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Introduction to Forestry and Lab Work

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Department of Forestry and Environmental Science
School of Earth and Environmental Science

Uttarakhand Open University
Haldwani, Nainital (U.K.)

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SCHOOL OF EARTH AND ENVIRONMENTAL SCIENCE

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Unit 1: Introduction to Forestry

Unit Structure

1.0 Learning Objectives
1.2 Introduction
1.3 Forest and Forestry
- **1.3.1 Definition of Forest**
- **1.3.2 Definition of Forestry**
- **1.3.3 Branches of forestry and their interrelationship**
- **1.3.4 Classification of Forest**

1.4 Importance of Forests
- **1.4.1 Direct roles of forests**
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1.6 Forests of World and India
Summary
References

1.0 Learning Objectives

After completing this unit you shall be able to:

- Define forest, forestry and silviculture
- Know the classification of forests and forestry
- Appreciate Forests in India and
- Describe the history of development of forestry in India

1.2 Introduction

Forests are the resources which render many services to the humans throughout the globe. They not only help in regulating the streams, winds but also provide wood (the most widely used material) and food in the form of wild edibles. Forests are essential for the well-being of humankind. The object of forestry is mainly to get the best services from the

forests not only for the present generation but also to the future generations. Thus, forestry means the uses as well as preservation of the forest. Thus, basically forestry is the growing of trees as a crop which can be cut and used. The true concept of forestry is that of devoting land permanently to forest production. Successive crops of trees are grown upon the same land and these crops are either cut clean and replanted or are made to reproduce themselves naturally by seeds or sprouts.

In this unit we will be acquainted with various terms related with forestry and with the practice of forestry. We will also learn about importance and uses of forests, historical developments in forestry, our national forest policies, and forests of India and world. At last we will also understand the definition and concepts of silviculture.

1.3 Forest and Forestry

1.3.1 Definition of Forest

The word forest is derived from the Latin word **'foris'** which means '**outside'**. Originally, forest meant simply wild or uncultivated land regardless of cover. The Indian word 'jungle' has been adopted in the English language to describe a collection of trees, shrubs, etc., which are not grown in a regular manner, as contrast with 'forest', which is any vegetation under a systematic management [1]. Forest has been defined by various scientists and organizations differently. These definitions are as follows:

According to American Society of Foresters, a forest is *"A plant association predominantly of trees or other woody vegetation occupying an extensive area of land"*[2].

According to another definition, *"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"*[1].

In simple words, it is *"A plant community predominantly of trees and other woody vegetation, usually with a closed canopy".* Or *"An area of land proclaimed to be a forest under a forest law"* [1].

There are great variations in the definitions of “Forest” which varies from place to place, region to region and one country to another country. It mainly depends upon the objectives of management, land use, vegetation type, composition and altitude, etc.

The definition of the word “forest” is not reflected in major conservation Acts of India, i.e., Indian Forest Act, 1927, and Forest Conservation Act, 1980. However, the word ‘Forest’ and “Forest land” were defined by Hon’ble Supreme Court of India. According to the court the word “forest” must be understood according to its dictionary meaning. This description covers all kinds of forests which are recognized in the law i.e., reserve, protected or other categories as mentioned in Section 2(i) of the Forest Conservation Act 1980. Further, the term "forest land" has its mention in Section 2 of the Forest Conservation Act (1980) and includes "forest" as understood in the dictionary meaning as well as any other area recorded as forest in the Governmental records irrespective of its ownership [3]. As mentioned in the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Right Act 2006), “Forest land” means land of any description falling within any area and includes unclassified forests, un-demarcated forests, existing or deemed forests, protected forests, reserved forests, Sanctuaries and National parks.

Our country has redefined forests after Kyoto Protocol as, **“A forest is a land area of at least 0.05 ha, with a minimum tree crown cover of 15%, and tree height of at least 2 m”.** Whereas as per the India State of Forest Report 2011, Forest Area means the area recorded as “Forest‟ in government records and the term “Forest Cover” includes **“all lands with more than 1 ha area with more than 10% tree canopy density irrespective of their legal status and species composition** [4]**.**

Food and Agriculture Organization (FAO) defines the term **“Forest”** as **the** Land having trees of more than 5 meters spread in over 0.5 hectares and with more than 10 per cent canopy cover, or trees able to reach these thresholds *in situ*[5].It does not include land falling mainly under agricultural or urban land use. International Union of Forest Research Organizations (IUFRO) defines ‘forest’ as a land area with a minimum of 10% tree crown coverage (or equivalent stocking level), or formerly having such tree cover and that is being naturally or artificially regenerated or that is being afforested. As per European

Commission, a forestland is defined as having at least 20% canopy closure (10% in the Mediterranean forests) and a minimum area of 0.5 ha.

1.3.2 Definition of Forestry

The term "Forestry" is defined as, "the science, art and practice of understanding, managing and using wisely the natural resources associated with, and derived from forest lands [6]http://www.forestry.ubc.ca/general-information/what-is-forestry/).

According to University of Maryland Extension [7], Forestry is the science of tending woodlands.

Canadian Forest Service **(**Glossary of Forestry Terms) defines **Forestry as, "**The science, art and practice of managing trees and forests and their associated resources for human benefit.

Forestry may thus be defined as, "Forestry is the theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization of their resources to provide for the continuous production of the required goods and services [1].

*As per Food and Agriculture Organization (FAO) 2015, the term "Forest" has been defined as "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 per cent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use***".**

Changes in SAF Definition of Forestry [12]

The science and art of managing forests in continuity for forest purposes, i.e., for wood supplies and forest influences (1916)

The scientific management of forests for the continuous production of goods and services (1944, 1958).

The science, the art, and the practice of managing and using for human benefit the natural resources that occur on and in association with forest lands (1967)

The science, art and business of creating, managing, and conserving

forests and associated resources in a sustainable manner to meet desired goals, needs, and values — note the broad field of forestry consists of those biological, quantitative, managerial, and social sciences that are applied to forest management and conservation; it includes specialized fields such as agroforestry, urban forestry, industrial forestry and international forestry (Adopted by IUFRO 2000).

1.3.3 Branches of forestry and their interrelationship

Forestry has five different branches:

1. **Silviculture**: If refers to certain aspects of theory and practices of raising forests crops, methods of raising tree crops, their growth and after care up to the time of final harvesting.
2. **Forest Mensuration:** It refers to the determination of dimensions, form, volume, age and increments of the logs, single trees, stands or whole woods.
3. **Silviculture system:** Process by which the crops constituting a forest are tended, removal and replaced by new crops
4. **Management:** Practical application of sequence technique and economics to forest estate for the production of certain desired results
5. **Utilization:** Branch of forestry which deals with harvesting, marketing conservation and applying the forest produce to a variety of uses eg. Timber, fuel, charcoal, pulp wood, ply wood.

Another way of classifying forestry is on the **basis of aims or objectives** and may be of the following type:

1. **Protection of Environmental Forestry:** Protection of land, regulation of water cycle, Wild life conservation Modernization of climate conditions, combination of above.
2. **Commercial or Production Forestry:** Timber and other raw materials.
3. **Social Forestry:** Raising forests outside the traditional forest with the involvement of society. Various forms of Social Forestry are:
    i). **Community Forestry:** The practice of forestry on lands outside the conventional forest area for the benefit of local population has been called Community forestry. Community forestry seeks the involvement of community in the creation and management of such forests. Thus it is raising of forests of public or community land
    ii). **Farm Forestry:** Farm Forestry is defined as the practice of forestry in all its aspect on farms of village lands generally integrated with other farm operations. It is raising forest trees on farms lands. It is further classified as:

a) **Noncommercial farm forestry:** raising of trees by individuals for domestic needs (usually by the farmers)

b) **Commercial farms forestry:** Farmers grow trees on commercial basis on farmlands.

iii). Extension Forestry: Extension forestry which includes the activity of raising trees on farm lands, villages wastelands and community forest areas and on lands along the sides of roads, canal banks and railway lines (Anon., 1976). More recently, there has been emphasis on dynamic land use planning and efforts are made to maximize production on farmlands under agroforestry.

iv). Agro-Forestry: Agro-forestry has been defined as a sustainable land management system which increases the yield of the land, combines the production of crops and forest plants and/or animals simultaneously or sequentially on the same unit of land and applies management practices that are compatible with the cultural practices of the local population.

v). Recreational Forestry: More recently, there has been considerable demand for recreational forestry, which is defined as the practice of forestry with the object of developing and maintaining forests of high scenic value. Recreational forests are being developed near towns and cities. The areas are being planted with flowering trees, shrubs and creepers to provide forest atmosphere near towns and cities.

1.3.4 Classification of Forest

Forests are classified in different ways.

A) Classification according to origin of forest

The forests may have their origin either from seeds or from sprouts arising from coppice cut. Accordingly forests are classified as:

i) High forest: forest originated from seeds

ii) Coppice forests: forest originated vegetative from suckers or sprouts from stump

B) Based on species composition- pure vs mixed crop

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 is defined as, "a forest composed of trees of two or more species intermingled in the same canopy; in practice, and by convention, at least 20% of the canopy must consists of species other than the principal ones".

Another terms used are **'virgin forests'** and '**second growth'**. The former term refers to express the original state of natural forest where cutting has never taken place, whereas later is used to express the crop that has come up in an area after harvesting or logging of older crop.

According to National Forest Policy of 1952, four (04) categories of forests were identified based on their functions. These are as follows:

1. **Protection Forests:** Those forests which must be preserved or created for physical and climatic considerations.
2. **National Forests:** Those forests which have to be maintained and managed to meet the needs of defense, communications, industry, and other general purposes of public importance;
3. **Village Forests:** Those forests which have to be -maintained to provide firewood to re-lease cow-dung for manure, and to yield small timber for agricultural implements and other forest produce for local requirements, and to provide grazing for cattle;
4. **TreeLands**: Those areas which though outside the scope of the ordinary forest management are essential for the amelioration of the physical conditions of the country.

According to National Commission on Agriculture (NCA) (1976), the forests were classified into three major categories. These are as follows:

1. **Protection Forests:** The practices of managing the forests for their protection function are called Protection forestry. The objectives of protection forestry are to protect the site due to instability of terrain, nature of soil, geological formations, etc. Such areas where manipulation of the forest cover is not desirable may be classed as protection

forests. The forests located on higher hill slopes, national parks and sanctuaries, preservation plots, biosphere or nature reserves and wilderness areas may be included under protection forests. The practice of forestry with a view to conserving flora, fauna, soil and water, increasing water yields, reducing floods and droughts, amelioration of climatic conditions, etc. is called Protection Forestry.

2. **Production Forests:** The practice of forestry with object of producing maximum quantity of timber, fuel wood and other forest produce is called Production Forestry. The production forestry can be further classified into:

   (i) Commercial Forestry: Commercial forestry aims to get maximum production of timber, fuel wood and other forest products as a business enterprise.

   (ii) Industrial Forestry: Industrial forestry aims at producing raw material required for industry. In Production forestry, there is a greater concern for the production and economic returns.

   (iii) Mixed Quality Forests

   (iv) Valuable Forests

   (v) Inaccessible Forests

3. **Social Forests:** Social Forestry is the practice of forestry which aims at meeting the requirement of rural and urban population. The object of social forestry is to meet the basic needs of community aiming at bettering the conditions of living through:

   - Meeting the fuel wood, fodder and small timber requirements
   - Protection of agricultural fields against wind
   - Meeting recreational needs and
   - Maximizing production and increasing farm returns

Check Your Progress

Q1. Define forestry and silviculture.
Q2. Discuss the various branches of forestry and their interrelationships.
Q3. What are the various ways of classifying forest? Discuss in brief.
Q4. Differentiate between high forest and coppice forest?

1.4 Importance of Forests

Forests and trees play a vital role in the life of humans as they provide many goods and services directly or indirectly to humans and society. Some of the direct benefits include tree products, wild edibles, medicines, fodder, fuels and timber for construction, fencing and furniture. The importance of the forests may be understood by the **direct and indirect** roles they play for humans or ecosystems or environment as a whole as discussed below.

1.4.1 Direct roles of forests

i) Timber uses: Trees are used as timber since the evolution of human civilization. The timber from trees is used commercial use as well as non-commercially. The timber uses include uses of poles in construction houses, manufacture of windows, doors and furniture etc. Wood-based panel and paper/paperboard production show steadily rising demand which is partially offset by reductions in the demand for sawn wood.

ii) Uses as fuelwood and charcoal: A large amount of wood is needed to get energy for cooking and keeping our houses warm particularly in cold winters or regions of cold climate particularly in rural areas. As per the estimates of FAO (2000) about 1.86 billion m^3 of wood is extracted from forests for fuel wood and conversion to charcoal. Of this total, roughly one-half comes from Asia, 28% from Africa, 10% from South America, 8% from North and Central America and 4% from Europe. According to an estimate, 11% of world energy consumption comes from biomass, mainly fuelwood [8]. IEA (1998) also estimated that 42% of India's primary energy consumption comes from biomass. It is observed that poor people in developing countries derive their household energy requirement from fuelwood and charcoal.

iii) Non-timber forest products (NTFP): Non-timber forest products (NTFPs) include all those products or services other than timber which are produced in forests. It includes tree products such as wild edibles, latex, wild cocoa, honey, gums, nuts, fruits and flowers/seeds, spices, condiments, medicinal plants, rattan, fodder, fungi, berries and also includes animals and their products. These products have a variety of uses to human society.

1.4.2 Indirect roles of forests

Apart from direct benefits, forests also provide many indirect benefits. Forests can significantly alter the environmental conditions in favour of human society and thus bring about the well-being of human and ecosystem as a whole. Some of these indirect benefits are as follows:

- Conservation of Biological Diversity
- Watershed protection
- Arresting landslides and erosion
- Control of floods
- Recharging of natural springs
- Carbon storage and sequestration
- Tourism and recreation values
- Amenity values
- Option and existence values

Check Your Progress

Q1. How forest are useful to humans? Discuss

Q2. What do you understand by indirect benefits? Discuss in context of indirect benefits derived from forests.

1.5 History of Forestry Development in India

Scientific forestry in India is attributed to a German Botanist named as Sir Dietrich Brandis. He was appointed as the first Inspector General of Forests of India in 1864. Thus, scientific forestry is almost over 150 years old in India. It was Brandis who formulated Indian Forest Act of 1865. He evolved the policy of tree cover measurement, demarcation of forests, survey and mapping of areas suitable to be designated as reserved or protected forests under the Indian Forest Act 1865. A revision in Indian Forest Act (1865) was passed in 1878 and it is in this act that provisions were made for the constitution of reserved and protected forests [1]. Dr. Voelcker, another German Forestry Expert was invited by Government of India in 1893 in order to examine the condition of Indian agriculture and to get expert opinion as how to improve upon it. Dr. Voelcker, in his report which he submitted in 1893, mentionedthe role of forests vis-a-vis agriculture and he also

emphasized on the need of having a national forest policy for the betterment of agriculture. Following his recommendations, the Government of India formulated its first National Policy in 1894.

1.5.1 National Forest Policy-1894

The purpose of this policy was to lay down general principles for forest management in India. Forest Policy of India triggered the development of forest policies in various other countries under the British Empire of that time. The basic principles of this policy were:

(i) The main objective of management of State forests is public benefit. In general, the constitution and preservation of a forest involve the regulation of rights and the restriction of privileges of the user of the forest by the neighboring population

(ii) Forests situated in hill slopes should be maintained as protection forests to preserve the climatic and physical conditions of the country, and to protect the cultivated plains that lie below them from the devastating action of hill torrents

(iii) Forests which are the store-house of valuable timbers should be managed on commercial lines as a source of revenue to the State

(iv) Ordinarily, if a demand for agricultural land arises and can be met from a forest alone, it should be conceded without hesitation, subject to the following conditions:

- Honeycombing of a valuable forest by patches of cultivation should not be allowed;
- Cultivation must be permanent and must not be allowed so to extend as to encroach upon the minimum area of forest that is needed to meet the reasonable forest requirements, present and prospective;
- Forests that yield only inferior timber, fuel wood or fodder, or are used for grazing, should be managed mainly in the interest of the local population, care should be taken to see that the user does not defeat its subject and the people are protected against their own carelessness.

1.5.2 National Forest Policy-1952

Substantial increase in population of humans as well as livestock by the first half of 20th Century, resulted into heavy pressure on forests as more and more land needed for agricultural production and pasture lands. Such land came from diversion of forest land. Apart from this, developmental projects such as river-valley projects, industries,

communications and defense needs, etc. all leaned very heavily on the forest produce. These all caused heavy loss in forest cover. Consequently evolution of Forest Policy of 1952 took place. This national policy stressed on the following points:

(i) Persuading the primitive people to give up the harmful shifting cultivation;
(ii) Increase of the efficiency of forest administration by having adequate forest laws;
(iii) Giving requisite training to the staff of all ranks;
(iv) Providing adequate facilities for the management of forests and for conducting research in forestry and forest products utilization;
(v) Controlling grazing in the forest; and
(vi) Promoting welfare of the people.

1.5.3 National Forest Policy-1988

Even after enunciation of NFP 1952, degradation of forests by overuse didn't stop. Thus, forests suffered serious depletion due to relentless cutting for meeting ever-increasing demand for fuel-wood, fodder and timber; inadequacy of protection measures; diversion of forest lands to non-forest uses without ensuring compensatory afforestation and essential environmental safeguards; and the tendency to look upon forests as revenue earning resource. Therefore, the need of having new forest conservation strategy was being felt in the decade of seventy. Accordingly the NFP was revised in 1988. Basic objectives of the policy were:

- Maintenance of environmental stability through preservation and, where necessary, restoration of the ecological balance that has been adversely disturbed by serious depletion of the forests of the country
- Conserving the natural heritage of the country by preserving the remaining natural forests with the vast diversity of flora and fauna, which represent the remarkable biological diversity and genetic resources of the country
- Checking soil erosion and denudation in the catchment areas of rivers, lakes, reservoirs in the interest of soil and water conservation, for mitigating floods and droughts and for the retardation of siltation of reservoirs.
- Checking the extension of sand-dunes in the desert areas of Rajasthan and along the coastal tracts

- Increasing substantially the forest/tree cover in the country through massive afforestation and social forestry programmes, especially on all denuded, degraded and unproductive lands.
- Meeting the requirements of fuelwood, fodder, minor forest produce and small timber of the rural and tribal populations.
- Increasing the productivity of forests to meet essential national needs.
- Encouraging efficient utilization of forest produce and maximizing substitution of wood.
- Creating a massive people's movement with the involvement of women, for achieving these objectives and to minimize pressure on existing forests

The principal aims of this Forest Policy, thus, were to ensure environmental stability and maintenance of ecological balance including atmospheric equilibrium which were vital for sustenance of all life-forms, human, animal and plant. The deriving of direct economic benefit are next to the principal aim.

1.5.4 Van Mahotsav

Van Mahotsav is an annual afforestation programme in India in which afforestation activity is carried out in the first week of July i.e., 01 to 07 July every year. It was in 1950 when this movement was first initiated in the leadership of then Union Minister for Food and Agriculture, Shri K.M. Munshi. Literally Van Mahotsava means “a Festival of Van or Jungle”. The concept behind this plantation programme is to strengthen our green cover and thus, to derive benefits for Country’s growth and development. Selection of July first week is probably because it is the time of rains and any afforestation programme done during this period usually meets with success.

Check Your Progress

Q1. What are various forest policies of India? Discuss.
Q2. Scientific forestry in India is attributed to _____.
Q3. The latest National Forest Policy of India is of year _____.
Q4. Van Mahotsav was started by _____.
Q5. Write a brief note on Van Mahotsav.

1.6 Forests of World and India

In 1990, the world had 4,128 million hectare of forests; by 2015 this area had decreased to 3,999 million hectare. This is a change from 31.6 per cent global land area in 1990 to 30.6 per cent in 2015. We can describe forest area change as a process of gain (forest expansion) and loss (deforestation). There was recorded a net loss of some 129 million ha of forest from 1990 to 2015 (an annual net loss at the rate of 0.13 per cent). It is as large as about the size of South Africa. The largest forest area loss occurred in the tropics, particularly in South America and Africa, although the rate of loss in those areas has decreased substantially in the past five years. Average per capita forest area declined from 0.8 ha to 0.6 ha per person from 1990 to 2015.

The bulk of world's forests are natural forests with reported natural forest area amounting to 93 per cent of global forest area, or 3.7 million ha in 2015. From 2010 to 2015, reported natural forest area decreased by a net 6.5 million ha per year. This is a reduction in net annual natural forest loss from 10.6 million ha per year from the period 1990 to 2000.

Total forest area in India in 1970-71 was 748 thousand sq km (23%) of the total geographical area as against 718 thousand sq km (22%) of total geographical area in 1950-51.

Region	Forest area, 2005 (mill. ha)
Africa	63,5412
Asia	571,577
Europe and all Russian Federation	1001,394
North and Central America	705,849
Oceania	206,254
South America	831,540
World	3,952,026

Source: FAO, 2006a

The increase in forest area from 1950 to 1971 was mainly attributed to transfer of forest area from private to public ownership and their inclusion in forest area statistics. This resulted into increase in State managed forest area from 83% to 93% during 1950-51 to 1970-71. Forests owned (or managed) by corporate bodies and private individuals constituted 4 per cent and 2 per cent respectively in 1970-71 as compared to 0.3 per cent and 16.7 per cent respectively during 1950-51.

In the latest report 2019 [4], the total forest and tree cover of the country is 8,07,276 sqkms (which is 24.56 per cent of the geographical area of the country) compared to 8,02,088 sqkims (24.39 per cent) as reported in 2017 (ISFR 2017). The report marked an increase

of 5,188 sqkms of forest and tree cover combined, at the national level as compared to the previous assessment [4].

The forests in our country have been grouped into 5 major categories and 16 types as per the classification of Champion and Seth (1968). The distribution of these groups indicates 38.20% subtropical dry deciduous, 30.30% tropical moist deciduous, 6.7% subtropical thorn and 5.8% tropical wet evergreen forests. Other categories include subtropical pine (5%), tropical semi-evergreen forests (2.5%) and other smaller categories. Temperate and alpine areas cover about 10% of the forest areas in the Himalayan region.

Summary

Forests are the resources which render many services to the humans throughout the globe and are essential for the well-being of humankind. As far as importance of Forests is concerned, Forests and trees play a vital role in the life of humans as they provide many goods and services directly or indirectly to humans and society. Some of the direct benefits include tree products, wild edibles, medicines, fodder, fuels and timber for construction, fencing and furniture whereas indirect benefits include Conservation of Biological Diversity, Watershed protection, Arresting landslides and erosion, Control of floods, Recharging of natural springs, Carbon storage and sequestration, Tourism and recreation values, Amenity values and Option and existence values.

The science of managing forests is known as Forestry. It means the uses as well as preservation of the forest. It may be defined as, “the theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization of their resources to provide for the continuous production of the required goods and services”. Scientific forestry in India is attributed to a German Botanist named as Sir Dietrich Brandis. Dr. Voelcker, another German expert, emphasized on the need of having a national forest policy for the betterment of agriculture. Following his recommendations, the Government of India formulated its first National Policy in 1894. Second Forest policy of India came into existence in 1952. At present we have National Forest Policy of 1988. Forests are the resources which render many services to the humans throughout the globe. Forests are essential for the well-being of humankind. Forestry means the uses as

well as preservation of the forest. Forestry has five different branches i.e., Silviculture, Mensuration, Silviculture system, Management and Utilization. Whereas based on the objectives forestry has three branches - Protection forestry, Commercial or Production forestry; Social Forestry.

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Unit 2: Factors of Locality I - Atmosphere and Climate

Unit Structure

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2.2 Factors of Locality
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2.0 Learning Objectives

After completing this unit you would be able to:

- Define factors of locality
- Explain the types of factors of locality
- Explain atmosphere and climate as a factor of locality
- Describe the importance and role of various climatic factors
- Explain bio-climate and microclimate

2.1 Introduction

In the previous unit, you get acquainted with the definitions and other terms of forestry and silviculture. Silviculture in its simplest sense is art and science of growing forest crop. But when growing of forest crops is concerned then it is a complex process and mainly governed by many factors operating in the area. In other words, the immediate environment plays an important role in growth and development this process. Environment includes abiotic as well as biotic components and these components affect directly or indirectly the various life processes of plants as the basic requirements for the germination, growth and development of plants is met up by its immediate surroundings. The

germinating plant sends its roots into the soil for stability, support and nourishments whereas stem comes above the soil surface into atmosphere from where it receives certain other requirements like heat, light and moisture. Therefore, it is the soil and the atmosphere which act upon forest vegetation and affect its growth and development processes directly or indirectly. These are known as locality and locality factors in silviculture.

In this unit, we will discuss various factors of locality with detailed emphasis on climatic factors and their effects on forests.

2.2 Factors of Locality

2.2.1 Definition

Factors of locality may be defined as **"Effective climatic, topographic, edaphic and biotic conditions operating in an area or site, which have influences on the biotic components of the area**". These are also referred to as '**site factors or habitat factors**'.

In other words, anything around the living organisms or vegetation or crop which affects them directly or indirectly includes what is known as **factors of locality**. It is our environment (living organisms and non-living components) that affects us or other living organisms. For example temperature conditions, moisture conditions, pressure conditions, soil conditions, biodiversity or a combination of these conditions affects the living organisms. Rate of photosynthesis in plants is affected by amount of light which in turn is affected by topography i.e., altitude, latitude or aspect of the area. Similarly, metabolic activities of the organisms are influenced by temperature and moisture conditions which also vary from place to place. The variations in these conditions from one place to another place results in variation on type of organisms or diversity of species. Thus, all these physical, chemical or biological agencies constitutes that is known as factors of locality. In reality, environment is a complex of many factors and these factors remain in a state of continuous interaction with other environmental factors. Therefore, they act in conjugation and their combined result is reflected in the form, types and diversity of vegetation or organisms.

2.2.2 Types of locality factors

Factors of locality are classified into four (04) main categories:

A) **Climatic factors (**Atmosphere and Climate): It includes Solar radiations (Light, Heat and temperature), Moisture, Wind, Pressure,

B) **Topographic factors:** It includes Configuration of land surface, altitude, latitude, slope, aspect and exposure

C) **Edaphic factors:** It includes physical properties of soil, chemical properties of soil.

D) **Biotic factors:** It includes plants, wild animals, insects-pests, man and his domesticated animals.

Check Your Progress 1

1. What do you understand by factors of locality? Define and explain.
2. Discuss the different types of Factors of Locality.

2.3 Climatic factors (Atmosphere and Climate)

Climate is defined as, "an average weather conditions prevailing in an area whereas weather is characterized by temperature, humidity and pressure conditions of an area at a particular time". Thus, climate is characterized by temperature, moisture, humidity and pressure conditions of an area, and it is these conditions that greatly influence directly the growth and development of all organisms. Thus, all those components which make up climate or which define the climate of an area come within the periphery of **climatic factors**. The climatic factors include conditions (temperature, wind, moisture, pressure, solar radiations) of atmosphere and include all factors associated with the atmosphere which influence life of organisms. It also includes atmospheric gaseous components i.e., Oxygen, Nitrogen, Carbon dioxide, Moisture, Solid bodies, Ammonia and Nitric Acid, which directly and indirectly have effects on various biological, physical and chemical processes and are of thus, special significance in Silviculture. The climate of a locality has comparatively greater influence upon germination, growth and development of plants, therefore, it demands special attention particularly in silviculture. This is because of this variation in climatic conditions which causes difference in plants species from one climate to another. Species found in cold climates of high altitudes regions of Himalaya are different from those found in lower altitudes or topical regions. The high pressure conditions in high altitudes results into stunted growth whereas the same species if found

in lower altitudes may grow to higher heights. The various climatic factors are discussed in the following paragraphs in detail.

2.3.1. Atmospheric gases

Among the important atmospheric gases are included oxygen, nitrogen, carbon di oxide etc. It also include

Oxygen: Earth's atmosphere contains 21 per cent of oxygen. Oxygen is needed for energy generation in almost all the living organisms except chemosynthetic bacteria. In case of plants, they also take up oxygen during day and night but during the days (in the presence of sunlight) another process operates which is called photosynthesis or a process food production. In this process more of oxygen is produced than utilized by plants and this more of oxygen is released into the atmosphere for use of other organisms. It is only the green plants that reduce CO_2 concentration in the atmosphere and purify atmosphere through production of oxygen. Anything that impairs with photosynthesis will have impacts of oxygen and thereby affect the life processes.

Nitrogen: About 79 % of nitrogen is present in the atmosphere. It is also an essential element which is needed in amino acids, nucleic acids and various other enzymes. Nitrogen is absorbed by plants from the soil as nitrates and then nitrogen compounds are transferred from plants to other organisms through food chain. Nitrogen is released back to atmosphere as a result of death and decay of organisms. Availability of nitrogen in the soil effects growth and development processes.

Carbon dioxide: About 0.04 % of the volume of the atmosphere consists of carbon dioxide which is received from a variety of sources, as combustion or decomposition of plants, the breathing of animals, volcanoes, spring water issuing from the interior of the earth, combustion of coal and lignite, from various minerals as for instance calcium carbonate. Plants, except certain parasites and saprophytes, take the carbon dioxide which they require through their leaves from the atmosphere. Subsequently, when they die and are decomposed, their carbon is converted back into carbon dioxide, and returned to the atmosphere; hence, plants form an important link in the movement of carbon dioxide. Being a greenhouse gas, Carbon di oxide has impacts on global as well as local climates and weather changes.

Solid bodies: The atmosphere always contains a certain quantity of organic and inorganic solid bodies, which remain in suspension due to their light weights and minute size. These bodies are carried about by air currents and may be deposited in certain localities. Further, certain quantity of these solid bodies is also distributed along with rain, snow, or hail. Amongst the substances which are brought to the ground in this way, are calcium carbonate, magnesium carbonate, sodium chloride, calcium sulphate, ferric oxide, alumina, silica, organic nitrogenous matter, etc. Further, these tiny particles also help in the condensation process and also enrich the soil, where they get deposited.

Ammonia and Nitric Acid: Ammonia and nitric acids are in limited quantities and they supply nitrogen to forest plants in adequate quantities sufficient for the formation of seeds. A certain quantity of ammonia and nitric acid is brought into the soil by the annual rainfall and helps in meeting the requirements of forest for its growth and development. Species belonging to Leguminosae family are capable of absorbing nitrogen directly from atmosphere and assimilating them into amino acids.

2.3.2 Light or Solar radiations

As we all know that light is very important for survival of organisms as it is an important factor required for food production i.e., photosynthesis by green plants and its subsequent transfer to other organisms of the ecosystem through food chain. The intensity and amount of solar radiations affects photosynthesis process and this is why it is one of the important climatic factors. It is important to know that the amount and intensity of solar radiation not only varies from one place to other but also from one season to another season of the year.

The importance of solar radiations can be understood by the fact that it provides us light as well as heat energy. Both of these are very important for the functioning of various ecosystems. The importance of light and heat can be explained as under:

- Sunlight is needed for the formation of chlorophyll in green plants. The amount of chlorophyll in turn affects the quality and quantity of photosynthesis by leave tissues.
- Sunlight influences daily opening and closing of stomata which in turn influences the vital processes such as transpiration, absorption and release of CO_2 and O_2, thereby, controls rate of respiration and photosynthesis (Weaver and Clements, 1929).

- Sunlight is required in the process of photosynthesis by green plants which in turn influence growth and development of whole plant. Therefore, light has been recognized as one of the important factors that influence growth, development and reproduction. Strong sunlight causes many of the chloroplasts to lie in line with the light rays, thus, screening each other from the full effect of the radiant energy. In shade leaves they are arranged at right angles to the light rays increasing the surface available for absorption (Weaver and Clements, 1929).
- The position of leave in many plants changes during the day in order to affect the angle of incoming light. Such leaves often have pulvini which enable plant to change the position of their leaves [1].
- Leaves are the plant part which is most susceptible and undergo the greatest change in response to light. The continuous exposure of leaves to sunlight results in the formation of palisade cells which are placed at right angles to the leaf surface. The amount of palisade tissue developed in the leaves of the same plant may vary from one position to another position. The leaves located in the upper part of a tree crown are fully exposed to the sunlight have rich amount of palisade tissue in comparison to the interior of the crown which remain in the shade of upper leaves.
- The Form and structure of plants is affected by Light and also influences certain physiological functions considerably. The elongation of stem and branches is a response to light in forest. Lack of light is the main stressor for vegetation on the forest floor. Therefore, at the edge of the forest, the plants at the forest floor bend outward so as to absorb maximum light. For example, low intensity of light and infra-red radiations causes elongation of axes of trees thus, height growth. The plants growing in shade are taller than the plants grown in light under other similar conditions. In presence of sunlight, the crown takes a larger shape which in turn results into faster growth and development. This effect of light is used in creating clear bole in trees through proper spacing between the individuals so that shading affect do not allow lower branches to grow. This way light is an important tool in developing proper form and structure of forest trees.
- Light intensity and light quality has a relation with phototropic effects. Most of the chlorophyll-bearing plants and their branches have a tendency to bend towards the

light. Therefore, a tree that is growing below a tree with large crown or spreading branches bends away from the axis of the larger tree (Strasburger 1930). However, if a tree is equally illuminated on all sides, it will not bend even if the intensity of light is very low. It is only the infra-red region that stimulates elongation process (Arthur, 1936).

- Intensity of light determines the growth of trees by affecting rate of photosynthesis. Growth is total photosynthesis minus the portion used up in respiration. Further, the quality of light greatly affects the height and diameter growth of the plants. The plants grown under blue light are short in height whereas UV light causes dwarfness e.g. stunted growth of plants in alpine regions in response to greater exposure to UV radiations. Contrary to this red light and infrared light helps in height increment. Very high intensity of light is, however, fatal for the protoplasm.
- Good light conditions have a positive role in improvement of resistance to cold and drought as well as to disease, insect attack, and other unfavorable influences. Light is known to have considerable influence on the hardening of plants against cold (Dexter, 1933). Further, the plants raised in the shade conditions are less resistant to drought than those grown in full sunlight.
- The amount of light is greatly influenced by latitude, altitude and season which in turn affect many processes directly which require light such as flowering, fruiting, and dormancy. It is now well understood that the length of day is an important factor in determining the time of beginning and ending of the dormant period. Plants have varying degree of sensitivity towards flowering. Some species flower more quickly in long days whereas others in short days.
- Photoperiodism is the phenomenon of physiological changes that occur in plants in response to relative length of day (i.e. photoperiod). The photoperiodism was first discovered by Garner and Allard (1920). Thus, the length of the growing season influences the degree to which a tree will stand shade. Thus, the kind of species or plants in a locality greatly depends upon length of photoperiod. Based on this, the plants are classified into three main categories:

i. **Short day plants (SDP) or long-night plants:** These plants require a relatively short day light period (usually 8-10 hours) and a continuous dark period of about 14-16 hours for subsequent flowering e.g., Rice, coffee, soybean, tobacco and chrysanthemum. The dark period has critical importance and must be continuous. If it is interrupted with a brief exposure of red light (660-665 nm wavelength), it will not flower whereas prolonging of the continuous dark period initiates early flowering.

Differences between short day and long day plants

Short day plant	Long day plant
Plants flower when photoperiod is less than the critical day length	Plants flower when photoperiod is more than the critical day length
Interruption during light period with darkness does not inhibit flowering	Interruption during light period with darkness inhibit flowering
Flowering is inhibited if the long dark period is interrupted by a flash of light	Flowering occurs if the long dark period is interrupted by a flash of light
Long continuous and uninterrupted dark period is critical for flowering	Dark period is not critical for flowering
Flowering does not occur under alternating cycles of short day and short light period.	Flowering occurs under alternating cycles of short day followed by still shorter dark periods Phytochrome

ii. **Long day plants (LDP):** These plants require longer day light period (usually 14-16 hours) in a 24 hours cycle for subsequent flowering. These plants are also called as short night plants e.g. Wheat, radish, cabbage, sugar beet and spinach. In long day plants, light period is critical. A brief exposure of red light in the dark period or the prolongation of light period stimulates flowering in long day plants.

iii. **Day neutral plants (DNP):**These plants flower in all photoperiod ranging from 5 hours to 24 hours continuous exposure e.g. tomato, cotton, sunflower, cucumber, peas and certain varieties of tobacco. During recent years, intermediate categories of plants such as **long short day plants** and **short long day plants** have also been recognized. **Long short day plants** are short day plants but must be exposed to long days during early periods of growth for subsequent flowering e.g. Bryophyllum. **Short–long day plants** are long day plants but must be exposed to short day during early periods of growth for subsequent flowering e.g., certain varieties of wheat and rye.

Light and shade in relation to tree growth are of the greatest importance in practical silviculture, especially in the regeneration, tending of woods, the composition of mixed woods, etc. The most important period in this respect is early youth, because at that time several species require some shelter, either against heat or frost. If that shelter, on the other hand, is excessive the young trees may be permanently injured or even die. Some species, which are shade bearing, require a certain amount of shelter, or protection, during early youth, therefore, are called "**shade demanding**".

2.3.3 Heat and Temperature

Heat and temperature are the two important climatic factors which play important role in the growth and development of organisms. Heat (unit of heat is joules) **represents to the energy transfer between two systems** whereas temperature represents to the total kinetic energy of a system (Unit of temperature is Kelvin or Celsius). The biggest source of heat in our planet is sun's energy or solar energy. The transfer of heat energy through electromagnetic radiations from sun to our earth maintains its temperature. It is heat or energy transfer that results into increase of temperature in earth. This is also applicable in case of various organisms in our ecosystem. However, temperature of an area is not constant but keeps changing depending on time and season or other changing conditions. Some of the important factors which determine the temperature of an area are:

- **Effect of elevation:** The temperature decreases with rise in elevation above the sea.
- **Effect of Aspect and gradient:** It is the aspect of an area which decides the angle of strike of sun's rays in the soil. This is why in the northern hemisphere; aspects between south-east and south-west are the warmest, and those between north-east and north-west the coldest. The degree of the gradient further modifies this effect, which also depends on the latitude. The aspect also affects the temperature in exposing a locality to air currents, or protecting it against them. This effect may be favorable or the reverse according to the nature of the air currents.
- **Presence or Absence of Forest Vegetation:** Localities which are bare of vegetation are struck by the full sun's rays, thereby because the temperature at soil surface to rise. Whereas presence of vegetation creates obstruction for sun's rays and lowers the soil surface temperature.

- **Water exchange between sea and land mass:** Exchange of air between dry land and sea makes the climate of the dry land more equable i.e., low temperature during the day and higher during night.

Temperature has a diversity of effects on vegetation and other living beings. The effects may be summarized in the following point:

- It affects the organisms through its effect on various metabolic processes.
- It increases rate of transpiration, respiration and photosynthesis which in turn results in growth and development of species or organisms.
- It enhances microbial activities in the soil which results in faster recycling of organic wastes and releases nutrients into soil which are subsequently taken up by plants for their growth and development. Thus, temperature results into diversity of species in an area. The more the temperature the more diversity of species will be there. For example, tropical region have very high species diversity in comparison to the colder temperate or alpine regions of the world.

  NOTE:

  I) Neither very high nor very low temperatures are useful for the organisms' growth and development as it causes many processes to cease.

  II) Vegetation having half (root) portion below the soil and half portion (shoot) above the soil, therefore, the air temperature and soil temperature differently affects the growth and development and other processes of vegetation.

Effects of very high temperature on plants

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 temperature varying with species and locality, increase of temperature upto 25° C increases photosynthesis, after that it decreases sharply, the rate of respiration increases as temperature rises from 0°C to 40°C but it decreases when temperature is below 0°C or higher than 40°C. Thus, temperature exerts a great

influence on the vital physiological activities of trees, it causes heat injury to the plants which decreases the activity of the enzymes responsible for photosynthesis or degenerates the enzymes, thereby affects photosynthesis. Even if heat stress injury does not occur, the rate of photosynthesis is expected to decline because of increase in photorespiration than photosynthesis, net result is less photosynthesis.

ii) Seed germination and seedling vigor are important traits for obtaining a sound forest stand and subsequent high crop yields. Seed germination is highly dependent on temperature. However, seeds performance regarding germination varies from species to species.

iii) Soil temperature is one of the major environmental factors that influence not only the proportion of germinated seeds, but also the rate of emergence and the subsequent establishment, even under optimum soil and irrigation conditions (Prasad & Allen 2006).

iv) It has been shown by Robert (1988) and Prasad (2008) that temperature affects the seed germination through three distinct physiological processes during seed germination. These are:

- temperature together with moisture content, determines the rate of deterioration in all seeds
- temperature affects the rate of dormancy loss in dry seeds and the pattern of dormancy change in moist seeds; and
- in non-dormant seeds, temperature determines the rate of germination

v) **High temperature,** although enhance seed germination but results into death of the plants in early stages due to damage to embryo or young seedling tissues. The optimal temperature for structural integrity and activity of most enzymes is within the range of 30–45°C. Beyond 45°C the enzymes are denatured and deactivated, however, it may vary depending upon species.

vi) Very high temperature results into loss of humidity and thus, adversely affects the plants.

vii) Seedlings are highly sensitive and affected due to wilting. Severe wilting results into seedling mortality.

viii) Excessively high temperature results into cracking of stems particularly those having thin bark.

