soil texture is defined as the relative proportion of the various size groups of individual soil particles; the individual size groups are referred to as soil separates. The following soil groups are recognized:

Clay – particles smaller than 0.002 mm

Silt – particles between 0.002 mm and 0.02 mm

Find sand – particles between 0.02 mm and 0.2 mm

Coarse sand – particles between 0.2 mm and 2.0 mm

Depending on the proportion of soil separates, soils are classified into different soil classes. A soil class is defined as a group of soils having same range in particle size and physical properties based on texture. For practical purposes, soil classes can be grouped as follows:

Coarse–textured soils, viz., sand and sandy loams

Medium–textured soils, viz., loams and silt loams and

Fine–textured soils, viz., clays and clayed loams

Coarse-textured soil is also called light soil. Similarly, the fine-textured soil is called heavy soil.

Importance of Soil Texture

i) Moisture relations – The percentage of finer particles governs the quantity of moisture that can be held by the soil and the amount that would be available to plants. Coarse-textured soil are easily drained and apt to be dry while, on the other hand, fine-textured soils are poorly drained and hold much water on the large surface area.

ii) Nutrient supplies – The percentage of finder particles governs nutrient status of the soil. The fine-textured soils are high in nutrient status, sandy soils, on the other hand, are low in fertility. The sandy soils support either pioneers or hardy species with low moisture and nutrient requirement, examples being sissoo and chir respectively.

iii) Aeration – Texture of the soil regulates pore space and consequently the aeration of the soil. Coarse-textured soils are better aerated than clayey soils.

iv) Root development – Texture of the soil affects root development.

2) Soil Structure

Soil structure is defined as the arrangement of individual soil particles into aggregates of definite size and shape. Thus, while texture refers to the actual size of soil particles, structure refers to the mode of grouping of these particles into aggregates. Soil aggregate is defined as a single mass or cluster of many soil particles held together, such as clod, prism, crumb or granule.

On the basis of structure, the soils are described as follows:

i) Single-grained – It is a structureless condition of the soil, each grain being independent, as in dune sand.

ii) Massive – It is a structureless compacted condition of the soil, showing no distinct arrangement of soil particles. It is common in podsols and ill-drained soils. It is often the result of overgrazing or agricultural misuse of land.

iii) Crumby – A soil is called crumby when it has crumbs. A crumb is a small aggregate of irregular shape and 3 mm or less in diameter, formed by the cohesion of a number of soil particles. The condition in which the soil particles form water stable crumbs largely by the physical and physico-chemical action of soil organic matter is called crumb structure.

iv) Granular –It is a type of soil structure in which the soil aggregates are more or less sub-angular or rounded in shape and of size upto 6 mm in diameter. It is commonly found in mull humus layers in brown earths.

v) Blocky or nutty – A soil is called blocky or nutty when it has a nut structure which is defined as a soil structure in which soil aggregates are compact, more or less rounded in shape and 6 mm to 25 mm in diameter.

vi) Cloddy – A soil is called cloddy when it has irregularly shaped aggregated of medium to hard consistency and more than 25 mm in diameter.

Importance of Soil Structure

i) Structure is the most important physical property of soil as it affects soil moisture and soil air relations

ii) It is an indication of nutrient status and activity of microorganisms in the soil

iii) If affects soil erosion. Crumb is least liable to erosion while single-grained structure is most liable to erosion

3) Soil Porosity

Soil porosity is defined as the extent to which the gross volume of the soil is unoccupied by solid particles. The space unoccupied by soil particles is also known as pore space. Soil porosity is of two kinds:

i) Capillary porosity – It is the portion in a soil which is not filled by water when the soil is wet but well drained.

ii) Non-capillary porosity – It is the air space in a soil at field moisture capacity.

Importance of Soil Porosity

Soil porosity is an important physical property of the soil as it determines the moisture and air relations of the soil. If affects internal drainage and diffusion of soil air. Clayey soil has very small pore spaces which get choked up on wetting. Thus, these soils may have too much water and too little air. Sandy soil, on the other hand, are well-aerated but are not retentive of moisture. The best condition is that in which capillary and non-capillary pore space occupy about half the soil volume and it is equally divided between the two categories.

