

E-Manual

On

Principles of Silviculture, Forest management and Agroforestry (Course Code: FOR-411)

Credits: 3(2+1) M. Sc. Forestry (Silviculture and Agroforestry) IstSemester



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PREFACE

Principles of Silviculture, Forest management and Agroforestry (FOR 411) is a deficiency course for students of PG Forestry, which includes Forest and Forestry, History Of Forestry Development In India, Definition And objectives of silviculture, Natural regeneration of forest, Factor of locality, Tending operation, Plant Succession, Forest Types of India, Forest Management, Definition And Scope, Forest Organization, Sustained Yield, Rotation or Production Period Introduction, Normal Forest, Increment, Concepts of Agroforestry, Classification of Agroforestry Systems, Constraints in Agroforestry, Agroforestry Diagnosis and Design. It has been long felt to develop a manual covering all the aspects of the above-mentioned course which will be very useful for the PG students to understand the various field activities such as produce introduction of forestry, regeneration, Forest management and agroforestry. In developing the material for this manual, authors have relied upon the literature from several sources which is highly acknowledged. The author extends her gratitude to our Hon'ble Vice Chancellor Prof. (Dr.) S.V.S. Raju, for his valuable guidance, encouragement and inspiration for preparation of this e manual. Dr. Sanjeev Kumar Dean CoF, Dr. A.C. Mishra Director of Research, Dr. A.K. Srivastav Director PMEC for their encouragement and help to write this manual. I hope, this manual will meet the requirement of postgraduate students studying Silviculture.

Date:

Authors

DECLARATION

This E-manual on course “**Principles of Silviculture, Forest management and Agroforestry (Course Code: FOR-411)**” is prepared according to the syllabus recommended by the ICAR 19th BSMA report. The course “Principles of Silviculture, Forest management and Agroforestry (Course Code: FOR-411)” is being offered by Department of Silviculture & Agroforestry to the postgraduate students of M.Sc. Forestry degree Programme. This study material is prepared by consulting different text book and reference books, package of practice manuals, online sources such as University websites, e-documents, e-books, e-data and other available off-line sources. The authors do not claim for originality of work. The purpose of this E-Manual is just to provide the study material to students of M.Sc. Forestry degree Programme as reference material for easy and better understanding of the course. This is not meant for the commercial use. The multiplication of this content for commercial activity is prohibited.

Authors

Table of Contents

Units	Chapters	Contents	Page no.
Ist	1.	FOREST AND FORESTRY	1-6
	2.	HISTORY OF FORESTRY DEVELOPMENT IN INDIA	7-9
	3.	DEFINITION AND OBJECTIVES OF SILVICULTURE	10-13
	4.	FACTORS OF LOCALITY	14-22
IInd	1.	NATURAL REGENERATION OF FOREST	23-26
	2.	FOREST TYPES OF INDIA	27-30
	3.	PLANT SUCCESSION	31-34
	4.	TENDING OPERATION	35-39
IIIrd	1.	FOREST MANAGEMENT, DEFINITION AND SCOPE	40-41
	2.	FOREST ORGANISATION	42-44
	3.	SUSTAINED YIELD	45-46
IVth	1.	INCREMENT	47-48
	2.	ROTATION OR PRODUCTION PERIOD INTRODUCTION	49-52
	3.	NORMAL FOREST	53-57
Vth	1.	CONCEPTS OF AGROFORESTRY	58-59
	2.	CLASSIFICATION OF AGROFORESTRY SYSTEMS	61-69
	3.	CONSTRAINTS IN AGROFORESTRY	70-73
	4.	AGROFORESTRY DIAGNOSIS AND DESIGN	74-76

Chapter 1

Forest and Forestry

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.

Forest and Forestry

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. 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.

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.

Functions & Types of Forest in India Function of forests:

Particulars	Functions
Productive	They provide timber, fuel, charcoal, beedi , leaves, wax and resins, fruits, tanning, materials, manure leaves, grass, bamboo, gums, lac etc.
Protective	Forests protect water sheds, catchments of rivers and streams against erosion.
Aesthetic	Forests add good appearance, landscaping and a thrilling atmosphere to the locality.
Recreational	Forest provides picnic resorts and opportunities for sport like hiking, trekking, wild life watching, bird watching.
Scientific	Study of ecological process can be made
Ameliorative	Forests improve climate and reduce pollution
Hygienic	Forests improve the environment and help in reduction of noise, purify the air and give out oxygen to the atmosphere.
Industrial developments	Forest meet the need for raw material for industrial development such as Paper pulp, rayon grade pulp, saw mill ply wood, hard board etc.

Forestry: Forestry has been defined as the theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization of their resources.

Branches of forestry and their interrelationship

Forestry has five different branches:

- 1. Silviculture:** It refers to certain aspects of theory and practices of raising forest 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. Forest Management: Practical application of sequence technique and economics to forest estate for the production of certain desired results .

5. Forest 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) **Non commercial 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. **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:

High forest: forest originated from seeds

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, 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, 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 consist of species other than the principal one.

Other 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 replace 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. Tree Lands: 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.

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.

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) 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 m³ 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. IEA (1998) also estimated that 42% of India 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. 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.

Chapter-2

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. 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, mentioned the 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.

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 neighbouring 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.

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.

National Forest Policy-1988

Even after enunciation of NFP 1952, degradation of forests by overuse didnot 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.

Chapter-3

Definition and objectives of silviculture

Silviculture is the art and science of cultivating forest crops. In broad sense, silviculture includes both silvics and its practical application. According to Toumey and Korstian: Silviculture is defined as “the branch of forestry which deals with the establishment, development, care, and reproduction of stands of Timber”. According to FRI, Dehra Dun: The art and science of cultivating forest crops. Champion and Seth define Silviculture as: The term silviculture, in English, commonly refers only to certain aspects of the theory and practice of raising forest crops.

Silvics: Silvics is the study of life history and general characteristics of forest trees and crops with particular reference to environmental factors as basis for the practice of silviculture. Silviculture can be described to include all practical and theoretical aspects of silvics. The knowledge gathered in silvics is applied to the production and care of forest crops. Thus, the practice of silviculture is applied silvics. The practice of silviculture is concerned with the social as well as the biological aspects of forestry. The important objective of forestry is to make forests useful to society.

Objective of Silviculture: The objective of study and practice of silviculture is to produce more useful and valuable forests to meet our requirements in a shorter time. The study of silviculture helps to attain the following objectives;

1. To produce the species of economic value: The production of timber species of economic value per unit area is low. If the forests have to produce timber of industrial and economic importance, it is necessary to study and practice of silviculture so that we can produce only the desired species.
2. To produce more volume per unit area: In the virgin forest the crop is generally either very dense or very open. Both these extremes are unsuitable for quantitative production. The study and practice of silviculture helps in raising sufficient trees per unit area right from the beginning to fully utilize the soil and as they grow up gradually reduce their number so that the requirement of light and food of the remaining tree is met. In this way silviculture helps to bring the production of more timber per unit area on a sustained basis.
3. To produce high quality timber: In the unmanaged forest because of much competition a large number of trees become crooked, malformed, diseased and defective. Silviculture techniques help to avoid these problems and to produce timber of a very high quality. Thus knowledge of silviculture is essential to ensure disease free timber production.
4. To reduce the rotation period: Rotation is the planned period of time expressed in years between the regeneration of a crop to its final felling. In unmanaged forests rotation tend to be longer because the growth of

individuals' tree is retarded. There is intense competition and it takes the trees a longer time to attain an exploitable size. With the knowledge and practical application of silvicultural techniques density of the crop can be properly regulated and consequently the rate of growth increased and rotation reduced.

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

6. To create of plantation: Plantations may be created in place of natural forest. This can be brought about under conditions where the natural forest has failed to regenerate itself or when the existing forest is too slow growing for exploiting its potential to the optimum extent possible.

7. To introduction of exotics: Knowledge of silviculture is highly beneficial for the successful introduction of exotic species for industrial environmental or related purpose e.g. Eucalyptus, Populus and Teak etc

8. To increase the employment potential: Increased employment potential is clearly one of the objectives of modern silvicultural techniques. In any plantation operation, the labor component accounts for between 60- 70% of the total financial input.

9. To increase the production of fuel and fodder: Silvicultural techniques help to bring about an increase in the production of fuel wood and fodder from the forest both of which are very essential for a developing country like India.

10. To develop forest industries: Silviculture contributes to the development of the industrial potential of a region as forests provide important raw materials e.g. Resin, pulpwood, industrial wood and minor forest products for various forest-based industries.

11. Derive environmental benefits: Silviculture helps to raise forests so that human beings may derive maximum environmental benefits from them such as soil and water conservation, control of air and noise pollution, wild life conservation, regulation of climatic conditions and regulation of water cycle.

Relation of silviculture with forestry and its other branches

Silviculture and Forest Protection Forest protection is defined as that branch of forestry which is concerned with 'the activities directed towards the prevention and control of damage to forests by man, animals, fire, insects, disease or other injurious and destructive agencies'. So while silviculture is concerned with the raising of forest crop, forest protection is concerned with its protection against various sources of damage.

Silviculture and Forest Mensuration

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

Silviculture and Forest Utilization

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

Forest Economics is defined as ‘those aspects of forestry that deal with the forest as a productive asset, subject to economic laws.’ Thus while silviculture is concerned with the cultivation of forest crops, forest economics works out the cost of production in raising the crops to decide whether raising of the crop is economically profitable or not. It is also the function of the Forest Economist to compare the cost of production of a particular crop by different methods and then decide the most profitable method of raising that crop.

Silviculture and Forest Management

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

Silviculture and Forestry

Forestry is defined as ‘the theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization their resources.’ From this definition, it is clear that forestry has a very wide scope and silviculture is only one of its branches. It has the same relation with forestry as agronomy has with agriculture. While agronomy and silviculture deal with cultivation of crops, agriculture and forestry deal not only with the cultivation of crops but also with their protection, management, mensuration, marketing, etc. In short, forestry is an applied science which has many branches, and forestry and its other branches are supported on silviculture without which there would be neither forestry nor its branches.

Forest: The word is derived from the Latin word “Eairs” means “outside” Therefore forests are areas covering practically all uncultivated or untended lands covered with rather tall and dense tree growth.