Effects of very low temperature on plants

Excessively low temperature below 5^0C results into **frost and snowfall**. Both of these phenomenons are harmful for plants. Frost is simply the chilling of air below freezing point. It is of three types i.e., radiation frost, pool frost and advective frost based on mode of occurrence. **Radiation frost** is the kind of frost that occurs on the nights with clear sky due to radiation cooling and **Pool frost** results from accumulation of heavy cold air to a considerable depth into natural depressions from adjoining areas. This has more deleterious effect on vegetation than the radiation frost. This kind of frost is characteristics of hilly regions and the valleys whereas the **Advective frost** is the kind of frost resulting from the cold air brought from elsewhere.

Snowfall results in winter season in higher altitude or latitude areas as a result of atmospheric moisture condensation at low temperature when water precipitates in solid form. It takes place upto 1200 masl in Himalayas, however, the snowfall occurring below 2000m altitude remains as snow for very short period of time whereas above 2000 m it remains as such in ground ranging from few days to months.

Harmful effects of frost are as follows:

i) During frost nights, the water below the soil freezes. In the morning when sun rises, the solar radiations causes leaf surfaces to heat up and accelerate the rate of transpiration. Whereas, the water below the soil is still frozen resulting into partial or permanent death of plants.

ii) Frost lifting is a phenomenon which results into uprooting of young seedlings as a consequence of volume increment inside the earth due to freezing of water. This causes unearthing of soil.

iii) Frost also causes damage to cells due to freezing of water which in turn results into damage to protoplasm and cell wall.

iv) Frost causes damage to the wood due to freezing of water and increase in volume, thus resulting into cracking of wood tissues. This breaking of woody tissues dues to frost is called as **frost crack.** Whenever frost damages a part of the plant, the plant tries to cure the damaged portion by callus formation, however, continued damage this site by frost

results into failure of the function of callus and develops a site which is easily affected by fungi. This is called **frost canker.**

Snow has both injurious as well as beneficial effects to plants. The beneficial effects include:

i) Heavy winter snowfall and thus, low temperature is essential for the germination of temperate species such as deodar

ii) Snow recharges streams and reservoirs

iii) Snow acts as blanket and prevents further drop in temperature and thereby safeguards seedlings and vegetation from the damaging effect of excessive cold and frost.

Injurious effects of snow include:

i) It causes mechanical bending of tree bole and branches

ii) Breaking of tree crown and branches results from heavy accumulation of snow

iii) Soil erosion and uprooting of trees results from sliding snow

Effect of air temperature

- The air temperature provides heat to the plant bodies and helps in completion of various physiological activities such as respiration, photosynthesis and transpiration. High temperature enhances transpiration whereas low temperature reduces it. Rate of photosynthesis is increased by temperature upto 25°C and decreases after that. Similarly respiration rate is increased as temperature increases from 0°C to 40°C however the same is decreased below 0°C and above 40°C.
- Air temperature increases microbial activities and thereby enhances decomposition or degradation processes in the ecosystem. It also helps in release of nutrients in the soil and thus makes them available to plants for absorption.
- Enzyme activities are influences by air temperature. Very high temperature (above 50°C) and very low temperature (below 0°C) causes ceasing of enzyme activities.
- Air temperature enhances metabolic and divisional activities in cambium cells in shoot.
- As air temperature affects various physiological activities through its effect on enzymes and other activities, thus, it affects growth and development of plants.
- Temperature is essential for seed germination.

Effect of soil temperature

- Soil temperature affects absorption of moisture and nutrients. However, temperature rise above 35°C causes adverse action on absorption as at this rise in temperature affects the permeability of plasma membrane.
- Soil temperature affects cambial activities particularly in temperate climate. The activity gets increased during warmer soils whereas decreased in colder soils.

2.3.4 Moisture

Moisture remains present in atmosphere and in soil. The source of moisture in the atmosphere is transpiration from plants and evaporation from various land surfaces, sea, lakes, rivers and moist bodies which in turn is the source of water to various parts of the globe and it occurs in the form of rain, snow, hail and dew. Vapor from various surfaces rises in the atmosphere until it again gets condensed into water. It either settles as dew on cool objects, or falls as rain, snow and hail from the cloud to the ground. Plants receive water from the soil through the roots and participate in the evaporation through their leaves. Heat action results into vapor from water which in turn causes evaporating bodies to become drier and cooler, and also reduce the temperature of the surroundings. Rate of evaporation is governed by the temperature i.e., the higher the temperature the higher will be rate of evaporation and accordingly the air at high temperature can hold more of moisture than air at low temperature. Hence, evaporation is more rapid in summer than in winter and it is generally also greater during the day than at night.

Water is fundamental to the vital processes of plants, animals and other organisms. The significance of water to organisms can be understood by the following facts:

- It supplies the soil with water, where it is taken up by the roots of the trees.
- It governs the degree of transpiration from the leaves of the trees.
- Water is present in all protoplasm, all cell walls and vacuoles. The water in vacuoles causes turgidity and growth of cells and thus, of organisms.
- Water is an important constituent of carbon / food assimilation process during photosynthesis and is, thus, directly assimilated. Carbon assimilation gets retarded in non-turgid plants and ceases in wilted plants.

- Ascent of sap in stems results in absorption of nutrients and its transfer to various organs.
- Respiration also requires water and the process is ceased when the water content drops below a certain minimum.
- Water causes cooling of plant and animal body through sweating in animals and transpiration in plants.
- Water is necessary for all movements due to swelling and irritability.
- Structure of plants is influenced to a great extent by the water in the atmosphere and soil. Water is available for the trees through air or through soil. Water is mainly absorbed from soil by the roots of the plants.

Snow and ice have a considerable effect upon trees. During early youth snow may protect forest plants against excessive cold. Later on, a heavy snow fall, or the formation of ice or rime, may break the branches and tops of trees, or even fell them to the ground, especially if snow and wind act together. The danger is generally greatest in densely grown young woods, more particularly those consisting of conifers or of broad-leaved trees with the dry leaves still adhering to the branches. Shallow rooted trees are more easily thrown than deep rooted species. Forest trees are also liable to be damaged by hail, which may injure, not only the soft shoots, but also the bark of species with a smooth surface.

2.4.5 Air currents or wind

The atmosphere is, practically, in constant motion. The principal cause of this is the uneven heating of the earth by the sun. The heat, which becomes free on or near the surface of the earth, warms the adjoining air and causes it to rise, its place being taken by colder air from other parts of the earth.

The ascending air, after cooling, sinks again in its turn. In this manner a circular motion exists between the equator and the poles as well as between dry land and large sheets of water.

Owing to a combination of these currents with the motion of the earth, modified wind directions are produced. The prevailing wind directions on the northern hemisphere are, therefore, from the south-west and the north-east, according as to whether the original current started from the tropics or the polar region.

A second cause of wind currents, especially of storms, is the sudden condensation of considerable quantities of aqueous vapour, which forces air to rush from all sides into the space of reduced pressure. Air currents are of paramount importance to all organic life on the earth, because they produce a thorough mixture of the constituents of the atmosphere. Without them, the land would soon lose all moisture. The motion of the atmosphere ensures a proper distribution of moisture, carbon dioxide, oxygen and nitrogen over the earth. Air currents may affect forest trees injuriously principally in two ways:

- By unfavorably modifying the temperature and moisture of a locality
- By injuring, breaking, bending, or overturning them

Dry winds frequently reduce the moisture of a locality to a dangerous degree; moist and cold winds may reduce the temperature, and thus, interfere with the healthy growth of the trees. Strong winds may break the leading shoots or side branches, cause trees to assume a curved shape, or even throw single trees and whole woods to the ground.

The damage done to trees by strong winds differs very considerably according to species. Shallow rooted trees, like the spruce, suffer most, while deep rooted trees, like oak are much less affected.

Check Your Progress 2

1. "Climate is regarded as a factor of locality" Justify your answer.
2. How moisture effect the life of organisms? Discuss.
3. Write an extended note on Light as a factor of locality.
4. Write a short note on photoperiodism.
5. Discuss heat and temperature with reference to their effect on life.

Summary

Factors of locality may be defined as "Effective climatic, topographic, edaphic and biotic conditions operating in an area or site, which have influences on the biotic components of the area". These are also referred to as 'site factors or habitat factors'. Broadly four (04) kinds of Factors of locality have been identified namely Climatic factors (Atmosphere and Climate), Topographic factors (Configuration of land surface, altitude, latitude, slope, aspect and exposure), Edaphic factors (physical properties of soil, chemical properties of soil), Biotic factors (plants, wild animals, insects-pests, man and his domesticated animals).

Climate is defined as, “an average weather conditions prevailing in an area whereas weather is characterized by temperature, humidity and pressure conditions of an area at a particular time”. The climate of a locality has comparatively greater influence upon germination, growth and development of plants; therefore, it demands special attention particularly in silviculture.

Among the important atmospheric gases are included oxygen, nitrogen, carbon di oxide etc. Earth has about 21 per cent of oxygen. Oxygen is needed for energy generation in almost all the living organisms except chemosynthetic bacteria and thus effect the life of organisms. Nitrogen is present in atmosphere and is about 79 per cent. It is important because it is an essential element of amino acids, nucleic acids and various other enzymes. Carbon dioxide is present in low amount i.e., about 0.04 per cent yet has important role as is used up by plants in preparation of food through photosynthesis and also acts as greenhouse gas maintaining the temperature of the globe. Among other important bodies are solid bodies which remain suspended in atmosphere along with gases.

One of the most important climatic factors is Light or Solar radiations which is very important for survival of organisms as it is an important factor required for food production i.e., photosynthesis by green plants and its subsequent transfer to other organisms of the ecosystem through food chain. The importance of solar radiations can be understood by the fact that it provides us light as well as heat energy which are very important for the point view of ecosystem functioning. Further, sunlight affects formation of chlorophyll in green plants, daily opening and closing of stomata, photosynthesis, Form and structure of plants. Its intensity determines the growth of trees by affecting rate of photosynthesis. It has role in resistance to cold and drought as well as to disease, insect attack, and other unfavorable influences.

The amount of light is greatly influenced by latitude, altitude and season which in turn affect many processes directly which require light such as flowering, fruiting, and dormancy. Photoperiodism is the phenomenon of physiological changes that occur in plants in response to relative length of day (i.e. photoperiod). The photoperiodism was first discovered by Garner and Allard (1920). Based on photoperiodism, the plants are classified into three main categories: Short day plants (SDP) or long-night plants, Long day plants (LDP) and Day neutral plants (DNP).

Heat and temperature are the two important climatic factors which play important role in the growth and development of organisms. The temperature decreases with rise in elevation above the sea. It is also affected by aspect and gradient, presence or absence of Forest Vegetation, water exchange between sea and land mass. The effects of temperature on the organisms are through its effect on various metabolic processes. It increases rate of transpiration, respiration and photosynthesis which in turn results in growth and development of species or organisms. Very high temperature when temperature exceeds the normal growing range i.e.,45°C, it causes heat injury. Seed germination is highly dependent on temperature. Temperature together with moisture content, determines the rate of deterioration in all seeds, it also affects the rate of dormancy.

Excessively low temperature below 5^0C results into **frost and snowfall and b**oth of these phenomenons are harmful for plants. Harmful effects of snow includes into partial or permanent death of plants, frost lifting of young seedlings, damage to cells and wood due to freezing of water, breaking of woody tissues due to frost **crack.** However, s**now** has both injurious as well as beneficial effects to plants. Low temperature is essential for the germination of temperate species. Snow helps in recharging of streams and reservoirs, it also acts as blanket and prevents further drop in temperature and thereby safeguards seedlings and vegetation from the damaging effect of excessive cold and frost. The injurious effects of now include mechanical bending of tree bole and branches, breaking of tree crown and branches, soil erosion and uprooting of trees.

Moisture remains present in atmosphere and in soil. Water is needed by all organisms as it is universal solvent and is present in all protoplasm, all cell walls and vacuoles. The water in vacuoles causes turgidity and growth of cells and thus, of organisms. It is an important constituent of carbon / food assimilation process during photosynthesis and is, thus, directly assimilated. Ascent of sap in stems results in absorption of nutrients and its transfer to various organs. Respiration also requires water and the process is ceased when the water content drops below a certain minimum. Water causes cooling of plant and animal body through sweating in animals and transpiration in plants. Water is necessary for all movements due to swelling and irritability. Structure of plants is influenced to a great extent by the water in the atmosphere and soil. Water is available for the trees through air or through soil. Water is mainly absorbed from soil by the roots of the plants.

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Unit 3: Factors of Locality II: Topographic, Edaphic and Biotic Factors

Unit Structure

3.0 Learning Objectives
3.1 Introduction
3.2 Topographic Factors
- **3.2.1 Configuration of earth's surface**
- **3.2.2 Altitude and Latitude**
- **3.3.3 Slope, aspect and exposure**
- **3.3.4 Non-living and living components on soil surface**

3.3 Edaphic factors
- **3.3.1 Soil structure**
- **3.3.2 Composition of soil**
- **3.3.3 Soil profile**
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- **3.3.5 Depth of soil**
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- **3.3.11 Inorganic soil matter**
- **3.3.12 Organic matter or humus**
- **3.3.13 Soil acidity or pH**
- **3.3.14 Effects of soil on plant growth and development**

Summary
References

3.0 Learning Objectives

After completing this unit you would be able to:

- Define topographic factors, edaphic factors and biotic factors
- Know the various components of topographic, edaphic and biotic factors
- Appreciate the roles of these factors in the life of organisms

3.1 Introduction

In the previous unit, we discussed about the factors of locality relating to climate i.e., solar radiations, rainfall, wind and pressure, and their effects on growth, development and reproduction of organisms.

In the current unit, we will discuss those factors of locality on which the climatic conditions of an area depend. The topographic or physiographic factors are those factors which influence climatic conditions of an area, affect the organisms or vegetation. Such factors include earth configuration, altitude, latitude, slope, aspect and exposure. These factors have important indirect effects upon forest environments through their influences on climatic and soil factors. The conditions of climate and soil are affected in a diverse manner by the physiographic factors such as earth's configuration, altitude, slope, exposure, aspects and surface conditions. We will also discuss edaphic factors.

3.2 Topographic Factors

Topographic factors are those factors which are related to land configuration such as altitude, slope, aspect, exposure, latitude and longitude. These factors by effecting climate and soil features bring about effects in vegetation of the area. These are again subdivided into following types:

a) Configuration of earth's surface

b) Altitude, Latitude and exposure

c) Slope and aspect

d) Surface conditions

e) Non-living and Living components on soil surface

3.2.1 Configuration of earth's surface

The configuration of the earth surface, the direction of mountain chains and distance from the sea has great climatic significance (Rubner, 1934). It is on these features in which the direction of wind, atmospheric humidity, rainfall and other type of precipitations are dependent. Rock types effect on the soil water supply, the location of springs and the type of vegetation. Similarly, effects of air are more on the hill tops in comparison to valleys. The topography of an area affects the forest vegetation through its influences on rainfall distribution. Rainfall on the other hand tends to be higher on the windward side in comparison to leeward side whereas wind-borne snow is likely to be carried away from windward side and deposited on the leeward side for a longer period of time. According to Braun-Blanquet (1932), the earth configuration has an increasing trend from south to north in northern hemisphere and with increasing elevation in mountainous regions. The soil of lower lands of the slopes has more fertile soil in comparison to soil in the higher ridges as

soil is deposited in the base along with water. Further, those areas which are close to large bodies generally have moist air and more favorable temperature than those areas located away from these bodies.

3.2.2 Altitude and Latitude

Altitude and latitudes greatly affects the climate of an area. Areas located at higher elevations receive more intensity of solar radiations particularly during clear weather and winds are also very strong at regions of high elevations than regions of low elevations. With regard to temperature of soil, it has been observed that it decreases with increasing altitude. These all factors in combination modifies the climate of these areas and this is reflected in the kind of vegetation and the difference can be observed very vividly. Further, the low density of atmosphere at higher elevations results into absorption of more heat. Studies around the world have shown that altitude has indirect effects on the increment and shape of forest trees. According to Honda (1892), increase in elevation has indirect effects upon individual trees in the following manner:

- Growth in height diminishes regularly and noticeably whereas growth in basal area at breast height does not diminish so rapidly. Similarly, total increment also decreases gradually.
- The period of development particularly maturity is prolonged.
- Shape of tree bole shape deviates from cylinder to conical or neiloid.
- The form factor at breast height becomes smaller.
- The height of crown development gradually decreases and reaches nearer to ground at higher altitudes. Similarly proportion of branches and branch-wood also increases.

Similarly latitude of a place also has influence upon the climate. It affects temperature, rainfall and wind patterns, thus, have effects on the vegetation. The kind of precipitation and its amount also changes with latitude. In higher latitudes snowfall is more whereas in lower latitudes rainfall. This can be reflected on the kind and diversity of vegetation found in lower latitudes than in the higher latitudes.

3.3.3 Slope, aspect and exposure

Slope (or gradient) may be defined as the angle the surface with horizon. It is this slope which controls the surface runoff, soil erosion, and amount of water that percolates

vertically downward. The higher the slope more will be surface runoff, higher chances of soil erosion, and low percolation. Slope also controls intensity of solar radiation by shifting its angle of incidence. In case of forest vegetation, better growth is observed on land with moderate slope due to better drainage than areas with flat angle. Grebe's (1886) has given forest classification based on its gradient as:

- Gentle - 5 to 10°
- Medium- 11 to 20°
- Steep- 21 to 30°
- Very steep - 31 to 45°
- Precipitous - over 45°.

It has been observed that slope gradients between 5 and 30° are best suited for forest growth whereas a gradient of above 45° is very negative for forest growth and it usually have little or no forest growth. On **low slope grounds**, deep soil is found and tree roots have scope for free development, however, usually the drainage is poor which results into swamps like situations. Highest yield (per acre) is noticed on **gentle slopes** provided that other climatic conditions are favorable. **Medium slopes** have moderately deep soil and usually supply of soil moisture is also adequate, therefore, supports dense forests and results in high yields of timber under favorable conditions. **Steep slopes** have shallow soil and only certain species thrive on them particularly shallow rooted ones. In **Very steep slopes** have a thin soil along with many rocks and boulders scattered on the surface. It is observed that tree species with short and stunted growth thrive on them. **Precipitous slopes** do not sustain a continuous forest but scattered individuals or groups of trees are found where soil has accumulated to sustain tree life. In mountains particularly in Himalayas, the vegetation on steep slopes is washed out as a result of heavy surface run-off, landslides and floods during rains.

The direction of the slope is called **aspect.** Aspect of the land or slope determines the amount of exposure to solar radiations which, in turn, modifies the moisture content, temperature of soil and air, and kind of vegetation and its density. For example a slope towards north or poleward is considerable high in moisture and thus, cooler in comparison to southward or equator-ward slopes in mountains. Aspect of a site has direct relation with solar radiations and thus, with temperature and soil moisture. This in turn affects the kind

and diversity of vegetation. The amount of heat absorbed by the soil and consequently the temperature of the soil on a given site mainly depends on how vertically or near to vertical the sun's rays strike at it. Generally, the sun's rays strike the soil surface much more obliquely on north aspects (or north-facing slopes) than on south aspects (or south facing slopes). Therefore, former receives much less heat than that of the latter. This also increased more vaporization in south facing slopes consequently are also drier. In mountains, the trees are observed to grow at altitudes lower than their normal range on the cooler (north aspect slopes) and above their normal altitudinal range on the more sunny and warmer southerly slopes. The warmer and drier southern slopes in dry regions are not favorable to forest vegetation. The effect of exposure to a considerable extent gets modified towards the higher latitude. Exposure decreases with distance from the equator and also slope gradient modifies it in response to action of air currents. The effect is greatest when the sun's rays strike the soil vertically.

3.3.4 Non-living and living components on soil surface

Non-living components and living components have direct as well as indirect effects on the soil and thereby on vegetation on it. All those non-living components which tend to help in absorption of water, retardation in water evaporation and reduces extremes of temperature, will promote the growth of vegetation. Among non-living components, there are two major kinds i.e., snow and forest leaf-litter (fallen leaves, twigs, and dead herbage).Snow protects vegetation during the winter by shielding the surface soil and root contained in it from excessive cold. The distribution of snow cover determines the vegetation boundary. The areas in alpine regions which are covered with snow in most part of the year remains devoid of trees and only grasses and small shrubs are found there. The snow acts as a blanket to forest growth and is important for seed germination and its success. In general, regions having a heavy snowfall coupled with adequate summer warmth usually sustain heavy forest cover. In mountainous regions, snowfall directs water to percolate in the deeper layers of water and thus, recharging the natural springs and our river systems. On sites of heavy snow accumulations, the snow acts as a water reservoir which results in luxuriance of vegetation in the following growing season. Snow influences plant form by its weight and often causing trees to assume prostrate forms. In regions of extreme cold, the parts of the tree exposed above the snow gets

regular freezing resulting trees appearance as shrub-like or to develop low, umbrella-like crowns. Deep snow acts as a defense against loss of moisture by transpiration. Thus, many tender shrubs and trees in their juvenile stage are able to survive in the winter because of protection offered by snow.

Another important non-living component which affects the vegetation is leaf-litter content over soil. Litter means the undecomposed organic matter lying on top of the humus layer. It is composed of fallen dead leaves, branches, twigs, dried herbage, and other debris lying in a forest floor. It is continually being replenished from vegetation and is continually being consumed by decomposition in the formation of humus. It has almost the same mechanical effect as snow in keeping the soil moist and more uniform in temperature. As the layer of litter is present in the growing season as well as in the winter, it has a well-marked influence on the kind and character of living ground cover such as moss, herbs, and tree seedlings, which it tends to suppress.

Living Soil Cover includes every kind of covering over the soil formed by living vegetation. Both the physical and chemical relations of soil are affected by the living ground cover. This green cover modifies local environment in variety of ways as follows:

- It regulates soil and air temperature.
- It acts as a screen against the sun's rays.
- It helps percolation of water inside the soil.
- It decreases the action of the wind.
- It helps in maintaining cooler air and moist conditions underneath the vegetation.

- **Check Your Progress 1**
- 1. What do you understand by topographic factors?
- 2. How topographic factors affect the climate? Discuss.
- 3. Differentiate between altitude and latitude.
- 4. What is the effect of altitude on temperature? Discuss.
- 5. Discuss the slope, aspect and exposure.

3.3 Edaphic factors

All those factors which are related to soil and which affect directly or indirectly to the various components of an ecosystem are known as **edaphic factors.** In other words, all those factors which relate to structure and composition of soil and its physical and

chemical characteristics are known as **edaphic factors**. Soil is a very important component of ecosystem and all living organisms directly or indirectly derives various nutrients from soil and these are very essential for their growth and development. Apart from this, soil substratum is essential for plants in which their roots penetrate for getting nourishment as well as support or anchoring. The various factors affecting growth and development processes of organisms particularly vegetation relating to soil may be categorized in three categories:

- Edaphic factors relating to physical properties of soil
    - soil structure
    - soil composition
    - soil profile
    - depth of soil
    - soil temperature
    - soil moisture
- Edaphic factors relating to chemical properties of soil
    - pH
    - mineral matter
    - soil air
    - soil water
    - inorganic soil matter
    - organic matter or humus
    - soil acidity
- Edaphic factors relating to biological properties of soil
    - soil biotic components (Soil organisms, microorganisms, mycorrhizae)

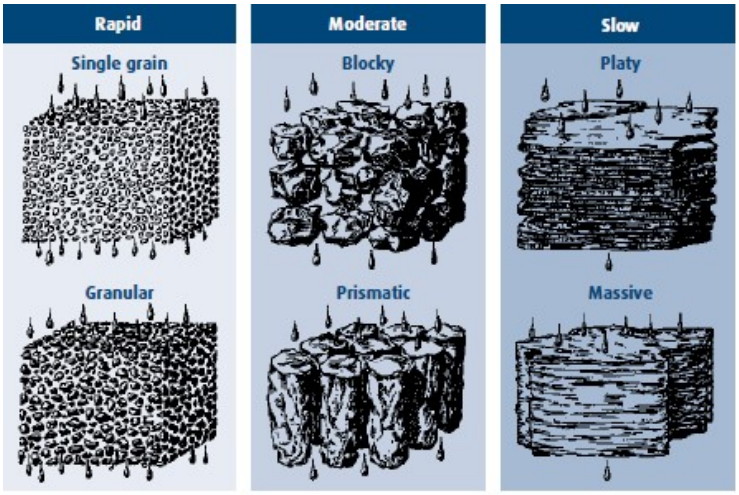
The vegetation of an area is greatly affected by the physical and chemical properties of soil and also by soil biotic components present in the soil. Therefore, the important factors determining the physical properties and chemical properties of soil are described as follows:

3.3.1 Soil structure

Soil structure refers to the arrangement of soil particles such as sand, silt and clay into aggregates. In other words soil structure is the size, shape and arrangement of solids which affect the pores size and thus, to the capacity of retaining and transmitting air, water and other dissolved substances. The ability to support vigorous root growth and development also depends on the soil structure. The various shapes and soil structure types that may exists include- Crumb, Granular, angular blocky, sub-angular blocky, prismatic, columnar, single grain, massive Crumb and granular structures.

A crumb structure is highly porous relative to a granular aggregate.

A platy structure occurs in some soils just below the surface horizon and creates obstructions in drainage.



Soil structural shapes and their associated permeability (Adapted from Bowler 1980. The Drainage of Wet Soils).

Blocky and sub-angular blocky types are common in sub-soils but may also occur in surface soils.

Prismatic and columnar structures are common in sub-soils of arid and semi-arid regions.

Single grain is characteristic of sands with very little organic matter content.

Massive soils have their particles adhering without any regular cleavage like many hardpans, puddled soils or soils repeatedly cultivated at the very wet moisture contents. Soils which are single grained or massive are also referred to as “structure less.”

An ideal soil contains about 50 percent solids, 25 percent water, and 25 percent air by volume.

Importance of soil structure

- It is the soil structure on which various soil characteristics such as soil capacity to hold water, air and other dissolved substances, depends.
- It is important for vigorous root growth and development.
- It is important as it affects soil productivity and is often regarded as a key to soil productivity.
- It affects plant growth through its influence on infiltration, percolation, water retention and runoff, aeration, and mechanical impedance to root growth.
- Large pores helps in good aeration and infiltration of water that results into reduced runoff and thus, reduced erosion. Further, good aggregation of soil holds particles together and thus, reduces the impact of surface runoff and raindrop in detaching particles.

3.3.2 Composition of soil

Soil generally includes mineral matter (sources are decomposed rock or carried to the area by water or air currents), organic matter (sources are remnants of plants and animals), water (partly liquid, partly in the shape of vapour) and gases (such as air, carbon dioxide and ammonia).

The mineral substances form the greater part of the soil in the form of ores, salts, acids and metals. Ores include silica, alumina, lime and magnesia which occur most frequently in soils. Silica is represented chiefly in sand which combines with alumina to form clay. Clay and sand together form loam. Lime appears mainly as calcium carbonate in calcareous soils, also as calcium sulphate in gypsum. Magnesia is the most frequent in dolomite, though smaller quantities are found in most other soils.

Among salts the most important ones are Potassium carbonate (potash), sodium carbonate (soda), sodium chloride (common salt), carbonates, sulphates and phosphates of iron and manganese. The quantity of salts in the soil does not, as a rule, exceed 0.5 per cent and rarely 1.0 per cent. Larger quantities are found only in certain soils such as salt plains in the vicinity of the sea coast or salt springs or in some peaty and swampy soils. Potassium carbonate is of importance since a fair amount of it is required by forest trees for their growth and development. Sodium chloride acts favorably only if present in small

quantities whereas higher quantities are harmful. Salts of iron often are injurious for growth of vegetation.

Among Acids are two free acids such as carbonic and humic acids which generally appear in soils.

Among metals, only iron is of importance in silviculture. It appears as ferrous oxide and as ferric oxide. The former is believed to be injurious to plant life whereas Ferric oxide may be mixed with soils and is not injurious below 10 per cent.

Soils may also be classified according to the rapidity with which the humus is decomposed, as very active soils, active soils, moderately active soils and inactive soils.

Soil classification

Soil Types	Clay	Sand	$CaCO_3$	OM
i) Loams or free soil	20-30%	50-70%	5-10%	2-5%
ii) Clays	> 40%	<50%	<5%	2-5%
iii) Clay-sands	>30%	<50%	<5%	2-5%
iv) Marls	>30%	<50%	5-10%	2-5%
v) Peat clay	>30%	<50%	<5%	>5%
vi) Sand	<10%	>80%	<5%	2-5%
vii) Calcarious sand	<10%	>70%	5-10%	2-5%
viii) Peaty sand	<10%	>70%	<5%	>5%
ix) Calcareous	<10%	50-70%	>10%	2-5%
x) Peats	<10%	<50%	<5%	>35%
Other kind of soil				
xi) Dolomite	a chalky loam with much Magnesium Carbonate			
xii) Gypsum	a soil which is rich in Calcium Sulphate			
xiii) Salt soil	excessive percentage of salts especially NaCl			
xiv) Ferruginous soil	excessive proportion of Ferric Oxide			

Very active soils are those soils in which the decomposition of humus is excessively quick such as dry porous sand and calcareous soils.

Active soils are those in which the decomposition of humus proceeds at a rate favorable for growth and development without actually exhausting the supply of organic matter. Eg., moderately moist loamy sand, sandy loam and loamy marl.

Moderately active soils are those where decomposition is too slow for a healthy development of most plants. e.g., stiff clay, wet soil, heather soil.

Inactive soils are that soil which has either excess of moisture or absence of humus thus, little or no decomposition takes place. e.g. peat soil, shifting sand, etc.

3.3.3 Soil profile

The soil profile is defined as the vertical section of the earth inside the earth more or less 6 feet. The profile composition varies while moving inside and also it varies from one place

to another place. It mainly depends on climate, vegetation type and parent rock. Normally the top soil is thicker inside the forest; however, it also varies from one forest type to another forest type.

The vertical section of the soil normally contains **five layers** which are called as horizons which are as follows:

i) O-horizon (organic horizon or litter zone)

ii) A-horizon (top soil)

iii) B-horizon (sub soil)

iv) C-horizon (weathering rock)

v) R-horizon (bed rock)

i) **O-horizon:** It is the topmost soil layer which is also known as litter zone. It is characterized by the presence of fresh or partially decomposed organic matter. This horizon is usually absent in desert, grassland and cultivated lands.

ii) A- horizon: It is the second layer after O-horizon in forest soils whereas topmost soil in in other kinds of soils. It is further subdivided into three sub types - A1, A2 and A3 horizons. **A1-horizon**, the topmost part of the A-horizon contains high humus and organic matter therefore also rich in bacteria and other microbes. **A2-horizon** is the zone of maximum leaching and has comparatively less organic matter. **A3-horizon,** the lowermost layer of A- horizon, acts as transition layer between B-horizon and A-horizon.

iii) B- horizon: It is also known as **zone of illuviation** where material from A-horizon are received. It also consists of B1, B2, B3 sub-divisions. It is deep coloured with aluminum, iron and organic colloids. This is the zone upto which roots of shrub and trees reach.

iv) C-horizon: It is comparatively thick layer and consists of large masses of withered mineral deposits.

v) R- Horizon: It is a bed rock and water is reserved over it.

3.3.4 Soil texture or physical nature of soil

The physical properties of soils are of great importance to vegetation growth and development as it affects supply of water and nutrients. The soil is composed of material varying in size from boulders to minute particles of colloidal size. It is on the percentages

of the various size classes of particles that the various physical soil properties (i.e., water holding capacity, water percolation etc.) depend. There are usually two extremes of soil particles i.e.,, some particles are very fine whereas others are very coarse, and between these two extremes, other soil particles of different sizes also remain present in the soil. Based on the particle's size, soils are of mainly three types- **clay, silt and sand**.

Clay is the soil having particles with diameter 0.002 mm or less.

Silt is the soil with particle size ranging between >0.002 mm and less than 0.05 mm.

Sand is the soil with particle size ranging from >0.02 and <2.0 mm.

Name of Particle	Size (mm)
Clay	<0.002
Silt	0.002-0.02
Fine sand	0.02-0.2
Coarse sand	0.2-2.0
Fine gravel	2.0-5.0
Gravel	>5.0

Apart from these three categories, **fine gravels** with particle size 2.0 to 5.0 and **gravels** with particle size >5.0 mm are also identified.

Texture is the relative proportion of clay, silt and sand present in soil. The proportion of above mentioned particles i.e., clay, silt and sand, in the soil influences the physical properties of soil such as aeration, water holding capacity, drainage etc. The principal physical properties of importance in silviculture are the following:

- **Consistency or binding power or the cohesion** between the different particles of the soil depends on the chemical composition of the different parts, the degree of division and the quantity of moisture in the soil. Generally, it is greatest in clay and smallest in sand. Presence of humus moderates both extremes.
- **Shrinking or the reduction of the volume of the soil** under the process of drying causes cracks in the soil, followed by the exposure of the roots. Heavy soils crack more than light soils.
- **Capacity to hold water** is generally proportional to the percentage of fine earth and humus in the soil.
- **Hygroscopicity (the capacity of the soil to attract and condense aqueous vapour from the atmosphere)** depends on the degree of division of the particles, and on the temperature. The finer the division, the greater the hygroscopicity and

more vapour is condensed at a low temperature than at high temperature. Soils rich in humus show the greatest hygroscopicity followed by loam and lime soils, and it is smallest for sandy soils.

- **Permeability** (the capacity to let water pass through) is greatest in sand with coarse grains and is smallest in clay soil. Clay soils are usually close to impermeable therefore waterlogging takes place. In many cases, the clay particles of a mixed soil are gradually carried into the subsoil where it forms an impermeable layer by binding with iron oxide.
- The Capacity to become heated is greatest in sand (hot soil) and smallest in clay (cold soil). Calcareous soils are close to sand and loam to clay in this property.

The physical properties are of special importance through their action upon moisture. In this respect, the chemical composition of the soil is of less important than the admixture of humus and the degree of division of the particles; hence, sand and clay represent the extremes. Thus, texture of soil is regarded as one of the important edaphic factors and affects the plants in the following ways:

- The status of nutrients in the soil depends on the texture e.g., clay soil has higher nutrient concentration whereas sand has low nutrient content. Thus, the nutrient supply is affected due to this.
- Soil aeration is good in sandy and coarse textured soil in comparison to silt and clay.
- Water holding capacity of coarse textured soil and sandy soil is very poor and water is drained out quickly whereas fine textured soils have good water holding capacity and poor drainage. At times very fine textured soils lock the water and result in water logging.

3.3.5 Depth of soil

Depths of the entire soil mass as well as thickness of its various horizons are important in the growth of a forest because of their bearing on the total amount of water stored in the soil and that available for plant growth. In addition the depth and physical character of the various horizons determine to a large extent the growth of tree roots.

3.3.6 Soil temperature

According to Vesque (1878), high soil temperature gives rise to abundance of sap and to short and thick roots, stems, and leaves. Low soil temperature, on the other hand, causes a diminution in amount of water and nutrients absorbed. This causes dwarfing, so characteristic of trees growing in cold soils. Willows and some other woody plants often assume prostrate forms in such soils. A naturally warm soil is favorable to early germination of seed, early start of vegetation, rapid decomposition of humus and, as a consequence, a larger production of timber. A cold soil tends to an excessive accumulation of organic matter. Warm soils are more variable in temperature than cold soils owing to their greater loss of heat through radiation on cold nights. Vegetation growing in warm soils is more subject to injury from spring frosts. The lowering of soil temperature under closed, natural forest canopies affects:

- Length of time that seeds remain viable in the litter.
- Germination.
- Survival of young seedlings.
- Development of seedlings.

One of the most important requisites for seed storage in the forest floor without deterioration is low temperature (Hofmann, 1917). Under natural conditions, seeds in the litter remain viable longer under a high forest of full density, owing to its effect in lowering surface temperature. Germination fails even when moisture and aeration conditions are at their optimum, if the temperature is too low (Hawley, 1922). A heavy thinning increases the temperature of the surface soil and hastens germination.

Heat and temperature of the soil depends on following conditions:

- Duration of direct sunlight and angle of incidence of the sun's rays. The nearer the sun strikes the soil at right angles the greater the heat it produces in soil.
- Latitude, slope, and exposure, all affect soil temperature. Soil temperature decreases with increase of altitude.
- The specific heat of soils depends on soil composition. Quartz sand heats quickly whereas peat heats very slowly.

- The amount of water in soils is of great significance as it influences temperature due high specific heat of water than soil.
- Dry soils heat quickly but soils containing much water retain heat longer. Thus desert soils are very warm in the day and cold at night, because they rapidly lose their heat by radiation.
- Clay soils are cold because they retain large quantities of water.
- The darker soils have greater absorptive capacity than lighter soils. Consequently darker soils get heated quickly when exposed to sunlight. Dark soils cool more rapidly than light soils, owing to their greater loss of heat through radiation.
- A porous, gravelly soil absorbs the sun's heat very rapidly and becomes highly heated on the surface however, the heat gets quickly lost.
- The conductivity of heat is greatest in rocky soil, particularly that containing limestone. Loose soil conducts heat slowly because of the larger air spaces.
- Vegetation that covers the soil affects soil temperature because it shields the soil from direct insolation and evaporation and intervenes in preventing loss of heat by radiation.

3.3.7 Soil moisture

Water is the most important component of the soil, as plant life is impossible without a certain quantity of moisture. It affects vegetation principally in the following manner:

- It assists in the decomposition of the rocks
- It assists in the formation of humus, and regulates both the admission of air into the soil and its temperature
- It is an important agent in the process of nourishing and shaping the plant. More especially, it carries through the roots the mineral substances from the soil into the plant.

However, a certain degree of moisture in the soil may act favorably whereas an excess of water especially if stagnant, is always injurious. Excess of water reduces the activity of the soil (by driving out air), lowers the temperature, and increases danger from frost. It also renders increase in soil acidity.

The soil receives water from one or more of the following sources:

- From the atmosphere, as dew, rain, snow, hail or as vapour condensed by the hygroscopic action of the soil
- From ground water resting in the subsoil
- From inundations, whether natural or artificial

Water derived from the atmosphere acts most favourably, provided the supply is suitably distributed over the different seasons of the year, and the soil is capable of retaining moisture sufficiently long during dry weather. Where these conditions are wanting, ground water is likely to act more favourably, because it produces a more even degree of moisture in the upper layers of the soil. Natural inundation water is in many cases objectionable, because it renders the soil too wet at one time, and too dry at others. Artificial inundation, or irrigation, produces very favourable results, but it is generally expensive.

3.3.10 Soil air or gases

It is only necessary to add that the amount of air in the soil varies within wide limits, and that the amount of carbon dioxide depends on the quantity of organic matter in the soil, and the rate at which it is decomposed.

3.3.11 Inorganic soil matter

The chemical analyses of rocks indicate that they contain all of the elements necessary for plant growth. However, during the processes of soil development many of the important elements such as calcium, magnesium, potassium, and phosphorus are leached from the surface soil, or 'A' horizon but usually a part of the total leached material is precipitated in the 'B' horizons or at lower depths and may again be brought to the surface in the periodic litter fall in a forest. The most important classes of soil-forming minerals are:

- silicates,
- oxides and hydroxides,
- carbonates, and
- phosphates

Of these silicates are by far the most important as they weather to form the finer fractions (silt, clay, and colloidal). The silicates are source of calcium, magnesium, sodium, potassium, fluorine, iron, aluminum, and silica to the soil. The oxides and hydroxides give quartz (SiO_2), manganese, iron and aluminum. The carbonates supply calcium,

magnesium, lead and copper. The phosphates contribute calcium, flourine and phosphorus. Most rocks contain many other minerals of different composition, so that in general, the parent rock from which soils are developed contains all the inorganic elements necessary for plant growth.

3.3.12 Organic matter or humus

Humus includes all organic matter which is gradually decomposed, and forms in mixture with the upper layer of mineral substances the black earth of the forest. The sources of humus are the annual leaf fall and fallen twigs and dead plants. The humus decomposition releases many important elements which are required for growth and development of the plants. Humus is of different kinds. **Mild humus or forest humus** is formed when air and water act in adequate proportion upon fallen leaves or moss, etc. **Dry mould** is formed when in the absence of moisture, excessive air acts upon certain plants. **Acid humus** is the result of decomposition when excess of moisture is available but air remains deficient in the soil. The best humus for forest vegetation is **mild forest humus**.

3.3.13 Soil acidity or pH

Acidity of soil solution is due to an excess of hydrogen ions (H^+) over hydroxyl ions (OH^-); but if the hydroxyl ions are in excess as compared to hydrogen ions, the solution becomes alkaline. pH value which is defined as, “the negative logarithm of the reciprocal of H+ ions concentrations. pH of 7 indicates neutrality, higher value indicate alkalinity and lower values to acidity”.