PLANT SUCCESSION

From the effect of factors of locality on vegetation and that of the forest community on factors of locality, it is clear that the interaction of the vegetation and the locality allow the growth and development of a plant community whose continued presence in that site changes the factors of locality so much that the conditions become unsuitable for the original plant community and the site is gradually invaded by the members of other plant community which gradually replaces the former. For example, take the case of a new sandy soil along the bank of a river. After the flood water recedes, the bare sandy soil is gradually colonized by some grass. As the grass covers most of the area, it gradually obstructs the flow of flood water and arrests silt in the area. The decay of leaves of grass improves the soil conditions to some extent. The soil, which was originally absolutely sandy and therefore, unretentive of moisture, becomes slightly retentive due to annual addition of soil and organic matter. Its fertility also improves. These slightly improved conditions make it suitable for the colonization by a few hardy tree species, because the conditions are still very difficult due to compete overhead sun and therefore full insulation, wider diurnal range of temperature, strong winds, poor retentivity of moisture and low fertility of the soil. The species which can grow in such difficult conditions is called pioneer. It is tolerant of the extremely adverse climatic and soil conditions and can grow there. The individual members of this species appear one by one in the area and gradually take the shape of a forest community. The presence of this plant community makes further changes in the locality factors. By the annual addition of organic matter and arrest of more and more silt, the moisture retentivity and the fertility of the soil improves. The tree canopy affects not only the atmospheric temperature inside the forest but also the soil temperature, making it more equable. These changed conditions make the place suitable for some other less hardy species which appear gradually and, in course of time, replace the original plant community. The new plant community, further in course of time, improves the soil and the climatic factors and thus makes the place suitable for some other exacting species which comes in gradually and replaces the previous plant community. Thus, there is a gradual replacement of one plant community by another because of the interaction of vegetation and the locality factors and consequent improvement in the conditions of both. This is called plant succession, which is defined as the gradual replacement of one community by another in the development of vegetation towards a climax which is the culmination stage in plant succession for a given environment. The plant communities involved in the succession before the climax is reached are called seres. Sere is defined as the series of plant communities resulting from processes of succession or any recognizable stage in plant succession.

Evolution of the Concept of Plant Succession

The concept of plant succession has been developed during the last century by observation of changes in isolated cases. Starting with Richard Peters who in 1806 described the departure of southern pine timber as a proof of the tendency in the nature to a change in products on the same soil. Dawson (1847) and Thoreau (1863) described the changes in localized places. It was Thoreau who, first, used the term forest succession. Later Cawles (1899) described the change in vegetation on sand dunes. It was, however, Clements (1916) who developed the idea and elaborated the theory of plant succession. While the American foresters were working on this concept, foresters of England and the continent were also working on the idea. However, it is the Clements theory of plant succession that is widely accepted. The basic features of the concept of plant succession are:

i) There is a continual change in the vegetation as a result of interaction of plant community and the habitat factors

ii) The succession is inherently and inevitably progressive and the end product is the climax and

iii) The succession is the progressive development of vegetation on the same site in course of time

Kinds of Succession

Succession can be classified mainly in two ways:

i) On the basis of moisture conditions of the place and

ii) On the basis of presence or absence of vegetation in the place

i) On the basis of moisture conditions of the place

On the basis of the moisture conditions, succession is classified into:

a) Xerarch succession which is defined as the succession initiated in extremely dry situations such as bare rock, wind blown sand, rocky talus slopes, etc. The successional stages of this succession are called Xeroseres, which are defined as the different stages in a xerarch succession. Xerosere may further be subdivided into Lithosere which is defined as Xerosere which originates on rock surface and Psammosere which is defined as the Xerosere which originates on sand.

b) Hydrarch succession which is defined as the succession beginning in water, or very wetland as in ponds, lakes, marshes, etc. The various stages of this succession are called Hydrosere.

ii) On the basis of the presence or absence of vegetation in the place

On the basis of the presence or absence of vegetation in the place, succession is classified into:

a) Primary succession which is defined as the succession which takes place on sites which have previously not borne vegetation. Primary succession is, sometimes, termed as autogenic succession because it takes place as a result of autogenic factors which are due only to the individuals in a plant community. In other words, autogenic succession is that in which vegetation affects the ecosystem to bring about consequential change in itself.

b) Secondary succession which is defined as the succession which takes place on site after the destruction of the whole or part of the original vegetation. This succession is, sometimes, termed as allogenic succession as it takes place due to allogenic factors which are defined as the factors which operate, independently of the plant themselves, to alter the habitat gradually and thus cause changes in vegetation. For example, clearing, burning, grazing, storm, erosion, deposition, landslide, etc., are various allogenic factors.