Silvics and its importance:

- Silvics is the study of life history and general characteristics of forest trees and crops with particular reference to environmental factors, as the basis for the practice of silviculture.
- Thus, Silvics implies the study of the trees and forests as biological units, the laws of their growth and development and the effect of the environment on them. It explains the natural laws of their growth and development and their behavior in a given set of environmental conditions. Though a lot of information on silvics has been collected by experiments, observations and experience of earlier foresters, a lot more information is yet to be collected to explain the unsolved complexities in the lives of trees and crops and the natural laws governing their reproduction, growth and development.
- The knowledge gathered in silvics is applied to the production and care of forest crops. Thus the practice of silviculture is applied silvics. It deals with the procedure of obtaining natural regeneration under the various silvicultural systems, artificial regeneration of various species and methods of tending young crops, whether natural or artificial, to help them to grow into forests of quality timber and great economic value (Khanna, 1999).
- **Importance of silvics/silviculture**
- Production of species of economic value
- Production of large volume per unit area
- Production of quality of timber
- Reduction of rotation
- Raising forest in blank areas
- Creation of manmade forest in place of natural
- Introduction of exotics etc.

FACTORS OF LOCALITY

INTRODUCTION

The trees and other vegetation forming the forest in a place are influenced by the climate, soil, topography and living beings of that place. In other words, the type of forests occurring naturally in a place is not an accidental aggregation of various plants but is the result of the complex influence of the climatic, edaphic, topographic and biotic factors of the locality. So, the factors of locality may be defined as the effective climatic, edaphic, topographic and biotic conditions of a site, which influence the vegetation of the locality. These factors are also referred to as environment which is defined as ‘all biotic and abiotic factors of a site’.

Classification: Factors of locality are classified into following four broad categories:

1. **Climatic Factors**

Climate is defined as the average weather conditions prevalent in any locality. Though it is dependent on various meteorological and weather conditions, the most important are **solar radiation** which gives light and heat both, moisture and wind. Therefore, climatic factors are defined as ‘light, atmospheric temperature, pressure and humidity, wind and other features of climate – regional, local and seasonal – that influence vegetation’.

Thus the climatic factors may be classified as under:

- (a) Solar radiation (i) Light (ii) Heat and temperature
- (b) Moisture
- (c) Wind

Solar radiation: The energy which is responsible for the growth of vegetation and all life depending on it, on the earth comes directly or indirectly from the sun (solar radiation). Thus, the nature and amount of solar radiation received on the surface of the earth is a factor of great importance. Solar radiation provides both light as well as Heat and temperature. Both light and temperature are very important. The short explanation of their importance is given below:

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

- **Chlorophyll formation** :Light is one of the important and essential factors responsible for chlorophyll formation in plants. Light of any wavelength or low intensity is sufficient to form chlorophyll. Without light, plants become pale yellow and have long thin internodes, a condition known as etiolation.
- **Functioning of stomata** – Light is an important factor influencing the daily opening and closing of stomata which, in turn, affects respiration and photosynthesis.

- **Photosynthesis** – Light is the most important factor of locality for photosynthesis as it can not take place in darkness. The light actually used in photosynthesis is a small fraction of the light that falls on a leaf. It has been estimated that light used in photosynthesis is less than 2 % of the light energy incident on well-illuminated leaves.
- **Growth** – Light influences the growth of plants and trees through its effect on photosynthesis. Best growth takes place in moderate intensity of light provided ample food is available. Because extremely high intensity of light increases transpiration excessively and in extremely low intensity of light, the growth is retarded.
- **Form and quality of trees** – The elongation of the growing axes of trees in the forest occurs mainly between sunset and sunrise because the low intensities of light and infra-red radiation tend to stimulate height growth. Height growth is retarded in intense light conditions.
- **Species stratification, and size, color and structure of leaves** – According to the requirement of light, there results in the stratification of species in different canopies. Light also affects the size, color and structure of leaves. The leaves exposed to full light are smaller than those in partial light. The trees growing in deep shade have foliage of darker color. Many forest trees develop different anatomical structure in their leaves in shade as compared to those grown in sun.

(B) TEMPERATURE

Factors affecting temperature: (a) Latitude (b) Altitude (c) Nearness to the sea (d) Direction of wind (e) Forest (f) Ocean current (g) Rainfall (h) Mountains Importance of temperature (Air temperature)

(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, i.e. transpiration, photosynthesis and respiration.

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

(iii) Air temperature increases cambial activity in the shoot portion. Through its effect on the vital physiological activities and cambial activity, air temperature affects growth of trees.

(iv) Temperature is essential for germination of seeds. Soil temperature – Soil temperature influences trees in the following ways:

- Soil temperature has a profound influence on absorption of soil moisture which increases markedly with the rise in temperature up to a certain limit.
- It also affects cambial activity which starts earlier in warmer soils than in colder soils. Thus growth starts earlier in warmer soils than in colder soils.
- Excessively low temperature results in frost and snow which cause injury to trees and forest vegetation.

(C) MOISTURE

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

activities → Water forms about 90 to 95 % constituent part of the cell wall and 80 % part of the protoplasm which is the physical basis of of all life.

- Water occurs in all call vacuoles as cell sap and on it depends the turgidity of the cells, which in turn, governs the growth of plants.
- It is the only medium for absorption of soil minerals and gases in the plants. → It is one of the raw materials required for photosynthesis.
- It is required for translocation of manufactured food as well as for all chemical reactions taking place in plant body.
- It is essential for respiration which can not take place in its absence.
- It is also necessary for transpiration which prevents excessive heating in the plant.
- It is responsible for various movements of plants.
- It is essential for germination and viability of seeds.

(D) WIND:

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

- a. Wind brings fresh supplies of carbon dioxide to the foliage of trees and thus helps in photosynthesis.
- b. Wind helps in pollination of anemophilous flowers.
- c. Wind helps in the dispersal of seed of many forest trees, i.e., Holoptelia, Bombax, Toona, etc.

Harmful effects (a) direct harmful effects

1. Because of the pressure of the wind, the tree in the open in the plains and on the ridges on the hills are short stature and have pronounced taper in their boles.
2. Trees often get bent if wind blows only in one direction.
3. Trees are often uprooted or their stem or branches get damaged.
4. The branches on the windward side get, often, killed and they remain only on the leeward side. This adversely affects the growth on one side.
5. The bole of the tree, often, becomes elliptic, instead of being circular with larger diameter in the direction of the prevailing wind.
6. As a result of strong winds, timber often gets ruptured.

(b) Indirect harmful effects

1. Wind fans up forest fire thereby increasing fire damage.
2. Wind affects the trees through its influence on humidity and dry winds increase transpiration.
3. Winds also increase evaporation from the soil.
4. In dry areas, wind causes wind erosion. It removes the top fertile soil or deposits sand on fertile fields, thereby deteriorating the soil in both cases.

2. Topographic Factors

Topography factors may be defined as factors ‘pertaining to the configuration of land surface, altitude, slope, aspect and exposure’.

Topographic factors may be classified into:

- a) Configuration of land surface
- b) Altitude
- c) Slope
- d) Aspect and exposure

Configuration of land surface - Configuration of land surface influences vegetation through its effect on temperature, wind movement, etc. In a hill and valley country, valleys are generally shaded. Configuration of land surface also affects wind movements. Therefore, hills which experience greater humidity and reduced temperature variation have a climate very different from a plain area with the same mean actual temperature.

Altitude – Altitude affects solar radiation, temperature, rainfall, which, in turn, has a great effect on vegetation. The air at higher altitude is clearer and rarer. So, the solar radiation has to pass through lesser turbid atmosphere at higher altitude than the places with low altitude. Consequently, solar radiation increases with increasing altitude. As the air gets rarer at higher altitude, it is increasingly incapable of absorbing and retaining heat. Consequently, there is fall in temperature with increase in altitude. Generally up to 1500 m, there is a fall of 10 C in the mean temperature with a rise of 270 m in the hills but after 1500 m, fall in temperature is more rapid. Rainfall increases with increase in altitude up to about 1220 m height above mean sea level after which it begins to decrease.

Slope – Slope affects run-off and drainage and thus has a profound influence on the moisture regime of the soil. As a general rule, the steeper the slope, the greater the run-off and better the drainage. Slope also affects erosion as well as depth of soil.

Aspect and exposure - Aspect is defined as ‘the direction towards which a slope faces’. Exposure, on the other hand, is defined as ‘the relation of a site to weather conditions, especially sun and wind’. Thus both of them have the same effect. In Nepal, all southerly aspects are comparatively warmer than the northern slopes. The intensity of light on southern aspects is about 1.6 to 2.3 times higher than that on the northern aspect. So there results in different vegetations on them.

3. Edaphic Factors

Edaphic factors are defined as ‘ecological influences characteristics of the soil brought about by its physical and chemical characteristics’.

Definition of Soil

Soil: It is defined as ‘the uppermost weathered layer of the earth’s crust’ and has the following two sub-divisions.

Forest soil : ‘A portion of earth’ surface which serves as a medium for the sustenance of forest vegetation; it consists of minerals and organic matter, permeated by varying amount of water and air and inhabited by

organisms; it exhibits peculiar characteristics impressed by the physical and chemical action of the roots and forest debris' - Wilde Soil formation:

The factors responsible for soil formation and development are:

- Climate
- Biological agencies including vegetation and animals
- Parent rock
- Topography
- Time

The active factors result in the formation of soil through their effect on a geological process known as 'weathering' which is of two kinds: –

- Physical weathering
- Chemical weathering

(a) PHYSICAL PROPERTIES OF SOIL Physical properties of soil have a profound influence on tree growth because of their effect on the supply of moisture, nutrients and air. They relate to its texture, structure, porosity, etc.

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

Various soil groups:

1. Clay – particles smaller than 0.002 mm.
2. Silt – particles between 0.002 mm and 0.02 mm.
3. Fine sand – particles between 0.02 mm and 0.2 mm.
4. Coarse sand – particles between 0.2 mm and 2.0 mm.
5. Gravel – particles over 2.0 mm.

Depending upon the proportion of soil separates, soils are classified into different soil classes as below:

1. Coarse-textured soils – sand and sandy loams
2. Medium-textured soils – loams and silt loams
3. Fine- textured soils – clays and clayey loams.

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

Importance of soil texture

Moisture relations – Coarse textured soils are easily drained and apt to dry while, on the other hand, fine-textured soils are poorly drained and hold much water on the large surface area.

Nutrient supplies – The percentage of finer particles governs nutrient status of the soil. The fine-textured soils are high in nutrient status; sandy soils, on the other hand, are low in fertility.

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

Root development – Texture of the soil affects root development.

(ii) Soil structure

Soil structure is defined as ‘the arrangement of individual soil particles into aggregates of definite size and shape’.

Various soil structures:

- Single-grained
- Plate-like
- Prism-like
- Block-like
- Sphere-like - Granular - Crumby

Importance of soil structure

- It affects soil moisture and soil air relations.
- It is an indication of nutrient status and activity of micro-organisms in the soil.
- It affects soil erosion. - Crumby structure is least liable to erosion. - Single-grained is most liable to erosion.