Soil acidity influences vegetation growth by its effects on nitrogen-fixing bacteria, effects on earthworms and by decreasing the solubility and, thereby affects the availability of salts. On the other hand certain species belonging to family Ericaceae grow well on acid soils. The degree of acidity depends largely on the kind of vegetation and the nature of the humus layers in any environment. However, forest vegetation may tolerate wide pH ranges.

3.3.14 Effects of soil on plant growth and development

All soils have their origin from rocks. In course of time certain other substances are added from different sources. In some cases, the soil covers the rock from which it has been derived whereas in others, it gets carried away in distant places by violent convulsions, or by water and air currents. The first kind of soil is called as “**indigenous soil**" whereas the

second kind is known as "**exotic soil**". All soils found in near the sea coast, river deltas, inland by water courses and lakes is exotic soil also referred to as alluvial soil.

Effect of the Soil upon Forest Vegetation: Soil has importance because it provide forest vegetation with stability, suitable space for spreading of the root system, moisture in adequate quantities and continuously, and nutrients in sufficient quantities and in a condition suitable for absorption by the roots. Any soil which provides these requirements is well to be called as fertile soil. It has been observed that a fertile forest soil must possess the following properties:

- A sufficient depth
- A suitable degree of porosity
- A suitable degree of moisture
- A suitable chemical composition

The depth is measured by the thickness of the soil layers and by the portion of the subsoil which can be penetrated by the roots. The root system varies considerably from species to species. Some have tap roots such as oak, chestnut, pine, silver fir, maple whereas others have strong side roots which send down deep going rootlets, such as alder. Some other kind of species go to a moderate depth e.g. beech and birch. There are some other species which spread mainly near the surface e.g. spruce. The nature, composition, and degree of moisture of the soil modify the root system to some extent, which in young trees frequently differs from that in a more advanced age. Because of this variation in root system that certain species thrive well only in deep soil while others can subsist in shallow soil though they prefer the former. The best indicator of the depth of soil is reflected in the height growth of trees. The more is soil depth the more is height growth of trees where in contrary to this, the deficiency of soil depth results in fall off in tree height growth. Thus, trees may be classified based on their demands for depth of soil:

i) **Shallow soil demanding species such as** Spruce, pine, birch etc.

ii) **Moderate depth demanding species such as** willows, alder, and horse chestnut

iii) **Greater depth demanding species such as w**hite poplar

iv) **Greatest depth demanding species such as** Silver fir, sweet chestnut and oaks

A suitable degree of porosity is needed for appropriate tree growth. Neither too firm nor too loose soils are favourable for tree growth. It is difficult for tree roots to penetrate the soil layers if soil is too firm and it also prevent the admission of the necessary air, interfere with the movement of water and have a tendency of waterlogging and thus swampiness accompanied by enhanced danger from frost, strong shrinking and cracking in summer. Whereas very loose soils, endanger the stability of the trees and are liable to be uprooted by water or wind. Such soils also suffer from rapid drying and rapid decomposition of the humus. The plants growing in such soils also suffer from frost lifting. The best soils are loam and calcareous soils with a good layer of humus.

A suitable Degree of Moisture is needed for proper development of vegetation although it varies from species to species. By suitable degree of moisture is meant that it should correspond to the natural requirement of any particular species. The more continuous supply of such water is maintained during the growing season, the more favourable will be the growth and development of the species. Apart from these conditions, the soil porosity, the nature and proportion of its component parts affect the degree of moisture.

A suitable Chemical Composition mineral and organic substances is essential for proper growth of species as it affects the development of the trees party by providing nutrients and partly by determining the physical properties of the soil. Woody plants take the greater portion of their nourishment from the air, more specifically carbon, but a certain portion, including the mineral substances is derived from the soil. Hence, it is of importance to ascertain the actual quantities of such substances in the plant. It is found that the amount of substances required by forest trees is more or less same as by field crops.

Check Your Progress 2

1. Define edaphic factors. Discuss its various categories.
2. Write a note on soil structure and its impact on various physical properties of soil.
3. Discuss various kinds of soil structure types.
4. Explain the importance of soil structure in plant growth
5. Write a detailed note on structure and composition of soil.
6. Write a brief note on soil profile.
7. Differentiate between soil structure and soil texture.

Summary

- In this unit, a detailed account of topographic or physiographic factors, edaphic factors and biotic factors gave been given.
- **Topographic factors** are those factors which are related to land configuration such Configuration of earth's surface, Altitude, Latitude and exposure, Slope and aspect, Surface conditions, Non-living and Living components on soil surface. These factors by effecting climate and soil features bring about effects in vegetation of the area.
- **Edaphic factors** are all those factors which are related to soil and which affect directly or indirectly the various components of an ecosystem. Soil is a very important component of ecosystem and all living organisms directly or indirectly derives various nutrients from soil and these are very essential for their growth and development. Apart from this, soil substratum is essential for plants in which their roots penetrate for getting nourishment as well as support or anchoring. The various factors affecting growth and development processes of organisms particularly vegetation relating to soil are - edaphic factors relating to physical properties of soil (soil structure, soil composition, soil profile, depth of soil, soil temperature, soil moisture), edaphic factors relating to chemical properties of soil (soil acidity or pH, mineral matter, soil air, soil water, inorganic soil matter, organic matter or humus), edaphic factors relating to biological properties of soil or soil biotic components (Soil organisms, microorganisms, myccorrhizae).

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Unit 4: Factors of Locality III: Biotic Factors

Unit Structure

4.0 Learning Objectives
4.1 Introduction
4.2 Competition – struggle for growing space, light and nutrients
4.3 Interrelationships among plants
4.4 Effects of Wild Animals
4.5 Domestic Grazing Animals
4.6 Interference by humans
Summary
References

4.0 Learning Objectives

After reading this unit you will be able to explain:

- Competition –struggle for growing space, light and nutrients
- Interrelationships between plants
- Interrelationships between plants and animals, particularly the effect of animals
- Interference by man.

4.1 Introduction

In the previous unit, we discussed about the topographic or physiographic and edaphic factors of locality relating to climate and their effects on growth, development and reproduction of organisms. In the current unit, we will discuss about the biotic factors of locality.

Biotic Factors

Living organisms in an area have direct or indirect influence on desired species and constitute what are known as **Biotic factors.** Biotic factors include associate tree species, microorganisms, parasites, or other life in the area which interact with one another or with desired species and modify the soil, moisture, climate or other conditions of the area. Such interactions among the living components are called as **Biological (Biotic) interactions.**

In nature, none of the organism exists in absolute isolation, but remain connected with other organisms or living components directly or indirectly and such interactions or connections are fundamental to the survival of organism and the functioning of the ecosystem as a whole.

Biotic interactions can involve individuals of the same species (**intraspecific interactions**) or individuals of different species (**interspecific interactions**). Pollination, symbiosis, predation, herbivore, or cannibalism, mutualisms are some important kinds of interactions operating among individuals of same or different species. In interactions, individuals may affect directly or indirectly depending upon whether there exists a direct relation or some intermediaries is involved in such interactions. Such interactions or inter-relationships among organisms profoundly affect growth and development of desired forestry species. Various kinds of interactions among the biotic factors can be categorized into following heads for the ease of study point view.

4.2 Competition – struggle for growing space, light and nutrients

Whenever trees grow close enough together to form stands, competition sets in i.e., there starts a struggle between individuals of the same species or among individuals of different species for the available space, nutrients or water or in brief for their existence. In both fully stocked and overstocked stands which have developed naturally, there occurs a intense competition for light and space aboveground and for soil moisture, nutrients as well as space below the ground (Korstian and Coile, 1938). The intensity of competition among the individuals of different species depends upon the ecological similarities of the species, i.e., the higher the same ecological demands the more intense will be the competition among them. In the process of competition results into the elimination of the weaker individuals by vigorous and healthier individuals in other words, it happens according to Darwin's theory of **"survival of the fittest**". It has been observed that indifferent parts of the earth, many species got eliminated due the intense struggle for growing space, light, water and nutrients.

Competition is an interaction between individuals of same species or different species in which one species is positively affected (beneficial) whereas other is negatively affected (harmful). This can be because of limitation of food, water or space or at least one of these three. According to the competitive exclusion principle, individuals of species less suited to

compete for essential resources should either adapt or die out although principle of competitive exclusion is rarely operates in natural ecosystems [1].

Competitions may be categorized into two types based on whether it operates among individuals of the same species or individuals of different species. Thus, competition if is two types:

- **intraspecific competition** (among members of the same species)
- **interspecific competition** (among individuals of different species)

A) **Intraspecific competition:** Intraspecific competition occurs when members of the same species compete for the same resources in an ecosystem. The organism that obtains fewer resources will usually perform less well than if it lives alone.

B) **Interspecific competition:** Interspecific competition may occur when individuals of two different species struggle for obtaining similar but limited resources such as nutrients, or light or space. In case, the resources are in limited quantity then at least individuals of one species are negatively affected in terms of lowered production, growth, or survival. Interspecific competitions are very powerful in altering populations or communities and thus, in evolution.

4.3 Interrelationships among plants

There are many interrelationships exists among the plant species. Some are beneficial whereas in some one species is benefitted whereas other get negatively affected or even sometimes other remains unaffected. Thus, interrelationships between or among forest species are many and with varying degrees of dependence. As emphasized by Warming (1909) interrelationship is shown in all degrees of bondage from parasitism to the interdependence of plant communities. There are mainly following kinds of interrelations exists in nature:

- Parasitism
- Commensalism
- Mutualism
- Symbiosis
- Predation
- Saprophytic association

a) Parasitism is the kind of interrelationship in which one species derives water or nutrient or both from other organism and also responsible for some kind of negative impact on it. Former individual is called parasite whereas later is called host and such relationship are always hostile or unfriendly in nature. Pure Forests are highly affected by parasitism because in such forests, parasites spread very rapidly in the host individuals as there are no barriers.

Plant Parasites and their impacts of forests: There are present a number of parasites in the forest which cause damage to trees in various stages of its life. Soon after arise of young plants above the ground, various fungi of the soil such as species of *Pythium, Rhizoctonia*, *Fusarium, Corticium,* and possibly *Phytophthora,* attack the root or the hypocotyl.

Damping-off is another kind of attack which occurs by root infection even after the stems have started to become erect and woody. Damping-off can be recognized by the signs of the young plants losing their erect position after coming out of soil surface. Soon after getting infected, the plants die within few days. One of the important thing to note here is that the seedlings of some tree species are much more susceptible to infection than others, therefore, it is one of the factors which indirectly help in shaping the composition of mixed stands.

There are many plant parasites which cause spotting in leaves or even defoliate the trees which results into reduced photosynthetic activity by reducing the area of functioning leaf surface and thus, yield is severely reduced.

Parasitic fungi infecting the living tissues of the bark and wood, especially the cambium, are much more destructive than parasites which are confined to the leaves. They may gain entry inside the plant body through the stomata, young branches before the cork tissue is developed, however, in the later stages they get access only through openings in the bark which may be caused by insects, fire, frost and other external agents. The main difficulty with such kind of diseases or infections is that it is very difficult to locate them.

In cases of bark and wood infection by parasites, it has been observed that disease usually progresses with passage of time and eventually tree gets killed.

There are examples of parasitic infections in which the parasite remains inactive for months or even years and even no signs of presence of parasite are visible, example

blister rust on white pine. However, when the parasite gets suitable conditions, it starts developing fruiting bodies on the surface of the plant and these reveals the presence of a parasite in the plant. Many of such parasites have capability of destroying both young and old timber; therefore, have far-reaching importance in determining the character of forest communities and the composition of stands. Normally bark of a tree is a protective layer from infections but when due to some or other reasons it gets injured and exposes sapwood or heartwood then infection may take place. Such infection gradually destroys the wood and the tree becomes hollow. Such wood becomes worthless.

The parasitic species which attack sapwood spread their mycelia in all directions soon after infection and cause large areas of dead tissue to appear on the surface of a tree. In such cases, the presence of wood-rotting fungi is revealed only after the damage has been taken place and infection is recognized by presence of fruiting bodies on the surface of stump or along the bole of a standing tree.

b) Commensalism is a relationship in which one organism is benefitted by the association whereas other is remains unaffected (neither benefitted nor harmed). It occurs when one organism takes benefits by interacting with another organism by which the host organism is not affected. Examples of commensalism are 'nurse plants' which are large plants that offer protection to seedlings from the weather and herbivores, thus, giving them opportunity to grow.

c) Mutualism is an interaction between two or more species, where both the species in relation derive some or other benefit from one another but the condition is that the species are not closely associated. An example of this is **Mycorrhizae in which** the roots of trees are intimately associated with fungal hyphae. It has been observed that there is an interchange of nutritive materials between the root and the fungus and fungus also helps in better absorption of water and nutrients from the soil. Association of fungus with roots may superficial which form a sheet around the roots and root tips. This kind is called as **ectotrophic mycorrhizae.** Whereas in another kind of association fungus lives in the root cortex are known as **endotrophic mycorrhizae.** Mycorrhizae aid trees in obtaining nitrogen from humus which contains little or no nitrates.

d) Symbiosis is also similar to mutualism in that both the species derive benefits from each other but the difference is that both are closely associated with each other and both species involved in the interaction may be obligate which means that they cannot survive

in the short or long term without the other species. Example is the relationship which exists between the bacteria in the nitrogen tubercles on leguminous plants. Another example are **Epiphytes** that remain attached to areal parts such as stem or branches. Here the epiphytes get mechanical support from the trees and thus to get access to light in turn they are capable of absorbing atmospheric humidity and provide the same to plants and thus help in overcoming injury from drought.

Lianas (climbing woody vines) are associated with other plants in that they depend upon them for mechanical support. Their presence in a forest gives it characteristic physiognomy. They exhibit diverse adaptations to facilitate mechanical support on other species. Certain species root climbers whereas others are twiners. A large variety of other lianas climb by means tendrils.

e) Predation

Predation is a biological interaction in which one organism feeds on other organisms, the former is called predator and later as prey (the organism that is attacked upon). The act of predation often results in the death of prey. Predator often consumes whole tissues of prey after its death. An example of this is carnivore which involves large animals such as a lion or a tiger, hunting smaller animals like rabbits or deer, etc.

f) Saprophytes obtain their carbon nutrients from the dead parts of other organisms. Some saprophytes appear to live on the dead tissues of particular species, hence are associated with those species. Most saprophytes, however, are associated with a great variety of species, often of widely different genera, for example, most of the fleshy fungi so characteristic of forest communities.

4.4 Effects of Wild Animals

The interrelationships between forest plants and animals are many and variable. All degrees of bondage or interdependence exist which may be either beneficial or even mutual need of both. They usually remain interdependent which is evident from the fact that certain kinds of animals are only found in defined forests. One can observe that the localities rich in insect life sustain the kind of vegetation which have attractive flowers.

Although there are many advantages of wildlife in forestry operations, yet many animals are disadvantageous also particularly when population of such animals is high. Such wildlife also affect the character of forest communities as some has positive and others

have negative impacts on plant communities. Many rodents which are beneficial in distribution of seed yet have also harmful impacts as they also eat seed or they cause injury or even destroy young plants. Whereas there are some mammals or many insects which are usually destructive. They feed upon foliage or fruit. Some of the wild animals and their impacts on forest vegetation are described in detail in the following paragraphs.

Deer and Elk cause the same injuries to forest vegetation as caused by domestic animals. They cause damage to seedlings and sapling through browsing and thus influence the forest composition.

Beaver (Rodent) engaged in various developmental activities in and around the forest stand can often change the physiographic characteristics of the site. Soil moisture conditions can get changed by erecting dams at the outlets of lakes and along streams. Composition of stands is changed as they do selective felling of trees for the purpose of fuel or fodder or timber. Beaver may fell or girdle all trees of the preferred species adjacent to their ponds.

Rabbits cause damage to seedlings and small trees by cutting off or chewing of buds, small branches or stems which frequently results in the death of trees. They usually prefer the growing shoots of seedlings. Rabbit damage to trees is more serious in regions where heavy snowfalls cover up other readily available sources of food (Baker, Korstian, and Fetherolf, 1921).

Squirrels eat the seeds and fruits and cut off young twigs and buds of many tree species (Hosley, 1928; Hatt, 1929). They may destroy almost all the seed produced by a species. However, sometimes squirrels and other small rodents bury, in the litter and soil, tree seed which later germinates and contributes additional reproduction (Korstian and Baker, 1922). Squirrels are also known to distribute the seed of oak, hickory, chestnut and also of some confer.

Porcupines cause the most serious damage by gnawing of bark of live trees. They often partially or completely girdle the main stems which results into weakening of trees, bushy topped shape or spike topped (Gabrielson and Horn, 1930; Taylor, 1935). Injury can be seen on any part of the bole as porcupine can climb a tree. Porcupines if present in abundance may completely consume the seedlings or may ruin the larger trees by causing serious injury enough to lead to their death.

Mice feed on the seeds of many forest species. Mice even gnaw the bark of seedling and young trees during the winter when there is scarcity of food. Sometimes population of mice may increase to such extent that it may cause serious damage to most of the trees on an area (Hatt, 1930). Preferential eating and thus girding for certain tree species by mice results into change of the forest composition particularly of mixed stands. The damage by mice can be minimized by maintaining the proper balance of predator animals inside the forest such as hawks, owls, snakes and carnivorous mammals. However, sometimes mice are also beneficial to a forest as they feed on pupae of harmful fly and thus, prevent epidemic (Graham, 1928).

Birds are beneficial as well as harmful to forest stand, however, they have more beneficial influences. They are important agents in the natural dissemination of seeds having fleshy fruits. Birds also feed on insects and pests and thus reduce the damage caused by them (Adams, 1923; McAtee, 1926). Some birds also eat the seeds of species. In general. birds because of their recreational and aesthetic values and generally beneficial influence, should be protected and encouraged to increase in forests.

An **insect** helps in pollination of many tree species. However, many species of insects are very much harmful to forest stands as they feed on seed, buds, foliage and some even on sap from the leaves. Their relation with trees results in the formation of abnormalities such as galls and other deformities, whereas others bore into bark, wood or pith of the shoots or roots and thus, may cause the death of trees or render the wood of little economic value. Accumulation of dead logs or trees inside the forest constitutes the flaming material and hence increases the fire hazards. Further, fungi infestation is easy inside the tree which have already worded upon by insects as they gain easy access through openings made by the insects.

4.5 Domestic Grazing Animals

The grazing of domestic animals on forested areas is of common occurrence everywhere in the world. Overgrazing results in its impact on natural reproduction and growth seedlings and saplings. Overgrazing causes more damage to broadleaved forests than coniferous ones as they like broadleaved species thus, results in favorable growth and development of coniferous species particularly in mixed stands. In general, over grazing has an effect on soil, moisture and reproduction. The soil is rendered compact and more or less

impermeable to air and water, thus, making it more difficult for reproduction to initiate and get established. The destruction of herbaceous vegetation on the forest floor through grazing, particularly on slopes, increases erosion. Grazing results in killing of many seedlings whereas other get trampled or otherwise injured. Seeds are eaten and young plants rooted up and destroyed by hogs or swine. The grazing of hogs in longleaf pine forests almost completely eliminates natural reproduction of that species in parts of the South (Chapman, 1926; Wahlenberg, 1946). Grazing animals even cause damage to young plants (when their crown gets elevated enough beyond their reach) by gnawing or peeling of bark, thus, killing or severely injuring it. However, in most cases, when the trees once elevate their crowns above the reach of domestic animals, they are free from further direct injury. The fire hazards are considerably reduced in overgrazed areas thus, greatly reduces the fire hazard.

4.6 Interference by humans

Humans are the most powerful and harmful agent leading to deforestation or tending to disturb natural conditions in forests. Many of the human needs are fulfilled from forests and this is why they cause damage to forests. They derive from forests timber, wild-edibles, fuel, fodder, medicinal plants and many more products, and these are the reasons which have profoundly resulted into modification of forest vegetation. Man has been engaged in clearing of forested land for agriculture, unregulated cutting of timber in lumbering operations, grazing of livestock on forest areas, burning of forest and range lands, depletion of game and predatory animals allowing an unnatural increase in the rodent population, drainage, elimination of native plants, and introduction of plants and animals. Thus, man has altered the condition of natural forests and has significantly affected the forests by conversion for agriculture expansion, cutting for lumbering industry, introduction of exotic plants and animals species, introduction of insect-pests and human-made forest fires and losses to vegetation and wild animals.

Check Your Progress 3

1. Define biotic factors.
2. Differentiate between intraspecific and interspecific interactions.
3. What is competition? Discuss in brief.
4. Write a note on interrelationship among placts.
5. Differentiate between commensalism and symbiosis.
6. Discuss the impacts of domestic and wild animals on growth and development of plants.

Summary

Among **biotic factors** are included various kinds of organism in the surrounding which includes vegetation, animals, microbes, insects and human. It affects through competition, interrelationship and association (negative and positive). Wild animals and domestic animals directly affect the vegetation as they may eat or trample the growing vegetation/ seedling.

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Unit 5: Tree and Forests

Unit Structure

5.0 Learning Objectives
5.1 Introduction
5.2 The Trees
5.3 Morphological characteristics of trees
5.4 The Forests and Forest types
Summary

5.0 Learning Objectives

After completing this unit, you will be able to:

- Define and differentiate tree and forest
- Discuss about the morphological characteristics of trees
- Differentiate the herb, shrub and tree
- Elaborate about the forest and forest types

5.1 Introduction

Recall your knowledge, from previous units in which got the understanding of basics of forest and forestry and various kinds of factors of locality which directly or indirectly influence the kind of vegetation through their influences on growth and development processes. We also discussed silviculture that can be distinguished in two distinct parts - growth and reproduction, and harvesting.

The objective of silviculture is to get maximum return in shortest time particularly of merchantable part of tree (i.e., bole). Therefore, in order to attain this objective, it is important to have understanding of the growth and development processes of the forest and how to bring about change in the forest structure, shape and composition. This is possible only when a forester or silviculturist has sound and clear understanding of processes relating to tree growth and development i.e., height growth and diameter growth as well as reproductions.

5.2 The Trees

Recall the lessons you learnt in the earlier classes regarding five kingdom classifications given by Whittaker (1969). According to this system, the whole living world has been divided into five major categories, viz. **Monera, Protista, Fungi, Animalia** and **Plantae**. Plantae is the category which includes **Algae, Bryophytes, Pteridophytes, Gymnosperms** and **Angiosperms**.

When one observes plants and their structure, they can easily divided into three types- herbs, shrubs and trees although sometimes another category of plants is also identified i.e., climbers (which may be herbaceous as well as wood kind).

Generally, the herbs are those plants which have delicate stems and their shoot portion usually die at the end of season or year although the underground portion may remain live for two years or more. The Shrubs are those plants that may grow up to six (6) meters in height but have many branches arising from the base. Further, they also have woody elements in them. The Trees are the large perineal plants with a well-defined wood stem and a well-defined crown.

In silviculture, we are generally concerned with the germination, growth, development, harvesting and reproduction of tree species which belong to Gymnosperms and Angiosperms only. Therefore, a general account of these two major sub-categories is discussed herewith.

A) Gymnosperms: The word Gymnosperms has its name derived from two latin words- 'gymnos' means naked and 'sperma' means seed. The seeds of Gymnosperms remain exposed before as well as after fertilization as the ovary wall around the ovule is lacking. This is the reason gymnosperms as also known as 'naked seeded plants'. The species belonging to Gymnosperms vary in size ranging from creeping one to the tallest trees of the world.The various examples of gymnosperms are Deodar (*Cedrus deodara*), Chirpine (*Pinus roxburghii*), Thuner (*Taxus buccata*) and the giant redwood tree species (*Sequoia gigantean*).

The roots of Gymnosperms are mainly tap roots. Roots of some of the plants have association with fungal species and forms what is known as mycorrhiza for example in *Pinus* sp. Whereas in some other cases specialized roots are found which are known as coralloid roots which also harbor to N2 fixing Cyanobacteria for example *Cycas* sp,.

The stems in Gymnosperms are mostly branched, however, in some cases it remains unbranched example *Cycas* sp. The leaves may be simple or compound which are well-adapted to withstand extreme climatic conditions such as temperature, humidity and wind. The needle shaped leaves are specifically adapted for reducing moisture loss from the leaf surface. Additionally, presence of thick cuticle layer and sunken stomata also help in minimizing water loss.

As far as reproduction is concerned, the gymnosperms are hetero-sporous i.e., two kinds of haploid spores are produced. These are known as microspores and megaspores. The organs which produce these spores are known as sporangia. Sporangia are located on sporophylls and sporophylls are arranged spirally along an axis to form a compact strobili or cones. Those strobili which bear microsporophylls and microsporangia are called microsporangiate or male strobili whereas the strobili or cones which bear megasporophylls and megasporangia are known as macrosporangiate or female strobili. The production microspores and its further development into male gametophyte (pollen grain) takes place in microsporangia. The male or female cones or strobili may be borne on the same tree (*Pinus sp.*) or in different individuals (*Cycas sp.*). On the other hand a female gametophyte is produced in megasporangia as a result of meiotic division of megaspore mother cell which is differentiated from one of the cells of nucleolus. The nucleus remains protected inside envelope and the composite structure what is known as ovule. One of the four daughter cells produced after meiotic division, develops into female gametophyte. The multicellular female gametophytes also retained within megasporangium. Unlike bryophytes and pteridophytes, in gymnosperms the male and the female gametophytes do not have an independent free-living existence. They remain within the sporangia retained on the sporophylls. The pollen grain is released from the microsporangium and carried through wind before coming in contact with the opening of the ovules borne on megasporophylls. The pollen tube carrying the male gametes grows towards archegonia in the ovules and discharges their contents near the mouth of the archegonia. Following fertilization, zygote develops into an embryo and the ovules into seeds which are always naked.

B) Angiosperms: Angiosperms are also known as flowering plants. The flowers are reproductive structures in which ovules are present inside the ovary which after fertilization develops into fruits. Thus, seed are always remain protected in contrast to gymnosperms where seeds are naked. Angiosperms are divided into two main categories- Di-cotyledons and monocotyledons based on the number of cotyledons present in the seed.

Difference between dicots and monocots

Dicots	Monocots
The leaves are net veined	Leaves are parallel veined
Vascular bundles are arranged systematically	Vascular bundle scattered
cambium tissue is present so secondary growth occurs	Cambium absent therefore, secondary growth is absent
Floral parts are present in four, five or multiples of these	Floral parts are multiples of three of three
seed contains two cotyledons	Seed contains single cotyledon
Life forms are herbs, shrubs and trees	Mainly herbs and grasses
Examples *Ranunculaceae, Leguminosae, Asteraceae, Apiaceae*	Examples: *Graminaceae, Liliaceae, , Palmaceae, Orchidaceae*

The Di-cotyledons are highly diverse category and there are about 200000 species so far recorded. All the broadleaved trees belong to Di-cotyledons. There are mainly three life forms found in nature- trees, shrubs and herbs.

5.3 Morphological characteristics of trees

A typical tree has some parts below the ground and some parts above the ground. The below ground part is root whereas above ground parts include stem and crown. These parts are discussed in the following para in brief:

A) The Crown and branches: The tree crown refers to the topmost aboveground part of a tree which includes stem and its branches along with leaves and reproductive structures. The shape and size of the crown vary greatly with species and growth conditions. Dicotyledonous trees and conifers develop a branch system carrying the foliage; however, the crown form is much influenced by environment. The typical outline of crown is an elongated cone becoming broader and more rounded with increasing size or age. The final shape may range from cylindrical or conical in conifers to more or less oblong (in majority of the trees) and spherical forms to umbrella shaped in *Acacia planifrons.*

Branching pattern and habit is a species specific character and there are found a great variation in branching. In the majority of the trees, it appears completely unsystematic on account of the development only few buds out of many. In trees with opposite leaves such as teak and adina, the branches also tend to develop in opposite pairs, but one of the pair usually gets ahead so that the feature is only noticeable in the ultimate twigs (Champion, 1948).

The angle of branches with main stem or axis also has variations from species to species. In most trees, the angles fall between 60° to 70°, however, in some species much steeper angle of 20° or 30° has also been found. Examples are *Populus nigra*, *Cupressus sp.* and *Acacia arabica*. At the same time, there are species having branches at right angle to the main axis or placed parallel to the ground whereas in some others the angle becomes narrower and braches grown in downward direction. This is characteristic feature of conifers growing in higher elevations where snowfall is a frequent phenomenon and as a result develop drooping habit.

As far as degree of branching from the main branch is concerned, again a lot variation is found from species to species. Trees exposed to severe wind generally have a dense twiggy crown and the internodes are shorter than usual.

The most important variation in tree foliage is its deciduous or evergreen habit. The deciduous tree is leafless every year for a period which varies from a week or ten days in the case of *Shorea robusta* to over six months in Hymenodictyon. The period also varies considerably for any given species according to the climate and conditions in which it grows. Thus teak and toon are practically evergreen in favorable moist and warm localities. The old foliage do not fall until new buds unfold. A very exceptional example is of sandal wood (*Santalum album*). It is an obligatory root parasite. It can be evergreen as well as deciduous depending upon the deciduous or evergreen habit of host tree.

The old leaves of evergreens remain persistent till new foliage become well developed. In general, the life of evergreen leaves is considerably longer, commonly 2 or 3 years, and even up to 7 years or more for conifers at high elevations. Evergreen leaves are usually thicker and stronger than deciduous leaves and cast a heavier shade however, this is not always true. In dry evergreen forest many deciduous trees cast a very heavy shade during the period they are in leaf.

Shedding of smaller twigs is also regular phenomenon in some species like Cryptomeria, oaks, Emblica, and all pine species whereas there are other species in which it happens only occasionally e.g. *Bombax*.

Leaf texture is also of diverse type. By leaf texture is meant the shape and size of leaves. The leaves which are large, thick and coriaceous do not decompose easily and form a thick layer on the forest floor. Sometimes such thick leave cover is hazardous particularly for being fire prone. Further regeneration is also negatively affected. Sal leaves and pine needles are examples of this kind. There are other kind of leaves also which are thin and fragile, and decompose easily. Such leaves are beneficial from silvicultural view point as increase fertility of the soil. Further, large leaves like those of teak and Dipterocarps or even of sal retain larger amount of water during rain and cause large drops to fall on the ground floor, and thus, is liable to be harmful to regeneration as it splashes mud over the seedlings. This drip action often results in the death of the seedling.

The Stem: The morphology of stem is influenced by the type of crown it carries. The lower branchless portion of the stem is known as bole.

Some trees have an inherent tendency to form a tall erect straight bole with relatively more or less free of branches, e.g. most conifers, *Dipterocarpus* sp, *Eucalyptus*, *Bombax* and *Michelia champaca*. Teak seedlings are branchless till three years. Many other trees species also show this tendency but for shorter time period.

Many species develop forked stems in response to external repeated injuries caused by lightening, hail storms or defoliation by humans etc. particularly during initial stages of growth. It is most commonly a response to external agencies or factors and can be found in individuals of many species, like deodar, chirpine, oaks etc.

Development of a clean bole is of great advantages in forestry as it is on this that quality of timber depends. In most species, however, side branches are formed and persist for varying periods, but their growth tends to cease as they are shaded by the rest of the crown above them. In some other species, it has been observed that during the period of bole formation no side branches of any size are developed and the small ones formed soon die and drop usually by or other external forces. Another important thing regarding clean bole is **Epicormics branches.** Epicormics branches are those

branches which have their origin from dormant buds on shoots that have elongated in a previous period of growth. Development of such branches can reduce the quality of timber and thereby market value of the tree particularly when they develop on boles of potentially high-value trees.

Buttressed stems and fluted stem is another morphological feature which profoundly influences the quality of wood. Buttress is simply the excessive swelling at the stem bases. This is particularly found in many trees of the wet tropical forest and also in some of dry tropical regions. The buttress may sometimes extend as long as 15 feet or more up in some species. Fluted stem is irregular involutions and swellings above the stem base. It is also regarded as a serious defect in timber that affects the quality for timber.

Diameter, height and volume of trees vary from species to species. Even for a single species it varies from initial growth phases to later phases of growth. Initially there is found mainly height growth and it is when the height growth ceases, then diameter and volume increment takes place. The maximum diameter, heights and volume has been recorded from different species are as follows:

Maximum recorded girth of trees from various localities

Species	CBH	Locality
Terminalia myriocarpa	46'	Assam (Lakhimpur)
Platanus orientalis	41'	Kashmir (Srinagar)
Cedrus deodara	38'9"	Jammu (Muhu Mangat)
Dipterocarpus turbinaius	28'	Burma (Thaungyin)
Tectona grandis	26'7"	Burma (Pahok)
Shorea robusta	25'8"	Uttarakhand (Ramnagar)
Picea morinda	24'8"	Jammu (Ramban)
Quercus semecarpifolia	22'8"	Jammu (Ramban)
		Source:HG Champion 1948

B) Root system

The Root: The roots are that portion of the plant which develops inside the soil and grows away from the light. Unlike stem it does not produce the leaves, flowers and 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 and maintaining their supply to above ground portion of tree which includes stems and crown. Roots are comprised of two kinds, viz., tap root and adventitious roots.

(i)Tap roots: The tap root is primarily descending roots formed by direct prolongation of the radicle arising from embryo. It is conical in shape, develops towards permanent moisture in the soil and sometimes, attains considerable length. According to

Champion (1948), it sometimes penetrates to great depths up to 100 ftin *Prosopis spicigera* and *Acacia arabica,* and as deep as 30-47 ft. in 10 years. In *Dalbergia sissoo* (Shisham) (HG Champion 1948). The tap-root of have been reported to extend downward. As the tap root grows, it develops horizontal branches and sub-branches forming rootlets, are known as lateral roots. The ends of the rootlets are covered with fine hairs, called as 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 horizontal roots on the other in *Dalbergia sissoo* (Shisham) are known to spread in a radius of 8 to 12 ft. However, in some trees, they are generally confined to the area covered by the crown, but for others they extend much further and so extensively overlap the roots of the surrounding trees. Trees growing along the edges spread their roots a long way out into it, 100 ft. or more especially in worked soil. This is one reason why trees in isolation for long time are much more wind hardy in comparison to those which are recently isolated due to felling of tree around them. On the basis of 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.

(ii) Adventitious roots: Adventitious roots are the roots produced from parts of the plants other than the radicle or its subdivisions. Following kinds of adventitious roots are commonly found in trees:

i) Prop roots: Those adventitious roots which remain suspended in the air till they reach the ground. On reaching the ground, they enter into it and get fixed in the soil and support the thick branches of the tree, e.g. *Ficus benghalensis*.

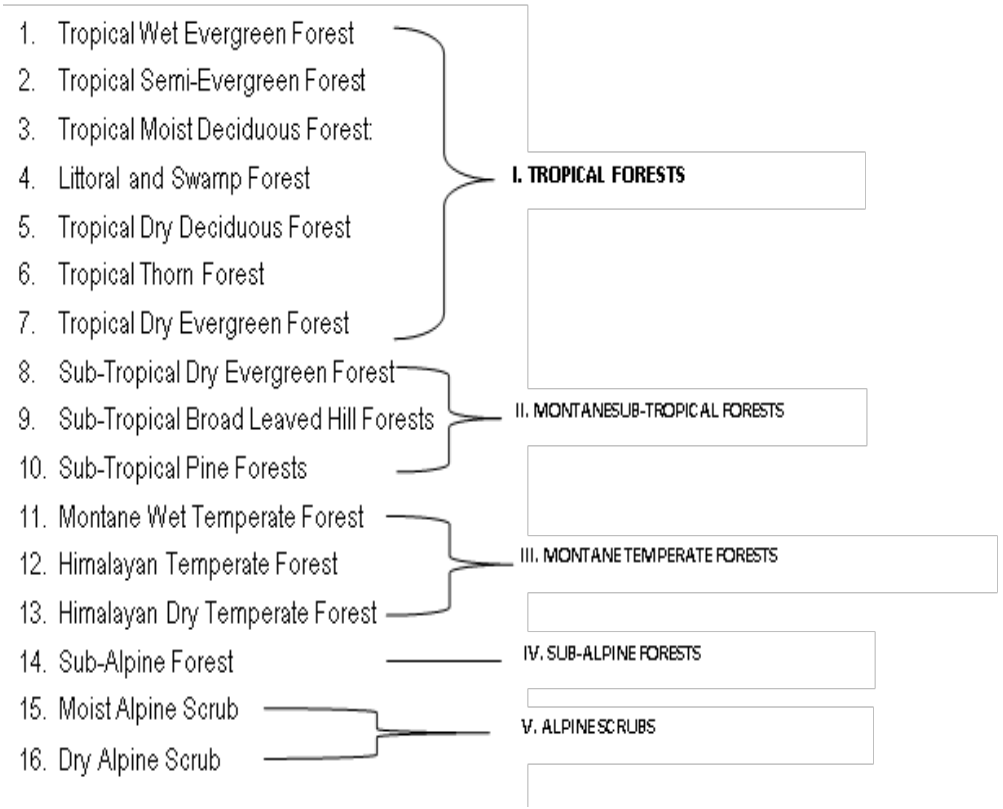
ii) Stilt roots: The adventitious roots which emerge from the butt of a tree above ground level, so that the tree appears as if supported on flying buttresses, e.g. *Pandnus* (Kewra)

iii) Pneumatophores: This kind of adventitious roots are knee shaped and spike like projection of the roots of swamp tree, enabling the submerged roots to obtain oxygen, e.g. *Rhizophora sp. Heretiera*, *Bruguiera*.

iv) Parasitic roots: These are the specialized adventitious roots meant for absorbing nutrition and water from the host plant e.g. *Santalum album* (Chandan).

5.4 The Forests and Forest types

In simplest meaning, Forest is an assemblage of trees maintained mainly for production of timber and other forest produce, or sometimes maintained for deriving certain other indirect benefits such as climatic regulation or land/ soil protection. However, forests and their composition is not static but it varies from place to place depending upon climatic and edaphic condition prevailing there. Therefore, forests are differentiated into various sub categories based on its composition. Such categories are known as forest types which may be defined based on their composition, geographical location, climatic conditions and edaphic features. The forests are classified because they vary from place to place and one single set of management practices can or cannot be applied in other kinds. The classification of Indian Forest types was given by Champion and Seth in 1968. In this classification, the forests of India have been divided into five major groups and are further subdivided into sixteen (16) type groups (Forest Types) based on climatic and vegetation. These are presented in the following figure:



1. **Tropical Wet Evergreen Forest:** Mainly found in Western Ghats along with its western face and south west (SW) of upper Assam through Cachar, and in Andaman's. These are very lofty, multi-strata, very dense and mesophytic evergreen forests. The height of trees is usually more than 45 meters. Such forests are very diverse with numerous epiphytic species but with few climbers. The important species of these forests are Mesua, white Cedar, Calophyllum, Toon, Dhup, Palaquium, Hopea, Jamun, Canes, Gurjan, Chaplash, Jamun, Mesua, Agar, Bamboo, etc.
2. **Tropical Semi-Evergreen Forest:** These forests are found in the Western Coast, Assam, lower slopes of the Eastern Himalayas, Orissa and in Andaman's. These are also the forests with high density and closed canopy but less than the Tropical Wet Evergreen Forests. They may have species which are evergreen also includes deciduous. These forests are also rich in diversity with heavy climbers, bamboos less prevalent and epiphytes are also in abundance. Important species include Aini, Semul, Gutel, Mundani, Hopea, Denteak, Kadam, Trul, Laurel, Rosewood, Mesua, Haldu, Kanju, Bijasal, Kusum, Thorny Bamboo, Bonsul, White Cedar, Indian Chestnut, Lilsea, Holloch, Champa and Mango etc.
3. **Tropical Moist Deciduous Forest**: These forests are distributed throughout Andaman's, moist parts of U.P., M.P., Gujarat, Maharashtra, Karnataka and Kerala. These are the forests with Irregular top storey and predominantly composed of deciduous species. Trees can attain a height of 40 m. or more. Trees are heavily buttressed. Trees in the lower canopy or second storey with some evergreens. Undergrowth includes shrubs, bamboos and heavy climbers. The important species include Padauk, White Chikrasi, Kokko, Kadam, Dhup, Teak, Laurel, Haldu, Rosewood, Mahua, Bijasal, Lendi, Semul, Dhaman, Garari, Amla, Kusum, Common bamboo, Sal, Lendi, Haldu, Pula, Litsea, Jamun, Mahul, etc.
4. **Littoral and Swamp Forest:** Mainly evergreen species of varying density and height, always associated with wetness. Littoral forests are found along the coast and swamp forests in the deltas of bigger rivers. For example Sundarbans in West Bengal. Important species to this type are Sundri, Bruguiera, Sonneratia, Agar, Bhendi, Keora, Nipa, etc.
5. **Tropical Dry Deciduous Forest**: The species belonging to this category are mainly deciduous. The upper canopy remains more or less closed. Species reaches to a

height of 20 m. Shrubs and herbs are present in the ground as enough light reaches the forest floor. Bamboos, climbers and epiphytes are also present. The forests are found from the foot of the Himalayas to Cape Comorin except in Rajasthan, Western Ghats and Bengal (Sangreia 1967). Some of the important species include Teak, Axlewood, Tendu, Bijasal, Khair Rosewood, Amaltas, Palas, Haldu, Kasi, Bel, Lendi, Common bamboo, Red Sanders, Anjan etc.