Causes of Succession

The causes of succession may be classified as under:

i) Initial cases and

ii) Continuing causes

i) Initial causes are the causes which provide the basis for succession to take place. Thus, in case of primary succession they are responsible for creation of a new soil, while, in case of secondary succession, they are responsible for making the soil bare. The initial causes of primary and secondary succession are listed below:

Initial causes of Primary Succession

a) Erosion – Wind and water erode the soil and deposit it elsewhere. Thus, new soils are created in the form of alluvial deposits, coastal sands, estuarian deposits, sand dunes, landslips and scree.

b) Physiography – The configuration of the land surface is an initial cause to the extent it helps the agents of erosion, i.e., wind, water and gravity, to create new soils.

c) Elevation and subsidence – Seismic disturbances result in elevation and subsidence of the soil resulting in the formation of new soils. Due to these disturbances, river beds are silted up or the rivers change their courses leaving their original beds for starting primary succession. Similarly, geological disturbances in the Himalayas result in the formation of new soil for primary succession.

Initial causes of Secondary Succession

a) Climate – Climate is the initial cause when the vegetation is destroyed by the action of drought, wind, snow or frost. For instance, a fair portion of a forest may be killed by drought. It left to self, secondary succession will start on this bare area. Wind may lay bare an area by uprooting the original crop. Snow may, similarly, destroy forest by sliding.

b) Physiography – Physiography is the initial cause when configuration of the land surface is responsible for the destruction of vegetation in combination with some other factors. For instance, landslide may take place on a steep slope, destroying the forest.

c) Biotic factor – Biotic factor is the initial cause where a forest is destroyed as result of the activity of man, his animals, or even wild animals. For instance, a forest may be destroyed by reckless cutting, clearing, burning, indiscriminate heavy grazing, etc.

Continuing causes – Continuing causes are those causes of succession which help the development of plant communities and their replacement by other plant communities. Thus, while the initial causes create suitable conditions for starting succession, the continuing causes help in the formation of plant communities and their gradual replacement by other communities leading to a climax. They consist of the following:

a) Migration, b) Ecesis or establishment, c) Grouping and aggregation, d) Competition and e) Reaction.

a) Migration – Migration is defined as the mass movement of plants from one place to another. It begins when the germule (spore, seed, fruit, offshoot, or plant) leaves the parent area and ends when it reaches the final resting place.

b) Ecesis or establishment – Ecesis is defined as the whole process whereby a plant establishes itself in a new area from germination or its equivalent to reproductions whether sexual or asexual.

c) Grouping and aggregation – Aggregation is defined as grouping, following establishment of scattered colonizing invaders as a result of propagation.

d) Competition – Competition is defined as the struggle for available food, light and moisture, which takes place among species and individuals in an assemblage of plants.

e) Reaction – Reaction is defined as the effect of vegetation on the site and is the most important factor responsible for succession. The effect of the vegetation on the site can be grouped into following two classes, viz., i) Effect on climatic factors and ii) Effect on soil.

i) Effect on climatic factors – The vegetation affects the climatic factors by:

a) Altering the light conditions

b) Decreasing the day air temperature and reducing the diurnal range

c) Reducing the wind velocity

d) Reducing the danger of radiation frost

e) Increasing relative humidity

ii) Effect on soil – The vegetation affects the soil by:

a) Addition of organic matter

b) Improving the structure of the soil

c) Improving moisture retentivity of the soil

d) Improving nutrient status of the soil

e) Improvement of the stability of the soil

f) Development of maturity of the soil

Primary Succession

As already defined, primary succession is the succession that takes place in areas which did not bear vegetation before. In our country such soils could be new alluvial deposits, new coastal sand, new estuarine deposits, sand dunes, land slips and screes. The first two of these have practically no soil and are completely devoid of humus. The estuarine deposits are rich in humus but are badly drained and usually contain high percentage of sea salts. The land slips are better sites because of the presence of original top soil mixed up in the rock pieces and good drainage. The screes have also no soil and are very dry and therefore rarely good for vegetation.

Secondary Succession

In nature, primary succession does not proceed as smoothly as appears from its description given earlier. Several unfavourable factors may delay or interrupt the progress of succession towards the climax. These factors may be natural or biotic. On account of these factors the primary succession may be held up at any stage or there may be some retrogression or regression which is defined as the reversion to some earlier stage of succession consequent on the introduction of an adverse factor. It is not possible to revert exactly to any earlier forest and soil. Generally retrogression stages are lower in height and more xerophytic in character. In extreme cases, e.g., fire, clearing, etc., the entire vegetation may be destroyed.