(iii) Soil porosity

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

Soil porosity is of two kinds:

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

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

Importance of soil porosity

- It determines the moisture and air relations of the soil.
- It affects the internal drainage and diffusion of soil air.

(b) CHEMICAL PROPERTIES OF SOIL– The chemical laboratory of nature in which various chemical decomposition and synthesis reactions keep on taking place in a hidden manner resulting in varying chemical properties of different soils.

Important chemical properties of soil:

1. Cation Exchange Capacity

- Clay and humus form the inorganic and organic colloidal fraction of the soil. It has the negative charges.
- As the surface of clay and humus particles have negative charge, it has the capacity to absorb cations (positively charged ions) from the soil solution.

- The cations absorbed are Ca, Mg, K, Na and H and the cations exchange takes place when any cation is added.
 - The exchange of cations in the soil takes place in equivalent quantities between cations in the soil solution and those on the surface of clay and humus particles
 - It is the process by which a colloidal fraction of the soil absorbs certain cations from the soil solution and gives up other cations held by it in equivalent quantities.
 - The cations released in equivalent quantities go into the solution and become available for absorption for plants.
- Cation Exchange Capacity (CEC)**
- It is defined as the total capacity of the soil for holding cations.
 - It is usually expressed in terms of milli-equivalent per 100 gms of oven dry soil.
 - An equivalent is that quantity which is chemically equal to one gramme of hydrogen.
 - The number of hydrogen in an equivalent is equal to 6.02×10^{23} .
 - A milli-equivalent CEC of a small quantity of soil means that the soil contains 6.02×10^{20} negatively charged absorption sites.

Importance of knowledge of CEC

- Cation exchange material is a sort of store house in which mineral nutrients are stored.
- CEC determines the rate at which fertilizers may be usefully applied to nursery and plantation soils.
- The strongly absorbed cations favor flocculation and thus improve soil structure.
- So, it helps in proper and complete soil utilization.
- It also helps in the choice of species for successful plantation.

2. Soil Acidity

- Acidity of the soil is due to an excess of hydrogen ions over hydroxyl ions.
- These concentrations of ions are indicated by pH.
- pH value indicates what species would be successful in a particular soil having a particular pH value, i.e. *Shorea robusta* grows best in soils with pH 4.5 to 5.5 and poor quality Sal may grow in soils with pH up to 7.
- *Tectona grandis* occurs best in soils with pH 6.5 to 7.6.
- In barren saline and alkali soils: Eucalyptus hybrid and *Acacia arabica* – up to pH 9.0 *Azadirachta indica*, *Terminalia arjuna* – up to pH 9.8
- pH value affects the availability of nutrients. → Increase in pH results in increased availability of Ca, Mg, Mo and K and decreased supply of Fe and Mn. → Nitrogen is best available when pH is between 6 and 8.

- pH value determines the degree of maturity of soil and the stage of development in plant succession. For example, in humid areas, soil acidity is associated with maturity of soil and climax vegetation, whereas basic soils are indicative of immaturity. But in dry regions, increase in alkalinity is associated with maturity of soil.

4. Biotic Factors

The vegetation of a place is the result of not only the climate, soil and topography of the place but also the community life of living organisms. Biotic factors are defined as ‘the influence of living organisms’.

Influence of biotic factors can be described under the following headings:

- o **Influence of plants**

- o **Influence of insects**

- o **Influence of wild animals**

- o **Influence of man and his animals**

Influence of plants

Besides the healthy competition between trees species there are always some undesirable species affecting the growth of trees of the favored species. The undesirable species may be weeds or other harmful plants. The following are some of the undesirable harmful plants found in the forest:

Parasites – Parasite is defined as ‘an organism that draws a part or whole of its nourishment from another living organism’. They grow on some living plant called host and penetrate their sucking roots, called haustoria, into the host plant. The parasites draw either their whole nourishment from host or only a part of it and on this basis, they are classified into total parasites or partial parasites. Among the total parasites, *Cuscuta reflexa* and *Cassytha filiformis* are common in forest areas. Among the partial parasites, *Viscum*, *Loranthus*, and *Arceuthobium* are the commonest. There is, however, one useful and valuable parasite tree species, *Santalum album*. Sandal wood is a root parasite as contrasted with the above mentioned stem parasites.

Epiphytes – Epiphyte is ‘a plant growing on, but not nourished by another plant’. Epiphytes do not draw food from the plant on which they occur. They only take the help of other plant in getting access to light. Epiphytes commonly found in forests are *Ficus bengalensis*, *F. religiosa*, orchids, etc. The first two sometimes attain such huge sizes that the trees, on which they grow, are completely covered and ultimately killed.

Climbers – Climber is a herbaceous or woody plant that climbs up trees or other support by twining round them or by holding on to them by tendrils, hooks, aerial roots or other attachments’. Climbers depend upon other plants for physical support as they cannot remain erect by themselves. They are very harmful to forest trees. Some of the common climbers are found in the forests are *Dioscorea*, *Mucuna*, *Ipomoea*, *Bauhinia vahlii*, etc.

Abnoxious weeds – One of the most important abnoxious weeds is *Lantana camara* which covers large areas of forests. It colonizes new areas by seed dispersal by birds and once it reaches in an area, it spreads fast. It coppices so well that efforts to eradicate it, have completely failed. It has become a serious obstacle in the natural

regeneration of important species including Sal. Other troublesome weeds are Eupatorium antidysentric and E. adenophorum. Like Lantana, these also adversely affect regeneration and growth of many economically important tree species including Sal.

Fungi - A large number of fungi attack forest trees and their attack, besides reducing quality of timber of trees attacked, sometimes, change the form and structure of forest communities. They cause damping off in seedlings, wood rot and root rot in poles and trees, thereby killing them or at least making the timber altogether useless.

Influence of insects – Insects is an integral part of the environment of forests. While some of them are very useful, others are definitely harmful. One of the most important of such harmful insects is *Hoplocerambix spinicornis*, popularly known as Sal borer. It makes tunnels in the timber of the trees and in case of heavy attack, it kills the trees. *Hapaliamechaeralis* and *Hyblaeapuera* are important defoliator and skeletonizer of teak. Some other harmful insects are *Hypsipyla robusta*, *Hylobius angustus*, *Cosmotrichelaeta*, etc.

Influence of wild animals – Like insects, animals are also an integral part of environment of forests. The animals help in dispersal of seed. They, however, often cause considerable damage to forest crops and make regeneration of certain species practically impossible. For example, excessive increase in the population of cheetals, sambhars and nilgai, has a great adverse effect on Sal regeneration. Porcupines destroy innumerable seedlings of bamboo, khair, and simal every year so much so that, unless the damage is kept under control, they make regeneration of these species absolutely impossible. Monkeys and langurs cause enormous damage to fruits and seeds. They pull out chir seedlings not only in [plantations but also in natural regeneration areas with the result that regeneration operation, often, fail completely on this account. Pigs do considerable damage to Sal, Teak and other species. They are so fond of bamboo rhizomes that they, sometimes, dig up whole plants planted in plantations. Bisons and elephants also do enormous damage to forest crops. Bisons repeatedly browse seedlings and saplings of *Dalbergia latifolia*, *Pterocarpus marsupium* etc. Elephants feed on *Ficus* spp., bamboos, etc. In the temperate coniferous forests, bark of deodar, spruce and blue pine is stripped off by black bears to lick the rising sap and cambium layer beneath the bark. In this way, a number of trees of these species are annually damaged by them.

Influence of man and his animals-

- Deforestation and denudation
- Forest degradation
- Fire
- Lopping
- Removal of dry leaves
- Collection of flowers and fruits
- Grazing etc.

Chapter-1

Natural Regeneration of Forest

Regeneration from seed or vegetative parts may observe in Natural Regeneration. Reforestation of a stand by Natural seedlings.

1) Natural Regeneration from Seed: Successful natural regeneration from seed depends upon Seed production, Seed dissemination, Seed germination, Establishment and seedlings.

a) Seed Production: Seeds are cultured ovules, which contain the embryo. An embryo is a miniature plant consisting of seed leaves (cotyledons) attached to rudimentary stem (hypocotyl) with a growing tip (Plumule) and a root tip (radicle) at the other end. Seed production depends upon various factors such a species, age of tree, site, weather conditions, season of maturity, alternate bearing, attack of pests and diseases and birds.

b) Seed Dissemination: For the continued existence of a species, it is necessary that seeds are carried away from the parent plant, because seeds germinating immediately below the parent tree commonly do not get established. Seed dissemination gives young seedlings a better chance of survival for they are saved to a large extend from competition with the parent plant. The means of dispersal adopted by the seeds of different species vary widely. The four important agencies by which seed dispersal is secured are:

i) Wind, ii) Water, iii) Animals, iv) Explosive mechanism or ejection mechanism in fruit itself.

c) Seed Germination: Germination of seed depends upon several internal and external factors such as Permeability of seed coat, Availability of moisture in seed, Oxygen, Nature of embryo (dormancy), Temperature, Moisture in soil, Oxygen and light.

d) Seedlings Establishment: Successful establishment of newly germinated seedlings in sufficient number as a member of forest crop is undoubtedly, the weakest link in the whole chain of process (a to c) which make up the regeneration of forest crops. The Factors Responsible, for Seedlings Establishment are as: 1)Climate: Light / moisture rainfall / temperature / frost 2) Edaphic - Soil / nutrient / aeration / texture / structure.

II) Natural Regeneration by Coppice and Root Suckers: Coppice : Stool shoots generally arise from the adventitious buds formed between the wood and the bark of the stump and are comparatively short lived than those produced by dormant buds. These shoots are called coppice shoots.

Classification of Coppice Regeneration:

- 1) Seedlings Coppice
- 2) Stool Coppice
- 3) Root collar Shoots
- 4) Pollard Shoots

Natural Regeneration by Root Suckers: Shoots arises from the roots, may occur naturally or artificially.

Regeneration by Artificial Method

The deforestation is still continuing and takes a heavy toll of forest wealth. This not only affects the forests but the wildlife and the whole ecosystem also. Deforestation is on alarmic rate (1.5 million hectare every year).

For carrying out artificial regeneration, there are some preliminary considerations which are urgently needed.