6. **Tropical Thorn Forest:** These are the forest found in xerophytic conditions. Such forests are mainly dominated by thorny leguminous species. Trees are of short boles and low branches, low storey has smaller trees and shrubs with spiny and xerophytic characteristics. Climbers are very few. These are found in a large strip in South Punjab, Rajasthan, Upper Gangetic Plains, the Deccan plateau and the lower peninsular India.Important species include Khair, Axlewood, Neem, Sandalwood, Dhaman, Acacia senegal, Kanju, Palas, Aak, etc.
7. **Tropical Dry Evergreen Forest:** Forests attain a canopy of upto 12 m. high with complete canopy, mostly of coriaceous leaved evergreen trees of short boles, no canopy layer differentiation, bamboos rare or absent, grass not conspicuous. Restricted to a small area of Karnataka Coast which receives some summer rain also. Important species found in these forest types are Khirni, Iamun, Kokko, Ritha, Tamarind, Neem, Machkund, Toddy Palm, Gamari, Canes etc.
8. **Sub-Tropical Broad-Leaved Hill Forest:** These forests are distributed in the lower slopes of Himalayas in Bengal and Assam and other hill ranges such as Khasi, Nilgiri and Mahableshwar. It includes luxuriant forest evergreen species such as Jamun, Machilus, Meliosma, Elaeocarpus, Celtis etc.
9. **Sub-Tropical Pine Forest:** These are pure forests of Chir pine. Usually fire frequencies are higher and few shrubs. Distributed throughout the whole length of North-west Himalayas between 1000-1800 m in Uttarakhand and Himanchal Pradesh. Not found in Kashmir probably due to weak SW monsoon. Important species are Chir, Jamun, Oak, and Rhododendron.
10. **Sub-tropical Dry Evergreen Forest:** These are the forest which includes small stunted evergreen trees along with thorny shrubs. Herbs and grasses also appear seasonally particularly during monsoon. These are found in the Bhabar, the Siwaliks

and the western Himalayas upto about 1000 m. important species include Olive, Acacia, Pisfacia, etc.

11. **Montane Wet Temperate Forest:** This forest type is found in the higher hills of Madras and Kerala from 150 m upward and in Eastern Himalayas on the higher hills of Bengal, Assam and NEFA from 1800 to 3000 m. Trees are mostly evergreen types, mostly short-boled and branchy attaining large girth, height rarely 6 m., crowns dense and rounded leaves. Important species include Machilus, Cinnamomum, Litsea, Magnolia, Indian Chestnut, Birch, Plum etc.
12. **Himalayan Moist Temperate Forest:** This includes pure coniferous forest. Trees attain a height from 30 to 50 m. Underwood mostly evergreen. Mosses and fern grow freely on trees. Extends along the entire length of the Himalayas between the pine and the sub-alpine forests in Kashmir, Himachal Pradesh, Punjab, U.P., Darjeeling and Sikkim between 1,500 and 3,300m. Important species include Oak, Fir, Spruce, Deodar, Celtis, Chestnut, Maple, Kail, Yew, Maple, Birch, etc
13. **Himalayan Dry Temperate Forest:** Predominantly coniferous forest with xerophytic shrubs, hardly any epiphytes and climbers. Found in the inner ranges of the Himalayas where SW monsoon is very feeble, precipitation below 100 mm. mostly snowfall occurs. These are distributed in Ladakh, Lahoul, Spiti, Chamba, Bashahr, Garhwal and Sikkim. Important species are Chilgoza pine, Deodar, Oak, Maple, Celtis, Parrotia, Olive, etc.
14. **Sub-Alpine Forest:** Dense growth of small crooked trees or large shrubs with coniferous over wood, mostly fir and birch. Conifers 30 m. high, broad-leaved trees 10 m. high. Occurs at the upper limit of tree forest in the Himalayas adjoining alpine scrub and grasslands. Himachal Pradesh. Important species are Fir, Kail, Spruce, Rhododendron, Plum, Yew, etc,
15. **Moist Alpine Scrub:** Low evergreen dense growth of Rhododendron and Birch. Mosses and ferns on the ground with alpine shrubs and flowering herbs. Occurs along the entire length of the Himalayas above 3000m. Distributed in Kumaun (Uttarakhand) upto 3,800m. Important species include Birch, Rhododendron, Berberis, Gardchuk, Uttis, Abies, Juniperous etc.

16. **Dry Alpine Scrub:** The uppermost limit of scrub xerophytic, dwarf shrubs, over about 3,500 meters. Found in High Himalayas over 4,000 m where rainfall is low. Important species are Juniper, Honeysuckle, Artemesia, Potentilla, Rhododendron etc

The most abundant types are Tropical Dry Deciduous (29.15%) and Tropical Moist Deciduous forests (23.3%), occupying over 70% of the country's forest area, followed by the Tropical Thorn forest (6.9%), Tropical Wet Evergreen (6%) and Sub-tropical Pine forest (5%)(Sangria 1967).

Check Your Progress 1

1. Differentiate the tree, shrub and herbs.
2. Differentiate between Gymnosperms and angiosperms.
3. Differentiate monocots and dicots.
4. Write an extended note on forest types of India.

Summary

The summary of this unit is as follows:

- Plants are divided into three types- herbs, shrubs and trees although sometimes another category of plants is also identified i.e., climbers (which may be herbaceous as well as wood kind). Herbs are those plants which have delicate stems and their shoot portion usually die at the end of season or year although the underground portion may remain live for two years or more. Shrubs are those plants that may grow up to six (6) meters in height but have many branches arising from the base. Futher, they also have woody elements in them. The trees are the large perineal plants with a well-defined wood stem and a well-defined crown.
- In silviculture, we are generally concerned with the germination, growth, development, harvesting and reproduction of tree species which belong to Gymnosperms and Angiosperms only. Therefore, a general account of these two major sub-categories is discussed herewith.
- Trees are only found in Gymnosperms and angiosperms. Gymnosperms are naked seeded plants some of the examples are Deodar (*Cedrus deodara*), Chirpine (*Pinus roxburghii*), Thuner (*Taxus buccata*) and the giant redwood tree species (*Sequoia* gigantean). Whereas a**ngiosperms** are the other category where trees are found. They are also known as flowering plants. Here the flowers are reproductive structures

in which ovules are present inside the ovary which after fertilization develops into fruits. Thus, seed are always remaining protected in contrast to gymnosperms where seeds are naked.

- A typical tree has two main parts - underground part (roots) and above ground parts (stem and crown). Roots perform activities like support and anchoring the tree, absorption of water and nutrients from the soil and their transport it to above ground portion of tree i.e., stems. Roots are of mainly two kinds- **Tap root and adventitious roots**
- **Tap roots** have their origin from radicle and has a main conical root in which rootlets and sub-branches arise. The branches and branch-lets have root hairs which are engaged in absorption of water and minerals.
- **Adventitious roots** do not have their origin from radicle but originate from node and internode of stems or branches. Prop roots in *Ficus* sp, stilt roots in Pandnus (Kewra), pneumatophores in *Rhizophora sp. a*nd parasitic roots found in Chandan are examples of adventitious roots.
- Forest is an assemblage of trees maintained mainly for production of timber and other forest produce, or sometimes maintained for deriving certain other indirect benefits such as climatic regulation or land/ soil protection
- The classification of Indian Forest types was given by Champion and Seth in 1968. According to the classification, there are sixteen (16) forest types which are as follows- Tropical Wet Evergreen Forest, Tropical Semi-Evergreen Forest, Tropical Moist Deciduous Forest, Littoral and Swamp Forest, Tropical Dry Deciduous Forest, Tropical Thorn Forest, Tropical Dry Evergreen Forest, Sub-Tropical Dry Evergreen Forest, Sub-Tropical Broad Leaved Hill Forests, Sub-Tropical Pine Forests, Montane Wet Temperate Forest, Himalayan Temperate Forest, Himalayan Dry Temperate Forest, Sub-Alpine Forest, Moist Alpine Scrub and Dry Alpine Scrub.

Unit 6: Germination, Growth and Development

Unit Structure

6.0 Learning Objectives
6.1 Introduction
6.2 Seed Germination
- **6.2.1 Phase of seed germination**
- **6.2.2 Seedling Emergence**
- **6.2.3 Storage Reserve Utilization**
- **6.2.4 Measures of Germination**
- **6.2.5 Environmental Factors Influencing Germination**

6.3 Growth and development in trees
- **6.3.1 Growth and Development**
- **6.3.2 Stage of tree growth**
- **6.3.3 Growth and Assimilation**
- **6.3.4 Flowering, Fruiting and Seeding**

Summary

6.0 Learning Objectives

After completing this unit, you will be able to:

- Explain germination and germination processes
- Illustrate growth and development processes
- Elaborate about the flowering, fruiting and seeding

6.1 Introduction

In the previous unit we have discussed about the growth and development processes of the forest and how to bring about change in the forest structure, shape and composition. Furthermore we developed the clear understanding of processes relating to tree growth and development. In this unit we will discuss the germination, growth and development of forests and trees, and the various processes involved therein.

6.2 Seed Germination

Seed germination is the beginning of the next generation and is the principal means of reproduction in most of the tree or woody species. It is through this process that transfer of information (i.e, genetic materials) from one generation to the next generation takes place.

The seed germination may be defined as, "the emergence and development from the seed embryo of those essential structures which indicate its ability to produce a normal plant under favorable conditions of temperature, moisture and nutrients".

As explained earlier in 5.2, the seed-producing organisms of the plant kingdom belong to the division Spermatophytes which are further subdivided into two sub-divisions- Gymnospermae (gymnosperms) and Angiospermae (angiosperms). The reproductive structures in these categories of plants begin with initiation of reproductive buds which develop into flower or strobili and finally after fertilization results into **the seeds**. When the favourable conditions come, the seed starts germinating and thus, develops into new seedlings.

6.2.1 Phase of seed germination

A seed is a ripened ovule which consists of an embryo, food storage tissue and a protective covering (Seed coat). There are three conditions which are needed in order to bring about seed germination. These are as follows:

- **viability of seeds** i.e., embryo should be alive and capable of germination
- **appropriate environmental conditions** i.e., availability of water, adequate temperature range, ample oxygen, and sometimes light also
- **Breaking of dormancy** i.e., in some of the seeds embryo remains dormant and in such cases breaking of dormancy occurs only when interaction of the seed with favorable environment happens, whereas in case of adverse environmental conditions, a secondary dormancy may develop which may cause further delay in germination of the seed.

There are normally three phases of seed germination which are explained in the following paragraphs:

Phase I - Initial phase of Germination: Most of the seeds are usually dry and contain less than 10 per cent of moisture and usually covered with a dry and hard seed coat. Therefore, in the initial phase of germination, first of all seed absorbs water for breaking of seed coat and this is followed by a tri-phasic (three-stage) increase in seed fresh weight due to water uptake. Seed germination initiates with **Imbibition** of water (characterized by an initial rapid increase in water uptake).

Phase II - Lag Phase: After imbibition of water starts a period of active metabolic activity and very low water intake. It is a period when seed remains highly active physiologically and metabolically which prepares seed for germination. Following are the cellular activities during the lag phase:

- **Maturation of mitochondria:** Dry seed contains inactive mitochondria which need to be rehydrated in order to make them active enzymatically.
- **Initiation of protein synthesis:** mRNA present in the dry seed can only become active after polysomes are formed as a result of seed hydration which further initiates protein synthesis. This process starts as soon as imbibition completes. Proteins are necessary for cell growth and development during germination.
- **Metabolism of storage reserve: The reserve food available in the seed is broken down** to produce substrates for energy production and to produce amino acids for new protein synthesis. This is the as enzymatic process.
- **Specific enzymes:** Some specific enzymes are produced which include those responsible for cell wall loosening in the embryo or tissues surrounding the embryo.

Phase III - Radicle Protrusion: Initially cell enlargement causes radicle to protrude and soon after this, cell division takes place in the radical tips. Radicle protrusion occurs when:

- the water potential of the cells in the radicle becomes more negative due to metabolism of storage reserves;
- cell walls in the hypocotyl and radicle become more flexible to allow cell expansion; or
- cells in the seed tissues surrounding the radicle weaken to allow cell expansion in the radicle

6.2.2 Seedling Emergence

Seedlings emerge out of the soil as a result of division and elongation of root and shoot meristems. The embryo of higher plants consists of a shoot axis bearing one or more cotyledons and a root axis (radicle). At the seedling stage, the stem has three parts - hypocotyl, cotyledonary node and the epicotyl. **The hypocotyl** is the stem between the cotyledons and the radicle whereas in some seedlings, there is a marked swelling at the hypocotyl-radicle junction which is known as **collet or collar**. **The epicotyl** is the section between the cotyledons and the first true leaves. With the initiation of growth, the fresh and

dry weight of new seedlings increases with the utilization of storage tissues and also increases the **oxygen uptake**. In the course of time, metabolic activities of seed storage decreases however, in some plants where persistent cotyledons participate in photosynthesis process. Roots also increase in size and their surface area also increases which in turn result into higher absorption of water and mineral nutrients. There are mainly two patterns of germination based on whether or not hypocotyl is raised above the ground. The one in which hypocotyl elongates forming a hypocotyl hook and raises the cotyledons above the ground is known as **epigeous germination** whereas in other pattern hypocotyl does not expand, thus, along with cotyledons also remain buried inside the soil. This kind of germination is called **hypogenous germination**. It is the epicotyl which expanses in this case.

6.2.3 Storage Reserve Utilization

Initially, new embryo remains dependent upon the storage reserves in endosperm, perisperm or cotyledons. The major storage reserves are proteins, carbohydrates (starch) and lipids (oils) which are converted to amino acids and sugars readily utilizable by early embryo for its growth and development. The embryo is dependent on the energy and structural materials from stored reserves until the seedling emerges into the light and can begin photosynthesis. Enzymes (proteinases) are required to catabolize storage proteins into amino acids that, in turn, can be used by the developing embryo for new protein synthesis. These enzymes can be present in stored forms in the dry seed, but the majority of proteinases are synthesized as new enzymes following imbibition.

Starch is a major storage material in seeds mainly stored in the endosperm but can also be found in the embryo and cotyledons. The non-living starchy substances in the endosperms are surrounded by a layer of secretary cells called as **aleurone layer**. Gibberellin initiates the synthesis of numerous enzymes in the aleurone that are secreted into the endosperm including **amylases** that hydrolyses starch to sugar (simple sugar and maltose) that are eventually synthesized into sucrose for transport to the embryo axis. Some enzymes break down the cell walls of the endosperm to allow movement of sucrose to the scutellum for transport to the growing axis.

Lipids are stored in specialized structures called **oil bodies** located in the endosperm and cotyledons of seeds. Glyoxysomes and mitochondria are involved in the catabolism of

lipids in the oil bodies. Lipids are mainly stored in the form of triacyl glycerides which are catabolized to glycerol and free fatty acids. Free fatty acids are moved to the **glyoxysome** (the specialized structures present in oil-storing seeds only). Free fatty acids are converted to the organic acids, malate, and succinate using enzymes in the glyoxylate in glyoxysomes through glyoxylate cycle. Glyoxysomes and glyoxylate cycle are unique feature of germinating seeds and are not found in any other part of the plant. The end product this biochemical process is the production of sucrose from storage lipids for use by the developing embryo.

6.2.4 Measures of Germination

Germination is said to have competed when either the radical protrudes through the seed coverings or the seedling emerges from soil or media. In either case, the time needed for individual seed among the seed lot to complete germination usually produces **a sigmoidal germination curve** which is indicative of the way a seed population behaves. There is an initial delay in the start of germination and then a rapid increase in the number of seeds that germinate, followed by a decrease in their appearance over time. It is not necessary that all the seeds of the seed lot germinate; only the viable seeds germinate. There are three different measure through which germination is measured. These are Germination percentage, Germination rate and Germination uniformity.

a) **Germination percentage** is the number of seeds that produce a seedling from a seed population expressed as a percentage. For example, if 75 seeds germinate from a seed lot of 100 seeds, the germination percentage would be 75 percent (75germinated seeds divided by 100 seeds in the seed lot multiplied by 100 to give a percentage).

b) **Germination speed or rate** is a measure of how rapid a seed lot germinates. It is the time required for a seed lot to reach a predetermined germination percentage. For example, the time required for a seed lot to reach50 percent germination based on the final germination percentage. This value is the **T50** and can be seen on the sigmoidal and normal distribution curves. Since this value is calculated as 50 percent germination based on the final germination, it is a more meaningful descriptor for high-germinating seed lots.

c) **Germination uniformity** measures how close in time seeds germinate or seedlings emerge. In some seed lots, the time between the first and last seedling emergencies clustered closely around the mean time to 50 percent emergence, while in others this time is spread out. One way to express germination uniformity is as the standard deviation around the mean. This can be reported as the time to 75 percent germination (T75) minus the time to 25 percent germination (T25).

6.2.5 Environmental Factors Influencing Germination

There are mainly four environmental factors which influence seed germination. These are temperature, water, gases and light. These are explained as follows:

i) **Effects of temperature:** Temperature is a most important environmental factor that regulates the time of germination. Temperature affects both germination percentage and germination speed. There are mainly three temperature points i.e., minimum, optimum, and maximum, are usually designated for seed germination. Optimum temperature is the temperature that produces the largest percentage of seedlings in the shortest period of time. It may vary from 25 and 30°C but can be as low as 15°C. Minimum is the lowest temperature for effective germination, while maximum is the highest temperature at which germination occurs.

   Germination speed is usually slower at low temperatures but increases gradually as temperatures rises. However, above an optimum level, a decline in germination rate occurs as with the increase in temperature chances of injury to seed are increased.

   Dry, non-imbibed seeds can withstand extremes of temperature. In nature, brush fires are often effective in overcoming dormancy without damaging seeds. Seeds show prolonged storage life when stored at low temperatures, even below freezing for dry seeds.

ii) **Moisture:** Water is one of the important factors that are essential to bring about germination. It acts as a limiting factor under favourable temperatures for many non-dormant seeds. The rate of water movement into the seed depends on the water relations between the seed and its germination medium. The water potential of the seed is more negative than moist germination substrates, so water moves into the seed. Osmotic potential in the soil solution depends on the presence of solutes (salts). Excess soluble salts (high salinity) may exert strong negative pressure (ex-osmosis)

and counterbalance the water potential in seeds. Surface evaporation from sub-irrigated beds can result in the accumulation of salts at the soil surface even under conditions in which salinity would not be expected. Planting seeds several inches below the top edge of a sloping seed bed can minimize this problem. Moisture stress strongly reduces seedling emergence rate from a seed bed.

iii) **Light:** It has been revealed through experiments that light is needed for the germination of certain seeds. Many seeds of temperate region need a minimum period of pre-chilling (cold-treatment). Such seeds remain dormant until favorable conditions. The seeds require light for germination; however they may also germinate in dark if pre-chilled at 2^{O}C. These observations suggest that light or pre-chilling treatment have similar action which triggers germination of seeds. It has been observed that light has an action in both dormancy induction and dormancy breaking. The effects of light on germination are dependent upon both the wavelength and photoperiod. The seed size of light sensitive seeds is usually very small and a shallow depth of planting is an important factor favoring survival whereas in case of seed being too deep in the soil, the epicotyl may not penetrate the soil. Some important flower crops requiring light for germination include begonia, coleus and primrose. Germination is also seen to be inhibited by light in certain species like *Phacelia*, *Nigelia*, *Allium* and *Amaranthus* etc.

iv) **Aeration:** Aeration or exchange of gases between the germination substrate and the embryo is essential for speedy and uniform germination. Oxygen (O_2) is needed for the metabolic processes i.e., respiration, in germinating seeds. In general, uptake of oxygen during germination is proportional to the amount of metabolic activity taking place in germinating seed. Oxygen supply gets reduced in the presence of excessive water for example in poorly drained seed beds, particularly after heavy rains or irrigation. Pores in such soils get filled with water which amounts expelling of oxygen consequently reduction in available oxygen for germinating seed. Further, oxygen has low solubility and slow diffusion in water. These all conditions result in reduced supply of oxygen even though presence of 20% oxygen in atmosphere or at soil surface. However, this response of seeds varies with species to species.

v) **Carbon dioxide (CO_2)**: High levels of CO_2has positive effect in overcoming dormancy in some seeds. Carbon Dioxide (CO_2) is produced during respiration and under conditions of poor aeration it can accumulate in the soil.

vi) **Nutrition:** Generally, good seed crop is a result of favorable nutrient conditions particularly for woody plants. It has been observed that seed production was increased after the fertilizers application especially nitrogen and phosphorus (Owens and Blake 1985).Further, high C/N ratio in shoot tissues has a role in abundant flowering (Kramer and Kozlowski 1979).

Check Your Progress 2

1. What are different phase of seed germination? Discuss in brief.
2. What is Lag phase of seed germination? Discuss.
3. Write a short note on seedling emergence.
4. What are different measures of germination? Discuss.
5. Discuss the impacts of various environmental factors on germination.

6.3 Growth and development in trees

6.3.1 Growth and Development

Growth is simply the change in size and volume of a plant or organism. It is usually an outcome of increase in size and volume of individual cells followed by their division which result into change in form and shape of plants. For example: growth of shoots or growth of leaf or root. Growth may take place in whole plant or may be limited to certain organ depending upon the stage or age of the plant. In the initial stage, whole plant body grows whereas in latter or older stage only certain parts of the plant grow. At cellular level, growth is the result of synthesis of various molecules such as nucleic acids, proteins and lipids which are generally referred to as macromolecules. These macromolecules organize into membranes and organelles such as chloroplast, mitochondria, ribosomes and others.

During the process of growth cells, some cells become specialized to perform some specific task i.e., division of labour sets in. This further result into cell division and formation of tissues. This process of cells becoming specialized is called **'differentiation'.**

Development on the other hand, is the process of growth and differentiation of cells into organs and organisms. For example, in angiosperms (flowering plants), formation of seeds and their germination, results in development of root and shoot. With further growth more branches and leaves are produced till a certain time when vegetative buds get converted to flowering buds. After the formation of flowers, fertilization takes place resulting in the development of fruits and seeds.

6.3.2 Stage of tree growth

There are broadly four growth stages identified through which a plant passes to attain a mature tree stage (Source: Directorate of Forest, Govt. of WB 2016, L S Khanna 1999 and Sangeiya 1967). These are as follows:

i) Seedling
ii) Sapling
iii) Pole
iv) Tree

i) Seedling stage: It is the first stage after germination till it reached a height of one meter. There are mainly three parts identified at this stage which are:

- the embryonic root
- the embryonic shoot, and
- the cotyledons (seed leaves)

Once the photosynthesis starts in seedlings, it stops taking energy from stored food reserve in seeds. The apical meristems start growing and give rise to the root and shoot. The first true leaves expand and can often be distinguished from the round cotyledons however; shape may vary from species to species. While the plant is growing and developing additional leaves, the cotyledons eventually grow old and fall off. The seedling grows and begins to develop woody characteristics. The stems harden, change color, and develop a thin protective bark. The stem may bend or develop branches that reach toward light. Seedlings compete for nutrients, water, sunlight, and space. At this stage the tree is susceptible to many threats that include fire, flood, drought, disease, insect attacks, and animals.

ii) Saplings stage: Sapling is defined as a young tree from the time when it reaches about one meter (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. As the tree starts to get taller, the main trunk thickens and lateral branches arise. A sapling has all the characteristics of a fully grown tree, however, lacks only in size and reproductive abilities. A sapling is characterized by the absence of dead bark and vigorous height growth.

iii) **Pole stage:** It is a stage between sapling and tree stage when lower branches start to fall off and crown expansion is conspicuous. Generally, poles are greater than four inches but less than eight inches in diameter. Depending on the species, trees in the pole stage could be as tall as 30 feet.

iv) **Tree stage:** It is the final stage of a plant individual when height growth gets slow down but expansion of the **crown** becomes more prominent. Tree is the stage of growth beyond the pole stage. With favorable conditions, a sapling or pole will grow into a mature tree (>8 inches DBH). During this stage, each tree will grow as much as its species and site conditions will permit. In addition, flowers develop, reproduction ensues, fruits form, and seed dispersal can occur. Trees provide the maximum environmental benefits to people during this stage.

At this stage, the **crown** gets a prominent shape**.** The crown is defined as, "the upper branchy part of a tree above the bole (L S Khanna 1999 Principles and Practice of Silviculture)". It contains live branches and foliage. Crown shape has importance in silviculture because it indicates the amount of growing space that is needed to maximize timber production. Further, it also controls light to ground surface and accordingly microclimate is defined inside the forest.

6.3.3 Growth and Assimilation

During the growth of plant individuals from seedling to tree, the growth occurs in belowground (root portion) and aboveground (shoot portion) of trees. This growth occurs in vertical and horizontal axis in different stages of life and results in height and diameter growth, respectively. Growth from the root and shoot tips that results in increases in height and length is called **primary growth**. Growth that increases the thickness of stems and branches is called **secondary growth**. Primary growth occurs in small areas called apical meristems which results in increased leaf size, height growth and increase in the length of branches and roots.

Stems and branches of trees and their roots also have growth in horizontal axis i.e., increase in thickness or diameter as a result of what is known as secondary growth. Secondary growth is actually takes place in cambium (The soft layer of cells next to bark) which after cell division and differentiation creates every year new xylem (new wood) and phloem (new inner bark) on the outside. The xylem carries water and nutrients from the

roots upward, while the phloem carries sugars from the leaves downward. In the temperate climates, the cambium does not grow during the winter and a dark line can be seen in the wood indicating slowing of cambial growth at year's end. These are the annual growth rings that are visible in many species. In tropical climates, growth may occur round the year, and annual rings may not be visible. In some species, the rings are pronounced, because wood produced in the favorable conditions of spring (early wood) is less dense than wood produced in the summer and fall (latewood). Cork cambium also produces a certain amount of diameter growth. As it grows the cork cambium produces cork, the outer layer of bark. While new cork is produced each year, the outermost layer is shed so that the bark thickness of a mature tree remains nearly the same from year to year. Thus, growth in cork cambium contributes greatly to diameter growth in sapling stage as a sapling develops a thick bark, but diameter growth of a mature tree is mainly due to the production of wood by the vascular cambium.

The growth mainly depends upon **assimilation** which is the result of available food materials, water and energy plus the ability to use them. During the process of growth, part of assimilate (a result of photosynthesis) is used up for in obtaining energy for various metabolic processes (respiration). Whether a tree is vigorous or weak, a certain amount of assimilate (photosynthate) is used up in the maintenance (own energy requirements and replacement of injured parts) of its own body and this kind of use has priority over all other uses. The balance of the assimilate remains available for addition to the body mass (Growth) of the tree.

6.3.4 Flowering, Fruiting and Seeding

Flowering: As the individual reaches tree stage and further gets matured, the reproductive structures are developed i.e., flowering takes place. Some plant species start flowering as early as in four years such as *Dalbergia sp.* (Shisham) and *Bauhiniasp etc.* whereas some species flower very late after 10 to 15 years of maturity. Generally, trees growing in open places flower earlier than the trees growing in dense forest. Similarly, the time of flowering has variation. Some species flower during winters whereas other flower during summer. Species like Sal and Shisham flower when new leaves develop, whereas Haldu and *Terminalia* sp. flower when there are ample leaves in them. Among the coniferous species flowering takes place in spring accept in deodar which flowers after rains.

The quantity of flowering also varies from species to species and also from one year to another year. Some years are good seed years whereas in others not. Deodar has a tendency to have good seed years every fifth year.

A specific type of flowering has been observed in bamboo. It has an irregular flowering. Some species flower after certain interval of years. Sometimes only some of the clumps of bamboo flower (known as **sporadic flowering**) whereas sometimes all the clumps of the bamboo flower (known as **gregarious flowering**).

Fruiting and seeding: After the fertilization process, fruits and seeds are developed. These seeds give rise to next generation after their falling to the ground floor and subsequent germination. Fruiting, shape and size of seeds and time of seed germination are species specific character and varies with species to species.

Check Your Progress 3

1. Briefly discuss growth and development.
2. Discuss the various stage of growth.
3. Differentiate primary and secondary growth.

Summary

The summary of this unit is as follows:

- Seed germination may be defined as, "the emergence and development from the seed embryo of those essential structures which indicate its ability to produce a normal plant under favorable conditions of temperature, moisture and nutrients".
- There are mainly three phase of seed germination i.e., Initial phase of Germination, Lag Phase and Radicle Protrusion.
- Seedling Emergence takes place as a result of seed germination. Seedlings emerge out of the soil as a result of division and elongation of root and shoot meristems. The embryo of higher plants consists of a shoot axis bearing one or more cotyledons and a root axis (radicle). At the seedling stage, the stem three parts - hypocotyl, cotyledonary node and the epicotyl.
- Initially, new embryo remains dependent upon the storage reserves in endosperm, perisperm or cotyledons until the seedling emerges into the light and photosynthesis initiates.

- There are three different germination measures that are Germination percentage, Germination rate and Germination uniformity. **Germination percentage** is the number of seeds that produce a seedling from a seed population expressed as a percentage. **Germination speed or rate** is a measure of how rapid a seed lot germinates. **Germination uniformity** measures how close in time seeds germinate or seedlings emerge.
- There are mainly four environmental factors which influence seed germination. These are temperature, water, gases and light. **Temperature** regulates the time of germination, it affects both germination percentage and germination speed. **Water** is essential for germination. **Light** is needed for the germination of certain seeds. **Aeration or** exchange of gases between the germination substrate and the embryo is essential for speedy and uniform germination as it has role in various metabolic activities. Similarly **Carbon dioxide (CO_2)** has a positive effect in overcoming dormancy in some seeds. Better n**utrition to parent crop** results in good seed crop. Further, high C/N ratio in shoot tissues has a role in abundant flowering.
- Growth is simply the change in size and volume of a plant or organism. In the initial stage, whole plant body grows whereas in latter or older stage only certain parts of the plant grow. During the process of growth, some cells become specialized to perform some specific task i.e., division of labour, sets in. This process of cells becoming specialized is called **'differentiation'. Development** on the other hand, is the process of growth and differentiation of cells into organs and organisms.
- There are broadly four growth stages – Seedling, Sapling, Pole, Tree
- The growth occurs in vertical and horizontal axis in different stages of life and results in height and diameter growth, respectively. Growth from the root and shoot tips that results in increases in height and length is called **primary growth**. Growth that increases the thickness of stems and branches is called **secondary growth**.
- **A specific type of flowering has been observed in bamboo**. It has an irregular flowering. Some species flower after certain interval of years. Sometimes only some of the clumps of bamboo flower (known as **sporadic flowering**) whereas sometimes all the clumps of the bamboo flower (known as **gregarious flowering**).

Unit 7: Natural regeneration

Unit Structure

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Summary
References

7.0 Learning Objectives

After completing this unit you will be able to:

- define forest regeneration
- define and explain natural regeneration
- explain natural regeneration from seed and various factors affecting it
- explain natural regeneration from vegetative parts
- explain natural regeneration from coppice

7.1 Introduction

In the previous unit you learnt about tree growth and development. As soon as a forest crop attains to a certain height and diameter, (which is sufficient to meet the objectives of forest owner) it is necessary to have harvesting of crop so that the owner may derive desired benefit or economic returns from the crop. Whereas if harvesting of such forest crop is not carried out, degeneration starts and results in economic / ecological losses. Therefore, harvesting and renewal (or regeneration) of forest crops are periodic and regular processes in forestry. **Forest regeneration** is the process of renewal of forest crop by establishing young crop of the same species or any other species in an area where harvesting of old forest crop has been carried out. Regeneration of forest crop is needed as with the passage of time the value of the standing forest crop depreciates and in order to get appropriate returns, harvesting is carried out followed by re-establishment of crop.

In this unit we will discuss the various kinds of forest regeneration methods and a detailed account of natural regeneration. We will discuss natural regeneration from seeds, vegetative parts and coppice. We will also discuss the various factors which affect natural regeneration.

7.2 Forest Regeneration- Concept and Definition

Regeneration is basically renewal of a forest crop by natural or artificial means. It is an essential feature in scientific forestry and the sustainability of forest yield depends upon it. A regeneration method may be defined as, “an orderly procedure or process by which a forest is renewed or established either by natural means or by artificial means or by a combination of these both”.

The process of regeneration starts only after the forest crop or stand is harvested. It includes both the **removal of the old stand** and the **establishment of a new crop**. Thus, there are two broad activities involved in the forest reproduction i.e., harvesting of the mature forest crop and thereafter, establishment of new crop. The former process (harvesting) can be controlled completely by humans, however, in regeneration humans have only partial control (limited up to seeding or sowing) whereas majority of it is under the control of nature in both natural regeneration as well as artificial regeneration. A number of factors relating to climate, soil, water and physiography have direct or indirect

effect on establishment of crop after seed germination (natural regeneration) or planting (artificial regeneration) processes.

7.3 Methods of Regeneration

The establishment procedure of new forest crop in a given area forms the basis of distinction between the regeneration methods. Three such methods have been identified. These are as follows:

1. **Natural regeneration:** Natural regeneration is defined as the renewal of a forest crop by self-sown seeds or by coppice or root suckers.
2. **Artificial regeneration:** It is carried out though seeds or plants which are brought to the plantation site by human beings.
3. **Through a combination of natural and artificial means:** Here the natural regeneration is assisted artificially by human beings.

7.4. Natural regeneration

Natural regeneration is defined as the renewal of a forest crop by **self-sown seeds** or by other vegetative parts such as **coppice shoots or root suckers**. Natural regeneration may originate from one of the following sources i.e., seeds, stool shoots, natural layering, suckers or Detached vegetative parts. However, natural regeneration takes place mainly by seeds. There are very few species in which it arises through stool shoots or by other vegetative means. Thus, natural regeneration in an area can be categorized on two main categories:

a) **Natural regeneration by seed:** Such forests are called '**high forest**' or '**seedling crop**'. This is the sexual method of regeneration in which the new plant exhibits the characters of both the parents.

b) **Natural regeneration by vegetative parts:** This is asexual method of regeneration and the new plant exhibits the characters of the parent plant only. When regeneration is obtained from coppice, it is called coppice crop, and the latter develops into a forest called **coppice forest**.

7.4.1 Natural regeneration from seed

Natural regeneration through seeds depends upon following conditions:

- Location of seed trees in nearby the regeneration area. Natural regeneration is impaired if seed trees or seed sources are remotely located.
- No. of seed trees should be sufficient to meet the regeneration needs of the area. Very few seed trees cannot fulfill the seed requirements.
- Edibility of seeds by rodents or other animals causes adverse impacts on natural regeneration even if seed supply is ample.
- Establishment of young plants make the site conditions unfavorable for seed germination, thus, cause hindrance in seed germination.
- Favorable conditions for seed production enhance the chances of natural regeneration
- suitable soil conditions for seed reception, seed germination and survival of seedlings
- Sufficient light and soil space for growth and development of young plants

There are mainly four important requirements of natural regeneration from seed on which depends the success or failure on the method. These are as follows:

- Seed production
- Seed dispersal or dissemination
- Seed germination
- Establishment of seedlings

7.4.1.1 Seed Production

The first essential requirement for a natural regeneration to take place in an area is the availability of **fertile seeds** (or quality seeds) in sufficient quantity. It depends on nature of species, age of the trees, soil conditions, temperature and climate, crown and other external factors.

Seed production is primarily a **species specific character** which is largely a reflection of its genetic makeup. Most of the species seed annually; however, there are some species which do not seed annually. Some species have abundant seed supply every year (examples *Tectona grandis* -Teak, *Dalbergia sissoo* - Shisham and *Acacia sp.*) whereas other either have abundant seed supply after certain period or other do not have seed

production in abundance or have a poor seed production yearly or periodically even. In such species, which do not produce seeds at the end of each year but produce after certain gap of years i.e., periodically, in such cases, the concept of **seed year** prevails. In such cases, **seed year** may be defined as, "**a year in which a given species produces large seed crop over a sizeable area**". However, the amount of seeds for same species in different seed years may not always be uniform. Amount of seeds also varies from species to species and also the interval of years i.e., periods, also vary from species to species. Seed years are categorized as Good, Normal and Poor seed years based on the amount of seed produced.

Species	Seed years
Cedrus deodara (Deodar)	4-5 years
Shorea robusta (Sal)	2 years
Terminalia chebula (Harar)	3 years
Source: Directorate of Forest Deptt., WB, 2016)	

Another factor that influences seed production is the **age of trees**. It has been observed that maximum seed production occurs when the height increment ceases. The main cause of this is the availability of ample amount of growth materials such as carbohydrates for seed production after increment cease otherwise most of it is utilized in height increment. It has also been observed that seeds produced in young trees, if any, are comparatively very less in number and that too with poor seed vigour and poor viability. On the other hand, trees with large crowns produce best quality seeds with large quantity.

Climate is another very important factor on which amount and quality of seeds depends. Generally, hot climatic conditions favor higher number of seeds. This is particularly attributed to metabolic activity which is more in hot climate than cold climate. A warmer **climate** favors early and heavy seed production. Best seeds are produced from middle-aged to medium-sized parent trees. **Soil condition** also influence seed production. Soils with sufficient bases, adequate nitrates and higher C/N ratio are favorable for it.

Other external factors include rainfall, fire injury, diseases and other external injuries. Rainfall particularly during the pollen dispersal reduces the seed production considerably as pollens are taken away with water. **Diseases or other external injuries** reduce seed production, whereas fire incidences catalyze seed production. **Pruning of trees** also enhances seed production. Fungus, insect attack and girdling also influence seed production.

7.4.1.2 Seed dispersal or dissemination

Another important factor that influences natural regeneration is dispersal of seeds. Good regeneration depends upon the adequate dissemination of seeds on the regeneration site. Seed dispersal takes place by air, water, insects, birds, animals or humans.

Seed dispersal by wind: Species in which seeds are light weighed, hairy or winged are disseminated by wind. **Winged seeds** are found in species of *Dipterocarpus*, *Termenilias*, Conifers, *Holoptelia*, *Dalbergia*, *Acer*, *Pterocarpus*, *Adina*, *Betula*, *Rhododendron*, and *Oroxylon*. **Hairy seeds** are found in *Bombax*, *Populus*, *Salix*, *Eupetorium, Saccharum* and *Imperata*.

Seed dispersal by water: Examples of water dispersed seeds are most mangrove species, *Shorea* (Teak), *Dalbergia* and *Trewia.*

Seed dispersal by gravity: Seeds are dispersed by gravity in case of the following species, namely, Acorns of Oaks, *Juglans regia*, *Diospyros* and other heavy seeded species on sloping ground.

Animals: Seeds of *Prunus*, Mulberry, Loranthus etc are **dispersed by birds**. Seed *Acacia arabica*, *Prosopis juliflora*, *Ziziphus*, *Anthocephalus* etc. are dispersed by animals.

Explosive mechanism: Some of the species has specific explosive mechanism for seed dispersal. Examples are Oroxylon and species of family acanthaceae.

7.4.1.3 Seed germination

Germination of seeds in natural conditions depend upon certain factors such as:

- Permeability of water through seed coat
- Permeability to Oxygen which is needed in metabolic activities
- embryo should be fully developed at the time of seed fall
- After ripening process- This is the most common cause of delayed germination due to the embryo being

Table: Germination capacity Species

10-20	*Abies pindrow, Anthocephalus cadamba*
20-30	*Cassia fistula*
30-50	*Bombax ceiba, Tectona grandis, Cypressus torulosa*
50-70	*Acacia Arabica, Dendrocalamus strictus, Terminalia, tomentosa, Toona ciliate*
70-90	*Acer campbellii, Butea monosperma, Acacia catechu, Albizzia procera, Juglans regia, Shorea robusta*
90-100	*Albizzia lebbek, Artocarpus chaplasha, Cassia siamea, Dalbergia sissoo.*

(Source: L S khanna 1999 Principles and Practice of Silviculture)

chemically unready. Such seeds germinate only when they have undergone a process of after ripening.

- Size of seed – Very minute seeds are washed away in the rain water, whereas very big seeds do not get properly covered by soil or humus, and do not germinate.
- **Viability of seeds** means potential capacity of a seed to germinate. Seeds of some species retain their viability for a long period while those of certain other species lose their viability very soon
- **Germination capacity** is the percentage of seeds in a given sample that actually germinate, irrespective of time. Germination capacity of some species is given below:
- **Plant percent:** All the seedlings that come up after successful germination do not survive owing to adverse environmental factors. An important indicator of how many seedlings will eventually establish them is the Plant Percent. Plant Percent is defined as percentage of the number of seeds in a sample that develop into seedlings at the end of the first growing season. Following table gives values of plant percent and germination capacity of some important species:

Species	Germination capacity	Plant percent
Acacia arabica	50	26
Shorea robusta	80	66
Tectona grandis	50	25
Terminalia tomentosa	70	29
Gmelina arborea	85	30
Dalbergia sissoo	90	78
Abies pindrow	13	6

(Source: L S khanna 1999 Principles and Practice of Silviculture)

- **External Factors such as** temperature, moisture, air (oxygen), light and location of seed inside the soil depth influence the seed germination in various ways. Although most of the species are indifferent to light conditions for germination, however, certain species require light while some others require shade for germination.