When the causes of retrogression are removed or when the area from where vegetation has been completely destroyed is left to itself, the nature starts its work again, i.e., the vegetation starts progress. This progress, which is called secondary succession, does not follow the same course as the primary succession. In other words, an entirely different series of successional stages of plant communities, which are normally not seen in primary succession, appear in the secondary succession.

The colonizing species of the bare areas in primary succession and secondary succession may sometimes be the same. For instance, Pinus wallichiana, Trema and

Anthocephalus cadamba not only colonize landslips and new gravel in primary succession but also invade clearings to start secondary succession. But certain species are characteristic of the secondary succession only. For instance, Macaranga is typical of secondary succession in moist forests. Thus, in tropical evergreen forests, secondary succession starts with the arrival of Acrocarpus fraxinifolius, Callicarpa, Trema and Macaranga. In the hills, secondary succession is often initiated by shrub growth. For instance, where vegetation has been destroyed by burning or clear felling in the hills, secondary succession starts with Woodfordia fruticosa, Indigofera pulchella and Berberis lycium depending on aspect and altitude.

Secondary succession is very important so far as the forests of this country are concerned because most of them have been subjected to fire, grazing and other maltreatments before they were taken over by government for scientific management. The stability of the three most important species of this country, viz., sal, teak and deodar, in the moister parts of their habitat, is result of these regressive factors and, therefore, they are just stable subclimaxes. When the factors of regression are withdrawn, further progression takes place and these species are replaced by more mesophytic vegetation. For instance, in the sal forests, continued fire protection results in the development of vegetation towards wet evergreen mixed forest.

Climax

If the succession is allowed to progress without disturbance, a stage is reached when no more improvement is possible in the soil and the vegetation. At that stage the vegetation is in equilibrium with the environment and stays unchanged indefinitely by reproducing itself. Thus, climax is the culmination stage in plant succession for a given environment. Clements believed that the most dominant community forming factor was climate and therefore, he called it climatic climax, which is defined as a climax which owes its distinctive characters to climatic factors in conjunction with only such biotic influences as plants and animals naturally occurring in the area, bring about. This is also, sometimes, referred to as formation which is defined as the major unit of vegetation comprising the climax communities of an area uniform in its major physiognomic features.

Proclimax, which is defined as a term applied to all communities that suggest something of a permanence or extent of a climax but are not typical of the existing climate.

FOREST TYPES

Definition

Forest type is a category of forest defined with reference to its geographical location, climatic and edaphic features, composition and condition. Champion and Seth define it as a unit of vegetation which possesses (broad) characteristics in physiognomy and structure sufficiently pronounced to permit of its differentiation from other such units. This is irrespective of physiographic, edaphic or biotic factors. It is selected in the first place subjectively from the ever-varying cover of vegetation, with boundaries arbitrarily imposed on what are in fact gradual changes.

Object of Classification

The main object of classification of forests into forest types is to find out correct silvicultural techniques and management practices for the development of forests. These techniques and practices cannot have universal application because forests vary from place to place. Therefore it becomes necessary to classify the forests into forest types, so that suitable silvicultural techniques and management practices may be evolved for each type to be applied to similar types in the field. This avoids waste of money and effort as well as disappointment from the failure resulting from the application of wrong techniques.

Bases of Classification

The forests can be classified into forest types on the basis of:

i) Physiognomy – Physiognomy means the general appearance of a forest community and therefore, forms an easy basis for rough differentiation of very broad classes. It is described by dominant growth-form (e.g., trees, shrubs, grasses, etc.), the seasonal changes (e.g., evergreen and deciduous habit) and such other features as may be associated with very dry or very wet sites.

ii) Structure – Structure of a forest is described by stratification (i.e., the way in which different species are aligned in different layers of the forest) and dimensions of trees including height and spacing. It is generally observed that more favourable the site to tree growth the greater is the number of strata and the less favourable the site, the lesser is the number of strata in which the forest is divided. Therefore, structural stratification gives good basis for classifying forest types.

iii) Function – Function refers to the most common morphological characters of the species such as leaf characters, leaf size, stem and root characters, e.g., buttress formation, development of stilt roots, etc., which form the basis of classification.

iv) Floristics – Floristics refers to the species present in a particular forest. While this forms an important basis for delimiting a forest type, there is a great difference of opinions as to whether the frequency of the species should be used as a basis or not. However, this can be used to distinguish subtypes.