Basic Steps in Artificial Regeneration:

1) Choice of Species:

- i) The choice of species is very important in artificial regeneration. Therefore, before choosing the tree species, the purpose of growing the trees has to be specified.
- ii) Climate and microclimate: The choice of species depends upon the prevailing climatic and micro-climatic conditions.
- iii) Soil requirements: a) Wet soils - *Salix* species, *Populus* species, etc.
b) Water - logged soils, *Eucalyptus robusta*, *E. saligna* etc.
c) Sandy loam - *Albizia procera*, *Acacia nilotica*, *Dalbergia sissoo*, etc.
- iv) Market faciities
- v) Growth rate: Fast growing tree species - *Acacia nilotica* (Babul), *Leucaena leucocephala* (Subabool), *Melia azedarach* (Bakain), *P. deltoides* (Poplar), *Salix* species (Willow)
- vi) Availability of Exotics: In simple it meaning pertains to, not native to the area of question. The exotic can be described as "an organism in an area which is not native of the area but has its origin in some other region. For example, *Eucalyptus* species, *Leucaena leucocephala*, *Robinia pseudacacia*, *Populus deltoides* etc.
- vii) Base of establishment.
- viii) Management objectives. The artificial regeneration depends upon the objectives of management. ix) Site conditions: The site is the complex of physical and biological factors of an area that determine what forest of other vegetation may carry.
- x) Succession: The succession is the gradual replacement of one community by another in the development of vegetation towards a climax.

xi) Cost of growing: This is also very important factor affecting the choice of species.

xii) Availability of seed /propagation material : The seed source should be sound.

2) Choice of Method:

The success of artificial regeneration depends, to a great extent upon the choice of method. There are mainly two methods of this regeneration, viz. i) Sowing and, ii) Planting.

- i) Sowing: Sowing, in the simplest words, is the process of scattering the seeds in a particular place e.g. nursery bed, field etc.
- ii) Planting: Planting is another method of artificial regeneration. However, planting is described as the transferring nursery stock to the planting site as contrasted with transplanting in the nursery. Advantages of Planting:
 - a) More Success, b) Less seed needed c) No damage, d) Cheaper weeding

3) Site Selection: The selection of site is also a crucial factor in artificial regeneration. There are several factors which affect the site preparation. Following are the factors which are essential to carry out the preparation:

- 1) Ground Cover
- 2) Physical Factors: a) Topography, b) Exposure, c) Soil type, d) Erosion hazards, e) Size of treatment area and f) Access
- 3) Preparation requirement: To create a suitable environment for establishment of desirable species.
- 4) Man Power and Equipment: The site selection and preparation methods require good skill and useful equipment.
- 5) External Constraints: a) Legal responsibilities, b) Smoke management guidelines, c) Proximity to sensitive areas and d) The attitude of adjacent farmers / land owners.
- 6) Spatial Arrangement: This is also called as Spacing.

Artificial Regeneration by Vegetative Method:

Planting material besides seeds for e.g. Bare root seedlings, containerized seedlings, cuttings, layering, rhizomes, suckers, offsets, bulbs, corms are also used for vegetative propagation material.

Propagation by Cuttings: Cuttings are of two types, 1. Stem cutting 2. Root cutting

1. Stem Cutting: Very few species response well for this method. The species, which easy to root are suitable for this method of planting. Particularly species of di-cotyledons group having active cambium layer e.g. Shisam, Nimbara Drumstick, Mulberry Inga dulcis, Dhaman, Pangara, Pimpal, and Banyan Tree etc. Depending upon the maturity of stem cutting are grouped into:

- i) Hard Wood Cutting: Mature woody branches are used.
- ii) Soft Wood Cutting: Recently mature branches are used e.g. mulberry-Inga dulcis.

iii) Root-cutting: Roots are used for preparation of cutting e.g. Sandalwood, Pangara.

2. Stumps: In few species, stumps are used for planting e.g. Teak, Shivan, Shisam, Cassia spp. Stumps are easy to transport, require less space and can be transported to long distance. These are prepared at the time of planting operation or just before planting operation. Fresh uprooted seedlings are used to transplant easily. 20% stem portion and 80% taproot is kept while preparing the stump. Fine edge knife or implement is to be used so as to avoid the damage, stem portion is cut 5 to 6 cm above the collar region is kept intact and remaining portion or roots are cut to prepare stump. The stumps are then packed in bundles, keeping stem portion on one side and roots on another side, the stumps should be transported immediately. For transportation stumps are covered with moist gunny bag cloth to avoid desiccation. They can be transported within 2-3 days without much loss. These stumps are planted on start of monsoon after 3-4 rain showers when soil becomes sufficiently moist and soil temperatures are warm. Stumps are planted by preparing small holes in slating portion with the help of crowbar so that new shoot will rise straight. Then the stumps are inserted inside and soil is pressed firmly so as to avoid water stagnation in the hole. The cooler region is kept just near to the soil surface.

3. Root Suckers: Root suckers can also be used for planting purpose e.g. Pomegranate, Kokum, Salaim Anjan, Shisam, Nimbara, Pangara, Erythrona etc. The layers, grafted plants, budded plants can be used to prepare planting material. These all are only used in forestry for conservation of superior genotype. It is used for commercial plantation as they are short lived, spreading and not develop long straight (trunk), particularly suitable for timber purpose. Planting by root cuttings in sandal wood, pangara. Planting by root suckers e.g. Pala, Anjan, Pomegranate, Kokum, Salai, Shisam, Nimbara, Erythrina Supersa.

Chapter-2

Forest types of India

The forest vegetation of India was categorized by HG Champion and SK Seth in 1968 in to 16 major groups and 221 types and sub types. The major groups have been given under:

1. Tropical Wet Evergreen Forests

- **Characteristics:**

- Found in areas with high rainfall (>200 cm) and short dry seasons, Dense, multi-layered canopy with evergreen trees., High biodiversity.

- **Location:**

- Western Ghats, Andaman & Nicobar Islands, northeastern states.

- **Key Species:**

- Rosewood (*Dalbergia latifolia*), Mahogany (*Swietenia macrophylla*), Dipterocarps (*Dipterocarpus* spp.).

2. Tropical Semi-Evergreen Forests

- **Characteristics:**

- Transition between evergreen and moist deciduous forests.
- Trees are partly evergreen, with some species shedding leaves in dry seasons.

- **Location:**

- Western Ghats, Odisha, northeastern states.

- **Key Species:**

- White cedar (*Dysoxylum* spp.), Terminalia spp., and bamboos.

3. Tropical Moist Deciduous Forests

- **Characteristics:**

- Receive moderate rainfall (100–200 cm).
- Trees shed leaves during dry seasons.
- Dominated by commercially valuable hardwood species.

- **Location:**

- Central India, Eastern Ghats, lower slopes of the Himalayas.

- **Key Species:**

- Teak (*Tectona grandis*), Sal (*Shorea robusta*), and Mango (*Mangifera indica*).

4. Tropical littoral and Swamp Forests

- **Characteristics:**

- Found in coastal and swampy areas, Salt-tolerant vegetation (mangroves)., Critical for coastal protection and fish habitats.

- **Location:**

- Sundarbans (West Bengal), Andaman & Nicobar Islands, deltas of Godavari, Mahanadi.

- **Key Species:**

- Mangroves (*Rhizophora*, *Avicennia*, *Sonneratia*), Sundari (*Heritiera fomes*).
- Fresh water swamp Arjun (*Terminalia arjuna*), Jamun (*Syzygiumcumini*) Makhi (*Phyllanthus reticulatus*)

5. Tropical Dry Deciduous Forests

- **Characteristics:**

- Receive 50–100 cm of rainfall.
- Trees shed leaves during prolonged dry seasons.
- Open canopy with grassy undergrowth.

- **Location:**

- Deccan Plateau, Gangetic Plains.

- **Key Species:**

- Teak (*Tectona grandis*), Babul (*Acacia nilotica*), Palash (*Butea monosperma*).

6. Tropical Thorn Forests

- **Characteristics:**

- Found in arid and semi-arid regions (<50 cm rainfall).
- Open forests with thorny shrubs and drought-resistant species.

- **Location:**

- Rajasthan, Gujarat, southern Punjab, Haryana.

- **Key Species:**

- Khejri (*Prosopis cineraria*), Acacia spp., Euphorbias.

7. Sub-Tropical Broad-Leaved Hill Forests

- **Characteristics:**

- Found in warm, moist areas in lower Himalayan ranges.
- Mixed species with broad-leaved trees.

- **Location:**

- Khasi, Garo, and Jaintia hills (northeast), Shivaliks.

- **Key Species:**

- Oak (*Quercus* spp.), Rhododendron spp., Magnolia spp.

8. Sub-Tropical Pine Forests

- **Characteristics:**

- Dominated by coniferous species.
- Found at elevations of 1000–2000 meters.

- **Location:**

- Western and Central Himalayas (Uttarakhand, Himachal Pradesh).

- **Key Species:**

- Chir pine (*Pinus roxburghii*), Blue pine (*Pinus wallichiana*).

9. Sub-Tropical Dry Evergreen Forests

- **Characteristics:**

- Found in semi-arid regions with low rainfall.
- Small-leaved evergreen species.

- **Location:**

- Eastern slopes of the Western Ghats, southern Andhra Pradesh, Tamil Nadu.

- **Key Species:**

- Olive (*Olea* spp.), Eugenia spp.

10. Montane Wet Temperate Forests

- **Characteristics:**

- Found at higher altitudes (1800–3000 m) in areas with heavy rainfall.
- Evergreen broad-leaved trees and moss-covered ground.

- **Location:**

- Eastern Himalayas, Nilgiris.

- **Key Species:**

- Oak (*Quercus lamellosa*), Rhododendrons, Magnolia spp.

11. Himalayan Moist Temperate Forests

- **Characteristics:**

- Mixed coniferous and broad-leaved trees.
- Found at altitudes of 1500–3000 meters.

- **Location:**

- Western and Central Himalayas.

- **Key Species:**

- Deodar (*Cedrus deodara*), Silver fir (*Abies pindrow*), Spruce (*Picea smithiana*).

12. Himalayan Dry Temperate Forests

- **Characteristics:**

- Open forests with xerophytic vegetation.
- Found in drier areas of the Himalayas.

- **Location:**

- Ladakh, Lahaul-Spiti, Zaskar.

- **Key Species:**

- Chilgoza pine (*Pinus gerardiana*), Junipers (*Juniperus* spp.).

13. Sub-Alpine Forests

- **Characteristics:**

- Found at the tree line in the Himalayas (3000–4000 m).
- Transition between temperate forests and alpine meadows.

- **Location:**

- Higher reaches of Uttarakhand, Himachal Pradesh, Sikkim.

- **Key Species:**

- Birch (*Betula utilis*), Rhododendrons, Junipers.

14. Alpine Forests and Grasslands

- **Characteristics:**

- Sparse vegetation with shrubs and grasses.
- Found above 4000 meters, beyond the tree line.

- **Location:**

- Himalayan regions of Jammu & Kashmir, Sikkim.

- **Key Species:**

- Mosses, lichens, sedges (*Carex* spp.), shrubs (*Rhododendron* spp.).

15. Moist Alpine Scrub

- **Characteristics:**

- Dense shrubs and small trees in moist alpine zones.