  Species requiring light – *Rhododendron sp.*, *Albizzia procera*, *Cassia fistula*

  Species requiring shade – *Swietenia macrophylla*, *Santalum album*

7.4.1.4 Seedling Establishment

Good germination does not necessarily ensure that plantation or regeneration is successful. There are many factors which cause death of a number of seedlings such as frost, drought or other climatic factors or biotic factors such as weeds, grazing, forest fires etc. Therefore, after germination, establishment of seedling is necessary so that it may

withstand the external factor. **Establishment** is defined as, "the development of a new crop to a stage when the young regeneration is considered safe from normal adverse influences such as frost, drought or weeds, and does not required any special protection measures or tending operations other than cleaning, thinning and pruning". The establishment of seedling is affected by soil moisture, soil nutrients, soil humus, soil aeration, development of root system, light conditions, grazing, browsing, forest fires and weeds etc.

Seedlings require water and food for their growth and development for which they are dependent on soil. Therefore, presence of soil moisture and availability nutrients in the soil positively affect seedling growth whereas presence of thick humus negatively influences seedling establishment as humus poses obstruction in penetration of roots to deeper layers of soil and it is particularly more harmful in dry or drought conditions. Presence of thick layer of humus is also indicative of deficiency of nutrients. Further, good aeration of soil coupled with good soil texture ensures adequate supply of oxygen and facilitates early establishment of seedlings. In addition to this, faster the root development in the seedlings the more easily and quickly such seedlings establish in the field.

Light is one of the important requirement of photosynthesis and thus, help in establishment of seedlings through quick root development. However, requirement of light varies from species to species. Therefore, plants can be classified based on their light requirements which are as follows:

i) Light demanders (requires abundant light for its best development)

ii) Shade bearers (capable of persisting and developing under shade) and

iii) Shade demanders (requires, at least in its early stage, some shade for normal development).

Note: *Seral species are generally light demanders and their regeneration can be obtained under overhead light conditions. However, climax species or species which occur in the later stages of succession are usually shade bearers, and their regeneration is best obtained under the shade of some over wood.*

7.4.2 Natural Regeneration from vegetative parts

Natural regeneration from vegetative parts in forest trees is mainly attained from coppice shoots, natural layering, suckers and detached vegetative parts.

7.4.2.1 From coppice shoots

The regeneration from coppice shoots is carried out by two ways i.e., seedling coppice and stool coppice.

Seedling Coppice is defined as, "the coppice shoots arising from the base of seedlings that have been cut or burnt back". This method of regeneration is applied to woody shoots and established reproduction which has not made satisfactory progress. It is generally used in case of Sal and Teak. In situations where advance growth of Sal or Teak remain stagnant, it is cut back and given proper light conditions to help grow fast.

Stool coppice, on the other hand, is the coppice arising from the stool or a living stump. Regeneration in this method is obtained from the shoots that develop from the adventitious buds of the stump of felled trees. The reproduction through stool shoots is made use of in the coppice silviculture system.

7.4.2.2 From other vegetative parts

Natural regeneration other than coppice occurs in forest tree by natural layering, suckers and detached vegetative parts, however, species of this kind are very few. Regeneration in mulberry sometimes arises by natural layering, whereas beech and black locust often reproduce from root suckers. Reproduction of certain willows and *Opuntia* are examples of natural regeneration from detached vegetative parts.

Check Your Progress 1

1. Define forest regeneration. Discuss in brief the methods of regeneration.
2. What is natural regeneration? Discuss natural regeneration from seed.
3. Discuss the various factors affecting seed germination.
4. What do you understand by 'viability of seeds'? Discuss in brief.
5. Write a note of germination capacity and plant percent.
6. Why is there need of care after seed germination? Discuss.

7.4.3 Factors affecting Natural Reproduction

There are a number of factors which directly or indirectly affect the establishment, growth and development of forest crops. Method of harvesting is most important factor which controls the establishment of natural regeneration. Other factors include climatic conditions, supply of seed, and occurrence of forest fire, and influences of biotic factors

(i.e, that of animals, insects, and fungi). In order to ensure successful natural reproduction there must be:

- Abundant seed supply in excess of that destroyed by rodents, insects, and other agencies
- Favorable conditions for germination of seed
- Favorable conditions for the growth of seedlings

Natural Regeneration in Virgin Forest

After attaining maturity in a virgin forest, the trees die and fall on the ground. The small openings so created here and there may receive seed from the surrounded seed trees. The other sources of natural regeneration are stool shoots, natural layering, suckers or detached vegetative parts. In such places, the soil happens to be in excellent condition for seed germination. Suitable light and soil conditions in the openings results in the germination of thousands of seeds and thus, seedlings fill every opening. However, in the presence of some external disturbances or agents which destroys a large number of trees at one time, it is usually seen that natural regeneration occurs very slow and with difficulty.

Theoretically, the reproduction method to large extent controls both the species composition and the arrangement of species in the new stand, however, practically it has been observed that the degree to which this control can be exercised is governed by the reproduction method employed, by the complex of factors affecting the establishment of reproduction, and by the degree of intensity with which in a given place silviculture is applied.

7.5 Natural regeneration from seed under various silvicultural systems

7.5.1 What is silvicultural system?

Silvicultural system as defined by Troup (1928) is " the process by which the crops constituting the forest are tended, removed and replaced by new crops resulting in the production of woods of a distinctive form". Based on the origin of forest crop, the various silvicultural systems are broadly categorized in to two categories:

A) **High Forest Systems:** Those having origin from seed or transplants. It includes Clear-felling system, Shelterwood system and Selection System

B) **Coppice Systems:** Those which have their origin from coppice shoots. It includes mainly coppice system and coppice with standard systems. However, there are other variations also.

7.5.2 Natural regeneration under clear felling system

In clear-felling system, the mature crop is removed in one operation and site becomes bare. If reproduction in the cut over site is planned to be established through natural regeneration, then it can be obtained by one or more of the following methods:

- Seeds from trees adjacent to the clear cut area;
- Seeds lying dormant on the ground or left in the slash and debris;
- Seeds borne by the trees in the coupe of the year before they are clear felled;
- Advance growth already existing in the annual coupe as a result of previous seed years.

7.5.2.1 Seeds from trees adjacent to the clear cut area

While undertaking adjacent trees as seed source, following point should be kept in mind:

- Seeds of the desired species must have mobility and should be dispersed in sufficient quantity to reach the extreme end of the clear felled area
- If seeds have low mobility, the clear cut area should be in the form of narrow strips
- The cutting should be done from the opposite end of the direction of wind
- The cutting should be done before seed-fall
- The species must be the one having good seed years annually

7.5.2.2 Seeds lying dormant on the ground or left in the slash and debris

- The seeds should be capable of lying dormant in the soil without loss of viability and germination power, e.g dehiscent fruits of Teak
- The felling refuse scattered all over the area should not be disposed by burning and may be collected from places of limited extent so that dormant seeds are not destroyed.

7.5.2.3 Seeds from the clear felled trees of previous year

- The felling refuse should be disposed of and the shrubs cut and burnt down so as to provide a clean ground for natural regeneration to come up

7.5.2.4 Advance growth of previous seed years existing in the annual coupe

- If the advance growth does not coppice, disposal of felling refuse by burning all over the area has to be ruled out.
- If the advance growth is a coppice, and is sufficient to restock the area, burning of slash may be done in the area.

7.5.3 Natural regeneration under shelter wood system

In shelterwood system, the mature crop is removed in a number of harvestings or stages depending on the progress of regeneration. The first felling is known as **seeding felling** whereas the last one as **final felling**. All other felling if any is known as **secondary felling**. The interval between the seedling felling and final felling on a particular area such as a compartment is called **regeneration period**. The Shelterwood systems are also of various kinds such as Uniform Shelterwood system and Group Shelterwood System. The basic principle of all the shelterwood systems is to allow regeneration to grow up under the shelter of seed trees so that appropriate protection is provided to the developing regeneration. The various operations carried out in order to augment natural regeneration are as follows:

- **Adequate supply of seeds:** In order to ensure adequate supply of seeds for natural regeneration in the felled areas, suitable number of middle aged trees with well-developed crown is retained. However, number of trees to be retained varies from species to species. For example, in case of *Adina cordifolia* one to two seed trees are sufficient to supply ample seeds per hectare whereas in case of *Shorea robusta* thirty to forty trees per hectare are usually needed.

- **Adjustment of light:** The function of the over wood is not only to supply seeds, but also to permit optimum light reaching the forest floor for germination. This is primarily achieved by suitable manipulation of canopy that is by removal of certain trees of over wood which are not required for supply of seeds. As light is obstructed by the middle storey and undergrowth as well, middle storey is suitably thinned, and undergrowth density is reduced to admit sufficient light to the forest floor. The standard method of

containing the density of undergrowth consists of regular cutting back, uprooting, controlled burning, use of weedicides etc.

- **Soil condition:** Soil needs to be permeable to help the tap roots of seedlings reach the depths of permanent soil moisture. It may therefore be necessary to undertake site specific soil working measures to improve the permeability and porosity of the soil. In order to correct the condition of moisture deficiency, soil works like contour bunds may be done.

- **Weeding and cleaning-** Immediately after the germination of the desired species, weeding is done to protect the young seedlings against weeds which compete with desired crop for light, nutrients and moisture. Generally weeding is done before the weeds get a chance to suppress the regeneration of desired species. When regeneration grows up to the stage of sapling, cleaning is undertaken. Cleaning consists of removal or topping of inferior growth and climbers etc, when the latter interfere with the growth of the favored species.

7.5.4 Natural Regeneration under Selection System

Selection system, in its simplest form, consists in harvesting the trees which have attained exploitable diameter/ rotation age. The trees are selected from the whole forest after defined period for felling and felling of which results in creation of gaps. In these gaps, natural regeneration is allowed to come up. However, keeping in view the large are of forests, it is not advisable to have such operations in entire area. But for the ease of convenience, such forests are divided into a number of coupes (cutting sections) in which harvesting and regeneration is carried out at defined interval of years. This defined interval is known as **Felling Cycle (F.C.).** Felling cycle may be manipulated to obtain regeneration of a desired crop. For example, selection system with a short felling cycle is suitable for regeneration of climax shade-bearing species, while a long felling cycle may be utilized for securing regeneration of sub-climax light demanding species. Selection system requires not only harvesting of selection or exploitable sized trees, but also undertaking of simultaneous thinning in all the age classes in the coupes so that normal distribution of age classes is maintained in the resulting regeneration.

7.5.5 Natural regeneration from coppice under simple coppice system

Simple coppice system is defined as, “the Silviculture System based on stool coppice, in which the old crop is clear-felled completely with no reservation for sheltered wood or any other purpose”. It is applicable to species which coppice vigorously. The coppice rotation is usually kept as 20 to 40 years. In the year following the clear felling, coppice shoots of inferior species which are found to interfere with the favored species are removed. If the number of coppice shoots per stool is more than two, the most promising two shoots are kept and the rest are cut back. After a year or two, only one shoot per stool is retained by cutting down the other. As stumps cannot continue to give out coppice shoots indefinitely, natural seedlings appearing at the site are allowed to grow. The blanks are regenerated by sowing or planting.

7.6. Assisting natural regeneration (ANR)

7.6.1 Gap planting in barren patches

When the forest area in question is not regenerated fully during the regeneration period, forest managers are presented with two alternatives. One is to increase the regeneration period and wait for the area to be regenerated over an extended period of time, and other alternative is to fill up the gaps artificially and complete the process of regeneration. The usual practice is to choose the second alternative and take up the failed patches of regeneration area for sowing or planting. It is always advisable to undertake the filling up work as early as possible, as otherwise the blank patches get quickly occupied by grass and weeds.

7.6.2 Tending Operations

As a measure of ANR, the regenerated crop is subjected to tending operations. The object of tending operations is to reduce the degree of competition for light, food and water among between the desired species and the undesired ones, and also among the individuals of the desired species.

Tending is defined as, “an operation carried out for the benefit of a forest crop, at any stage of its life between the seedling and the mature stages (L S Khanna 1999)”. It covers operations both on the crop itself and on the competing vegetation. Tending includes

weeding, cleaning, thinning, improvement felling, pruning, climber cutting, girdling of unwanted growth and coppice thinning etc.

7.6.3 Soil and water conservation measures

A growing natural regeneration, like any other developing forest stand, would require favorable soil and water conditions for optimum growth and early establishment. The natural regeneration will, therefore, be aided considerably if soil and water conservation measures are undertaken at the regeneration site. The measures may include construction of suitable earthen dam, contour bunds or trenches and gully control measures, etc.

Check Your Progress 2

1. Discuss the various factors affecting natural regeneration.
2. Discuss the natural regeneration from seed under clear-felling and shelter wood systems.
3. What is ANR? Discuss in brief.

Summary

In the previous unit you came to know about germination, growth and development of trees which ultimately result into a mature forest. In this unit, forest regeneration and its types have been discussed. A detailed discussion on natural regeneration of forest crop has been carried out. It can be summarized as follows:

- Regeneration is defined as,"the renewal of a forest crop by natural or artificial means". In other way, a reproduction method is, "an orderly procedure or process by which a forest is renewed or established either naturally or artificially or a combination of both".
- There are broadly two activities involved in the regeneration process which are - harvesting of the mature forest crop and re-establishment with new crop
- There are two methods of forest regeneration - natural and artificial, however, in practice, a combination of these two methods is also sometimes practiced. Thus, regeneration in a forest may be brought about by- **Natural regeneration, Artificial regeneration and through a combination of these two.**
- Natural regeneration may be obtained from the two sources such as f**rom seed and from vegetative parts.**

- Success of natural regeneration depends upon the availability of sufficient amount of fertile seeds, viable seeds and dissemination of seeds to desired places.
- Success in seed germination depends upon various internal and external factors. The internal factors include permeability of water, maturity of embryo, viability of seeds, size of seed and Germination capacity whereas external factors include Temperature, Moisture, Air /oxygen, light and soil depth above the seed.
- Another important step that ensures plantation success is seedling establishment which is affected by soil moisture, soil nutrients, soil humus, soil aeration, development of root system, light conditions, grazing, browsing, forest fires and weeds etc.
- Seral species are generally light demanders and their regeneration can be obtained under overhead light conditions. However, climax species or species which occur in the later stages of succession are usually shade bearers, and their regeneration is best obtained under the shade of some over wood.
- Natural regeneration from vegetative parts in forest trees is mainly attained from coppice shoots, natural layering, suckers and detached vegetative parts.
- Natural regeneration under clear felling system can be obtained by seeds from trees adjacent to the clear cut area, seeds lying dormant on the ground or left in the slash and debris, seeds borne by the trees in the coupe of the year before they are clear felled and advance growth already existing in the annual coupe as a result of previous seed years.
- Natural regeneration under shelter wood system is obtained from the seeds available from shelterwood. Here the mature crop is removed in a number of harvestings or stages depending on the progress of regeneration. The first felling is known as **seeding felling** whereas the last one as **final felling**. All other felling, if any, are known as **secondary felling**. The interval between the seeding felling and final felling on a particular area such as a compartment is called **regeneration period**. The basic principle of all the shelterwood systems is to allow regeneration to grow up under the shelter of seed trees so that appropriate protection is provided to the developing regeneration.

- Natural Regeneration under Selection System is obtained in the gaps created by harvesting the mature trees which have attained rotation age. The trees are selected from the whole forest for harvesting and it results in creation of gaps. In these gaps are filled up through natural regeneration.
- Natural regeneration under simple coppice system is obtained from the stool coppice which arises in the stool resulting from the harvested tree. This is possible only in species which coppice vigorously. The coppice rotation is usually kept as 20 to 40 years.
- Assisting natural regeneration (ANR), is the gap planting in barren patches when the forest area under natural regeneration has some patches remain incomplete due to some reason like failure or injury or other reasons. Such areas are regenerated through sowing or planting.
- Tending Operations are carried out as a measure of ANR. The objective is to reduce competition for light, food and water among the desired species and also with the undesired ones. Tending includes weeding, cleaning, thinning, improvement felling, pruning, climber cutting, girdling of unwanted growth and coppice thinning etc. Further, soil and water conservation measures are also essential for successful regeneration. These are also part of ANR in natural regeneration.

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Unit 8 Artificial Regeneration I

Unit Structure

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8.3 Preliminary activities before artificial regeneration
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Summary

8.0 Learning Objectives

After completing this unit you will be able to:

- define artificial regeneration
- explain artificial regeneration
- list out various activities which are carried out in regeneration site
- identify the various factors which influence it

8.1 Introduction

In the previous unit, we discussed about forest regeneration and its kinds. The two kinds of forest regeneration are – Natural and Artificial regeneration. Natural regeneration was also discussed in detail.

In the present unit, we will discuss about artificial regeneration. It is a kind of regeneration in which humans play a major and important role. Artificial regeneration refers to involvement of human beings in all processes such as seed collection, germination, sowing, and other measures in nursery and fields. Thus, in artificial regeneration, regeneration of desired crop is carried out from the seeds collected from some seed source or transplants developed by sowing seeds in a nursery which are then sown or transplanted in plantation site by humans or by machines. In this unit, we will discuss the principles of artificial regeneration, methods and activities in artificial regeneration.

8.2 Artificial regeneration and its objectives

Artificial regeneration is defined as, "the renewal of forest crop by sowing, planting or other artificial means or methods". The crop resulting from artificial methods of regeneration is commonly known as 'plantation' or 'plantation crop'.

As far as objectives of artificial regeneration are concerned, they are reforestation and afforestation activities. **Reforestation** means re-establishing or stocking of an area which has been harvested earlier or otherwise cleared whereas **Afforestation** means establishment of a forest stand or crop of desired species in an area by artificial methods where forest vegetation has always or long been absent.

Reforestation is carried out for:

- Supplementing natural regeneration (ANR)
- Replacing natural regeneration, where natural regeneration of the desired species has not been successful or in areas where plantation has been failure or cannot be accomplished within reasonable time and money
- Where there is need for changing species' composition and objective is to increase the proportion of a more valuable species in order to derive more benefits
- Introducing valuable exotic species

Afforestation is carried out for fulfilling one or more of the following objectives:

- **Productive purpose** (raising a particular kind of forest crop, for example, afforestation of wastelands, afforestation of grasslands
- **Protective purpose** (conservation of soil and water, for example, afforestation of catchment and swampy areas)
- **Bio-aesthetic objects** (conservation of biodiversity, wild life and recreation purpose for example ecological parks)

Artificial regeneration demands appropriate planning, time and investment of money. Therefore, it is adopted when these basic requirement particularly time and money are available and is expected to give more benefits in return. Artificial regeneration is adopted when there is/ are:

- absence of natural seed source for the desired species
- a need to change the species composition of the forest stand
- a need to make genetic improvements in the species
- strict requirement to have adequate density or spacing of the crop
- need to control time and duration of establishment period
- repeated crop failures

8.3 Preliminary activities before artificial regeneration

Certain preliminary activities are required to be carried out before the start of artificial regeneration activity in an area or land selected for the purpose. Broadly, these preliminary works or activities include following three categories:

- Choice of species.
- Fencing.
- Reclamation of the soil.

8.3.1 Choice of species

The first preliminary requirement for artificial regeneration is judicious selection of species for regeneration. It is this step that is important in order to be successful in meeting the

object of management under a given set of conditions. Once a selection is made and plantation is done, one cannot rectify the mistake, if any, done in selection of species. .

Artificial regeneration in an area demands large amount of money, labour and other technical inputs, therefore, selection of species is one of the important considerations. The choice of species for artificial regeneration in an area is usually governed by the following factors:

1) **Climate and micro-climate:** Species that are suitable for local climatic conditions are generally preferred. Such species are generally indigenous or native ones and which grow well in the nearby areas, and are also observed to have performed well in such localities. However, if exotic species are planned to be opted for artificial regeneration, then the climatic conditions of their land of origin should be suitably matched with the local climatic conditions of plantation site and only after climate is matched such choice should be made.

(2) Soil conditions: Choosing species well adapted to the soil and moisture conditions is another important factor on which the success of a species depends. Such species grow better and tend to have less health related issues. In immature soils, seral species which come early in the succession are selected, and in mature soil, climax species which come in the advance stage of succession, are selected. The undergrowth growing on a site also sometimes gives a good indication of species that can be successfully raised.

(3) Object of management: Object of management is another factor that governs the choice of species. For example, if the objective is to raise pulpwood, the species which can yield pulp of good quality and quantity (Example- Popular) may be chosen. If the object is to produce timber, a major part of planting stock could be of *Dalbergia sissoo* (Shisham) or *Tectona grandis.* (Sagaun) or *Shorea robusta.* (Sal). Objects of forest managements are usually written on working plan along with prescription of the species to be raised.

(4) Market requirement or stakeholders' requirement: It is generally the market requirement on which depends the choice of stakeholders. Therefore, choice of species is dependent on market demand and stakeholders' requirement. Besides the Forest

Department of the State, members of the Joint Forest Management Committee (JFMC) are the major stakeholders in the forest management. The requirement of the JFMC members should, therefore, be ascertained while making choice of species.

(5) The silvicultural system: The silvicultural system, under which the forest stand is to be worked, forms a guiding factor. For example, strong light demanding species are preferred in clear-felling system, whereas species of intermediate light requirement are preferred in shelterwood system. In selection system, shade-bearing species are found suitable.

(6) Availability of suitable exotics: If indigenous species cannot meet some specific demand of the locality or some industrial demand, exotic species with proven suitability for the site can be selected. Examples are *Eucalyptus* and *Acacia auriculiformis* in the south-western part, *Casuarina equisetifolia* in the coastal area, and *Cryptomeria japonica* in north Bengal hills.

(7) Growth rate: The growth rate also influences the decision on choice of species. To meet the increasing demand of industrial timber and fuelwood, fast growing species must be selected.

(8) Ease of establishment: The ease with which a species can be established affects the choice of species. Examples are choice of *Eucaluptus* in the south-west Bengal, and Dhupi and Utis in north Bengal hills. While there is reason to favor the species that can be raised easily, such consideration should not overplay in ignoring those indigenous species which have great ecological or medicinal value or are otherwise important.

(9) Effect on site: The long-term effect on the site factors should be considered while making the choice of species. A species, apparently attractive, may in the long run prove to be causing deterioration of the site. In the hill catchment area, where the aim is to get maximum usable water, species with low transpiration rate should be favoured. For arid and dry areas, non-exacting species are preferable. Pure Teak may not be good for soil health; it

Important consideration

In artificial regeneration such species are never taken up for plantations which are outside its natural range until and unless such species has been tested practically and results

should be mixed with suitable shade-bearing and soil improving species like bamboo, Swietenia etc.

8.3.2 Selection of site

Selection of site is one of the important considerations and needs study of a number of factors in order to ensure success of plantation activity, if, afforestation is to be carried out in barren areas or grasslands or other areas whereas clear-felled or otherwise cleared area, this step is automatically skipped as the plantation site is predefined. In case of afforestation of barren land or other lands, it is very important to select the site according to the species. It is on this selection in which success or failure of the plantation depends. Bio indicators are sometimes advantageous in this process as such species give some indication about the soil conditions and suitability of soil for particular species.

8.3.3 Methods of artificial regeneration

Artificial regeneration in the plantation site can be carried out either directly by sowing seeds or by transplanting seedlings or cuttings raised in nursery or by adopting a combination of sowing as well as planting methods.

As far as planting vs direct seed sowing are concerned, the former:

- tends to have higher costs of operations
- is adopted only when natural regeneration is likely to receive failure
- is adopted when important considerations like species selection and genetics are the main objectives

In practice, a combination of these two is practiced.

8.3.4 Choice between sowing and planting

Choice between sowing and planting methods depends on:

- **The species to be raised:** Generally slow growing species or the species whose seeds remain enclosed in a hard coat are preferably raised by planting method.
- **Conditions of the site:** In areas with poor soil conditions or adverse climatic conditions, the method of plantation is by planting method due to higher probability of success than seed sowing method.

- **Availability of seed:** Species having poor seed production or hard to regenerate are preferably raised by planting.
- **Cost:** The factor of cost has to be considered together with degree of success of the method. The method which gives success at reasonable cost is preferred.

8.3.5 Spacing

Spacing is the distance between the plants in the plantation site. In order to describe the spacing, the distance between line to line and plant to plant is mentioned. For example 4 m X 2 m spacing means the distance between lines to line is 4 meter whereas distance between plants in a line is 2 meter. The working plan of coupe should have clear mention of plant spacing. Generally 2m x 2m plant spacing is adopted; however, it may vary from place to place. A spacing of 2m x 2m means 2500 plants per ha whereas 2.5m x 2.5m spacing gives a crop density of 1600 per ha. However, considering that there are blanks in the plantation area in the form of inspection path and blank strip around the boundary, the actual crop density would be slightly less than the figures mentioned above.

8.3.6 Arrangement for staff and labour

Plantation is a programme which is impossible in the absence of suitable labour force. It requires all kinds of labour i.e., skilled, semi-skilled as well as unskilled in order to carry out various plantation activities. Therefore, before any plantation activity is undertaken, the arrangement of labour force is a prerequisite and it is on this availability in which success of plantation depends.

8.4 Seed collection, extraction, drying and storage

8.4.1 Collection of seeds and seed sources

In order to collect seeds, first requirement of the identification of suitable seed source. Ideally, the seed source should be a tree which is genetically superior. Superiority of species can be judged from certain physical parameters like size, length, shape of stem, height, diameter, volume increment, timber quality, resistance to disease and other specific desired qualities. However, it is very difficult to ascertain the internal traits of a tree as those are determined by its genotype. Therefore, collection of seeds are carried out from middle-aged trees with good phenotypes (as physical appearance of an organism is

reflection of its genetic makeup). These seed trees of good phenotypes are called **Plus trees** and are marked with paint, there location, species and visible characters are also recorded for future reference.

Plus trees are isolated trees in the forest and cannot fulfill the seed requirements of large scale plantation activity. Furthermore, it is not advisable to have dependency solely on few plus trees on account of their vulnerability to damage by many factors, particularly biotic ones. However, in order to meet the seed requirement of large areas, seed orchards or seed production area or seed stand are established from the seeds obtained from plus trees. Seed production area or seed stand is defined as, "a crop of vigorously growing middle-aged to mature trees of good quality, properly thinned and left to contain trees of good vigor and well developed crowns, with clear boles and managed exclusively for seed collection (Khanna, 1999)". Only those areas are selected as seed stand where the proportion of desirable trees is high. After selection of the seed stand or seed production area, following operations are generally undertaken:

- The best phenotypes are identified and distinctly marked with paint in circle. The remaining trees are removed or marked with different paint so that they may be removed in future. Thus, only the best phenotypes are retained for seed production.
- If there is congestion even after removal of inferior trees, the selected trees are properly thinned so that the trees retained have sufficient space to develop good crowns so as to maximize seed production.
- Inferior trees in vicinity are removed in order to prevent cross pollination. This is usually obtained by creating an **isolation strip of width 100 to 150 m** around the seed stand and all the inferior trees of this strip are removed.

8.4.2 Seed production- seed tree and seed orchard

Seed stands are created from the seeds obtained from superior phenotypes of the existing crop (whose origin is not known) and is just an interim arrangement in order to meet immediate or short term seed requirements. However, in order to ascertain the superior seed quality, seed orchards are established from genetically superior seeds. Seed orchards are thus, defined as, "a plantation of genetically superior trees isolated to reduce pollination from genetically inferior ones, and intensively managed to produce frequent,

abundant, and easily harvested seed" (Khanna, 1999). There are two kinds of seed orchards:

(1) Clonal Seed Orchard (CSO): CSO are raised by **grafting clones** in the form of a scion or bud of plus trees on the stock of 2 or 3 year old seedlings, or by planting rooted cuttings of plus trees at proper spacing.

(2) Seedling Seed Orchard (SSO): These are raised from the seedlings obtained from the seeds of plus trees.

Clonal Seed Orchard (CSO) starts producing seeds earlier. Since CSO is obtained by vegetative propagation of genetically superior plus trees, the resulting trees are likely to be sound and healthy and bear seeds of good genetic quality. However, seeds from individual CSO trees should be put to trial by planting seedlings from such seeds in experimental plots. If the performance of any seedling on several replications is found to be unsatisfactory, the corresponding seed source, that is the tree in CSO is identified and removed from the CSO. Similarly seedlings of SSO origin are put to trial, and if some are found to under-perform, their parent trees in the SSO are identified and removed. Thus, individual trees in CSO or SSO which breed inferior seedlings are eliminated and the chances of getting superior plants from the seeds of CSO and SSO are enhanced.

Advantages of seed orchards

i) Seed orchards produce superior seeds;

ii) Seed collection becomes a concentrated activity, and therefore becomes an easy operation and less costly;

iii) They can be used for controlled crossing programme between selected clones to achieve improved seed source.

Isolation of seed orchard is carried out in order to exclude the chance of pollen contamination from inferior trees of the same species. This can be done by:

(1) Keeping a strip around the orchard free from any plantation or self-grown tree of the same species, or

(2) By screening off the orchard by planting a belt of some other suitable species which does not intercross with the species of the orchard.

8.4.3 Season or time of seed collection

Seed should be collected on maturity before dispersal. It means that proper time for collection of seeds is immediately after ripening when they are ready to fall from the trees. Change in colour and softening of the tissues of the fruit give some indication that the seed is approaching maturity. Most fruits turn reddish brown when ripe; pulpy fruits start getting soft and wrinkled skin. Most of the species have a fairly definite period in which they ripen and such information can be obtained from the literature. However, time of seed maturity of a species vary with locality, and sometimes varies from year to year in the same locality due to change in climatic conditions. Therefore, constant field observation is necessary for reaching at appropriate time of seed collection apart from knowledge as mentioned in the literature. The seeds which ripe very early or very late are often found to be infertile, therefore, such seeds should be avoided.

8.4.4 Method of seed collection

There are mainly three ways of collection of seeds which are as follows:

(1) Collection of fallen seeds from the ground: it is applied to large fruits and heavy seeded species. One has to take care that only freshly fallen seeds are collected. The ground should be made clean by removing previously fallen seeds. Examples: Sal, Teak, Gamar, Kadam, Oaks etc.

(2) Collection of seed by lopping the branches: This method is applied to fruits which are too small to be economically picked from the ground, or which are easily wind dispersed. Example: Betula, Khair, Sissoo, Albizzia, conifers etc.

(**3) Collection of seed from standing trees:** Seeds which are likely to be damaged in falling with branches are collected from standing trees by hand or with a sickle tied to a bamboo carrying a small bag. Example: *Acer*, *Morus,* etc.

8.4.5 Seed extraction

Although most of the seeds or fruits can be sown or stored as such as collected from the source but in some species, there is a need to separate fruits from the seeds before they are sown.

1) Seed extraction or sowing from dry fruits

There are three categories of such species:-

- The entire fruit is sown with seed contained in it, e.g Teak, Walnut, Oak etc. Dry fruits of this category do not require any extraction.
- Part of the fruit is sown with seed contained in it, e.g Sissoo. Fruits are placed in gunny bag and given beating to break each fruit into as many parts as contain a seed or two.
- Seeds are sown, e.g Conifers, Leguminous species, Lagerstroemia, Acer etc. In this category of fruits there is a need to extract seed completely from the fruit. Usually fruits are dried in sun which results into coming out of the seeds.

2) Pulpy and fleshy fruits

The pulpy portion should be removed as early as possible. The method depends on the kind of fruit. The usual method is to keep the fruits in water in a container for some time, followed by pounding and squeezing while still under water until the seeds are freed. The soft pulp floats on water and the seeds sink to the bottom. The two can be separated by decantation. After the seeds have been extracted and dried, they should be cleaned off in order to free it from all foreign materials by winnowing or sieving. They are now ready for grading, sowing or storage.

8.4.6 Drying of seeds and Seed storage

There are different methods of seed storage depending upon the kind of species. Storage of seeds become necessary if the time of ripening of seeds does not coincide with time of sowing. Naturally, seeds need to be stored after collection till the time of sowing. Seeds having long viability should also be stored for use in lean (poor) seed year. In general, the ideal storage condition should be similar to the environment in which seeds of the species are stored in the nature. **Species with seeds of short viability** must be sown immediately after their collection like Neem and Sal. However, if it becomes necessary to store such seeds for a short period, they are stored in shade by spreading the seeds, if possible, sprinkling with water from time to time. Sal and most of the Dipterocarps can be stored in this manner.

There are some **species whose seeds ripen in autumn and germinate in spring.** Such species are found in temperate regions and they seed in autumn. Seeds after falling to the ground remain lying under the snow all through the winter. Such seeds germinate when snow melts in spring. If seeds of such species are collected, they required to be stored in low temperature. Conifers, generally, require dry cold storage. However, broad-leaved species are reported to require wet cold storage i.e., moist and cold condition. Darjeeling district seeds of *Quercus*, *Machilus* and *Juglans* are stored in pits. **Species whose seeds ripen in winter or summer and germinate in the following summer:** Most species of the plains fall in this category. Seeds can be stored either by spreading them out in dry places with good circulation, or by light packing in loose gunny bags, and occasionally spreading them out in the sun to prevent dampness. For storing large quantity of seed, a special shed is built up. The shed may be fitted with bamboo shelves and movable trays to facilitate drying. The shed should be so constructed that it is not exposed to excessive damp or over-heating.

8.4.7 Testing of seeds and Pre-sowing Treatment

In order for plantation to be successful, seed germination should be quick and uniform. There are some pre-sowing treatments that ensure and hasten germination process. These are as follows:

1. **Cold water Treatment**: For seeds which need lot of water for germination, and at the same time have certain chemicals inside, which inhibit germination, the cold treatment is a good method. Examples: Pine, Aonla, Kanchan, Kalasirish, Patka sirish, Khair etc. In the process seeds are put in water, five times the volume of seeds and allow the seeds to soak for 1-2 days, change the water every 12 hours. Discard the seeds that float on the top. All the swollen seeds are ready for immediate sowing.
2. **Hot water treatment:** The method is applied for seeds which contain hard seed coat, such as *Cassia*, *Sesbania* and *Albizia*. In this process, five times the volume of seeds are taken and allowed to soak in boiled water after it has cooled for 10 minutes and keep the seeds in this water for 2 days or until most of them have

swelled. Discard the seeds that have floated on the top. Change the water every day with cold water. Once the seeds swell, sow them immediately.

3. **Boiling water treatment:** The method is applied for seeds which contain very hard seed coat, such as *Acacia*, *Albizia*, *Prosopis*, *and Oaks* etc. It includes boiling of a volume of water that is five times the volume of seeds. Take the container off the fire and soak the seeds immediately for 1-2 minutes only. After 2 minutes replace the hot water by cold water and allow the seeds to soak for 2-3 days or until the seeds swell. Keep changing the water every day. Sowing is carried out immediately once the seeds swell.
4. **Alternate wetting and drying:** Seed is alternately wetted for some hours and then dried. This is used for Teak.
5. **Passage through animals:** Seeds are passed through the digestive system of animals or poultry. It is applied for treating *Santalum album* (Sandal tree), *Azadirachta indica* (Neem) and *Acacia arabica* (Babool) seeds.
6. **Cow dung slurry treatment:** Fruits of *Terminalia chebula* and *Melia azedarach* are mixed with cow dung and slurry is made. It is then kept in pits for about 7-14 days in order to remove the thick seed coat. This process also helps to overcome seed dormancy.
7. **Chemical treatment:** Soaking in various chemical solutions softens the hard seed coat and hastens germination. Some chemicals are H_2SO_4, HCL, H_2O_2, etc.
8. **Mechanical treatment:** Shell cracking - Seeds of some species needs to be cracked using a wood or light hammer before sowing e,g, *Zizyphus spp..*, *Sapindus spp., Juglans spp.* etc.
9. **Other specific treatment:** Some tree spp. require specific treatment to seeds for initiation of germination:
   - Dry fruits of *Arjun* need to be placed in sunken bed and covered with straw. Watering is done in regular intervals till germination. Germinated fruits are put into polypots / root trainers.

- Fruits of Raktachandan are placed on sand bed under straw cover and kept wet by regular watering. Then germinated fruits are put into filled up polypots / root trainers for further germination.

8.5 Artificial regeneration by seed sowing

8.5.1 Methods of seed sowing

Artificial regeneration by sowing involves the sowing of seeds collected from some seed source either form nature or from existing seed trees. Seed sowing is carried out in various ways in the plantation site. These are as follows:

1. **Broad-cast sowing:** This is the simplest method of sowing in which seeds are broadcasted manually or by machine in the whole area. The seeds are scattered after ploughing or digging up and levelling of soil in the plantation site. This kind of sowing is used for stocking burnt areas, desert areas, landslides, grassy blanks and rocky barren sites. Various thinning operations become more important in this method because of crowding of seedlings or future young crop.
2. **Line sowing:** In this method, sowing is carried out along the lines. After digging and weathering the soil-levelling of the soil is done and in this levelled soil, lines are drawn at regular interval. A drill, i.e a shallow depression, is made on the filled up earth with a hoe or a wooden peg. When the drill runs continuously from one end of the plantation to the other end and sowing is done along the drill, it is called continuous line sowing. The line sowing can be continuous, interrupted or staggered.

Advantages and disadvantages sowing

Advantages

- *It is cost effective and takes less time than planting.*
- *As seeds are sown directly on the site, there is no disturbance to roots which normally happens while transferring planting stock from nursery to planting site.*

Disadvantage

- *It requires large quantities of seed. Birds and animals may destroy or eat away the seeds.*
- *Seedling mortality is quite high.*
- *The resulting seedlings require intensive weeding over a relatively longer period, which increases the cost of plantation.*

3. **Strip sowing:** Here sowing is done on narrow strips prepared usually at definite intervals from one another. The soil is dug up in strips, allowed to weather and then made into seed bed. Seeds are sown in two or more rows along the strip. Like line sowing, strip sowing may be continuous, interrupted or staggered. As there are multiple

rows along the strip, chances of failure of germination is very less. This method is very suitable for areas infested with grass and other weeds. Strip sowing is done in Sal plantations wherein strip of 30 cm width sowing is done in three rows 10 cm apart.

4. **Patch sowing:** It is sowing of a number of seeds in specially prepared patches made at regular intervals. Soil is dug upto a depth of 15 to 25 cm and filled back after weathering. Sufficient number of seeds, depending on the seed-size, is sown, though one is expected from each patch. This method requires less seed compared to line or strip sowing. Seeds are less damaged by birds or animals on account of the scattered nature of the patches. The method is useful for rough sites covered with stones, stumps etc where line or strip sowing is not feasible.
5. **Dibbling:** It is defined as sowing of seeds in shallow holes made with suitable instruments or a wooden stick at regular intervals. Soil working and sowing is done simultaneously. It is applied for large and heavy seeded species.
6. **Ridge or mound sowing:** In moist soils, in high rainfall areas, sowing is done on ridges or mounds, and it is called ridge or mound sowing.
7. **Trench or Pit sowing:** In dry or low rainfall areas, seed is sown in trenches or pits and accordingly it is called trench or pit sowing. In Sal plantations in south-west Bengal, Sal seeds are sown in contour trenches.

8.5.2 Time of seed sowing

As a general rule, sowing should be done shortly before the time when the seed germinates in nature. It provides the seed with an opportunity of using the maximum length of growing season and also reduces the risk of seeds being eaten by birds and rodents due to reduction of exposure to risk (birds and rodents). In temperate zones, seeds are sown before snow fall whereas in tropical deciduous forests it is carried out before the rains or just after the first shower. This way the regeneration gets maximum time period for growth.

8.5.3 Depth of sowing

As a general rule, the seeds should be sown so deep as to have a covering not more than its minimum diameter. A drill of the required depth is made with the help of a wooden stick

or iron hoe and seed is sown. The seed is then covered by shifting the soil of the sides of the drill by hand. Minute seeds are sown on the slightly leveled top of the ridge and covered by sprinkling fine earth over them.

8.6 Artificial regeneration through plantation

8.6.1 Methods of plantation

This is carried out by the following ways:

i) **Planting natural seedlings from the forest:** Natural seedlings of *Michelia champaca*, and *Anthocephalus cadamba* can be used for plantation work. However, as a rule, use of natural seedlings is discouraged.

ii) **Planting nursery grown seedlings:** In this method, plants are grown from the seed bed in the nursery and the entire plants are directly planted in the field without transplanting or pricking out. This method can be used for many species under favorable conditions.

iii) **Planting of transplants/containerized seedlings:** These are plants which have been hardened in the nursery and then planted out in the field. The recent practice, however, consists in pricking out seedlings from the mother seed bed and transplanting into polythene bag or root trainer. That is, pricked out seedlings are not transferred in transplant beds, rather put in polythene bag or root trainer. For many species, seeds are directly sown in polythene bag or root trainer. The transplants in containers, when ready for planting, are taken to the field.

Advantages and disadvantages planting

Advantages

- Much less quantity of seed is required.
- Damage to seeds by birds is eliminated
- Damage to seeds by animals is considerably reduced.
- Success rate is high
- Weeding is less cost-intensive
- Through proper screening or culling of nursery seedlings in the nursery, it can be more or less ensured that only healthy planting stock is transferred to planting site. The resulting crop is likely to be of good health and quality.