v) Dynamics – As a result of interaction between vegetation and the site, there is continual change between the two. This results in succession and development of climax communities. Though the general view favours Whittaker's theory of vegetational gradients, it is convenient for the time being to classify the relatively stable types as climax, those still developing as seral, the stable community resulting from the special soil peculiarities as edaphic climax and that resulting from the biotic interference as biotic climax.

vi) Habitat – Habitat refers to the effective environmental conditions in which a forest community exists. Thus, climate and edaphic factors often form the basis of classifying forest vegetation.

vii) Physiography – Physiography refers to the natural features of the earth surface. As it modifies the microclimate and results in different vegetation occurring in the same climate on different aspects of the hill slope, it forms a good basis for classifying vegetation.

viii) History – History refers to past biotic influences on a site and its vegetation. Though these are very important in determining the present condition and future potentialities in vegetational communities, it is often difficult to assess these factors correctly.

Systems of Classification of Forest Types

Environment has the profoundest influence on vegetation which not only grows and develops in its environment but remains in equilibrium with it. Therefore, the system of classification of vegetation can be either:

i) Botanical, i.e., based mainly on vegetation

ii) Climatic, i.e., based mainly on climate or

iii) Ecological, i.e., based mainly ecosystem consisting of vegetation environment complex

i) Classification based mainly on vegetation – The classification based mainly on vegetation is made on the basis of study of plant communities. The data collected as a result of the study is grouped on the basis of physiognomy, structure, composition and dynamics. There are two ways of arranging the data. In the one case, the primary unit is plant association and a number of such associations are grouped together on the basis of similarities to form a forest type. In the other method, a vegetation type is broken into successively smaller units on the basis of differences. The classifications put forward by Braun-Blanquet, Beard, Fosberg and Webb are examples of classification based mainly on vegetation.

ii) Classification based mainly on climate – This system has been followed by many workers. The method of their classification is briefly described below:

a) Schimper (1898) classified vegetation first according to temperature zones and with in each temperature zone he made further classifications on the basis of moisture conditions. He considered mountains separately as they had their own climatic peculiarities.

b) Mayr (1909) adopted temperature zones combined with latitude and altitude as the basis for primary classification. The other factor to which he attached importance next was the mean temperature during the growing season from May to August. He differentiated between coastal and continental climates also.

c) Koppen (1931) adopted temperature of the hottest and coldest months and the relative rainfall of the wettest and driest months and season of rainfall as a basis for classification.

d) Thornthwaite (1933) adopted temperature efficiency (T.E.) as the basis for classification. Later in 1948, he used potential evapotranspiration as the basis.

e) Shanbhag (1958) adopted thermodynamic principles, especially the relation between the rise in temperature and the speed of chemical reaction, as the basis for differentiating humid and arid climates. He also made a supposition that 30°C marks critical boundary below which growth stimulating factors are dominant and above which inhibiting factors become dominant.

iii) Classification based mainly on ecosystem – This systems gives sufficient weightage to both vegetation and climate. The most important classification of this system have been proposed by Burtt-Davy, Swain, Gaussen and by Champion and Seth in the revised classification of forest types of India.

Revised Classification of Forest Types of India

On the basis of additional information available Champion and Seth revised the preliminary classification of forest types of India prepared in 1935. In this classification, the forests of India have first been divided into the following five major groups:

i) Tropical forests

ii) Montane subtropical forests

iii) Montane temperate forests

iv) Sub-alpine forests and

v) Alpine scrub

The major groups have, as described below, been further divided into type groups or, simply, groups on the basis climatic data and vegetation. The tropical forests have been differentiated into seven groups, the montane subtropical forests into three groups, montane temperate forests into three groups, sub-alpine forests into one group and alpine scrub into two groups. Most of these groups or type groups have been further differentiated into two subgroups describing southern and northern forms.

Each subgroup is again divided into types in which climax formations have been designated by letter C, edaphic climax formation by letter E, primary sere by IS and secondary sere by 2S, the tropical swamps by letter TS and fresh water swamps by FS. Within each subgroup, the types are given in serial number as C_1, C_2, E_1, E_2 and so on. These types are differentiated into subtypes by suffixing letter a, b, c and so on for each subtype. Subtypes are sometimes further classified into varieties by suffixing number, e.g., i, ii, iii. Thus a variety of type C_1 is designated as $C_{1a(i)}$.