- **Location:**

- Eastern Himalayan slopes.

- **Key Species:**

- Rhododendrons, Junipers.

16. Dry Alpine Scrub

- **Characteristics:**

- Xerophytic shrubs adapted to cold, dry conditions.

- **Location:**

- Ladakh, western Himalayas.

- **Key Species:**

- Artemisia spp., Caragana spp.

Importance of Forest Types in India

1. **Ecological Value:** Maintain biodiversity, soil conservation, and water regulation.
2. **Economic Value:** Timber, non-timber forest products, and livelihood for forest-dependent communities.
3. **Climate Regulation:** Carbon sequestration and temperature regulation.
4. **Cultural Value:** Sacred groves and traditional practices linked to forests

Chapter-3

PLANT SUCCESSION

Plant succession, defined as the gradual replacement of one community by another in the development of vegetation towards a climax which is the culmination stage in plant succession for a given environment. The plant communities involved in the succession before the climax is reached are called 'seres'.

Evolution of the concept of plant succession

The concept of plant succession has been developed during the last century by various authors. It was Thoreau who, first, used the term 'forest succession'. It was, however, Clements who developed the idea and elaborated the theory of plant succession in 1916. So, it is the Clements' theory of plant succession that is widely accepted.

Basic features of the concept of plant succession

- There is a continual change in the vegetation as result of interaction of plant community and the habitat factors;
- The succession is progressive and the end product is the climax; and
- The succession is the progressive development of vegetation on the same site in course of time.

Kinds of succession

(a) On the basis of moisture conditions of the place, succession is classified into:

1. Xerarch succession – It is defined as 'the succession initiated in extremely dry situation such as bare rock, wind blown sand, rocky slopes, etc.
2. Hydrarch succession – It is defined as 'the succession beginning in water, or very wet land as in ponds, lakes, marshes, etc.

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

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

2. Secondary succession - It is defined as the succession which takes place on site 'after the destruction of the whole or part of the original vegetation'. This succession is, sometimes, termed as allogenic succession as it takes place due to allogenic factors, such as clearing, burning, grazing, storm, erosion, deposition, landslide, etc.

The following are some typical examples of primary Succession:

(i) Riverain succession in the Terai

The various stages of this succession leading to the establishment of a Sal forest are given below:

1. *Saccharum spontaneum, Tamarix dioica*
2. *Acacia catechu, Dalbergia sissoo*
3. *Acacia catechu, Holoptelia, Adina cordifolia, Albizzia procera*
4. *Holoptelia, Adina cordifolia, Lagerstroemia parviflora, Bombax ceiba, Terminalia belerica.*
5. *Adina cordifolia, Lagerstroemia parviflora, Terminalias, Shorea robusta.*
6. *Shorea robusta, Lagerstroemia, Terminalias, Adina cordifolia.*

(ii) Coniferous Succession

1. Shrub associations
2. *Pinus wallichiana*
3. Mixed forest of deodar, spruce and blue pine.
4. Mixed forest of spruce, fir and deodar.

Causes of succession

(i) Initial causes –

These are the causes which provide the basis for succession to take place. Thus, in case of primary succession they are responsible for creation of a new soil, while in case of secondary succession, they are responsible for making the soil bare.

Initial causes of primary succession

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

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

Elevation and subsidence – Seismic disturbances result in elevation and subsidence of the soil resulting in the formation of new soils. Similarly, geological disturbances in the Himalayas result in the formation of new soil for primary succession.

Initial causes of secondary succession

Climate – Climate is the initial cause when the vegetation is destroyed by the action of drought, wind, snow or frost.

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

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

(ii) Continuing causes

Migration – Mass movement of plants from one place to another is called migration. It begins when germule (spore, seed, fruit or plant) leaves the parent area and reaches the final resting place. This depends upon the degree of mobility of their seeds, nearness of the parent area, topography, etc.

Ecesis or establishment – The whole process whereby a plant establishes itself in a new area from its germination to reproduction whether sexual or asexual. Establishment of species on a new area can only be accomplished when seeds germinate and it depends on the condition of seed and site.

Grouping and aggregation – The colonizers invade new areas gradually. The first immigrants after establishment grow while more migration keeps on taking place. Thus, in course of time, the colonizers make a closed canopy.

Competition – As soon as the crowns of the colonizers start touching each other, competition starts between them for the limited food and water in the soil and for light. Competition is usually very intense between the individuals of the same species as their demands are similar. As a result of this competition, the weaklings are left behind in the struggle for existence.

Reaction – The effect of vegetation on site is called reaction, which can be grouped into two classes:

(i) Effect on climatic factors

- Altering the light conditions
- Decreasing the day air temp. and reducing the diurnal range
- Reducing the wind velocity
- Reducing the danger of radiation frost
- Increasing the relative humidity

(ii) Effect on soil

- Addition of organic matter
- Improving the structure of the soil
- Improving moisture receptivity of the soil
- Improving nutrient status of the soil
- Improvement of the stability of the soil
- Development of maturity of the soil

Concept of climax

If the succession is allowed to progress without disturbance, a stage is reached when no more improvement is possible in the soil and the vegetation. At that stage, the vegetation is in equilibrium with the environment, and stays unchanged indefinitely by reproducing itself. Thus climax is the culmination stage in plant succession for a given environment. Clements believed that the most dominant community-forming factor was climate and, therefore, he called it **Climatic Climax**.

Classification of climax

Climatic climax – It is the climax which owes its distinctive characters to climatic factor in conjunction with only such biotic influence as plants and animals naturally occurring in the area bring about.

Edaphic climax - Edaphic climax is defined as 'a community which differs from the climatic factors of the area owing to the influence of special soil factors'. In other words, within the general climatic climax, there may be characteristics vegetation locally due to the influence of soil peculiarities. *Terminalia tomentosa* forest in the moist deciduous forest is an example.

Preclimax –Preclimax is 'the plant community immediately preceding in seral development of the climatic climax of the region and found under conditions drier than are usual in the climate of the region. For example: Chir pine on the ridges in sub-tropical broad-leaved forest.

Post climax - Post climax is 'a plant community more exacting than the climatic climax of a given region and found under exceptionally favorable site conditions within that region'. It actually occurs on sites very much moisture than the normal sites in that climatic region. Presence of evergreen and semi-evergreen species in Sal forest is an example.

Biotic climax or sub climax – A climax which differs from the climatic climax of the area owing to the action of biotic factors. It is a vegetation whose development towards climatic climax has been arrested at some stage of the normal climax by the action of certain factors, natural or artificial, other than the climate and which is more or less stable under the prevailing conditions. Grassy riverain sub climax is an example of this climax. Since this vegetation is stable under the influence of biotic factors, it is called biotic climax or sub climax.

Chapter-4

Tending operation

Concept and definitions

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).

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.

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

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. 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.

Salvage cuttings

It 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**".

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. However, with passage of time growth and development of individuals in horizontal and vertical direction results into intense competition among the same species. 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

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

Objectives of thinning

- 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

Types or methods of Thinning

The methods of thinning are as follows:

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

Mechanical thinning

It 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.

Low thinning method

Low thinning 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

This method of thinning 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 favourable conditions of light and space, thus, opportunity for continuous and rapid growth and development. This is characteristic feature of crown thinning method.

The selection thinning

It 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.

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 silviculturist in naturally regenerated or artificially regenerated forest crops. 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.

Girdling

Girdling, also called ring-barking, is the circumferential removal or injury of the bark (consisting of cork cambium or "phellogen", phloem, cambium and sometimes also the xylem) of a branch or trunk of a woody plant. Girdling prevents the tree from sending nutrients from its foliage to its roots, resulting in the death of the tree over time, and it can also prevent flow of nutrients in the other direction depending on how much of the xylem is removed. A branch completely girdled will fail; and, when the main trunk of a tree is girdled, the entire tree will die if it cannot regrow from above to bridge the wound. Human practices of girdling include forestry, horticulture, and vandalism. Foresters use the practice of girdling to thin forests.

Chapter-1**FOREST MANAGEMENT****DEFINITION AND SCOPE:**

Forest Management is defined in the Glossary of Technical Terms as the practical application of the scientific, technical and economic principles of forestry (BCFT). The term is variously defined by different authors, embodying, in essence, the same essential ingredients. Some of these are reproduced below:

- (i) “Forest Management is that branch of forestry whose function is the organization of a forest property of management and maintenance, by ordering in time and places the various operations necessary for the conservation, protection and improvement of the forest on the one hand, and the controlled harvesting of the forest on the other.”
- (ii) “Forest Management is the application of business methods and technical forestry principles to the operation of a forest property” (SAF)

Management of forests broadly involves three main tasks viz,

- (i) Control of composition and structure of the growing stock,
- (ii) Harvesting and marketing of forest produce, and
- (iii) Administration of forest property and personnel.

Scope of Forest Management:

Management of Forests, as that of any other enterprise, involves a process of making and implementing policy decisions to achieve the objectives of the owner. These decisions involve, in turn, a plan of action. Planning is the responsibility of the States and the Centre in case of State-owned forests, broad principles for which are embodied in the National and the State Forest Policies. Detailed plans are prepared by Forest Managers at the professional level, and executed by the technician level staff. Forest Manager has to constantly manage the growing stock to achieve given objects of management; in this process he has to decide: ‘how much, when where and how to cut.’

Scope of Forest Management is very extensive; it encompasses broadly, the following main activities:

- A. Control of Growing Stock, its Structure and Composition:
 - i. Site adaptation
 - ii. Choice of species
 - iii. Manipulation of stands

- iv. Harvesting the produce
- v. Regeneration
- vi. Protection.

B. Distribution and Marketing of produce:

- i. Transportation and communication.
- ii. logging Plan
- iii. Marketing data
- iv. Sale of produce
- v. Revenue

C. Administration of Forest Property:

- i. Forest organization
- ii. Management of Personnel
- iii. Monitoring and control or works
- iv. Labour management and welfare
- v. Financial control and economy efficiency
- vi. Fulfillment of social obligations
- vii. Record for present and future reference.

MANAGEMENT OF PRIVATE FORESTS VIS – A – VIS PUBLIC FORESTS:

A private owner of a small forest estate seldom looks beyond the immediate gains from sales of trees, as and when required to meet his financial obligations, or when the market rates are high. He is not much concerned with sustained production for the posterity or for the indirect benefits which the forest bestows. However, there are some exceptions; some of the princely States protected and conserved their forest estates zealously, though mainly for wild life and shikar. Now with the abolition of Zamindari and merger of the princely States, most of the Indian forests (95.8%) are under the State ownership which have to be managed not only for production of tangible or the material products alone, e.g., wood (timber and industrial raw material) and a host of minor forest products but also for the intangible services – protective, regulative and sociocultural.