Disadvantage

- Planting is costlier than sowing
- It requires more labour, particularly skilled labour
- It requires maintenance of a nursery.

iv) **Planting root and shoot cutting or stump planting:** This is used for Teak and many other species. In case of Teak, one or two year old stumps are used.

v) **Planting branch or stem cutting:** Some of the species can be artificially propagated by branch and stem cuttings. For example, *Ipomea, Vitex, Lannea, salix, Dalbergia*, *Dendrocalamus* etc. Clones obtained from stem cuttings in nursery are usually used on a large scale for *Eucalyptus* plantation. Cuttings are placed in the rooting medium in root trainers in a mist chamber. The object of the mist chamber is to produce a micro environment of high humidity and moderately high temperature. Such environment facilitates early rooting. When the cuttings have developed a sufficient root system, they are taken out of rooting chamber and placed in hardening chamber for about 15 days before they are considered ready for planting in the field.

vi) **Planting root cuttings:** Sections of tap root of *Stereospermum* and *Bombax* can be used in plantations.

8.6.2 Season of planting

The season or time of planting depends upon local climatic conditions, the silvicultural characteristics of species and method of planting. However, based on season, the planting can be classified into following categories:

i) **Monsoon planting:** This is the main planting season in India, as most parts of the country receive bulk of the precipitation from south-west monsoon. Planting should be carried out as soon as the monsoon has fully set in, so that the regeneration gets full advantage of the rains. Planting is normally done in early to mid-June to early July depending upon the climatic conditions which vary from place to place. The ideal condition of planting is when the sky remains overcast or there is a little drizzle.

ii) **Pre-monsoon planting:** Where irrigation facility is available or when there are good showers in the summer, pre-monsoon planting of certain species can be done.

iii) **Winter planting:** Planting is done during winter rains which usually occur in January- February. Winter planting has been reported to be successful in north Bengal for many species, e.g. *Toona, Chukrassia, Cinnamomum, Dalbergia latifolia* etc. (L.S Khanna 1999).

iv) **Spring planting:** Spring planting of conifers is done in parts of Kashmir where southwest monsoon does not reach. As the snow melts during this time, the resulting water is used in irrigating the plantation area.

8.6.3 Pattern of planting

A number of planting pattern is in practice which varies from place to place. The pattern to be adopted in a working circle is usually prescribed in the Working Plan of the area and accordingly the planting operation is done. It is advisable that the pattern adopted should be simple and easy to implement by the work force at the grass root level. Of the various planting patterns, the one which is most common is the 'square planting'. The different kinds of planting patterns are discussed as follows:

i) **Line planting:** In this pattern of planting, lines are drawn on the site in specified distance apart and the plants are planted at a specified spacing in the lines. The distance between successive plants in a line may or may not be the same as distance between two adjoining lines. Therefore, a rectangle is formed by the planted plants. In the line planting, the number of plants required per hectare is calculated as follows.

$$\text{Number of plants per hectare} = \frac{100X100}{dXD}$$

Where, d = distance in meter between plants in a line,
D = distance in meter between the lines apart,

ii) **Square planting:** In this pattern, plants occupy the four corners of each successive square. In other words, in this pattern the spacing of plants in a line is the same as the distance between the lines. In this case, the number of plants required per hectare is calculated by the following formula:

$$\text{Number of plants per hectare} = \frac{100X100}{d^2}$$

Where, d = Length in meter of a side of the square or 's' is distance between successive plants in a line or distance between the two lines, which are identical in square planting.

Summary

- This unit deals with artificial regeneration in which all the operations from sowing or planting till tending are carried out by human beings. Here the regeneration of desired crop is carried out from the seeds or from transplants raised in nursery. The objectives of artificial regeneration are reforestation and afforestation activities.
- Preliminary activities before artificial regeneration is conducted are choice of species, fencing of the plantation site and reclamation of the soil.
- The choice of species for artificial regeneration in an area is usually governed by climate and micro-climate, soil conditions, object of management, Market requirement or stakeholders' requirement, the silvicultural system, availability of suitable exotics, growth rate of species, ease of establishment and effect on site etc.
- Selection of site is done according to the species to be planted. Artificial regeneration can be carried out either directly by sowing seeds or by transplanting seedlings or cuttings raised in nursery or by adopting a combination of sowing as well as planting methods.
- Choice between sowing and planting depends on the species to be raised, conditions of the site, availability of seed and cost. Next step before plantation is seed collection, extraction, drying and storage. Usually seed sources should be located nearby the plantation area. Ideally, the seed source should be a tree which is genetically superior usually known as **Plus trees. Seed production** is carried from seed tree and seed orchards. In order to ascertain the superior seed quality, seed orchards are established from genetically superior seeds. There are two kinds of seed orchards - clonal Seed Orchard (CSO) and seedling Seed Orchard (SSO), seed orchards have certain advantages like they produce superior seeds, seed collection becomes easy operation and less costly.
- Season or time of seed collection varies from species to species. Ideally seed should be collected on maturity before dispersal. There are three methods of seed collection namely collection of fallen seeds from the ground, collection of seed by lopping the branches and collection of seed from standing trees. After seed collection seed extraction and drying of seeds is carried out. Thereafter, seeds are stored. Seed testing

and pre-sowing treatment are conducted before sowing seed directly in the site or sowing in nursery.

- Based on season, the planting can be classified into four categories as- monsoon planting, pre-monsoon planting, winter planting, spring planting
- Among the patterns of planting the important patterns are line planting and square planting.

Unit 9: Artificial Regeneration II

Unit Structure

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9.3 Artificial vs. Natural regeneration
9.4 Pure vs. Mixed Crops
9.5 Kinds and patterns of mixtures
9.6 Exotics
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9.0 Learning Objectives

After completing this unit you will be able to:

- define artificial regeneration
- explain artificial regeneration
- List out various activities which are carried out in regeneration site
- Identify the various factors which influence it

9.1 Introduction

In the previous unit, we discussed about the artificial regeneration. We discussed in detail about preliminary activities needed before artificial regeneration, seed collection, extraction, storage. Further, we also discussed about artificial regeneration by seed sowing and plantation techniques in detail.

In the present unit, we will discuss about common activities needed or done at plantation site while taking up artificial plantation operation. We will also study a comparative account of artificial and natural regeneration, advantages and disadvantages of pure versus mixed crop, various kinds of patterns and mixtures. At the last, exotics will also be discussed in brief.

9.2 Common activities at plantation site during artificial regeneration

Plantations can be carried out either by sowing or by planting or by both the methods. In practice, plantation involves combination of both the methods. Depending on species, one takes a bigger role than the other. However, for most of the species, plantation is carried out through planting supplemented with sowing. Plantation work is the procedure of artificial regeneration, and aims at renewing of the forest crop by sowing or planting. Whether artificial regeneration is carried out through seed sowing or plantation, it involves certain common activities or operations, which are discussed below:

9.2.1 Selection of site

Selection of site is needed when regeneration to be carried out in a new barren area or a site which is devoid of vegetation for a long time. Else in clear-felled or otherwise cleared area, selection of site is automatically done as the same area has to be regenerated. The major factors to be taken into consideration, while selecting a new site for regeneration are aspect, topography and soil conditions.

9.2.2 Survey and Boundary demarcation

After selection of site, the work to be undertaken is survey and boundary demarcation. The boundary of the plantation area is required to be demarcated on ground, and the plantation area should be surveyed. After survey of the outer boundary, a map of the plantation area on a scale of 1: 5000 should be prepared. The map may also preferably indicate nature

and topography of the soil. The map should clearly indicate the location and orientation of the site, identifiable objects across the boundaries, area of the plantation etc. It should also include information on latitude and longitudes of the prominent points along the boundary and GPS (Global Positioning System) are used for the purpose. These coordinates should also be mentioned in the map. The map should bear name and designation of the surveying officer.

9.2.3 Geo tagging of site photographs

Geo-tagging is the process of adding geographical identification data to various media such as a geo-tagged photograph or video, websites etc. This data usually consists of latitude and longitude coordinates, though they can also include altitude, distance, and place names. Geo-tagging can help users find a wide variety of location-specific information. For instance, someone can find images taken near a given location by entering latitude and longitude coordinates into a suitable image search engine. Geo-tagging can tell users the location of the content of a given picture or other media, and conversely on some media platforms show media relevant to a given location. Recent guidelines on documentation are to do geo-tagging of the plantation-site photographs so that information on a specific plantation becomes readily available.

9.2.4 Regeneration plan map

On the plantation area map, brief description of regeneration plan should be mentioned. It should also indicate principal species to be established, spacing to be adopted, blocks, if any, or some specific kind of planting stocks like clones etc. The regeneration plan map which carries information about location, area, soil conditions, regeneration plan etc is required to be approved by the divisional forest officer or any other officer, authorized in this behalf, before undertaking plantation work on ground.

9.2.5 Preparation of planting site

The plantation site should be cleaned of felling refuse, slashes, debris and bushes by necessary cutting, burning, stump uprooting etc. Small depressions or rise may be leveled. The object is to obtain a clean and level site as far as possible.

After preparation of the site, it should be divided into suitable number of blocks which usually depends upon plantation area. These blocks should be separated by roads to facilitate inspection of plantation. In case of large plantation, there is needed one or two main motorable paths. Other branch roads may be about 1 meter wide to allow inspection on foot. Besides, a path about 1.5 m wide should be left on the outer periphery of the plantation inside the fence.

9.2.6 Boundary and contour trench

Alignment of individual segments comprising interrupted boundary and contour trenches, and width of the segments are clearly marked on the ground as per approved specifications with the help of spade. When the position of trench segment has been marked on the ground, the trench of required size is dug along the marked line. Normally, the boundary trench has a width of 1 m at the top, 45 cm at the bottom, and a depth of 60 cm. The boundary trenches are dug in interrupted manner, i.e., the trench is not made a continuous one, so that it does not turn into a channel of water flow. The primary purpose of the boundary trench is to have the plantation boundary demarcated. Whereas **contour trenches** are short staggered trenches, 5 to 10 meters long laid in rows along contours with suitable interspace between them. Usually, an interspace of 5 meters is left between two 5-metre long trenches in a row. The trenches in successive rows will be staggered in such a manner that the interspaces in the upper row are directly above the trenches in the lower row. The optimum spacing or the distance along ground between two successive rows depends on the slope and the rainfall. The section of the trench may be trapezoidal or square depending on the nature of the soil.

The dug up earth is arranged as a ridge on the lower side of the trench. Sowing and planting are done in the rainy season on the ridges as well as in trenches (partly filled) to make allowance for the vagaries of rainfall. In extremely wet seasons, the plants on the ridges do well, but in drier monsoons, the plants in the trenches survive and establish better. (R.C.Ghosh 1976 Handbook on Afforestation Techniques)

9.2.7 Staking out

Having done the inspection path, the boundary and contour trenches, the position and alignment of sowing/planting lines and pits are clearly marked on the ground by fixing

wooden or bamboo pegs as per spacing envisaged. This operation is known as staking out. It is necessary in order to maintain the planting lines in system and to maintain proper spacing. For digging trench for sowing, the ends of lines are marked by stakes and a rope is stretched between the two stakes to mark out the straight line with spade. When the line has been marked on the ground, the stakes and the rope are removed and trench of required size is dug along the marked line. For digging pits for planting, their positions as per envisaged spacing along the line of planting are marked by stakes. Pits of required size are dug around each stake. The stake may be retained beside each pit in order to provide support to the plants in post-planting stage against wind pressure.

9.2.8 Fencing

Even as soil work starts, the plantation site should be fenced. A few commonly used fences are described below:

i) **Cattle proof barbed wire fence:** This is the normal type of fence used to keep out domestic cattle from forest plantation. It comprises of 4 to 5 strands of barbed wire, starting at about 30 cm above ground. Wooden stakes of a durable species are employed to support the fence. Iron rods or cement concrete posts are also used for the purpose.

ii) **Game-proof fence:** This is a fence of special type meant to protect the plantation from wild animals. The lower part of the fence consists of 1.25 m high woven wire, and the upper part comprises 3 to 4 strands of barbed wire.

iii) **Stone-wall fence:** This fence is constructed by laying stones, one above the other, without using any cementing material. Such fences are erected in areas where stones of required shape and size are available.

iv) **Brushwood fence:** When fencing is required to stay for a short period, say for the first year of plantation, an economic method is to go for brushwood fencing. The purpose is to keep away the cattle during the first growing season. Brushwood fence include thorny branches of bushes.

9.2.9 Cattle proof Trench

When the dimensions of the boundary trench are enlarged (top width 2 meters, bottom width 1.25 m and depth 1.25 m), it may serve the purpose of cattle proof trench. Since

erecting barbed wire or other type of fence is a costly operation, digging of cattle proof trench is preferred in many occasions. However, one major disadvantage of cattle proof trench is that soon it tends to become partly filled up with the loose soil that has been dug, and the very purpose of having the trench to keep away the cattle gets defeated.

9.2.10 'Dig and plant' method

In this method, planting is normally done by digging pit and planting process simultaneously. This is carried out in order to prevent the fertile soil eroding away along with monsoon rains. In this method no soil work for pits is done prior to planting. With the onset of monsoon, soil is dug out to the required depth with the help of spade at the places identified by stakes and the seedlings are planted. It is usually practiced in north Bengal. As it does not require elaborate soil work, and this way some expenditure is also minimized.

9.2.11 Digging advance pits before planting

Pits are usually dug in advance before taking up plantation. The soil is dug up to a required depth and size about a couple of months before the planting time. The soil is heaped up on the side of the pit to weather. Weathering of the soil is done with the following objects.

- Soil structure is improved; bigger clods are broken into smaller ones.
- The roots of the weeds dry up and thus menace of the weeds is reduced.
- Birds feed on the injurious insects.

Size of the pit (rectangular), normally adopted, is as follows:

- Length – 60 cm at the top, 45 cm at the bottom
- Width – 45 cm presumed to remain unchanged along the depth
- Depth – 45 cm.

9.2.12 Filling up of pits

After weathering the pits are filled up with the dug up soil in such a manner that the soil makes a raised heap. Unless the dug up soil left for weathering is partly washed away, the raised heap of soil is obtained naturally in view of the increase in bulk volume of the loose soil after digging. During filling up of pits, sometimes basal dose of manuring is done.

Earlier, the method of core manuring was in practice. In this method, the pits are filled with pulverized soil leaving a blank space of about 10 cm at the center. Farm yard manure is then placed at the core with the help of two concentric tin cylinders. The seedling with the potting medium is planted in the center of the pit. As an alternative, manuring in the pit is done by mixing intimately the manure with the filled up pulverized soil.

9.2.13 Sowing of seed

After preparing the site sowing is carried out. Methods of sowing and other details have already been discussed in 6.6 of the previous unit.

9.2.14 Planting or transplanting

After filling up of the planting pits, the plantation site becomes ready for planting which of course has to be done at the appropriate time. The different methods of planting have been described in previous unit under 8.7.

9.2.15 Dispatch of plants for planting

Only those seedlings which are fit for planting should be transferred from the nursery. Only the balanced medium sized seedlings with sturdy stems, and well-developed fibrous root system are the quality stock because they have a higher survival rate and they make better initial growth than do either larger or smaller seedlings. The quality nursery stock should be set apart for transfer to the plantation site. Before transferring from nursery, the seedlings should be irrigated so that the potting medium does not get dislodged from the root on movement during transport and planting. The mode of transport is more often determined by the availability of transport and the cost. Carriage of seedlings by humans is usually undertaken but is a costly affair. The criteria for selection of transport should be such that it is able to reach the site and dispatch the seedlings within reasonable time. Tractor or small motorized van can be a convenient mode of transport if terrain of the site allows it.

9.2.16 Plantation in the field

As soon as the monsoon gets steady, planting stock is transferred to the field which by this time with filled up pits is ready for the planting operation. Individual potted seedling of specified species is placed beside the pit where it has to be planted. It should be properly

supervised that the seedlings have taken appropriate position beside the right pit as per approved planting pattern.

Before putting a plant in the pit, the plant needs to be freed of the poly tube which has so far held the plant. The tube which is normally open at both ends is removed by giving a vertical cut down its length with the help of a blade or a sharp instrument. In case of a root trainer, the plant can easily be taken out of the container by gently tapping from outside. A cylindrical space of required depth is made by hand at the center of the pit. The plant with the mass of potting media around its root is carefully placed in the space at the center of the pit. After this, soil is pressed and consolidated from all sides taking care that the plant remains in a vertical position and the plant collar is about 5 cm above the general ground level with soil sloping all around.

9.2.17 Weeding-Cleaning

Immediately after the planting operation, the next activity is weeding and cleaning. As explained earlier the object of weeding and cleaning is to remove and cut back plants of unwanted species which otherwise would interfere with the growth of the desired species. During the operation, the grasses and weeds are removed from around the base of the plants and the space between the plants is cleaned of unwanted species, climbers etc.

In areas, where weeds are a serious problem, they often completely suppress the desired species and results in mortality. Thus, in order to save the seedlings of desired species from the weeds, the operation of weeding and cleaning is required to be carried out at appropriate time. The number of weeding/cleaning to be carried out in a plantation depends on the intensity of growth of weeds and unwanted species. Generally, cleaning is required to be done 5 times in the first year. Cleaning with progressively fewer frequencies is carried out till the plantation becomes 5 years old. It is to be borne in mind that the requirement of weeding and cleaning is situation specific i.e., the more the weed density and more the frequency the more frequency of weeding and cleaning operations needed, and it is a very important operation for establishment of the plantation.

9.2.18 Fertilizer application

Application of fertilizer is not conventionally practiced in forest plantations. Since, in general, the forest land is fertile and rich in organic matters, use of fertilizer is not

considered necessary. However, while raising plantation on infertile lands, or undertaking afforestation outside forest area, application of fertilizer becomes necessary to establish the plantation. For example in most of the forest land in laterite zone of south west Bengal, the soil lacks in nutrients, thereby necessitating addition of nutrient from outside is needed. In general, application of NPK fertilizer is carried out in the plantation in the first year. About 40-50gm of fertilizer is applied per plant either in single dose or at times in two split doses. Fertilizer is applied while carrying out the weeding and mulching operation. The first weeding-mulching operation is normally done 3 weeks after the planting (during the 4th week). The operation consists of:

i) Cleaning of weeds from the base of the plants

ii) Over a circular area of about 45-60 cm around the base of the plant, the soil is lightly worked with a spade. The soil around the base is loosened and bigger clods are broken with the head of the spade. Due care is taken that the base of the plant is not damaged in the process.

iii) The fertilizer in desired dose is applied uniformly along a ring around the plant at the center ensuring that the raw fertilizer does not come in contact with the plant. The ring of fertilizer is covered with light soil.

iv) The best time to do mulching with fertilizer is after one or two heavy shower so that the fertilizer gets dissolved into the soil easily. If considered necessary, the second dose of fertilizer is given during the second weeding mulching which is normally undertaken after about a month or two. Forking in the base of the soil improves soil aeration, improves water infiltration and breaks the continuity of micro-pores, thus, reduces the loss of soil moisture through evaporation.

9.2.19 Irrigation

Forest plantations are mostly rain-fed. Conventionally, the plantations are not irrigated, as it does not require irrigation. However, there may be exceptions for plantations in dry arid areas where soil moisture goes very low during part of the year. The situation of moisture stress is often found in the laterite tract of south-west Bengal. From the month of December till the next monsoon, the soil becomes so dry that young seedlings, particularly those of the exacting species, suffer mortality. In fact, one major reason for failure of

several attempts in the past to regenerate Sal artificially is the moisture stress the young Sal seedlings had been subjected to. Lately in south west Bengal Sal has been successfully raised by irrigating the plantation during the dry season in the first and second year. It has also been noticed, and was so expected, that growth and health of other species associated with Sal improved considerably due to irrigation.

9.2.20 Casualty replacement (Beating up)

There is no guarantee that sowing or planting will be 100 per cent successful. Casualty replacement is the operation of restocking blanks in a plantation area by sowing or planting. Following points are important while the operation is carried out:

- **i)** Blanks may be identified in the sown area soon after the normal germination period is over. Sowing should be done immediately. If there is still mortality or some blanks are identified late in the growing season, it should be replaced by planting
- **ii)** Blanks in the planted area are filled up by planting only
- **iii)** If some blanks exist even after the growing season is over, they should be filled up in the next monsoon by planting, preferably with seedlings that have been maintained in the nursery for about a year
- **iv)** There should be appropriate stock available in the nursery for casualty replacement

9.2.21 Nurse Crop

Nurse crop is the crop of trees or shrubs grown to foster the growth of another and more important tree crop in its early stages. Its function is to help the growth of principal species which may remain tender in the initial stages. As soon as the purpose is served, the nurse crop is removed. It has been an old practice to raise *Cajanus cajans* (Arhar) between two seedlings and close to lines in Sal plantation in south-west Bengal. On account of drought tolerance of *Cajanus cajans,* it grows rapidly and thus, provides shelter to young Sal seedlings and also reduces evapo-transpiration. Being a leguminous crop, it also serves nitrogen fixation and helps enriching the fertility of the soil.

9.2.22 Fire and general protection

The plantation requires close supervision for protection against fire and grazing in the first couple of years. Cattle and animals can be kept away from the plantation by erecting and maintaining fences. During the dry periods after January onward, the plantation becomes highly prone to fire damage. A preventive measure is to create fire lines around the periphery of the plantation. The width of the fire line should be at least three (3) meters. Fire lines of shorter width (about 1.5 m) should be made within the plantation also. In fact, the network of inspection paths already created can be cleaned of vegetation and dry matters, so that it also serves as fire lines within the plantation.

9.2.23 Plantation Journal

Plantation Journal is a register in which all activities and works carried out in plantation area related to plantation are recorded from time to time. Generally following information is recorded in plantation journal:

- The administrative beat, range and division in which the plantation has been carried out
- Location with boundary
- Regeneration plan map with certification about survey, checking of the area, brief regeneration plan and approval by the authorized officer
- History of the site, that is whether clear felled coupe or barren land etc.
- General topography, soil and climate (temperature, rainfall etc.)
- Details of planting stock species wise
- Advance soil work done that is, information about boundary trench, contour trench, pits with spacing
- Sowing and planting done with dates
- Details of inputs applied
- Weeding-cleaning-mulching with dates
- Financial data/Expenditure for each work in every financial year.
- Pages containing remarks of inspecting officer and action taken there upon

9.3 Artificial vs. Natural regeneration

The choice between natural and artificial regeneration is governed by the following considerations:

- **Risk of deterioration of soil:** Natural regeneration involves least exposure of soil, while artificial regeneration exposes the soil for a longer period. Long exposure of soil may result into soil erosion, particularly in hilly slopes, which in turn affect soil fertility.
- **Crop composition**: Natural regeneration does not give the desired proportion of valuable species, whereas in artificial regeneration, it is easy to manipulate the crop composition. Artificial regeneration has become the standard practice to enrich the crop with larger proportion of valuable species and increase the productivity.
- **Crop quality:** In natural regeneration, despite exercising the best control, one is never sure that regeneration comes from only genetically superior trees, but in artificial regeneration, one has the option to use seeds and clones from genetically superior trees and produce a quality crop.
- **Risk of damage by pests:** In general, mixed crops resulting from natural regeneration are far more resistant to attack by insect pests than those resulting from artificial regeneration.
- **Time factor:** Time is the factor that pre-dominates other factors most of the time while making a decision between natural and artificial regeneration. Natural regeneration is a long, uncertain and prolongs process. The gaps may be invaded by weeds, or the sites while remaining exposed may undergo serious deterioration through intensive leaching, erosion and desiccation. On the other hand, artificial regeneration can bring vegetation cover quickly in open barren areas. One great advantage of artificial regeneration is that it is independent of occurrence of good seed years and can continue every year if there is available good stock of seeds or transplants.
- **Cost:** This is definitely an important factor of consideration. Artificial regeneration is apparently a costly method, as it involves elaborate operations like procurement

of seeds, creation of planting stock, maintenance of nursery, carriage of seedlings, fencing, planting , tending etc. all of which require spending on account of material and labour. In contrast, natural regeneration does not involve any initial cost of formation except slash disposal and fencing, where necessary. However, in natural regeneration the weeding and shrub cutting may have to continue for a very long time and may turn out to be very costly. Cost has also implication in the operation of harvest. In natural regeneration, removal of mature trees has to be deferred till regeneration has been obtained on ground. As a consequence, some of the mature trees may become over mature and unsound, resulting in financial losses. Besides, in natural regeneration, harvest of mature trees is done over a number of years in several stages, and it is done after taking due care of not damaging the young regeneration. This makes the operation of logging and extraction costly. Artificial regeneration allows removal of mature trees without any loss in the value of timber. Besides, logging and extraction becomes short and simple operation without any chance of damage to young reproduction.

There is no thumb rule to decide as which method of regeneration to be adopted. The choice should be made keeping in view the above factors in consideration. It is suggested that natural regeneration may be followed for a reasonably short period and then regeneration operation may be completed by supplementing natural regeneration with artificial regeneration. However, the recent trends are in favour of artificial regeneration.

9.4 Pure vs. Mixed Crops

While making a choice of species to be raised in artificial regeneration, it will be worthwhile to assess the merits and demerits of pure and mixed crops. The ultimate object of having a mixed crop is to obtain the maximum sustained yield of crops in terms of value. The 'value' may mean financial returns or local requirements (A.B. Lal, 1967). The main arguments on the question of choice of pure or mixed crop are summarized below:

(1) Soil deterioration: it is believed that pure crop, particularly of light demanding species, adversely affects the soil conditions and soil fertility. However, there are different opinions on the subject, and the belief perhaps needs to be grounded on more sound scientific data than what is now available. The trend of preferring mixed and irregular crops is largely

based on the belief that mixtures of dead leaves of various kinds produce a favourable type of humus and keep the soil in a better state of fertility than the pure crops. Following points are important to note:

- **Teak is an exacting species;** it remains deciduous for a number of months in a year. As the soil remains exposed during the period when the crop is nearly leafless, in such periods the soil gets deteriorated. Therefore, teak is usually planted in the mixture.
- Pure Eucalyptus plantation in south-west Bengal forests renders the soil compact and devoid of humus.

(2) Resistance to disease: it has been observed that pure crops are more likely to be damaged by insects and pests. In West Bengal, pure crops of *Michelia champaca* are observed to have been attacked by *Urostylis punctigera* (sap sucker); those of *Toona ciliata* by shoot borer *Hypsipyla robusta*; pure *Gmelina* plantation by *Loranthus*. Mixed crops are supposed to minimize epidemic attack due to:

- the mechanical separation of the sensitive species, and
- providing a reservoir of parasites and predators which feed on the main pest

(3) Damage by wild animals: The species of a pure crop may be a favourite food for any wild animal available in large population in the locality. In such a case, the plantation may be damaged severely. For example, bamboo plantations in areas having elephant population are generally destroyed by them. Again, choice of species in a mixed crop may be such as to invite damage by wild animals. For example, if Teak is mixed with *Gmelina* or *Dalbergia latifolia*, the wild animals which browse the latter, damage the latter by rubbing against them. Thus, the key issue of consideration is the susceptibility of the desired species as well as accessory species to be damaged by local animal population.

(4) Total yield: In pure crops, the site qualities are not fully utilized resulting into reduction in volume yield per unit area. In the mixed crops, the soil and the atmosphere are utilized in a greater extent and so there is more volume production per unit area compared to pure crops. However, necessary conditions for achieving enhanced crop production in mixed plantation are:

- that the species in the mixed crop should be compatible and do not cause any interference with each other's growth and development, and
- that they should get matured more or less at the same time. However, if the more number of species are planted in the same site, in such case it becomes difficult to satisfy these conditions.

(5) Difficulty in management: If the species in a mixed crop have varying silviculture requirements particularly the rate of growth and rotation (exploitable age), the crop management becomes tedious or difficult. For example, if a fire tender species is mixed with a species which needs controlled burning, the controlled burning becomes a risky operation. Thinning operations become difficult if fast growing species is mixed with slow growing species. Again if the crop contains species of different rotation age, felling has to take place in more than one operation, and removal of shorter rotation crop creates gaps inviting grass and weeds. Thus, in general, mixture of species with different silviculture requirements, varying rates of growth and rotations should be avoided.

(6) Conservation of biodiversity: Object of management is not always to have maximum production of tangible resources. While part of forests may be worked for production of timber and other marketable produce, other parts may be worked with the object of conservation of biodiversity. Focus of management in the latter case is to sustain the regulating and supporting services of forest ecosystem. It is obvious that mixed crop being richer in biodiversity serves this focus much better than the pure crop.

9.5 Kinds and patterns of mixtures

Mixtures may be of two kinds, viz. **Temporary Mixtures** and **Permanent Mixtures**. **Temporary Mixtures** are those in which the secondary species remain with the main species only for a part of the rotation period. The purpose is (a) protection of the main species from adverse influences like browsing, frost and insolation, (b) providing crown competition in the early stages in order to get better bole form, and (c) providing additional revenue.

Permanent mixtures are those in which the mixed species remain with the main species for the entire rotation period. Permanent mixtures are again of two kinds, namely, Horizontal or Even-aged mixtures and Vertical or Uneven-aged or Storied Mixtures.

i) **Horizontal or Even-aged mixtures** are those in which species mixed are in the overwood and of the same height. For example, in north Bengal Sal plantation, the main species Sal is mixed with many associates and the association is horizontal and even-aged. The main species Sal and the associates are worked on the same rotation.

ii) **Vertical or Uneven-aged or Storied Mixtures** are those in which the main species is in the top canopy while the accessory species are in the middle canopy. This may be due to varying rate of height growth or late sowing or planting of accessory species.

Patterns of mixtures

The mixtures may be of the following patterns:

(1) Intimate mixture: Intimate mixture is one in which all species are raised throughout the area. For example, seeds of all species are mixed together and then sown.

(2) Line Mixture: Line mixture is one in which one line is sown or planted with one species and other lines with other species. Thus, different species occupy different lines as against intimate mixture where all species occur in every line.

(3) Strip mixture: Strip mixture is one in which the mixed species are raised in different strips. In case of sowing, seeds may be sown in the strips in lines or scattered all over. In case of planting, each strip will consist of lines in which seedlings are planted.

(4) Block Mixture: Block mixture is one in which different species are raised in different blocks of the plantation.

9.6 Exotics

Exotic species are introduced when indigenous species cannot meet the fast growing requirement of industrial timber or any specific requirement of a forest area. However, exotics are normally discouraged as they pose negative impacts in the ecosystems and also pose threat to the native species. In cases where there plantation is inevitable, certain points are taken into consideration while selecting such species. An exotic:

- should serve the purpose in view better than an indigenous species.
- must be suited to the climatic and soil conditions of the locality.

- should be easy to grow and regenerate.
- must not suffer from local risks.
- must be more valuable than the indigenous species
- One has to be sure that the exotic is not vulnerable to attack by an indigenous parasite against which it may not possess any resistance, and that it should not inadvertently introduce a foreign pathogen.

Any exotic that is to be introduced, should pass the experimental trial to prove its suitability to the local conditions. It is also to be borne in mind that performance of an exotic over a short period may not guarantee that it will have disease-free life cycles in the long run, because pathogens and pests take time to build up. Examples of successful exotics are *Cryptomeria japonica* in Darjeeling hills, though large scale plantation (carried out in the past) is now discouraged; *Acacia auriculiformis* in south-west Bengal; *Eucaluptus hybrid* in south-west Bengal; *Casuarina equisetifolia* in coastal areas. Example of failed exotics are *Paulownia* tried in north and south-west Bengal; *Acacia mangium* and *Acacia holosericea* tried in south-west Bengal (Govt. of West Bengal, 2016)

Summary

This unit deals with various activities required in a plantation site during plantation operation whether by seed or by transplants. Such activities are common to both. Further, advantages of artificial regeneration and natural regeneration are explained. The choice between natural and artificial regeneration is governed by the certain considerations like risk of soil deterioration, crop composition, crop quality, risk of damage by pests, time factor and costs. However, there is no thumb rule to decide as which method of regeneration to be adopted. The choice should be made keeping in view the above factors in consideration. At last, a brief about exotics has been given. The purpose of plantation of exotics is that in certain cases indigenous species cannot meet the fast growing requirement of industrial timber or any specific requirement of a forest area. However, exotics are normally discouraged as they pose negative impacts in the ecosystems and also pose threat to the native species. However, exotics may be selected for plantation after considering certain points that such species serve well than indigenous ones, better suited to climate, and must be more valuable than the indigenous species.

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Unit 10: Tending operations

Unit Structure

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10.0 Learning Objectives

After going through this unit, the learner will be able to:

- define the term tending
- explain the concept of tending
- describe the various kinds of tending operations

10.1 Introduction

After the establishment of a forest, best care is needed in order to provide the crop favorable conditions for the growth and development so that desired objectives of management may be achieved. The young crop is exposed to several harmful effects from external agencies which may impair with desired returns. Therefore, suitable care of crop is needed right from the time of its formation till the time it is finally harvested. In other words, a continuous monitoring of the crop is needed and accordingly suitable measures are to be adopted to maintain appropriate composition of crop all the time from regeneration and establishment till final harvesting. This care of forest stand is known as "**Tending of Forests**" and is one of the most important silvicultural operations on which depends the ultimate success of objects of forest management.

In this unit you will get to understand the various tending operations in detail. We will discuss concept of tending, types of intermediate cuttings, need and time of intermediate cuttings, and finally we will discuss in detail about weeding, cleaning, liberation cuttings, improvement felling, salvage cuttings, thinning, pruning and their importance.

10.2 Concept and definitions

During the establishment of regeneration and subsequent development of the forest crop till its maturity, several operations are required to be carried out in order to maintain the desired structure and composition of forest stand. These are particularly required in order to provide healthy and favorable environment to the forest crop for its growth and development at various growth phases. The concept of tending is to provide crop with best conditions of nutrients, space and light by reducing unnecessary competition offered by weeds, diseased and weak plants, branches, climbers or undesirable plants of other species or undesirable individuals of the same species. Tending mainly includes weeding, cleaning, improvement felling, pruning, thinning and control of climbers and undesirable plants. In general, tending operations are carried out in order to improve site or locality factors with an objective to achieve best growth of desired forest crop.

In any crop production activity, there is need to preserve physical and chemical conditions of the soil in which a healthy and vigorous growth of crop depends. In case of agricultural crops, it is maintained through soil working and manuring, however, same is not possible in silviculture on account of being expensive (except where the increased returns of valuable species are the objects of management). Although trees are less demanding in comparison to field crops, yet a sufficient depth, a suitable degree of porosity, suitable moisture and chemical compositions of soil are needed for proper growth and development of forest crops also. In silviculture, these conditions can be maintained by preserving suitable canopy cover, preserving natural soil cover through enriching soil humus.

The main fact is that the soil health and a speedy development of the crop growing on it are closely co-related and are complementary to each other. In tending operations, the basic concept is to ensure appropriate preservation of the soil fertility particularly in case of fully stocked forests or newly established forest crops. However, when forest crop reaches full canopy stage then steps for opening up leaf canopy are required to be undertaken in order to enhance the soil health. In addition to this, in the initial stages of crop

establishment different set of factors or harmful factors operate in the site which are eradicated through tending whereas most of these harmful factors disappear in the later stages.

10.3 Need of tending operations and time of application

Forests in various stages of their growth and development need various kinds of tending operations as mentioned in 9.3 of unit 9, for protection from various harmful factors or for preserving the proper density or composition in order to achieve the desired objects.

10.3.1 Tending of forests during early growth

By early growth period is meant for the initial stage up to sapling stage. In this stage, the forest crops need to be protected from a number of external harmful factors such as:

- **Protection from wild animals** such as deer, rabbits and hares. This is achieved either by keeping their population down or through creating fences around the forest crop. Other measures include application of noxious substances such as tar, glue, fluid lime, and evil smelling preparations which keep these animals away from the crop. However, the cost of these chemicals is a limitation for their usage, therefore, fencing is the cheapest and most effective in long term.
- **Protection from fire:** Fires poses threat in all the stages of growth of forest crop from seedling till harvesting, however, threat during the early growth phases is more devastating. Therefore, protection from fire during the early period of growth is necessary as the young seedlings and saplings are very much sensitive to fires. It is achieved by removal of all inflammable material and checking fire events even smaller ones. Additionally proper watch of area is needed so that in case of fires they may be promptly extinguished.
- **Protection from frost and drought:** The young regenerations require artificial shelter for tender species. It is particularly important in open areas which are created post clear felling. Protection is ensured by **special shelter-wood or nurse crops**. The trees selected for this purpose should essentially be frost-hardy and should possess a thin or moderately dense crown. The nurse trees should be present evenly over the entire area, or may also be placed in alternate lines. The

nurse crops are removed as soon as the tender species reach a stage when no more protection from frost or drought is needed.

- **Protection from cold winds:** The cold wind and frost are usually disastrous for young crops, therefore, shelters are needed. This is ensured either by adjoining forests of sufficient height and density, or otherwise by erecting artificial shelterbelts or wind-breaks. As far as possible such species should be selected for wind breaks which are evergreen and have a tendency to form dense crowns. Under the selection system, trees of all ages are intermixed on the same area. In such case lateral protection to the young growth is provided by middle aged / younger trees and vertical shelter by the old trees.
- **Protection from noxious weeds:** Noxious weeds are also very much harmful and impair with the growth of young regenerations. Therefore, they need to be eradicated from the area during weeding and cleaning process. However, moderate degree of weeds act beneficially by providing shelter to young crops.
- **Protection from insects and fungi:** Although insects and fungi offer dangers to standing crops throughout its life, however, young crops particularly seedlings and saplings are much more sensitive. Therefore, regeneration areas are required to be carefully watched for harmful insects. If such insects are seen, a prompt action is needed in order to destroy them as soon as they make their appearance. In case of attacks by fungi, the diseased plants should be removed and destroyed as promptly as possible.
- **Preservation of proper density of crop:** In the process of regeneration of crops, some of the individuals do no succeed, thus, results in small or large blank spaces. Therefore, blanks should be filled up as promptly as possible so that the required density and composition is maintained. In case of young crop originating from direct sowing or from natural regeneration, it is often seen that they are densely stocked in the absence of any action, it is possible that the young trees have a weak development as they start competing with one another for light, space and moisture. However, some of them needs to be removed so that suitable room is provided which may, in turn, result in adequate density and composition of the crop.

- **Cleaning of young crops:** The objective of cleaning is to remove all growth which impairs the proper growth and development of the main forest crop. It may include stool shoots of seedling trees, spreading young trees, accidentally established trees and diseased trees. At this stage some pruning may be done. Where double leaders have been produced, one must be removed.

10.3.2 Tending of forests in fully stocked forests (after early growth period)

At this stage, different set of tending operations are needed. As soon as the crop reaches this stage, several sources of injury disappear, i.e., weed growth is subsided by the effect of the trees, effects of frost and drought damages are reduced to a minimum and fire effects also get minimized. The main purpose of tending is to provide best conditions of space, light and moisture for attaining best density and composition of the desired crop. Thus, the focus of tending operations is directed towards removal of dead, injured, or otherwise undesirable trees. Pruning of over-canopy trees is done in order to avail the below canopy species with suitable light, and space for growth. In thinning operation, those trees are removed which are not in dominant position so that dominant or better canopy trees may get more suitable conditions for their growth and development.

10.3.3 Time of tending operations

The application of the kind of intermediate felling or cutting varies from species to species. It is also not true that all kinds of intermediate cuttings are required in all species. It may or may not be required. The weeding is generally required in initial stages whereas cleaning and liberation cuttings are carried out in young stands (not past the sapling stage). Whereas Improvement felling, Salvage cutting and thinning are carried out in young stands after the sapling stage particularly in fully stocked stands. Pruning is advisable only in special cases.

10.4 Types of tending operations

The various kinds of tending operations (or intermediate cuttings) which are conducted in different phases of growth and development of forest crop from germination to establishment till harvesting are as follows:

1. Weeding and cleaning
2. Liberation cutting
3. Improvement felling

4. Salvage cutting
5. Pruning
6. Thinning

These are explained separately in the following sub-heads.

10.4.1 Weeding and Cleaning

It includes **removal of undesired individuals or species** from the forest crop, however, both these terms are not synonyms. **Weeding** is "the removal of competing growth in seedling phase whereas **cleaning** is "the removal of inferior individuals from a sapling crop, i.e., a crop over three (3) feet height." The main purpose of both the activities is to free the regeneration area from weeds and inferior individuals for the advantage of the better individual of the desired species in the stand.

In even-aged pure crop, the cleaning is meant to remove individuals showing poor growth as evident from their form. Thus, cleanings are the first cuttings made in newly regenerated stand after the crop has established. It should be carried out as soon as it is observed that the individuals of desired species are having trouble directly or indirectly from injury or from undesired species. Cleaning includes the removal of:

- trees and other plants of undesirable species
- sprouts of a desired species
- advance growth of a desired species having inferior form
- shrubs and vines

In sub-tropical and tropical regions, cleanings is required to be carried out in the first year of regeneration after establishment. This is needed so early because such climate is very favorable not only for the growth and development of desired species but also for un-desired or unwanted species and obnoxious weeds. In such areas, not only early cleaning is enough but several such cleanings operations in a year are needed to control unwanted species else they would impair the growth and development of desired crop. On the other hand in temperate conditions, the first cleaning is usually carried out in the third year and till tenth year. General rule of cleaning practice is that it should be carried out as soon as the need of it is felt. Any delay in cleaning operation would only add to the cost, and the overtopping trees would cause irreparable injury to desirable trees very quickly.

One important point to note here is that the undesirable species are harmful only after certain stage i.e., after the crop has established itself. But in the initial seedling stages, these undesirable species may be beneficial to the small seedlings of desired species as they provide a shelter or protective cover. They should be removed only when the individuals of desired species reach a stage when the overtopping individuals hinder their growth and may cause the death of the better individuals. It is at this stage when direct competition between these sets in. Sometimes mechanical injury to desired individuals is caused by the overtopping tree branches of undesired species.

The number of cleaning operation depends upon the climate and site conditions. Usually 2 to 4 cleanings are carried out at an interval of 3 to 5 years. However, sometimes one cleaning is sufficient to regulate the mixture whereas more frequent cleanings are needed in case of trees with better sprouting ability.

10.4.2 Liberation cuttings

Those cuttings which are made for the purpose of freeing the young growth from older overtopping individuals in a young stand before the sapling stage, are known as **Liberation cuttings**. The purpose of such operations is to free the young growth from older overtopping individuals usually referred to as “wolf trees”. **Liberation cuttings are also made in the forest stand during the same period in which cleanings but they differ in the sense that they take out trees larger and older than the young stand whereas cleanings remove trees of approximately the same age as those young stand.** The trees removed in a liberation cutting are either individuals which were left standing when the previous stand was harvested, or on open lands which have been reforested. Liberation cuttings should be carried out as soon as possible in young stands when the shading and protection offered by these ceases to be beneficial and no longer needed. In the absence of such operation the overtopped young desired tree individuals may die.

10.4.3 Improvement and Salvage cutting

Improvement cuttings include those cuttings which are made in a forest stand after the sapling stage. The purpose of improvement felling is to improve the structure, composition and character of the stand by removal of undesirable trees which occupy dominant positions in the main crown and canopy are likely to interfere with growth and development

of desired species. It is only conducted when reasons are sufficient that such action will create better conditions and assist the growth and development of desired stems or species.

As far as number of improvement cutting is concerned, usually only one such cutting is sufficient to regulate the mixture in the stand. However, sometimes removal of many trees in one felling of undesirable species or individual with poor form may result into severe opening up of the canopy. Therefore, in order to avoid such situation second and even third improvement cutting may be carried out.

Early cleaning operations carried out carefully and timely usually eliminate the need of having improvement cuttings at a later stage. Therefore, from the point of view of silviculture and cost of operations, emphasis is given on careful and timely cleaning operations which results in escaping of improvement cuttings.

Improvement cuttings may be carried out in even-aged stands as well as in stands of irregular form. In fact, best outcome of such cuttings is seen in irregular forests where irregularity in the stand structure as well as accumulation of undesired trees competing the desired ones, has taken place. Improvement cuttings are almost always needed in building up forests with better shape and composition.

Improvement cutting vs selection thinning

An improvement cutting is almost identical with a selective thinning but the distinction between the two is that an improvement cutting is applied mainly for the removal of undesirable stem of desired species, whereas in selective thinning removal of the larger trees which are inferior in form to adjoining co-dominant or intermediate individuals is carried out.

Another distinction is that selection thinning, like all other thinning, is made within an even aged stand or group whereas an improvement cutting finds application in both

In case of irregular forest stand, improvement cuttings are applied with an objective of improving the existing crop as primary consideration whereas reproduction is only secondary consideration often not needed at all

The types of trees usually removed in an improvement cutting include:

- over mature trees
- crooked, extremely limby, or otherwise badly formed trees
- trees seriously injured by insects and pests or other causes
- inferior species and climbing vines

Usually it is impossible to remove all such trees at one improvement cutting and therefore, the improvement cutting should be repeated at an appropriate interval, usually not less than 10 years.

In our country, the large areas under forests are mismanaged, have irregular stand structure and accumulation of inferior trees. In such forests, improvement cuttings should be done frequently. As applied in India (Champion and Trevor 1938, pp. 278-281, 341-343), improvement cuttings function both as a silvicultural operation in tending the crop and as a provisional silvicultural system that will later lead to management under one of the standard methods i.e., shelterwood or selection system. While executing improvement cutting, removal of dead, dying, over mature and poorly formed trees and inferior species is mainly done.

The removal of trees injured by their neighbors in the struggle for existence does not constitute a part of salvage cutting but falls under the operations of thinning

Salvage cuttings includes removal of those trees which are **killed or damaged** by various injurious agencies i.e., fungi, insects and fire. These are also applied at the same stage in forest stand as improvement cuttings. It is also a kind of improvement cuttings but the difference is that here removal of those trees is done that are killed or damaged by various injurious agencies such as fungi, insects and fire. It is also sometimes referred to as "Damage cuttings". There are many agencies present in the forest which are continuously involved in damaging the wood. These include fungi, insects, fire, wind, snow, frost and others. It is through salvage cutting by which damaged individuals are removed. Salvage cuttings, as the name indicates, attempts to utilize the injured trees with the idea of minimizing the loss. The amount of cutting depends upon the proportion of the stand occupied by the damaged ones. Therefore, a salvage cutting may be a light cutting to a heavy clear cutting**. It is important to note here that salvage cuttings are not carried out unless the material taken out is expected to meet at least the expenses of the operation.** However, there are exceptions to this rule when it becomes essential for the safety reasons of other surrounding forests to remove un-merchantable trees attacked by insects or fungi. Wherever extensive injury has taken place, reproduction cuttings should be initiated and a new stand be established provided that the condition of the stand permits it. In case larger area of the stand is injured, it is a better idea to harvest all the trees including healthy ones because too much open canopy may injure few healthy

standing trees. After heavy salvage activity, regeneration of undesired species, weeds or grasses take place and this is more so when the area had a recent fire injury. Artificial regeneration is often required after a salvage cutting operations. Although injury from fire, fungi, insects or wind takes place accidentally yet injuries from these causes is commonly seen and therefore, salvage treatment is carried out frequently.

10.4.4 Thinning

Thinning includes removal of tree species in an immature stand for the purpose of increasing the growth rate of desired individuals and mainly those individuals are removed which are not in a dominant position. It should not be confused with improvement felling in which under the canopy tree individuals are removed whereas in case of thinning individuals overtopping the desired ones are removed. Thinning can be differentiated with cleanings, liberation cuttings, and improvement cuttings in the sense that in the former mostly trees not in a dominant position are removed whereas in other mainly overtopping individuals are removed. Further, thinning are those cuttings which are carried out after cleanings or improvement cuttings or salvage cuttings. In other words, thinning is a term which covers almost any kind of cutting which removes stems of desired species but impairing the growth and development of desired one.

Generally, with an objective to stock the area quickly a much larger number of seeds are sown or transplanted. This is particularly for preserving soil nutrients and soil moisture. However, the development of individuals in horizontal and vertical direction results into intense competition among the same species with passage of time growth. In such forest stand, following four (04) kinds of individuals of trees may be noticed:

- Dominant trees forming topmost canopy which enjoy full sun light
- Dominated trees below the dominant trees
- Suppressed trees which are alive but over shadowed
- Dead and dying trees

In the thinning operations, the selection of the trees is based on the following considerations:

- Relative position and condition of the crown
- The character and condition of the bole
- The health of the tree

The above mentioned considerations are mainly applicable for pure stands; however, in mixed stands the choice between species affects the selection.

In general, individuals of the same species with same age occupying the topmost canopy are the most suitable to retain, however, some of the top canopy trees may also be infested by various kinds of diseases. Similarly, character and condition of the bole is closely associated with individuals placed in top canopy yet they are also influenced by factors as density of the stand and by injuries to the bole by insects, diseases, fire and other causes. Therefore, a need was felt of having crown classification based on points mentioned above. According to Society of American Foresters, there are certain recognized crown classes for the purpose of thinning. These are as follows:

a) **Dominant**

   i) Individuals of desired tree species with crowns extending above the general level of the crown cover

   ii) Receive full light from above and partly from the side

   iii) Larger than the average trees in the stand and,

   iv) Crowns well developed but possibly somewhat crowded on the sides

b) **Codominant**

   i) Individuals with crowns forming the general level of the crown cover

   ii) Receive full light from above but comparatively little from the sides

   iii) Usually with medium-sized crowns more or less crowded on the sides

c) **Intermediate**

   i) Individuals shorter than those in the two preceding classes but with crowns extending into the crown cover formed by codominant and dominant trees,

   ii) Receive a little direct light from above but none from the sides

   iii) Usually with small crowns considerably crowded on the sides

d) **Overtopped (**suppressed)

   i) Trees with crowns entirely below the general level of the crown cover

   ii) Receive no direct light neither from above nor from the sides

In practice, most priority should always be given to trees having injuries from any source that affects the bole and health of the desired species. As far as timing of trees is concerned thinning should be carried out as soon as struggle among the individuals of the same species sets in and it becomes injurious for the health of forest stands. This condition arises after establishment of forest crop in the first year in a densely stocked stand in tropical climates. There are some factors such as stock density, productivity of the site, type of species, habit of species and tolerance of species which necessitate early thinning. High density of stock results into severe intraspecific completion among the same individuals for light, space, nutrients and moisture. Therefore, as soon as such signs are observed, thinning should be carried out.

10.4.4.1 Objectives of thinning

The main objectives of thinning are as follows:

- Production of quality timber from desired species
- Enhancing the production capacity of the site by felling of unnecessary competing inferior class of individuals
- Maximizing the returns or profit from the land
- Reduction of fire hazards
- Fulfilling of the market requirement of small timber
- Reduction in rotation period

10.4.4.2 Advantages of Thinning

The advantages of thinning are as follows:

- The length of time required to grow products of the desired sizes can be shortened by means of thinning as it creates openings and reduces competition, thereby, better light, ample nutrients available for growth for both diameter and height growth.
- Thinning raise the quality of the product composing the final crop as inferior trees are removed from the lot.
- Total yield both in quantity and in value of product obtained from a given area in a defined period will be increased. Further, it removes and utilizes trees which otherwise

may die in un-thinned stands. Thus, it increases the actual benefits derived from the stand.

- The yield during the rotation is increased in value for as a higher quality of product is produced, furnish financial returns comparatively early in the rotation, thus, early returns mean higher profits. Thus, an appreciable portion of the total production may be removed relatively early in thinning operations.
- The expansion of the crown and root system after thinning process increases the power of trees to become resistant to wind, ice, snow etc.
- It keeps the stand free of unhealthy and dying trees, in which insects and fungi find the best opportunities for development.
- Thinning may favorably affect water yield from forested areas by increasing snow storage and lengthening the period of snow melting.

10.4.4.3 Types or methods of Thinning

The methods of thinning are as follows:

- Mechanical thinning
- Low thinning method or ordinary thinning (German Thinning)
- The crown thinning (French Thinning)
- Selection thinning
- Free thinning
- Maximum thinning
- Advance thinning

Mechanical thinning is the removal of trees in rows, strips at fixed intervals. It is applied as the first thinning in young stands that are densely crowded or relatively uniform with little differentiation into crown classes. However, the method is less useful when the crop starts differentiation and the size and quality of the trees increases. While conducting such thinning in rows, the trees are cut in lines or strips at fixed intervals throughout the stand or in other words, the trees at fixed intervals are chosen for retention and all others are felled.

The low thinning method is also known sometimes as “thinning from below," or the “ordinary thinning" or “German thinning" method. It is the removal of trees from the lower crown classes to favor those in the upper crown classes. It removes only suppressed to intermediate trees and thus, facilitate utilization of the trees that would probably die due to suppression. , but the release of the remaining trees from competition is minimal. However, heavy low thinning which is generally recommended, removes suppressed, intermediate, and the poorest codominant trees. This creates canopy openings and releases the crowns of crop trees to stimulate their growth.

The crown thinning differs from the low thinning in two respects:

1. ***In crown thinning the principal cutting is in the codominant or dominant classes, and***
2. ***The bulk of the intermediate class and the healthier portion of the overtopped class remain after each thinning.***

The crown thinning method is also known as ‘**French method**’ because of its origin in France. Other names to this method are ‘high thinning’, ‘Danish thinning' and ‘thinning in the dominant’. The principle of the crown thinning method is to cut in the upper crown classes in order to favor the development of the most promising ones in these classes. This way the best trees of the crop get favorable conditions of light and space, thus, opportunity for continuous and rapid growth and development. This is characteristic feature of crown thinning method.

<u>The advantages of the crown thinning</u>

- *Bigger timber can be produced in the same time or timber of a required size in a shorter time*
- *It gives higher immediate cash returns from the thinning because the material removed is larger and better in quality*
- Any part of the area not occupied by the main stand is utilized by the understory trees which are able to continue growth, slowly producing cordwood as the principal product.

The selection thinning is the kind of thinning in which the largest dominant trees and the overtopped trees which are likely to die before the next thinning, are removed. It was developed by Borggreve in 1891. The dominant trees to be removed are selected on the basis of their form and the quality of the timber they can eventually produce as compared with their associates. This method has certain clear advantages and disadvantages in contrast to low thinning and crown thinning.

Advantages and disadvantages of Selection thinning

Advantages

- The thinning returns are better due to thinning carried out at late stage.
- Thinning product is easily saleable in the market on account of having appropriate size of product.
- Lumber is the main product in this kind whereas it is mainly cordwood under other methods.
- The quality of timber produced is better as only clean-bole and small-branched trees are allowed to remain until the end of the rotation.

Disadvantages

- The rotation must be long enough to secure timber of a given size.
- Removal of larger individuals is done in this kind of thinning which demands skill as well as high cost.
- One has to wait for longer time as given dimensions of timber is produced in longer duration
- There are chances of damage to other standing crop during felling of larger trees
- Transportation of comparatively larger crop is not easy. Further, probability of damage and injury to standing crop is higher during transportation.
- Removal of most vigorous individuals may result in occupancy of the area by less vigorous race (Hartley 1927).
- A large opening is created due to removal of larger trees and may also be filled up by trees of inferior crown classes.

10.4.5 Pruning

Pruning is **the kind of** cuttings in which green or dry branches are removed from standing forest crops or trees for the purpose of increasing the quality of the final product. Based on the kind of branches removed (dry or green), pruning is of two types- pruning of dry branches and pruning of green branches.

Another way of classifying pruning is based on natural or artificial means involved in pruning operation. Therefore, two kinds are recognized i.e., natural pruning and artificial pruning. In natural pruning natural agencies such as wind, storms, snow, falling boulders etc., causes removal of dry or green branches from trees. It is also known as ‘self-pruning’.

Whereas artificial pruning is carried out by human beings or silviculturists in naturally regenerated or artificially regenerated forest crops.

Since pruning is a costly affair, therefore, pruning is carried out only for those crop species where principal aim is to obtain knot-free timber with clear bole. Further, the cost may also be minimized if the operation is carried out during young stage when cutting of branches is comparatively easy. Additional cost minimization may be affected by selectively choosing the best trees of the lot.

Another way of pruning is 'bud pruning' in which buds are removed as soon as they arise in order to reduce no. of branches. This is a very cost effective measure of pruning.

The branch pruning is done by the following methods:

- Climbing the bole of the tree and pruning from this position. This is carried out by reaching near the branches to be pruned with the help of climbing irons or ladder and pruning progressively upward. The other way is by climbing the tree and pruning progressively downward. This method is also known as **Tarzan method.**
- Standing on the ground and pruning to desired height with tools mounted upon poles.

Different kinds of tools are available in market for pruning purposes. These tools include Saws (hand, pole, power), Edge tools which cut by impact (axes, billhooks, brush hooks, chisels and pullers). In both methods branches within the reach are cut off with a hand tool. The best pruning is achieved when the cuts is done close to the tree trunk and flush, leaving no splinters of wood and made without tearing or loosening the bark around the branch and without wounding the stem of the tree. Therefore, for good pruning it is important to select a good tool. A good pruning tool can be the one which has ability to satisfy the requirements of good pruning, with a minimum time, minimum energy and highest safety to the operator.

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Unit 11: Categorization of Important Species

Unit Structure

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11.0 Learning Objectives

After completing this unit you shall be able to:

- Differentiate between herb, shrub and tree
- Discuss about the uses of important species
- Developed the basic knowledge about the medicinal and aromatic plants.
- Describe about the MPT's.

11.1 Introduction

Recall your knowledge, from previous units in which got the understanding the basics knowledge about the trees, forests, morphological characteristics of trees. In the current unit we will discussed about the basic difference of the herb, shrub and tree and try to list out the some important tree shrub and herb species commonly found in India.

11.2 Trees, Shrubs and herbs

11.2.1 Tree

Despite the fact that the word "tree" is widely used, neither in common English nor in botany, there a no single, accepted definition of tree.[1][2]

In its broadest sense, a tree is any plant with the general form of an elongated stem, or trunk, which supports the photosynthetic leaves or branches at some distance above the ground.[3]

The National Forest Inventory (IFN) takes a similar approach. It defines a tree as a woody plant that has a bare stem at its base and can grow to a height greater than or equal to 5m when it reaches maturity. The definition from the Food and Agriculture Organization of the United Nations (FAO) says that for a plant species to be a tree, it should reach 5m tall if the growing conditions are good. That's in developing countries – in developed countries the height goes up to 7m.

According to Forest Survey of India (FSI) any woody plant with a height of 4.5 feet and a diameter of more than 10 centimeters can be considered as a 'tree'. A commonly applied narrower definition is that a tree has a woody trunk formed by secondary growth, meaning that the trunk thickens each year by growing outwards, in addition to the primary upwards growth from the growing tip.[4][5]

A tree is a type of perennial plant that often has an extended trunk that holds up its branches and leaves. In other contexts, a tree may merely be defined as a woody plant with secondary growth, a plant that may be used for timber, or a plant that is taller than a certain amount.

Trees are not a single, monophyletic taxonomic group; rather, they are made up of many different plant species that have separately developed trunks and branches in order to surpass other plants for sunlight. Most species of trees are either gymnosperms or softwoods; the remainder is angiosperms, or hardwoods. Trees often have long lifespan—some can survive for many thousand years.[6]

The trunk of a tree usually supports a large number of secondary branches that extend above ground. Usually, this trunk is made up of vascular tissue to transport materials throughout the tree and woody tissue for support. The bark on most trees acts as a barrier to keep out harmful elements. In addition to pulling moisture and nutrients from the soil, the tree's extensive network of branched roots reaches below the surface. Lower branches and shoots split out from the main branch above ground. Usually, the shoots bear leaves,

which function as the tree's food source by absorbing light energy and using photosynthesis to transform it into sugars.

Mostly, trees need seeds to propagate. However, it cans also be propagate through cuttings in some species. Trees with pollen and seed cones, like conifers, may have flowers and fruit, but they may also have other features. Tree ferns generate spores, but palms, bananas, and bamboos also yield seeds.

Trees are important because they mitigate erosion and regulate the temperature. They sequester carbon dioxide from the environment and retain substantial amounts of carbon inside their tissues. For several animal and birds species, forests and trees provide a home. In addition to offering many additional benefits, trees may produce fruits for food, wood for building, shade, and fuel for cooking and heating. Trees have always been valued for their lifespan and practicality; in fact, many societies have sacred groves in various cultures, and they are mentioned in several global mythologies.[6]

11.2.2 Shrubs

A shrub is a small- to medium-sized perennial woody plant (sometimes called a bush). Shrubs have woody stems that remain above ground, unlike herbaceous plants. Evergreen or deciduous shrubs are also possible. Their many stems and shorter height set them apart from trees. [7 & 8]

Shrubs are perennial woody plants with woody stems that stay above ground, unlike the succulent stems of herbaceous plants. Generally speaking, shrubs can be distinguished from trees by their height and abundance of stems. Some bushes, like holly, are evergreen, while others, like hawthorn, are deciduous [8].

According to most definitions, shrubs have several stems without a main trunk beneath them [8]. This is as a result of the stems' underground branching. While some shrubs do have primary trunks, these are usually quite small and split into many stems around ground level without having a discernible length earlier. However, Oaks and Ash are two examples of trees that can grow tall enough to be considered trees yet can also have many stems.

Compared to trees and herbaceous plants, perhaps a relatively small number of shrubs have agricultural or commercial uses. With the exception of a few species that grow berries (defined in a culinary context rather than a botanical one), very few are consumed raw, and unlike trees, they are often too little to be used for much lumber [9].

A variety of plants with medicinal properties are employed, as well as various fragrant species like rose and lavender. The plants that are typically picked for tea and coffee are on the border between shrubs and trees. If allowed to develop, however, these plants would reach the size of small trees [10 & 11].

11.2.3 Herb

The term herb refers to a small, seed-bearing plant with no woody stem that, at the conclusion of each growing season, dies back to the ground in all of its aerial parts [7]. Herbaceous, which means "grassy," is a Latin term that derives from herba, which means "grass, herb" [9]. Although herbaceous plants can also be annuals (plants that die at the end of the growing season and reappear from seed the following year) [8] or biennials, the term is typically used to describe perennials [6]. This is not the same as shrubs and trees, which have woody stems [7].

In general, herbs are a widely dispersed and collection of plants for commonly utilization with aromatic qualities that are used for food flavoring and garnishing, medical uses, or scents. This category of plants does not include vegetables and other plants ingested for macronutrients. Most of the time, culinary applications separate herbs from spices. Herbs are typically defined as the leafy green or flowering portions of a plant, whether they are dry or fresh. In contrast, spices are typically made from dried plant parts such as seeds, bark, roots, and fruits.

In addition to being used in cooking and medicine, herbs can also be aromatic and, in certain situations, have spiritual properties. When used medicinally or spiritually, any component of the plant, including leaves, roots, blossoms, seeds, root bark, inner bark (including cambium), resin, and pericarp, may be referred to as a "herb." The term "herb" is generally used differently when used in culinary and medicinal contexts.

11.3 Climbers

Climbing plants made significant contributors to plant communities because they affect ecosystem processes, habitat heterogeneity, vegetation structural diversity, and ecosystem services including carbon sequestration [16]. Actually, for underground resources like soil, water, and nutrients, trees and climbers compete with one another. Climbers drastically diminish tree survival, fertility, recruitment, and growth by limiting light and subsurface nutrients [17, 18, 19]. Plants classified as climbers have flexible, thin, rapidly developing axes that can be attached to a number of surfaces. They may swiftly reach a forest's uppermost layers while protecting supporting tissues and avoiding slipping or falling [20,21].

Tropical rainforests have an exceptional variety and quantity of climbing plant species, despite the fact that climbing plants are prevalent in both tropical and temperate environments [22, 23 and 24]. There haven't been many researches on them, despite the fact that they are crucial to the ecology of nutrient cycling and forest dynamics and hence define a key tropic level within an ecosystem [24, 25, 26 and 27]. In addition to providing a range of resources and preserving biological diversity, climbers, or lianas, are essential for many aspects of forest functioning, such as pollination patterns, dispersal, and phenological systems [18].

11.4 Multipurpose Tree Species (MPT's)

Multipurpose trees or multifunctional trees are trees that are deliberately grown and managed for more than one output. They may supply food in the form of fruit, nuts, or leaves that can be used as a vegetable; while at the same time supplying some other combination of multiple outputs. "Multipurpose tree" is a term common to agroforestry, particularly when speaking of tropical agroforestry where the tree owner is a subsistence farmer.

Multipurpose trees and shrubs are woody perennials that are intentionally grown to provide a variety of beneficial contributions to the overall functions of the land-use system in which they are planted. These benefits include shelter, shade, and improved land sustainability [28]. Woody perennial plants that are purposely grown to provide multiple significant

contributions to the production and service activities of a land-use system are referred to as multipurpose trees and shrubs [29].

Multipurpose trees have a stronger influence on a farmer's well-being since they satisfy more than one basic human need, even though all trees can be said to serve many purposes, such as habitat, shade, or soil enhancement. When it comes to multipurpose trees, their main function is usually to serve as a windbreak, ally cropping system, or component of a living fence. Besides this, they will play one or more supporting roles, usually providing food or firewood.

A multifunctional tree can serve several purposes and meet multiple needs at once. They can provide the owner with a staple food source and act as a windbreak. They serve as the owner's primary supply of firewood and can also be utilised as fenceposts in a living fence. They can be planted in existing fields as an intercrop to add nitrogen to the soil and provide fuel and food at the same time [30].

11.5 Medicinal and Aromatic Plants (MAP)

Medicinal plants, also called medicinal herbs, have been discovered and used in traditional medicine practices since prehistoric times. Plants synthesize hundreds of chemical compounds for various functions, including defense and protection against insects, fungi, diseases, and herbivorous mammals [31, 32].

Medicinal and aromatic plants are well appreciated for their antioxidant and biotical activities. Nevertheless, there is a great variation in these activities that is related to the species, the environmental/climatic conditions (temperature, UV radiation, and light density), the age of the plant, the cultivation practices applied, and the harvesting period [33].

Cultivation management is essential to balance fundamental parameters for medicinal and aromatic plants (MAPs) such as biomass and the production of high-quality essential oils and extracts, with remarkable properties. Nowadays, there is a growing interest in industry, academia, agriculture, and health sciences in MAPs, due to the significant biological properties of these plants, which are related to the presence of a series of compounds

(phenols, flavonols/flavonoids, alkaloids, polypeptides, vitamins, catechins, phytoestrogens, carotenoids, chlorophyll, minerals, etc.) [33].

Table 1. List of Some Important Tree Species
(Source: https://mahenvis.nic.in/Pdf/Knowledge/Important%20Trees%20Of%20India.pdf)

S. No.	Botanical Name	Common Name	Family	Use
1	*Acacia catechu*	Khair	Fabaceae	Used against the throat infections cough, diarrhoea, chronic ulceration, epistaxis and eruptions of the skin, leprosy, leucoderma and wounds. It is also useful in treating anaemia, diabetes, inflammations and intermittent fever.
2	*Abies pindrow*	Himalayan fir	Pinaceae	An important timber tree in the western Himalayas, where the tree is commonly harvested from the wild and traded. A list of plants under threat and facing possible extinction, usually with brief details of the threats and information on habitat.
3	*Aegle marmelos*	Bel	Rutaceae	Spiritual and Medicinal, one of the constituents of “Dashmoola”. Roots and bark are used to treat melancholia, intermittent feversand palpitation of the heart. Fruit pulp is nutritious and prevents heat stroke. Leaf juice extract is applied externally in abscess.
5	*Alangium salvifolium*	Ankol	Cornaceae	Spiritual and Medicinal. Seed oil used for treatment of other seeds.
6	*Betula utilis*	Bhurja, Bhojpatra	Betulaceae	Considered useful in dyspepsia, diarrhoea, epilepsy, haemophilic conditions and diseases of the ear.
7	*Bowellia serrata*	Salai guggul	Burseraceae	The gum exudate posesses anti-arthritic activity. Used in the treatment of ulcers, cystic breast, piles, skin diseases convulsions, dysentry, bronchitis, asthma, cough, jaundice, diarrhoea and dysentry.

8	*Buchanania cochinchinensis*	Chironji	Anacardiaceae	Rich source of vitamin E. The roots are acrid, astrigent, cooling, depurative & constipating and used in leprosy, skin diseases and diarrhoea. The leaves are reported to be cooling, digestive, expectorant, purgative, and aphrodisiac. The fruits are useful in treating leprosy, skin deases, burning sensation, cardiac debility, abdominal disorders, constipation cough, asthma, seminal weakness, fever, emaciation, ulcers, general debility and as a laxative.
9	*Butea monosperma*	Palash	Fabaceae	Spiritual and Medicinal. Seeds and gum are useful in worm infestation and in the treatment of ringworm, boils and pimples. The bark is used to treat dyspepsia, diarrhoea, dysentry, intestinal worms, bone fractures, rectal diseases, gonorrhoea, ulcers, tumours and diabetes. The leaves are useful in treating pimples, boils, flatulence, colic, worm infestations and inflammations. Flowers are used to treat leprosy, skin diseases and bone fractures. These are considered very efficacious in birth control. It is an excellent source of lac and natural dye.
10	*Canarium stricturn*	Dhup	Burseraceae	Spiritual and Medicinal. Gum is used alon with til (seaamum) oil, in the treatment of rheumatic pains and chronic skin diseases.
11	*Cassia fistula*	Indian Labernum	Fabaceae	Ornamental. The dried fruits have a laxative property and are useful in constipation. An extract from the root bark is used in the treatment of black water fever. Flowers are useful in skin diseases, burning sensation, dry cough and bronchitis.
12	*Cedrus deodara*	Deodar	Pinaceae	Deodar is the most important timber tree providing soft wood. It can be easily worked and it is moderately strong. It possesses distinct annual rings. It is used for making cheap furniture, railway carriages, railway sleepers, packing boxes, and structural work.

13	*Commiphora wightii*	Guggul	Burseraceae	It is reported to be astringent, antiseptic and aphrodisiac. It is also employed for treatment of snake bite and scorpion sting.
14	*Diploknema butyracea*	Cheura	Sapotaceae	Traditionally, different parts of this plant have been utilized by ethnic groups of Nepal and India, mainly for food and medicinal purposes. The butter is also used as massage oil for rheumatism, headache, cracked feet and hands, acne, and boils.
15	*Dalbergia sissoo*	Shisham	Fabaceae	Excellent timber. It is useful as stimulant and appetiser and also in dyspepsia, diarrhoea, leprosy, obesity and worms.
16	*Emblica officinalis*	Amla	Phyllanthaceae	Rich inVit C, antiviral, excellent liver tonic. Fruits are reported to be good for diabetes, cough, asthma, bronchitis, dyspepsia, collic flatulence, peptic ulcers, skin diseases, leprosy, inflammations, diarrhoea, dysentry, cardiac disorders, intermittent fevers and greyness of hair.
17	*Mallotus philipinensis*	Indian Kamla	Euphorbiaceae	Glandular hairs on the fruits, which are reddish brown are reported to be used in constipation, flatulence, wounds, ulcers, cough, renal and vesical calculi, haemorrhages, poisonous affections, scabies, ringworm, herpes and other parasitic skin affections. This red powder is also used as vermillion by women.
18	*Mesua ferrea*	Nag-champa	Calophyllaceae	Spiritual, Ornamental & Medicinal. The flowers are astringent and are useful for asthma, cough, leprosy, vomiting, dysentry, ulcers, burning sensation of the feet, dyspepsia, impotency, fever and cardiac debility. The seed oil is used for skin diseases.
19	*Michelia champaca*	Champa	Magnoliaceae	Aromatic & Medicinal. Flowers are reported to be used in dyspepsia, nausea, fever and also useful as a diuretic in renal diseases. Flower oil used in cephalagia. Bark is a stimulant, diuretic and febrifuge. Dry roots are reported to be used as a purgative and immounogogue.

20	*Mimusops elengi*	Bakul	Sapotaceae	Aromatic & Medicinal. The bark, flowers and fruits are acrid, astringent, cooling and anthelmintic. Bark is reported to be used as a gargle. It is also useful in urethrorrhoea, diarrhoea and dysentery. Flowers are reported to be used for preparing a lotion for wounds and ulcers; powder of dried flowers is considered a brain tonic and is used as a smuff to relieve cephalagia. Unripe fruit is reported to be used as a masticatory help to fix loose teeth. Seeds are used for preparing formulations to treat constipation especially in children.
21	*Nothapodyyates ovata* *(Mappia foetida)*	Narkya	Icacinaeae	Recent research has indentified presence of an antitumour compound, named "Camptothecin", in this species. This could be the reason for its large scale smuggling out of India.
22	*Oroxylon indicum*	Tetu	Bignoniaceae	One of the constituents of "Dashmoola". Roots are reported to be used to treat rheumatism, diarrhoea and dysentery. Seeds are reported to be used as a purgative. The leaves made into a decocotion are reported to be given in stomach ache and rheumatism and are used externally for enlarged spleen. Tender fruits are refreshing and stomachic.
23	*Pongamia pinnata*	Karanj	Fabaceae	Its seed oil is useful as biodiesel and seed cake as excellent manure.
24	*Pterocarpus marsupium*	Bijasal	Fabaceae	It is coarse-grained, durable and strong but difficult to work. Termites (also known as white ant) do not easily attack it. It is used for ordinary building construction and for cart wheels.
25	*Pinus roxburghii*	Chir-Pine	Pinaceae	Pine wood is hard and tough except white pine which is soft. It decays easily if it comes into contact with soil. It is heavy and coarse grained. It is used for pattern making, frames for doors and windows, and for paving material. White pine is light and straight grained and is used in the manufacture of matches.
26	*Pterocarpus*	Rakta	Fabaceae	The heart wood is reported to be used

	santalinus	Chandan		for treating intrinsic haemorrhage, fracture, chronic fever, diarrhhoea, and spider poisoning
27	*Rhododendron arboreum*	Buransh	Ericaceae	The bark and flowers are used to treat digestive and respiratory ailments. - Burans have excellent antioxidant, anti-inflammatory, and anti-diabetic properties making it not just appealing to the eye but potent for health too. - Burans is considered good for heart, liver, diabetes, and is used for treating diarrhea.
28	*Santalum album*	Chandan	Santalaceae	Medicinal & Cosmetic. It`s wood is used to manufacture musical instruments like Guitars and Fengshui products. A paste of the wood and oil are reported to be used for treating burning sensation, skin diseases, cardiac debility, jaundice, cough, bronchitis cystitis, malaria. The bark is used for treatment of dysoeoeia, cystitis (inflammation of bladder), gonorrhea and cough.
29	*Sapindus emarginatus*	Soapnut	Sapindaceae	The roots and are expectorant and demulcent. The roots are good for hysteria and epilepsy. A decoction of the bark is good for cattle suffering from ulcers due to worm infestation after calving. The fruits are good for asthma, diarrhoea, cholera, verminosis and gastralgia due to dyspepsia. Its fruits are natural substitutes for chemical soaps and hair dyes.
30	*Shorea robusta*	Sal	Dipterocarpaceae	Sal is one of the most important sources of hardwood timber in India. The wood is resinous and durable, and is sought-after for construction, although not well suited to planing and polishing. It is used as an astringent in Ayurvedic medicine, burned as incense in Hindu ceremonies, and used to caulk boats and ships.
31	*Saraca asoca*	Sita Ashok	Fabaceae	An evergreen shady tree the bark is reported to be used in treating uterine affections and gynecological problems. The seeds taken with water are supposed to alleviate suppression of

				urine and calculus. The flowers are pounded, mixed in water and are used for treatment of dysentery.
32	*Schrebera swietenioidess*	Ghantifal	Oleaceae	Leaves are reported to be used in treating enlargement of spleen and urinary discharges. Roots reported to be used in leprosy. Bark is used against boils and burns. The fruits are digestive, purgative and stomachic and reportedly useful in flatulence, anorexia, colic anaemia and diabetes.
33	*Syzygium cumini*	Jamun	Myrtaceae	Spiritual, fruits anti-daibetic & liver stimulant
34	*Taxus wallichiana*	Talispatra	Taxaceae	Used in anorexia, rheumatism, cough catarrah. It also checks vomiting and diarrhoea. It is an ingredient of drug formulations used in treatment of haemoptysis, asthma, and bronchitis and as a tonic given after parturition.
35	*Tecomella undulata*	Marwar Teak,	Bignoniaceae	Excellent Timber. It attracts birds.
36	*Terminalia arjuna*	Arjun	Combretaceae	Bark is reported to be a cardiac tonic, used in bilious affections, for sores and as an antidote to poisons. Fresh leaves juice is used against earache.
37	*Terminalia bellirica*	Behada	Combretaceae	The bark is reportedly used in treating anaemia and leucoderma. Fruits are reported to be effective in curing cough, bronchitis, insomnia, dropsy, dyspepsia, flatulence, vomitting, skin diseases, leprosy, fevers, ulcers and general debility. The mature and dry fruit is constipating and is useful in diarrhoea, dysentery and rheumatic swellings.
38	*Terminalia chebula*	Hirda	Combretaceae	The fruits are laxative and reported to be used for treating wounds, ulcers, inflammations, gastropathy, flactulence, jaundice, skin diseases, leprosy, intermittent fever and cardiac disorders. The fruit pulp is used as dentrifice.

39	*Tectona grandis*	Teak (Sagaun)	Lamiaceae	Moderately hard, teak is durable and fire-resistant. It can be easily seasoned and worked. It takes up a good polish and is not attacked by white ants and dry rot. It does not corrode iron fastenings and it shrinks little. It is among the most valuable timber trees of the world and its use is limited to superior work only.
40	*Toona ciliyata*	Toon	Meliaceae	The timber is red in colour, easy to work and very highly valued. It was used extensively for furniture, wood panelling and construction, including shipbuilding, and was referred to as "red gold" by Australian settlers.

Table 2. Medicinal and Aromatic Plants for which sustainable collection can be done from wild in Uttarakhand (Source State Medicinal Plant Board Uttarakhand http://www.smpbuk.org/details.php?pgID=sb_30)

S.No.	Common Name	*Botanical Name*	Family	Habit
1.	Ratti	*Abrus precatorius*	Fabaceae	Climber
2.	BansaVasa	*Adhatoda zeylanica*	Acanthaceae	Herb
3.	Bael	*Aegle marmelos*	Rutaceae	Tree
4.	Satawar	*Asparagus racemosus*	Lilaceae	Herb
5.	Pashanbhed	*Bergenia ciliata*	Saxifragaceae	Herb
6.	Priyangu	*Callicarpa macrophylla*	Verbenaceae	Tree
7.	Amaltas	*Cassia fistula*	Caesalpiniaceae	Tree
8.	Malkanjani	*Celastrus paniculatus*	Celastraceae	Climber
9.	Tejpat	*Cinnamomum tamala*	Lauraceae	Tree
10.	Patha	*Cissampelos pareira*	Menispermaceae	Climber
11.	Amla	*Emblica officinalis*	Euphorbiaceae	Tree
12.	Kapur kachri	*Hedychium spicatum*	Zingiberaceae	Herb
13.	Marorphal	*Helicteres isora*	Sterculiaceae	Shrub
14.	Lajwanti	*Mimosa pudica*	Mimosaceae	Herb
15.	Karipatta	*Murraya koengii*	Rutaceae	Shrub
16.	Gandhpasarni	*Paederia foetida*	Rubiaceae	Climber

17.	Jhula	*Parmelia perlata*	Parmeliaceae	Lichen
18.	Chitrak mool	*Plumbago zeylanica*	Plumbaginaceae	Shrub
19.	Bidarikand	*Pueraria tuberosa*	Fabaceae	Climber
20.	Bhutkesh	*Selinum tenuifolium*	Apiaceae	Herb
21.	Kedarpati	*Skimmia laureola*	Rutaceae	Shrub
22.	Ginjaru	*Stephania glabra*	Menispermaceae	Climber
23.	Gugule	*Tanacetum dolichophyllum*	Asteraceae	Herb
24.	Sarpunkha	*Tephrosia purpurea*	Fabaceae	Tree
25.	Baheda	*Terminalia bellirica*	Combretaceae	Tree
26.	Harad	*Terminalia chebula*	Combretaceae	Tree
27.	Indrayan	*Trichosanthes* spp.	Cucurbitaceae	Climber

Table 3. Medicinal and Aromatic Plants Open for collection from wild in Uttarakhand (Source State Medicinal Plant Board Uttarakhand http://www.smpbuk.org/details.php?pgID=sb_30)

S. No.	Common Name	*Botanical Name*	Family	Habit
1.	Atibala	*Abutilon indicum*	Malvaceae	Shrub
2.	Apamarg/ Latjira	*Achyranthes aspera*	Amaranthaceae	Herb
3.	Neem	*Azadirachta indica*	Meliaceae	Tree
4.	Punarnawa	*Boerhavia diffusa*	Nyctaginaceae	Herb
5.	Aank	*Calatropis procera*	Asclepiadaceae	Shrub
6.	Agyaghas	*Cymbopogon* spp.	Poaceae	Herb
7.	Dhatura	*Datura metel*	Solanaceae	Herb
8.	Bhringraj	*Eclipta alba*	Asteraceae	Herb
9.	Shahatara	*Fumaria indica*	Fumariaceae	Herb
10.	Gurhal phul	*Hibiscus rosa sinensis*	Malvaceae	Shrub
11.	Pudina	*Mentha arnensis*	Lamiaceae	Herb
12.	Kamal phul	*Nelumbium spiciosum*	Nelumbonaceae	Herb
13.	Tulsi	*Ocimum sanctum*	Lamiaceae	Herb
15.	Mungparni	*Phaseolus trilobus*	Fabaceae	Climber
16.	Bhumi amla	*Phyllanthus urinaria*	Euphorbiaceae	Herb
17.	Arandi	*Ricinus communis*	Euphorbiaceae	Shrub
19.	Gulab phul	*Rosa damascena*	Rosaceae	Shrub
20.	Bala	*Sida cordifolia*	Malvaceae	Herb

21.	Makoi	*Solanum nigrum*	Solanaceae	Herb
22.	Mansparni	*Teramnus labialis*	Fabaceae	Climber
23.	Gokharu	*Tribulus terristris*	Zygophyllaceae	Herb

Table: List of some medicinal and aromatic plants restricted for collection from wild in Uttarakhand
(Source State Medicinal Plant Board Uttarakhand http://www.smpbuk.org/details.php?pgID=sb_30)

S. No.	Trade/ Local Name	Botanical Name	Family	Habit
1.	Hattajari/Salam panja	Dactylorhiza hatagirea	Orchidaceae	Herb
2.	Riddhi	Habenaria intermedia	Orchidaceae	Herb
3.	Vriddhi	Habenaria edgeworthii	Orchidaceae	Herb
4.	Kakoli	Fritillaria roylei	Liliaceae	Herb
5.	Chhir kakoli	Lilium polyphyllum	Liliaceae	Herb
6.	Jivak	Malaxis muscifera	Orchidaceae	Herb
7.	Rishibhak	Melaxis cylindrostachya	Orchidaceae	Herb
8.	Salam Mishri	Eulophia dabai	Orchidaceae	Herb
9.	Jatamansi	Nardostachys jatamansi	Vallerinaceae	Herb
10.	Karvi	Gentiana kurroo	Gentianaceae	Herb
11.	Satuva	Paris polyphylla	Liliaceae	Herb
12.	Chirayita	Swertia chirayita	Gentianaceae	Herb
13.	Atis	Aconitum heterophyllum	Ranunculaceae	Herb
14.	Mitha bish	Aconitum balfourii	Ranunculaceae	Herb
15.	Kutki	Picrorhiza kurrooa	Scrophulariaceae	Herb
16.	Genthi	Dioscorea deltoidea	Dioscoreaceae	Climber
17.	Salparni	Desmodium gangeticum	Fabaceae	Herb
18.	Prishnaparni	Uraria picta	Fabaceae	Herb
19.	Bach	Acorus calamus	Araceae	Herb
20.	Giloy	Tinospora cordifolia	Menispermaceae	Climber
21.	Maida	Polygonatum verticillatum	Liliaceae	Herb
22.	Maha Maida	Polygonatum cirrhifolium	Liliaceae	Herb
23.	Dolu Archa	Rheum emodi	Polygonaceae	Herb
24.	Sarpgandha	Rauvolfia serpentina	Apocynaceae	Herb
25.	Kalihari	Gloriosa superba	Liliaceae	Climber
26.	Timru	Zanthoxylum armatum	Rutaceae	Shrub

27.	Van pyaj	Urginea indica	Liliaceae	Herb
28.	Sankhapushpi	Canscora decussate	Gentianaceae	Herb
29.	Manjith	Rubia cordifolia	Rubiaceae	Climber
30.	Balchari	Arnebia benthami	Boraginaceae	Herb
31.	Thuner/ Talispatra	Taxus baccata	Pinaceae	Shrub
32.	Dhup	Jurinea dolomiaea	Asteraceae	Herb
33.	Tagar	Valleriana wallichii	Vallerinaceae	Herb
34.	Choru	Angelica glauca	Apiaceae	Herb

Summary

Communities all throughout the world place a great significance on forest resources like trees herb and shrubs for timber, firewood fodder, medicinally and other multipurpose uses. For the sake of indigenous local communities that depend on these resources for their livelihoods as well as the preservation of environment, we must work towards sustainable collection of this priceless resource over the coming ten years. This new plan would contribute to securing their long-term viability. The final decision-makers in the sustainable use and conservation of biodiversity are the farmers and rural communities that depend on biological resources for their survival and income, despite the fact that government officials and technical experts are frequently regarded as important decision-makers.