Chapter-2

FOREST ORGANISATION

FORESTS are classified into various categories for purposes of description, administration, management and record. These subdivisions are:

- (i) Geographical & Climatic (or Ecological)
- (ii) Functional
- (iii) Legal (or Statutory)
- (iv) Territorial
- (v) Administrative (or Organizational) and
- (vi) Management (or Silvicultural)

TERRITORIAL CLASSIFICATION:

For executive and protective works, forests are divided into Blocks, Compartments and Sub-Compartments.

Block:

It is a main territorial division of the forest, generally bounded by natural features and bearing a local proper name. Each block has a clear-cut boundary all round it with numbered pillars.

Compartment:

A block is divided into several compartments which are territorial Units of a forest permanently defined for purposes of administration and record (preferably designated by Arabic numerals 1, 2, 3, etc.). It is the smallest permanent Working Plan unit of management, location of works and record; as such, its boundaries are carefully chosen on the ground and marked on the map. Compartments can be quite small, whatever the Silvicultural System adopted. As far as possible a compartment should be homogeneous throughout its extent as regards soil, aspect and composition of growing stock. In protection and Selection forests, working intensity is light and compartments are usually large in size.

Sub-Compartment:

If a compartment does not carry one forest type uniformly, and is not suitable for a uniform descriptive inventory and treatment, it may be temporarily, or permanently, divided into sub-compartments, which then form the Silvicultural Units of management. A Sub-Compartment is defined as: a sub-division of a compartment, generally (but not necessarily) of a temporary nature, differentiated for special description and silvicultural treatment (preferable designated by small letters, a, b, c, etc.). The sub-division may be revoked when the crops have been brought into a condition when they do not require different treatments.

ADMINISTRATIVE (ORGANISATIONAL) CLASSIFICATION:

At the Central Government level, all Govt. owned forests in the Union Territories are under the control of the Govt. of India, and administered on their behalf by the Inspector General of Forests, India (I.G.F), with head quarters at Delhi. He is assisted by an Additional Inspector General of Forests (Addl. I.G.F.), a number of

Deputy Inspectors General (D.I.Gs.) And Assistant Inspectors General (A.I.Gs.) of Forests, incharge of various wings or special works, such as General Administration, Wild Life, Central Forestry Commission, Forest Industries, Social Forestry, etc. He is currently, ex-officio Special Secretary to the Govt. of India in the Ministry of Environment & Forests, and is technical advisor on forestry matters to all the State Governments as well. The Govt. owned forests in the States are under the control of the respective State Governments. Summing up, hierarchy of the State Forest Department is, generally, of the following pattern

S.No.	Administrative Units	Officer Incharge
1.	State Forest Department	C.C.F.
2.	Circle	C.F.
3.	Forest Division D.F.O.	(D.C.F.)
4.	Forest Sub-Division	Sub-D.C.O. / S.D.P. (A.C.F.)
5.	Range	R.F.O. / R.O. (F.R., or D.R)
6.	Sub-Range, Section or Block	Sub Range Officer; S.O. or B.O. (D.R or Forester)
7.	Beat	Beat Officer (Forest Guard)

MANAGEMENT (SILVICULTURAL) CLASSIFICATION:

From the point of view of Silvicultural management, forests are classified into:

1. **Working Circle:** The units of forest management are a Working Plan, usually covering an area of a Forest Division. As already defined, Working Plan is a written Scheme of management aiming at continuity of policy and action and controlling the treatment of the forest. Since the entire Working Plan area is usually large and heterogeneous in site conditions and crop composition, different silvicultural treatments may have to be given in different parts of the Working Plan area and different working rules, called prescriptions, drawn up for different parts. Such parts are known as Working Circles (W.C); a W.C. may be defined as: a forest area (forming the whole or part of a Working Plan area) organized with a particular object and subject to one and the same silvicultural system and the same set of Working Plan prescriptions. In certain circumstances Working Circles may overlap. (BCFT).

Felling Series: If isis considered undesirable for silvicultural, social or economic reasons to concentrate fellings in any one place, e.g., if it is desired to provide a sustained yield of forest produce to one or more markets, or to distribute works of all kinds over one or more ranges, a W.C. may by divided into Felling Series (F.S.). A F.S is defined as: a forest area forming the whole or part of a Working Circle and delimited so as: (i) to distribute felling and regeneration to suit local conditions and (ii) to maintain or create rately for each F.S. which should

have an independent representation of age-classes (BCFT Modif.). Each F.S. is a self-contained unit of management with a separate calculation of yield and a separate series of silvicultural operations. Divisions of a W.C. into several F.S. enables effective control and distribution of work in different ranges. When a W.C. is not divided it is, of course, one Felling Series.

Coupe: In clear-felling system, a F.S (or W.C., if undivided) is divided into a number of Annual Coupes (annual felling areas), equal to the number of years in the rotation, say R, size of each coupe being equal to the area of the F.S (or W.C., as the case may be), say A hectares divided by R, i.e. A/R hectares. Each F.S. will have all the R age-gradations.

Cutting Section: Sometimes it may be desirable to avoid fellings in contiguous coupes in successive years for silvicultural considerations, such as danger from fire and / or insect attack. In such cases, a F.S. is sub-divided into a number of Cutting Sections; a Cutting Section being defined as: a sub-division of a F.S formed with the object of regulating cuttings in some special manner: a planned separation of fellings in successive years.

PERIODIC BLOCKS: FELLING SERIES IN UNIFORM SYSTEM:

Under the Regular Shelterwood (or Uniform) System of natural regeneration, age-classes take the place of age-gradations and periodic blocks take the place of annual coupes, each containing one age-gradations. A Periodic Block (P.B.) is defined as: the part or parts of forest set aside to be regenerated, or otherwise treated, during a specified period. The regeneration block is called “Floating” or “Single” when it is the only P.B. allotted at each Working Plan revision. When all P.Bs. are allotted and retain their territorial identity at Working Plan revision they are termed “Fixed” or “Permanent”. (Glossary)

FELLING CYCLE – FELLING SERIES IN SELECTION FOREST:

In an ideal Selection Forest, the entire area will be worked every year and will represent a complete and undivided Felling Series. Such annual working of the entire area of the Working Circle is neither practicable nor desirable. The usual practice is to divide the area into a number of coupes (also sometimes known as Cutting Sections) each of which is worked at an interval of a planned number of years, known as Felling Cycles (F.C.), which is defined as: the time that elapses between successive main fellings on the same area (Glossary).

FELLING SERIES IN COPPICE-WITH-STANDARDS (C.W.S.) SYSTEM:

In C.W.S., the arrangement of the age-gradations in over wood (Standards) is the same as in theory in Selection forests, regarding each coupe to be a Cutting Section, except that the age-class 0 to r (rotation of coppice) is missing; it being included in the underwood (Coppice). The age-gradations in the underwood are arranged as in Clearfelling high forest system. The rotation of the over wood (Standards), R, is a multiple of the rotation of the underwood (Coppice), r.

SUSTAINED YIELD

INTRODUCTION

DEFINITION: The principle of Maximum Sustained Yield has been the backbone of forest management ever since forests were brought under scientific management. Many foresters consider sustained yield synonymous with good management. It is one of the aims of National Forest Policies of all Progressive countries of the world. Sustained Yield is defined and / or expressed variously as:- (i) (a) “ The material that a forest can yield annually (or periodically) in perpetuity. (b) As applied to policy, method or plan of management (Sustained Yield Management), it implies continuous production with the aim of achieving at the earliest practical time at the highest practical level an approximate balance between net growth and harvest by annual or somewhat longer periods.” (BCFT) (ii) “The regular, continuous supply of the desired produce to the full capacity of the forest.” (Osmaston) (iii) “The yield of timber or other forest produces from a forest which is managed in such a way as to permit the removal of approximately equal volume or quantity of timber or other forest produce annually or periodically in perpetuity.

CONCEPT AND PRINCIPLE OF SUSTAINED YIELD (EVEN FLOW) MANAGEMENT: Concept of Sustained Yield (or Sustainance) has been evolved from the basic consideration that the later generations may derive from the forest at least as much of the benefits as the present generation. It is an accepted norm in forest management and forms the core of organized forestry. The principle of Sustained Yield envisages that a forest should be so exploited that the annual or periodic fellings do not exceed the annual or periodic growth, as the case may be. Sustained Yield is, therefore, expressed as the allowable cut which may differ little from net increment (i.e., gross increment minus natural loss due to fire, wind, epidemics, etc.) Depending on the growing stock and distribution of age-classes. Basic aim of management is to keep forest lands productive. Sustained productivity may be visualized in two respects, viz., continuity of growth and continuity of yield or harvest.

Pre-requisites for Sustained Yield Management – Its Scope and Limitations: Considering forestry from the economic point of view, investment in forestry should yield continuous return in terms of definite class of produce, and in greatest possible quantity within a reasonable time and to the best financial advantage. The simplest method of achieving this objective of sustained annual yield is to maintain a complete succession of equal areas of crops of all ages from one year old upto the age of maturity and remove the 10 year old wood annually, and plant up the area again. The mature wood would represent the increment on the whole forest and the difficulty of removing the annual increment from each unit area, say one hectare, is overcome by removing accumulating production of 10 hectare on 1/10th part of the total area. As the forest in the above example has equal area of every age in it, an equal area will be available for felling at maturity.

CONCEPT OF INCREASING AND PROGRESSIVE YIELDS: The concept of Sustained Yield has now been replaced by that of progressive yield, originally advocated by a German forester, Hartig. This takes into account both the gradual evolution of the economy as well as the progress in the silvicultural techniques, as a result of experience and research, which is considered as an important ingredient of scientific management. The concept of Progressive Yield envisages raising the productivity of soil, and of the crop, by silvicultural treatments, judicious tending, enrichment of the forest by changing the crop composition and by replacement of the original inferior forest by valuable forest species. It also stipulates avoidance of loss of increment by effective protection and tending and adoption of quick and efficient regeneration techniques. The new concept signifies a dynamic outlook in Man to build up and maximize productive enterprises through technological efficiency. It connotes a synthesis of ecological and economic considerations, and a long range view of forest products requirement for economic self sufficiency. The principle of Progressive Yield as against the Sustained yield principle was discussed at the VI Indian Silvicultural Conference held in Dehra Dun in 1939 and the III World Forestry Conference held in Helsinki in 1948, and adopted.

Chapter-1

INCREMENT

GENERAL REMARKS – TERMS - DEFINITIONS

Increment is the increase in growth of a tree or a crop with age. It may be in terms of physical increase of wood content, or may refer to any of the factors which increase with age – diameter, height, basal area, volume, quality, price or value. It may be determined for any given period, by measuring/evaluating these parameters at the beginning and at the end of the period.

Methods of measurement of diameter, height, basal area and volume are covered in the subject of forest mensuration. In forest management, the term increment refers usually to only volume increment, and that too of crops rather than of individual trees. Increment of both individual trees and crops is influenced by species, site quality, silvicultural treatment (tending operation) and also the nature of the crop – whether even- aged or uneven- aged.

The increment of a crop may be expressed in the form of its CAI, MAI or increment per cent. Glossary definition of these technical terms connected with increment (explain above) are given below:

- i) Increment:** The increase in girth, diameter, basal area, height, volume, quality, price of individual trees or crops during a given period.
- ii) Current annual increment (CAI):** Strictly the increment in a specific year. Usually taken as the periodic annual increment over a short preceding period.
- iii) Periodic annual increment (PAI):** The average annual increment for any short period; sometimes referred to as periodic mean annual increment.
- iv) Mean annual increment (MAI):** The total increment upto a given age divided by that age.
- v) Final mean annual increment:** The MAI at rotation age.
- vi) Increment per cent:** The average annual growth in volume (or basal area) over a specified period expressed as percentage of the volume (or basal area) either at the beginning or, more usually, half way through the period.

Current and mean annual increments (CAI and MAI)

CAI is small in early stages (seedlings and saplings), increase slowly at first, then more rapidly to the maximum, after which it begins to decline, and finally ceases with its mortality. This is true both of individual trees and crops. The sum of the CAIs laid on for the entire period gives the total volume, which when divided by the age gives the MAI – the average of the past production. It is an arithmetically derived value and coincides with actually only twice in the life of a crop; once at the end of the first year and once later, when it culminates and equals the CAI.

The current annual increment tends to increase constantly upto a maximum. During this period the volume laid each year to the total volume of the stand is greater than the average of MAI upto that year. The rising CAI raises the MAI also; but the curve of the latter cannot show as steep a rise as that of the CAI, since the effect of the increasing growth each year is spread over all the previous years. When the CAI curve reaches its culmination and begins to decline, the successive average increments, i.e., the MAI figures for each year still continue to rise inspite of this fact, since the amount of growth added to the stand during the year, although less than formerly is still greater than the average or mean. When the CAI for the year finally falls to an amount equal to the average or mean for the entire period, the curve of MAI has reached its highest point, i.e., has culminated. During the following years, the CAI is less than the mean, hence the MAI curve begins to drop but only to the extent that it is pulled down by the effect of this lesser CAI for single years, spread over the age. Hence, as before, the MAI curve shows a fall, more gradual than the CAI curve. Unless the stand is felled, the losses in the stand will finally exceed the growth, and the CAI will then become negative. But until the entire stand is destroyed, the curve of the MAI will still be positive. Conclusions from the above description, tabulated data and trends of the MAI and CAI curves may be summed up as:

i) To begin with the MAI keeps below the CAI

ii) While the CAI is more than MAI, the MAI is rising

iii) The CAI attains the maximum before the MAI

iv) The CAI is falling when the MAI is still rising

v) When the CAI is equal to the MAI (the two curves intersect) the MAI is stationary, and has attained its maximum – the culmination point. The MAI curve is flat at this point and the MAI is about the same for some years before and some years after it. If the crop is felled at this age, at which the MAI is maximum, maximum average volume per unit area per annum will be obtained – this age is the rotation of maximum volume production.

INCREMENT PER CENT

The term has already been defined; it is an expression of the relation between the increment and volume. Current increment per cent: is the relation of the increment during a given year to the volume at the beginning of the year.

Chapter-2

ROTATION OR PRODUCTION PERIOD INTRODUCTION

DEFINITION

Agricultural crops are sown; they ripen and are harvested once or twice a year. As a rule, all plants ripen at the same time and are also harvest at the same time; their period of maturity is easily determined. However, it is not so in case of forest crops. The main forest product, timber, takes a long time to mature for harvest; neither does it ripen the way agricultural crops do. Though trees are utilizable / saleable even at a younger age, there is a steep size / price gradient and the price per unit volume rises sharply with the size of trees. Ripeness of the trees can be estimated from the age beyond which quality of timber starts falling off; this age varies, not only from species to species but also from tree to tree. Trees should be harvested after they have reached utilizable size, and before their timber quality starts deteriorating. The maturity of timber depends on natural conditions of growth on the one hand and economic conditions on the other. In some cases, however, other considerations, such as protective, recreational and scenic value may also come into the picture. Unlike agriculture, trees have variable standards of ripeness or maturity as they satisfy different demands at different times and different sizes. What standard of ripeness we may then apply to trees size, age, vigour of growth or a combination of these? Such considerations complicate decisions on forest policy, finance and planning. Object of management will be an important consideration in this respect. The period which a forest crop takes between its formation and final felling is known as Rotation or Production Period. This term is also defined in various other ways by different authors; some of these definitions are given below:-

- (i) “The planned number of year between the formation or regeneration of a crop and its final felling. In the case of a selection forest, the average age at which a tree is considered mature for felling.”
- (ii) “The number of years fixed by the Working Plan between the formation or regeneration and the final felling of a crop.”
- (iii) “Rotation age is the age of trees or crops at which when they are felled, objects of management for the time being are best served.”
- (iv) “Rotation or Production Period is the interval of time between the formation of a young crop by seeding, planting or other means and its final harvesting.”
- (v) “Rotation is the period which elapses between the formation of a wood and the time when it is finally cut over.”

CONCEPT OF ROTATION IN REGULAR AND IRREGULAR CROPS: The term Rotation, strictly speaking, is correctly applicable to regular crops only. In Clear-felling System and plantations, rotation is a definite period of interval between the year of formation and final felling. In these, and regular forests in general, entire

crops of trees of a sizeable area are felled at a time or during a comparatively short period (regeneration period in Regular Shelterwood System) when ready for felling. There is, more or less, a clear production period which can be planned in advance to give timber which satisfies the object of management. In the latter case, rotation is fixed for the whole working circle a unit, as the average length of time between the establishment of crops and their harvesting. Though this system facilitates better planning and organization of work, it does not take into consideration that: (i) Rate of growth will vary with site variation, even for the same species. (ii) It involves sacrifice of immature trees / crops, as some will not have reached exploitable size. (iii) Accidents, such as fire, disease, and wind-throw may happen, necessitating gelling earlier than planned. (iv) If profit is the main object of management, some difficulties may arise, as the degree of profit is affected by rotation, rate of growth, size / price gradients of timber and the cost of growing it. To obtain desired profits, stands will have to be finally at various times depending on their rate of growth. From the foregoing, it is evident that whatever the object of management size of timber or profit rotation is associated with final felling age or removal age and, even with a planned rotation, the removal age may vary with rate of growth. On better sites rotation will be shorter; damage / mortality due to accidents may necessitate earlier removal of some parts thereby increasing the tendency to break up uniformity of original crops into smaller segments, until they start approaching the structure of uneven aged forest. In uneven aged (irregular) selection forests, trees are selected individually on their merit for felling, depending on:

(i) Qualities of size, vigour and suitability for markets. (ii) Adjustment of proportion of different sizes. (iii) Silvicultural principles; e.g., removal of inferior stems in favour of better ones. Such a system clearly has greater flexibility, and enables forester to adopt fellings to suit different rates of growth caused by variation in site or species. Moreover, forest is a perpetual entity and never suffers complete clearance of trees on any part of the area, except periodical thinning. Therefore:- (i) Size being the criterion for felling, age is known, and (ii) There being no final harvesting, there is no rotation as defined above. However, one could say that its rotation period is equal to that of the average age of the exploitable size trees removed the exploitable age, at which they attain the size required to fulfill the objects of management. Therefore, in selection / irregular forests, concept of Rotation assumes, by and large, only an academic importance for accounting purposes. In these forests, there is no definite correlation between age and diameter; the latter depending on site and available light conditions and even individual characters also. The trees of all ages are mixed together and the crop as a whole, on any unit area, does not reach the age of final felling at a time. Consequently, the term Rotation or Production Period, is not correctly applicable to the age at which individual trees reach the age of maturity and are removed. Maturity in selection forests is related to size, and exploitable size is fixed for removal of individual trees. Correct term expressive of maturity in selection forests is, as stated above, exploitable age, or size. Size should therefore, be used as a standard of exploitability, and not age. more in conformity with requirements of an out-of date king of Yield Regulation that with timber production.

TYPES OF ROTATION: Rotation is an important factor in the regulation of yield and proper management of the forest as a whole. As stated earlier, it will depend on, mainly, the objects of management.

Various types of rotation recognized in forestry are:-

1. Physical Rotation: It is the rotation which coincides with the natural lease of life of a species on a given site. The natural life-span (longevity) of trees varies greatly with species and the site factors. This rotation is applicable only in case of protection and amenity forests, park lands, and in some case roadside avenues. It is very variable, fairly long and also indefinite. Another interpretation of Physical Rotation is the age upto which the trees remain sound, or produce viable seed in high forests and, in coppice crops, can put forth reliable coppice shoots. This rotation is not of any relevance to economic forestry.

2. Silvicultural Rotation: It is the rotation through which a species retains satisfactory vigour of growth and reproduction on a given site. It can neither be lower than the age at which trees start producing fertile seed in sufficient quantity, nor beyond the age when they stop doing so. It is also necessary that soil conditions remain satisfactory for germination and establishment of seed. It is not only long but has also very wide range of limits hence somewhat vague and may be used in combination with other rotations, such as Technical Rotation.

Silvicultural Rotation may be useful in forests managed primarily for aesthetic and recreational purposes, where large old trees with accompanying regeneration provide scenic beauty. Some foresters do not distinguish between Physical and Silvicultural Rotations.

3. Technical Rotation: It is the rotation under which a species yields the maximum material of a specified size or suitability for economic conversion or for special use. It aims at producing the maximum material of specific dimension / quality for specific purposes, such as railway sleepers, saw- logs, mine-props, transmission poles, match-wood, paper-wood, etc. Since one and the same tree any yield different assortments of material, and the trees in a crop may attain given size at different times, the technical exploitable age offers no reliable fixed point for fixing the rotation. It does, however, allow for fixation of limits within which a tree or stand is adopted for the production of assortments in greater number or better quality. Technical rotation is adopted, particularly, by industrial firms which own forests / plantations for the purpose of supplying raw material for their plants (e.g., NEPA and West-Coast Paper Mills, WIMCO match factory).