Check you progress

Q.1. Differentiate the tree, shrub and herb.

Q 2. What do you understand by the term MPT's?

Q 3. Explain about the MAP's

Q 4. List out some important timber producing trees of India.

Q 5. List out some medicinal and aromatic plants of India.

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Unit 12: Morphological Characters of Some Important Trees

Unit Structure

12.0 Learning Objectives
12.1 Introduction
12.2 Tree Crown and Branches
12.3 Evergreen and Deciduous Trees
12.4 Diameter and Its Measurement
12.4.1 Diameter Measurement
12.5 Leafing, Flowering, Fruiting and Seeding
12.5.1 Leafing
12.5.2 Flowering
12.5.3 Fruiting and seeding
12.6 Exercises
12.6.1 Exercise-1
12.6.1 Exercise-2
Reference

12.0 Learning Objectives

After completing this unit you shall be able to:

- Define Morphological Characters
- Discuss about the Diameter of the trees
- Describe about the crown cover of the tree
- Explain about the leafing, flowering and fruiting

12.1 Introduction

Learners recollect the fifth unit, which covered the morphological characteristics of trees as well as their growth and development. The current unit covered the morphological characteristics such as flowering, fruiting, leafing, crown, diameter, etc., of several important tree species. The following paragraph provides a quick discussion of these characteristics:

12.2 Tree Crown and Branches

The uppermost portion of a tree that is above ground, consisting of the trunk and its branches, leaves, and reproductive organs, is referred to as the tree crown. Depending on the species and development environment, the crown's size and shape might vary significantly.

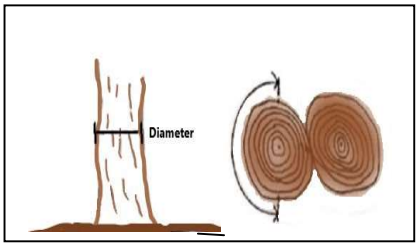
Though the environment has a significant impact on the crown morphology, dicotyledonous trees and conifers establish a branch system to carry the leaves. An elongated cone with a rounded tip that widens and becomes more rounded with age or size is the usual crown outline. The ultimate shape can be umbrella-shaped, spherical, or cylindrical in conifers, or more or less oblong in most other trees. There is a lot of variation in branching patterns and habits, which are unique to each species. Due to the emergence of a few buds out of many, it appears to be fully ad hoc in most trees.

As far as degree of branching from the main branch is concerned, again a lot variation is found from species to species. Trees exposed to severe wind generally have a dense twiggy crown and the internodes are shorter than usual.

12.3 Evergreen and Deciduous Trees

The primary feature between a tree's deciduous or evergreen leaves is its habit. Every year, the deciduous tree loses its leaves for a period of time that varies depending on the species—*Shorea robusta* for a week or ten days, or *Hymenodictyon* for more than six months. For any particular species, the duration also varies significantly based on the climate and growing environment. Thus, in suitable wet and warm environments, Teak and Toon are nearly evergreen. It is not until fresh buds open that the old leaves fall. Sandal wood is one highly special example (*Santalum album*). It is an essential parasite of roots. Depending on the host tree's deciduous or evergreen habits, it can be either evergreen or deciduous.

12.4 Diameter and Its Measurement



Tree species differ in terms of diameter, height, and volume. There are differences between the early and later stages of growth even in a single species.

At first, the primary growth observed is in height, and after this stops, there is an increase in diameter and volume.

12.4.1 Diameter Measurement

A straight line that joins the two ends of a cross section (circular) and passes through its centre is called its diameter. The most significant tree dimension is its cross-section area, which is used to calculate the volume, fuel wood, circumference, basal area, and amount of timber. Tree cross-sections are typically circular, but occasionally they may not be; in these instances, the cross-section is presumed to be round. When a tree's cross section is elliptical, the major (d1) and minor (d2) diameters can be used to calculate the average diameter.

A. **Tree Calliper:** Tree calliper and measuring tape are the two most often used tools for measuring standing tree diameters at breast height (DBH) at 1.37m from tree base). The diameter of fallen trees and stumps can be measured using a wooden scale that is marked in centimeters and millimeters.

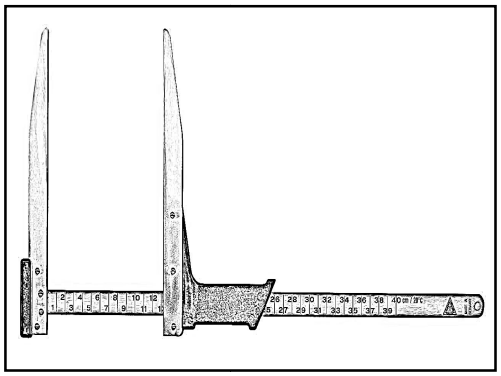


Fig 1: Callipers

B. **Tape:** The measuring tapes come in different lengths and are composed of steel, plastic, reinforced cloth, or cloth. The circumference, or girth, of logs and trees is measured with it. A tree's diameter can be calculated as follows:

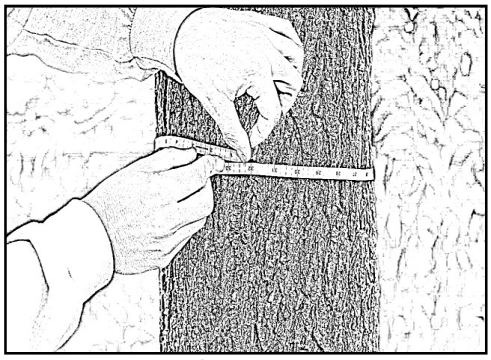


Fig 2: Measurement of girth by using measuring tape

$$\text{Circumference } (C) = \pi \times \text{diameter } (d)$$

or

$$d = C / \pi$$

12.5 Leafing, Flowering, Fruiting and Seeding

It involves the timing and duration of different events at species level, their interrelations and possible causal links between environmental variables[3].These all events such as leaf drop, leafing, flowering, fruiting and seeding of different species all take place in due season. The studies of such events are important to understand the species interactions and community function because each events of each species occurs in its own calendar slot[5]. Seed dispersal cannot occur before fruiting, even if a single flower goes through a series of activities. Fruiting must occur after flowering [1, 2 & 3].

12.5.1 Leafing

In order to identify plants to the family, genus, or species levels, external leaf characters like shape, margin, hairs, the petiole, and the presence of stipules and glands are typically crucial. Scientists have established a terminology for defining leaf characteristics. Physically, leaves nearly always grow in definite patterns. Seasonal variations occur in physical events of leafs like leaf drop and the leafing of various species. They develop into a certain form and pattern. A variety of leaf textures exist as well. Leaf size and form are referred to as leaf texture. The thick, big, and coriaceous leaves leave a dense coating on the forest floor since they break down slowly. Occasionally, such dense foliage can be dangerous, especially if it is flammable.

12.5.2 Flowering

The development of the reproductive structures, or flowering, occurs when the individual reaches the tree stage and continues to mature. Tree species that flower as early as four years of age include *Dalbergia* sp. (Shisham) and *Bauhinia* sp., among others. On the other hand, other species flower only after ten to fifteen years of maturity. In general, trees that grow in open spaces blossom before those that grow in dense forests. In the same way, blossoming period varies. Certain species flower in the winter, while others flower in the summer. Certain species, including Shisham and Sal, flower when fresh leaves appear, while *Terminalia* sp. and Haldu flower when their leaf stocks are sufficient. The coniferous tree species produced needles instead of leaves and cones instead of flowers. Along with species-to-species variations, flowering abundance also differs from year to year. While some years are not ideal seed years, others are. Every fifth year, deodar tends

to have favorable seed years. In bamboo, a particular kind of flowering has been noted. Its blossoming is erratic. Certain species only blossom after a specific number of years. Sporadic flowering occurs when only a portion of the bamboo clumps flower, while gregarious flowering occurs when all of the clumps flower.

12.5.3 Fruiting and seeding

Fruiting and seeding initiates in the trees during the process of fertilization. As soon as these seeds fall to the ground floor and germinate, they produce the regeneration. Specific characteristics include fruiting, seed size, shape, and germination period that differ between species.

12.6 Exercises

Learners now you have the basic knowledge of the different morphological characteristics of the tree. On the basis of this knowledge some field based observational exercises can be done which are as follows:

12.6.1 Exercise-1

Objective: To estimate the diameter of various tree species in a forest by using tree capllier

Field equipment: Tree Calipers, note sheet, data file, pen etc.

Principle: A standing tree's diameter is measured at 1.37 metres above ground, and it is represented by dbh (diameter at breast height).

Measurements: To determine the diameter of, a tree calliper is used to measure the diameter of various individuals at a straight angle, and then the mean diameter is noted and tabulated as follows:

Table X. Diameter (cm) of different tree species.

Species	Number of tree individual										Average diameter (cm)
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	
A											
B											
C											
D											

For each species, the average diameter will be calculated as follows:

Average diameter = sum of diameters of all individuals of a species / total number of individuals of that species.

Conclusion: The average diameter for species A is…, B…, C …. and D….cm.

12.6.1 Exercise-2

Objective: To determine the circumference or girth of various tree species in a forest by using a measuring tape and determine how diameter and circumference are related.

Field equipment: Measuring tape, note sheet, data file, pen etc.

Principle: In general, trees have a round or cylindrical shape. The measurement of the tree's circumference (c) or girth (g) at 1.37 meters above the ground is referred to as the circumference at breast height (cbh) or girth at breast height (gbh). The following represents the relationship between diameter and circumference, or girth:

$$g \text{ or } c = \pi d \text{ or } d = c / \pi$$

$$\pi = 3.1416, d = \text{diameter}$$

Measurements: The Circumference (cbh) or girth (gbh) of different trees is measured by using a measuring tape and tabulated as follows:

Table X2. Girth (cm) of different trees

Species	Number of tree individual										Average (cm)
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	
A											
B											
C											
D											

The following formula is used to determine the average tree girth for each species:

Average tree girth = Sum of girth of all individuals of species / total number of individuals

Conclusion: The average girth for species A is…, B…, C …. and D….cm..

The relationship between girth and diameter is developed as follows:

$$g = \pi d \quad \text{or} \quad d = g / \pi$$

Table X3: Relationship between girth and diameter

Girth (cm.)	Diameter (cm)
1	0.318
10	3.180
100	31.800
1000	318.000

Reference

1. *Singh N, Mittal A. (2018). Response of phenological events of* Aesculus indica *Colebr. to climate change along an altitudinal gradient in Kumaun Himalaya, Uttarakhand.* International Journal of Environment. *8(1):1-16.*
2. *Singh N, Ram J, Tewari A, Yadav R P., (2015). Phenological events along the elevation gradient and effect of climate change of* Rhododendron arboreum *Sm. in Kumaun Himalaya.* Curr Sci. *108(1):106-110.*
3. *Fenner M. (1998). The phenology of growth and reproduction in plants.* Perspectives in Plant Ecology, Evolution and Systematic. *1998; 1(1):78-91.*

Unit 13: Soil Properties

Unit Structure

13.0 Learning Objectives
13.1 Introduction
13.2 Soil and its structure
13.3 Soil Profile
13.4 Soil Texture
13.5 Laboratory Exercises
13.5.1 Exercise 1 (Soil texture)
13.5.2 Exercise 2 (Soil Bulk Density and Porosity)
13.5.3 Exercise 3 (Soil Moisture Content)
13.5.4 Exercise 4 (Soil Water Holding Capacity)
13.5.5 Exercise 5 (Soil pH)
References

13.0 Learning Objectives

After completing this unit you shall be able to:

- Define physical characters of the soil
- Describe about the soil texture
- Know how soil samples can be collected
- Determine the soil physical properties

13.1 Introduction

Learners recall the third unit, which explain about the edaphic factor in detail and different physical and chemical properties of soil were discussed in detail. The current unit explains about the different soil characteristics or properties such as soil profile, soil texture, bulk density, porosity, pH, moisture content, and water holding capacity etc.

13.2 Soil and its structure

Soil provides numerous nutrients that are necessary for all living things to grow and develop, as a vital component of any ecosystem directly or indirectly. In addition, the

substratum of soil is necessary for plants to grow because it allows their roots to pierce it and obtain support and sustenance. Soil properties including the soil's ability to store water, air, and other dissolved chemicals are essential for strong root growth and development.

13.3 Soil Profile

The makeup of the soil as observed in its habitable area in a vertical section is studied as soil profile. This shows various layers / strata of the soil at varying depths. This process of layer / profile formation may be of recent origin; few decades or very ancient say thousands of years. It is chiefly affected by the climate, specific geological up-levels and activities of its biotic communities.

Soil profile is a vertical section of the soil that shows the composition of the soil of an area. Here, different soil strata and layers are displayed at various depths. It could be a few decades old or thousands of years old, depending on how recently this layer/profile formation process began. Climate, certain geological elevations, and the activity of its biotic populations are its main determinants. The soil profile is only few feet deep layer system of varying coloration and sometimes components also. Soil profile is the sequence and nature of the various soil layers (horizons) covered. The soil profile is generally divided in the following five horizons:

O- Horizon	Fresh material
Oi-zone	Un-decomposed matter
Oe-zone	Partly decomposed
A- Horizon	Mineral Soil layer
A 1- zone	Dark & rich with Humus
A 2- zone	Soil Raw Material
B- Horizon	Mineral Strata
C- Horizon	Weathered /broken Rock
R- Horizon	Parent Rock

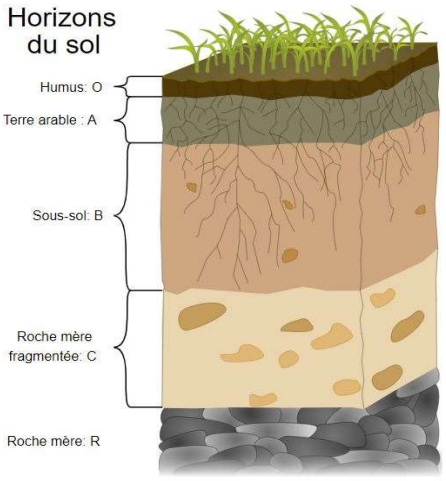


Figure-1. Soil Horizon (Source: https://commons.wikimedia.org/wiki/File:Horizons_du_sol.svg)

O-Horizon consists of the fresh or only partially decomposed organic matter and is highly variable in most of its physico-chemical characteristics. This horizon is very dynamic and full of biotic activities. The O-horizon consists of the following sub divisions:

O-Horizon is made up of fresh organic matter or organic matter that has just partially decomposed. Its physico-chemical properties vary significantly. This horizon is rich in biotic activity and extremely active. The following subcategories make up the O-horizon:

Oi zone: This is the topmost layer and is made up of things like recently fallen leaves, fruits, and dead animals. There is no degraded substance in it.

Oe zone: It is located immediately below the Oi zone, where organic matter has begun to decompose. Therefore, this layer includes biotic communities of tiny insects, fungi, bacteria, and other microorganisms that are vital to the breakdown of organic matter, as well as partially digested organic materials. Hence, debris and duffy materials in varying states of breakdown make up this stratum.

A-Horizon is the topmost layer of minerals and contains a lot of stored organic materials. Additionally, this zone exhibits a downward loss of different soluble salts, clay, iron, and so on. Typically, the bottom layers of this zone have higher concentrations of silica. This layer is sometimes referred to as the layer of downward loss or the zone of eluviations. The following two subzones comprise a further division of this zone:

A1 zone: This layer is rich in organic matter and dark; in this zone, organic matter that is finely split and amorphous mixes with mineral materials. The richest area in humus matter is this one. it is also called "humiclayer" occasionally.

A2 zone: There is typically less organic material in this zone and raw mineral stuff with light colours.

B-Horizon is the soil's mineral strata that are directly below the A Horizon. Along with clay and humus, it is rich in iron, aluminum compounds, and other minerals.

C-Horizon is primarily made up of loosely textured, worn, or decomposed parental rock.

R-Horizon is where that specific soil originated, the parent rock zone.

13.4 Soil Texture

The size, texture, and structure of the soil's elements determine its physical characteristics. Particle size determines texture, whereas the dispersion and aggregation of these particles are responsible for structure. There are many texture classifications based on the proportions of different particle sizes in the soil, including sand, loamy sand, sandy loam, silt loam, silt, clay loam, silt clay loam, sand clay loam, and clay.

13.5 Laboratory Exercises

Learners now you have the basic knowledge of the different soil characteristics or properties. On the basis of this knowledge following basic laboratory exercises can be done to determining the various physical properties of the soil:

13.5.1 Exercise 1 (Soil texture)

Objective: To determine the soil texture of given forest site.

Requirements: A weighing balance, an oven, and various-sized sieves etc.

Principle: Soil texture: It basically determines to assess how different soil properties are influenced by the size of the soil particle. It is the percentage of soil that is made up of sand, silt, and clay in terms of weight. There are many texture classes based on the differing amounts of different sized particles in the soil. e.g. sand, loamy sand, sandy loam, loam, silt loam, silt, clay loam, silt clay loam, sand clay loam and clay.

Table 1: Soil particulates with their size

Particulates	Particle size
Stones and gravels size	More than2.0 mm
Coarse sand	0.2 –2.00 mm
Fine sand	0.02 –0.2 mm
Silt	0.002 –0.02 mm
Clay	<0.002 mm

Methods: Composite soil samples from various forest sites are collected in order to determine the texture of the soil. The samples are bring to the lab in soil sample collection bags. After that, the soil is oven-dried, mix together, and crushed before being weighed and going through various-sized sieves. Particle size is used to classify the texture, and

the percentage of each class is found out. Particles larger than 2.0 mm will be separated from the soil and defined as gravel. The amount of each particle size's percent is determined as follows:

$$\textbf{Proportion of particle size} = \frac{\textbf{Weight od foil in a texture class}}{\textbf{Total weight of soil sample}} \times 100$$

Results: The proportion of various soil particles are given in table 2.

Table 2: Soil texture of the forest

Texture classes	Weight of soil (gm)	Percent (%)
Coarse sand		
Fine sand		
Silt		
Clay		

Conclusion: Depending on the percentage of various soil particles, the soil is ……..

13.5.2 Exercise 2 (Soil Bulk Density and Porosity)

Objective: To determine the soil bulk density and porosity of given forest site.

Requirements: A known-volume metal core, soil sample collection bags, an oven, and a weighing balance etc.

Principles:

Bulk density: It is the amount of soil material dry weight per unit of soil volume. Porosity can be estimated primarily through bulk density measurement. It is expressed in g/cm^3. Bulk density is important for the purpose of determining the chemical characteristics of soil. It can be estimated as:

$$\textbf{Soil Bulk Density } (D) = \frac{\textbf{Dry Weight of Soil}}{\textbf{Volume of Soil}}$$

Porosity: This indicates the volume of soil that is free of solids or the quantity of pore space in a soil. It is essential for determining how organisms and roots are active through the flow of gases and water in the soil. Porosity (P) is determined as:

$$P\ (\%) = \frac{\textbf{Specific Gravity} - \textbf{Bulk Density}}{\textbf{Specific Gravity}} \times 100$$

The specific gravity of soil is about 2.6.

Methods: The methods below are used to determine the bulk density and porosity of the soil. A soil core is used to gather composite soil samples from various forest locations. A known-volume metal tube makes up the soil core. The metal core is used to force the core into the soil, assisting in the extraction of the soil. Soil is taken out and putt in sample collection bags once the core surface has been cleaned. Subsequently, the samples are carried to the laboratory where they are oven dried until they attain a constant weight, and then measurement is done. The volume (V) of soil core is determined as:

$$V = \pi r^2 l$$

Where r = radius, l = length

Results: The bulk density and porosity is estimated as:

$$\textbf{Bulk Density } (D) = \frac{\textbf{Dry weight of soil}}{\textbf{Volume of soil}}$$

$$\textbf{Porosity } P\ (\%) = \frac{\textbf{Specific Gravity } (2.6) - \textbf{Bulk Density}(D)}{\textbf{Specific Gravity } (2.6)} \times 100$$

Conclusion: The bulk density of the forest soil is ….. gm / cm^3 and porosity is …. %.

13.5.3 Exercise 3 (Soil Moisture Content)

Objective: To determine the soil moisture content of given forest site.

Requirements: Soil core extractor, weighing balance, oven, sample collection bags, datasheet and pen etc.

Principle: The amount of water in the soil at any particular time is called its moisture content. It is determined using either dry weight or fresh weight.

Dry weight method:

$$\textit{Moisture content} = \frac{\textbf{Fresh weight} - \textbf{Dry weight}}{\textbf{Dry weight}} X\ 100$$

Fresh weight method:

$$\textit{Moisture content} = \frac{Fresh\ weight - Dry\ weight}{fresh\ weight} X\ 100$$

Methods: The composite soil samples are collected in sample collection bags from different study sites and brought to the laboratory. Then collected soil samples putt into the oven and dried till constant weight is reached and then dry weight is recorded.

Results: The moisture content of the given soil is varied from .....to ..... % in different sites.

Conclusion: The moisture content indicated that the soil is ……

13.5.4 Exercise 4 (Soil Water Holding Capacity)

Objective: To determine the soil water holding capacity of given forest site.

Requirement: Soil collection bags, water-holding sieves, filter paper, petri-dishes, oven, weighing balance, datasheet, pen etc.

Principle: Water holding capacity is the total quantity of water that soil pores can hold, or the volume of water that per unit weight of dry soil can hold. The ability to store water is vital for maintaining the forest's vegetation. Water functions as a solvent to transfer nutrients from plant roots to other components of plant.

Methods: Samples of composite soil were taken from various forest locations and brought to the laboratory in soil collection bags. This soil is crushed, oven-dried, and sieved to a size of 0.5 mm. A standard quality filter paper (Whatman filter paper) is placed in water holding sieves, which is weighed afterward (w_1). After evenly filling the sieves with soil of a given weight, they are put inside the petri dishes. Eventually, the water level is raised in the petri dishes after being added to a depth of one centimeter. After a 24-hour period, the sieves are removed, and weighed (w_2). The sieves are put in the oven and dried, once a stable weight is achieved after that, weighed (w_3). The water absorbed by the filter paper is determined by saturating a few filter papers of similar size with water and then, weighed (w_4). Following is the method used to calculate the forest soil's water-holding capacity:

$$\text{Water holding capacity} = \frac{w2 - w3 - w4}{w3 - w1} \times 100$$

Where
Weight of sieves + dry filter paper = W1 gm.
Weight of sieve + filter paper + wet soil = W2 gm
Weight of sieve + filter paper + oven dry soil = W3 gm
Weight of water absorbed by filter paper = W4 gm

Results & Conclusion: The water holding capacity of the forest soil is …. %.

13.5.5 Exercise 5 (Soil pH)

Objective: To determine the soil pH of given forest site by using pH meter.

Requirements: pH meter, different buffer solutions, beakers, datasheet, pen etc.

Principle: There are free hydroxyl (OH-) and hydrogen (H+) ions in all aqueous solutions. An acidic solution results from an H+ ion concentration greater than that of OH- ions, and a basic solution results from an OH- ion concentration greater than that of H+ ions. H+ and OH- ion concentrations are identical in a neutral solution. The logarithm of the reciprocal of the H+ ion concentration is used to denote it, and it has the symbol pH. A digital pH meter is used to measure the soil sample's pH.

pH meter: pH sensitive glass electrode and reference electrode are the two electrodes that form its basis. A force corresponding to the pH of the solution is produced by those electrodes when they are submerged in an aqueous solution. A pH 7.0, 4.0, or 9.2 buffer solutions are made, and the electrodes are connected to the pH metre. After distilled water wash, darying, and dipping in a 7.0 pH buffer, the electrodes are temperature-controlled to match the solution's temperature. The pH meter shows a value of 7.0. Use the standardize control knob to change the pH to 7.0 if it is not indicated. After being taken out, the electrodes are cleaned, dried, and dipped in pH 4.0 or 9.2. The slope control knob is used to change the meter's display, which shows either 4.0 or 9.2.

Methods: Samples of composite soil are taken from various forest locations and depths. To measure the pH, 20g of soil are dissolved in distilled water and then shaken. The electrodes are then submerged in the soil mixture.

Results: The pH of the soil for different forests and depths is measured and tabulated as following:

Table 2: pH of the forest soils in different layers (depths)

Forest Sites	Surface Layer	Middle Layer	Deep Layer
A			
B			
C			

Conclusion: The soil pH varied from ……. to …… for different depths and forests. Based on the observation acidic soil is at .....site, basic soil is at .....site.

References

[1] *Mishra, R. (1968). Ecology work book. Calcutta: Oxford and IBH Publishing.*

[2] *(Source: https://commons.wikimedia.org/wiki/File:Horizons_du_sol.svg)*

Unit 14: Regeneration Status of Forest

14.0 Learning Objectives
14.1 Introduction
14.2 Exercise – 1
14.3 Exercise – 2
14.4 Exercise – 3
14.5 Exercise – 4
14.6 Exercise – 5
14.7 Exercise – 6

14.0 Learning Objectives

After completing this unit you will be able to:

- Determine the density, frequency, abundance, basal area of a forest
- Calculate the relative values and importance value index (IVI) for a forest
- Determine the mean cbh and dbh of a tree.
- Draw the population structure and determine the regeneration status of a forest

14.1 Introduction

Learners recall the previous units (7, 8 and 9) in which we discussed in detailed the about the Forest regeneration, various kinds of forest regeneration methods and a detailed account of natural regeneration as well as artificial regeneration. We also discussed in detail about natural regeneration from seeds, vegetative parts and coppice and the various factors which affects the regeneration. We have also studied a comparative account of artificial and natural regeneration, advantages and disadvantages of pure versus mixed crop, various kinds of patterns and mixtures. Further we also discussed in detail about preliminary activities needed before artificial regeneration, seed collection, extraction, storage and artificial regeneration by seed sowing and plantation techniques.

The current unit deals with how we can study as well as estimate the regeneration status of any forest. In this unit we discuss in detail about the various ecological exercises in which we learned how to determine the density, frequency, abundance, basal area etc., and on the basis of theses analysis how we can estimate the regeneration of the forests.

14.2 Exercise – 1

Objective: To find out the tree density of a given forest.

Field equipment: Measuring tape, data sheet, pen etc.

Principle: Density is the number of individuals per unit area and expressed as the number of individuals per unit area (eg. Trees/ha or individual/ha) it is calculated as:

$$\textbf{Density} = \frac{\textbf{No. of individuals of a species in all quadrats}}{\textbf{Total number of quadrats studied}}$$

Methods: To find the tree density, choose a forest. Placed ten randomly scatter appropriate-sized quadrats around the forest. The appropriate quadrat size determine through the objects to be measured. For tree vegetation, a 100 m2 (10 x 10 m) quadrat is the ideal size. Determine the number of individuals in each species and record the findings as follows:

Table X1: Number of individuals of a species in different quadrats

Species	Quadrats No.										Total number of Individuals in all quadrats	Density (individual/100 m^2)
	1	2	3	4	5	6	7	8	9	10		
A												
B												
C												
D												
E												
F												
Total												

Calculations: You can calculate the density by using the above formula.

Results: The density of species A is …….. indi./100m^2, B..…. indi./100m^2, C……. indi./100m^2, D…… indi./100m^2, E…… indi./100m^2 and F…… trees/100m^2.

Conclusion: The total density of the given forest is estimated and it is …….. indi./unit area. The species with the highest density individual/unit area is ……. whereas the species with the lowest density of trees/unit area is …..... in the given forest.

14.3 Exercise – 2

Objective: To find out the tree frequency of a given forest.

Field equipment: Measuring tape, data sheet, pen etc.

Principle: The degree of dispersal of a species' within a forest is known as frequency. Certain species are found in small groups, whereas others are found in scattered distributions of individuals**.** Frequency is expressed in terms of per cent value (%) and calculated as:

$$\textbf{Frequency} = \frac{\textbf{Total number quadrats in which species occured}}{\textbf{Total number of quadrats studied}} \textbf{ x 100}$$

Methods: To find the tree frequency, choose a forest. Placed ten randomly scatter appropriate-sized quadrats around the forest. The appropriate quadrat size determine through the objects to be measured. For tree vegetation, a 100 m2 (10 x 10 m) quadrat is the ideal size. It is noted as follows, with the plus (+) or minus (-) indications designating the species' existence or absence, respectively:

Table X2: Presence or occurrence of species in different quadrats.

Species	Quadrats No.										Total number quadrats in which species occurs	Frequency (%)
	1	2	3	4	5	6	7	8	9	10		
A	+	+	+	+	+	+	+	+	+	+		
B	-	-	+	+	+	+	+	+	+	+		
C	+	-	+	-	-	+	+	+	-	-		
D	+	+	-	+	-	+	-	-	+	+		
E	-	+	-	-	-	+	-	-	-	-		
F	+	-	-	-	+	-	+	+	-	+		

Calculations: The frequency can be calculated by using formula described above.

Results: The frequency of species A is …… %, B …….. % , C ……%, D …….%, E ……%. and ……. for F in the forest.

Conclusion: The highest dispersion of individuals is shown by higher frequency, while poorer dispersion of the species is shown by lower frequency. Species ..... shows the highest frequency, whereas the species ……... shows the lowest.

14.4 Exercise – 3

Objective: To estimate the species abundance and A/F ratio in a given forest.

Field equipment: Measuring tape, data sheet, pen etc.

Principle: Generally, abundance is the number of a species' individuals. In actuality, it relates to the population density in the quadrats that a certain species inhabits.

Abundance is simply the number of individuals of a species. It refers actually to the density of population in those quadrats in which a given species occurs. It is expressed as tree per unit area and estimated as:

$$\textbf{Abundance} = \frac{\textbf{Total number of individuals of a species in all quadrats}}{\textbf{Total number quadrats in which species occured}}$$

Methods: Choose a forest for determining the abundance. Placed ten randomly scatter appropriate-sized quadrats around the forest. Count the individuals of each species and noted as follows:

Table X3: Individuals of a species in different quadrats.

Species	Quadrats										Total number of Individuals in all quadrats	Total number quadrats in which species occurs	Abundance (indi./unit area)
	1	2	3	4	5	6	7	8	9	10			
A													
B													
C													
D													
E													
F													

Calculation: You can calculate the abundance by using the above formula.

A/F Ratio: The distribution of various species in the forest is also displayed by calculating the abundance/frequency ratio, or A/F ratio. According to Curtis and Cotton (1956), an A/F ratio of less than 0.025 denotes a regular distribution, 0.025-0.05 a random distribution, and >0.05 a contagious distribution pattern. Table X4 shows the A/F ratio calculated based on the frequency and abundance values above.

Table X4. A/F ratio determined from above frequency and abundance data

Species	Frequency (%)	Abundance (Trees/100m^2)	A/F ratio
A			
B			
C			
D			
E			
F			

Results: The abundance of species A is ……. indi./unit area, B ……. indi./unit area C …… indi./unit …D……. indi./unit area, E …… indi./unit area and F…….. indi./unit area. The A/F ratio of species A is …., B…., C…, D …, E …. and F ….

Conclusion: The species with the maximum abundance is ..... and the ones with the lowest abundance is ……..... The regular distribution is shown by …….. and species ……. shows the random distribution in the given forest.

14.5 Exercise – 4

Objective: To calculate the mean and total basal area of various species of trees within a given forest.

Field equipment: Measuring tape, data sheet, pen etc.

Principle: The cross sectional area of a tree stem at breast height, or 1.37 metres, is known as the basal area. It is considered as an index of dominance.

Basal area is the cross sectional area of the tree stem at breast height (1.37m). It is regarded as an index of dominance. To express the basal area of a tree, use:

$$\textit{Basal Area} = \pi r^2$$

cbh = 2 πr or π d, r = cbh/ 2 π or r = d/2

Where, π = 3.142 and r = radius of a cross section or

By using the cbh, the basal area can be determined directly as:

$$\textit{Basal Area} = \frac{(cbh)^2}{4\pi}$$

The mean basal area can be expressed as cm^2/individual or cm^2/unit area, or m^2 /unit area (multiplying by the conversion factor).

Methods: To find the tree frequency, choose a forest. Placed ten randomly scatter appropriate-sized quadrats around the forest. The appropriate quadrat size determine through the objects to be measured. For tree vegetation, a 100 m2 (10 x 10 m) quadrat is the ideal size. Measure the diameter at breast height (dbh) or the circumference at breast height (cbh) for several individual of a species. In a similar manner, cbh or dbh will be measured for the individuals of other species found in the forest. The values of cbh or dbh are recorded as:

Table X5: Circumference or diameter (cm) at breast height of different individuals of a species:

Species	Cbh (cm) of Individuals										Total cbh or dbh	Average cbh or dbh
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10		
A	130	70	110	140	-	90	80	60	70	100		
B	120	-	90	100	110	70	-	80	90	50		
C	160	-	90	-	-	90	70	-	-	60		
D	90	80	-	110	140	-	100	90	100	90		
E	110	120	70	-	170	-	130	-	-	-		

Calculation: The following formula is used to estimate the mean and total basal area for a species and the forest:

$$\boldsymbol{Basal\ Area = \frac{(cbh)^2}{4\pi}}$$

Total basal area of a species = Mean basal area × density of that species.

Total basal area of a forest = Sum of total basal area of all the species

Results: The mean basal area for species A is …, B…, C…, D…. and E… cm^2/individual and total basal area..... cm^2/unit area respectively.

Conclusion: The total basal area of the various species varied from ……. To ……. cm^2 / unit area.

Total basal area of different species ranged between …….. and …….cm^2 / unit area. The higher …… cm^2/unit area for …….. species and lower value …… cm^2 / unit area is for ……. species. The total basal area of the given forest is …… cm^2/unit area.

14.6 Exercise – 5

Objective: To assess the tree relative density, relative frequency, relative dominance and importance value index (IVI) in a given forest through quadrat method.

Field equipment: Measuring tape, data sheet, pen etc.

Principle: Relative density (RD) is the proportionate density of a species within a forest, while relative frequency (RF) is the distribution of a species in respect to all other species. The ratio of a species' basal area or cover to the total basal area or cover of all species is known as relative dominance, or RDo. The relative values of different vegetation parameters will be estimated or calculated as:

$$\text{Relative Density (RD)} = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Total Frequency of all species}} \times 100$$

$$\text{Relative Dominance (RDo)} = \frac{\text{Basal area of a species}}{\text{Total basal area of all species}} \times 100$$

$$\text{Mean cbh of a species} = \frac{\text{Total cbh of individuals species}}{\text{Total number of individuals}}$$

The relative contribution of a species to the entire forest is measured by its importance value index (IVI). The IVI was described by Curtis and McIntosh (1951) as the total of relative density, relative frequency, and relative dominance as:

$$\text{IVI} = \text{RD} + \text{RF} + \text{RDo}$$

Methods: Select a forest for the determination of relative and importance value of different species. Place the 10 or 20 quadrats of appropriate size (determined with the help of species area curve) randomly in the forest. The number and cbh for individuals of a species is recorded as follows:

Table X6. Circumference at breast height (cbh) of individuals of different species.

Species	Quadrats										Total circumference
	1	2	3	4	5	6	7	8	9	10	
A											
B											
C											
D											
E											
F											

Calculations: Calculate the Mean cbh of a species, Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDo) and then calculate the IVI by using above formula.

Results: The relative values and IVI of different species are tabulated showed in table X7.

Table X7: The relative values and IVI of different species in the given forest.

Species	Relative density	Relative frequency	Relative dominance	IVI
A				
B				
C				
D				
E				
F				

Conclusion: The higher relative density was shown by ……. species and lowest by …… species. The higher relative frequency was shown by ……. species and lowest by …… species. In the given forest, ……..... species is the most dominant, and ……..... species is the least dominating.

14.7 Exercise – 6

Objective: To draw the population structure for different tree species of a given forest through density- diameter or girth distribution.

Field equipment: Measuring tape, thread, ruler, data sheet, pen etc.

Principle: The distribution of individuals of various species across different diameter, girth, or age classes is shown in the population structure. It indicates whether the population is increasing, reducing, or staying the same for a given age, diameter, or girth. There is a correlation between changes in habitat and changes in population structure. The population is shown as the percentage distribution of each species in terms of age, girth class, and diameter. The population structure can be make thorough estimating relative density which is calculated as:

$$\text{Relative Density (RD)} = \frac{\text{Individuals for a species in a girth or diameter class}}{\text{Total number of individual in all girth or diameter class}} \times 100$$

Methods: Select a forest area to study the population dynamics. Various individuals from different species are measured for their diameter or girth. The individuals are divided into three categories: seedlings (less than 10 cm in girth), saplings (10–30 cm in girth), and trees (more than 30 cm in girth). The trees are further divided into classes according to girth or diameter: 30–40, 40–50, 50–60, 60–70, 70–80, 80–90, 90–100, and >100 cm. To

represent the population structure, the girth or diameter classes are plotted on the X-axis and the relative density on the Y-axis.

Calculations: The relative density for each diameter or girth class is calculated by using above formula.

Results: The relative density for each diameter/girth class is tabulated bellow against each diameter/girth classes:

Table X8: Relative density for different girth classes

Species	Girth class(cm)									
	Seedlings <10	Saplings 10-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	>100
A										
B										
C										
D										
E										
F										

Draw the population structure by using the bar diagram on the graph sheet for each species. The forest's regeneration status as well as potential is also assessed using this population structure. The high relative density in seedlings is showed by ....., in sapling by ....., in young trees by ..... and ..... species in old trees.

Conclusion: In general, a higher proportion of seedlings and saplings indicate a growing population, whereas a smaller proportion of young individuals indicate a declining population. They also reveal the forest's regeneration status, indicating whether old growth or regeneration is occurring.

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