4. Rotation of Maximum Volume Production: It is the rotation that yields the maximum annual quantity of material; i.e., the ge at which the Mean Annual Increment (M.A.I) culminates. The M.A.I referred to is that of the stand and not that of individual trees. The quantity (usually the volume of wood above a minimum thickness) referred to naturally includes material from all thinnings, as well as the final volume felled at the end of rotation. The length of this rotation will coincide with the year when the average rate of growth, or volume increment per unit area, reaches the maximum, i.e., the age indicated by the point of intersection of C.A.I. (Current Annual Increment) and the M.A.I. curves (dealt with in greater detail in Chapter VII-INCREMENT). This rotation yields largest volume per unit area, per annum, and is an important rotation which is adopted frequently as such, or in combination with some other rotation (e.g., Technical Rotation).

5. Rotation of Highest Income / Revenue (or Forest Rental): It is the rotation which yields the highest average annual gross or net revenue irrespective of the capital value of the forest. It is calculated without interest and

irrespective of the times when the items of income or expenditure occur. This rotation is important from the overall national point of view. With Forestry in the public sector, attainment of highest gross revenue is more important than that of net income because larger expenditure and investment generates several social benefits, and indirect advantages to the trade and industry. The private owner of a forest estate is interested in maximum net revenue (gross income minus expenditure, both discounted to date) by keeping the rotation period as short as possible.

6. Financial (or Economic) Rotation: It is rotation which yields the highest net return on the invested capital. It differs from the Rotation of Highest Net Income in that all items of revenue and expenditure are calculated with compound interest at an assumed rate, usually the rate at which the Govt. is able to borrow money. It is also defined as: (i) “the rotation which gives the highest discounted profit, usually at its commencement.” (ii) “the rotation which is most profitable.” (iii) “the rotation which gives the highest net return on capital value, i.e., under which the Soil Expectation Value (Se) calculated with a given rate of interest is the maximum.

SOIL EXPECTATION VALUE (Se): “If a piece of land is expected to provide a continual net income of X rupees yearly, then that land can be valued at a sum, which at an acceptable rate of interest gives the same yearly income of Rs. X; that value is known as Soil Expectation Value (Se). Expressed by formula,

$Se = X/0.0p$; where p – rate of interest,

CHOICE OF THE TYPE / KIND OF ROTATION

For considering the choice of most suitable rotations under different social, silvicultural and economic conditions, the above mentioned types may be sub-divided into three main groups which satisfy three different broad objectives, viz., :- (i) Rotations controlling the supply of certain services i.e., the Silvicultural and Physical Rotation. (ii) Rotations controlling the output of material forest products in form or quantity i.e., the Technical and maximum volume rotations. (iii) Rotations controlling the financial returns, i.e., the Rotations of maximum Gross or net Income and the Financial Rotation. Choice of rotation, as already pointed out, is one of the most important decisions in forest management. Different arguments have been advanced in favour of one or the other type. Two controversial views expressed in forestry literature are :- (i) Forest means capital and, as such, it should yield the maximum revenue or interest, i.e., it should satisfy economic and financial aspects of investment. (ii) The second view is that more important than the financial aspects is the general usefulness of products specially in case of state-owned forests. Before making a choice of a suitable rotation, the forester has to carefully consider the following:-

(i) Objects of management. (ii) Silvicultural requirements of the species. (iii) Productivity of the site. (iv) The market demands and / or national requirements. (v) Socio economic policy of the State (labour conditions, employments, etc.) (vi) Financial and economic aspects.

Chapter-3

NORMAL FOREST

GNEREAAL REMARKS DEFINITION:

Normal Forest is an ideal state of forest condition which serves as standard for comparison of an actual forest estate, so that the deficiencies of the latter are brought out for purposes of sustained yield management. On a given site and for a given object of management, it is forest which has an ideal growing stock, an ideal distribution of age- classes of the component crop and is putting on an ideal increment. From such a forest, annual or periodic yields equal to the increment can be realized indefinitely, without endangering future yields and without detriment to the site. In forestry, concept of Normal Forest envisages an ideal state of perfection, serving the purpose of good scientific management. Normal series of age-gradations, normal growing stock and normal increment form the 'Trinity of Norms' in forestry, as Osmaston calls it. The word normal does not mean usual, common, or regular as one ordinarily understands it; it means an ideal condition in the context of forestry.

Normal forest is, thus, a conception of forest management based on the principle of Sustained Yield. It was evolved in early 19th century by German Foresters.

The term is variously described or defined as:-

- (i) "A forest which, for a given site and given objects of management, is ideally constituted as regards growing stock, age class distribution and increment, and from which the annual or periodic removal of produce equal to the increment can be continued indefinitely without endangering future yields. A forest which by reason of its normalcy in these respects serves as a standard of comparison for sustained yield management."
- (ii) "A forest which, corresponds in every way to the objects of management is called a Normal Forest. It serves as an ideal to be aimed at, though it may never be altogether reached or, if established, not permanently maintained. Normal state of a forest, under given set of conditions, depends chiefly on the presence in it of:-
 - a. A normal increment.**
 - b. A normal distribution of age-classes,**
 - c. A normal growing stock."**
- (iii) "That forest which has reached and maintains a practically attainable degree of perfection in all its parts for the full satisfaction of the purpose of management".
- (iv) "A forest which has (a) a normal series of age-gradations or age-classes, (b) a normal increment, and consequently, (c) a normal growing stock, it termed a normal forest. It follows that there is nothing absolute in the term. A forest normal under one method of treatment or rotation, would be abnormal under any other treatment or rotation."

(v) “A forest which contains a regular and complete succession of age- gradations or classes (several age-gradations thrown together) in correct proportion so that an annual or periodic felling of the ripe woods results in an equalization of the annual or periodic yields.”

(vi) “Normality is that practically attainable degree of perfection in a forest which we strive to secure in all parts of the forest and to maintain it in perpetuity.”

BASIC FACTORS (ATTRIBUTES / CHARACTERISTICS) OF NORMALITY:

The above definitions stipulated the presence of three main attributes of an ideal forest managed for sustained yields in perpetuity (called normal forest):-

- (i) A normal series of age-gradations or age-classes.
- (ii) A normal increment.
- (iii) A normal growing stock.

By normal series of age-gradations or classes is meant the presence in the forest, in appropriate quantity, trees of all ages from one year old to rotation age. When the trees of each age occur on separate areas, they constitute a series of age- gradations. When trees falling within certain ago limits occur mixed together on the same area, they form an age-class.

In very irregular forests there may neither be age-gradations nor age-classes; in such cases is the sign of normality the proper distribution of trees of all ages. Normal Increment is the best or maximum increment attainable by a given species and for a given rotation, per unit area on a given site. An abnormal increment may be caused by faulty formation, faulty treatment injurious external influences and also unequal distribution of age-classes.

NEED FOR AN IDEAL STANDARD:

As started already, a normal forest is an ideal model after which we aim to mould our forest. Attaining that ideal is within practicable possibilities but the requirements are such that some of these may not be found over the whole of the series, or they may get disturbed quickly and cannot be maintained in that condition for long. This is, however not to suggest that the ideal condition of normality should not be the aim under the apprehension of its likely failure at some stage. Such an attitude would not only be defeatist but will also leave us without a goal. We have neither any criterion to compare the existing conditions of the forest, nor any idea of the direction we should proceed to get the maximum benefit from our forests. To be able to improve his forests, the Forester must know its deficiencies, hence the conception of an ideal forest as standard for comparison is essential. This is also necessary for proper appreciation of the principles of Yield Regulation.

NORMALITY CONCEPT NOT ABSOLUTE: RELATED TO TREATMENT AND ROTATION:

As a result of growth of trees, harvesting and other unforeseen influences, the condition of forest changes. Even if normality ideal condition is achieved in a forest, it is seldom possible to preserve it for long. There is no absolute normality, remaining unaltered every where in the forest, and for all time, but only a relative one

which corresponds best to the circumstances for the time being. The normal forest is purely an artificial conception developed to meet the needs of forest management. No virgin forest is normal. The nearest approach to theoretical normality is made in plantations which are entirely artificial. There is no such thing as absolute normality, independent of treatment. The concept of normality is related to both rotation, and the system of management. What is normal increment, normal age-classes and normal growing stock for a forest on a sixty year rotation is obviously not normal for a hundred year rotation. Similarly the data for normality may vary for a coppice forest, an even-aged high forest and a selection forest, although the species, the site and the rotation may be the same in all cases. The normal forest is created not by nature, but by progressive scientific treatment. It is a mathematical abstraction, on which all methods of yield regulation are based.

KINDS OF ABNORMALITY:

Forest may be abnormal usually in the following ways:-

- (i) They may be over-stocked. A forest past the age of maturity, or having excessive distribution of older age-classes, will have more volume per unit area than the normal.
- (ii) They may be under stocked. This condition may be caused due to preponderance of younger age-classes, poor density or extension in rotation. In such cases conservative treatment, i.e., felling less than the permissible amount in order to build up a proper reserve of growing stock is indicated. The accumulation of growing stock to remedy a deficit is often secured by adopting a rotation longer than that necessary, or by cutting less than the possibility.
- (iii) They may have normal growing stock volume but abnormal distribution of age-classes or age- gradations; i.e., they may be disproportionate, some of them may be even missing. This is the worst form of abnormality because the entire forest may be practically of one age-class. The conversion of such a forest to normality is a very difficult problem, and involves either an interruption in sustained yield or sacrifice of material by decay or unsoundness.
- (iv) The increment may be sub-normal. This condition may be caused by defective density, fire disease, etc., or it may be due to preponderance of over-mature trees.
- (v) Normal increment volume in an abnormal forest: Annual increment of a forest may be the correct volume for normal increment, but unless it is laid on to trees of the right size-class in the right proportion it is not a normal increment.

EFFECT OF SILVICULTURAL SYSTEM ON NORMALITY:

Silvicultural systems can be broadly classified into two main groups:

- (i) Even-aged system - e.g., Clear felling, Coppice and Uniform.
- (ii) Uneven-aged system – e.g., True or Single Tree selection and group selection.

The basic difference between the two groups is that in an even-aged system any small unit of area, even half an hectare, contains trees of only one age, although the forest as a whole contains all ages upto maturity. In the uneven-aged forest, however, each small unit or area contains trees of all ages; in the single tree selection system the unit of area is very small, say only half an hectare or even less, but in group selection system it will

be larger perhaps two hectares or even more. In very intensive even-aged forestry, in order to take full advantage of differences in site individual stands of one age may also be small, perhaps 0.2 or even 0.1 hectare. The forest then approaches and begins to merge into an uneven-aged one. The basic difference between the two groups is whether separate ages and areas can be distinguished, and delineated on the ground and on the map or not. In even aged forestry they can be distinguished so that management can be based on area and age. If they cannot be distinguished, as in true selection forests, then management must be based on individual trees and their size and not on age and area.

Therefore, there must be two main types of Normal Forest, viz.,

- (i) The Normal Even-aged Forest and
- (ii) The Normal Uneven-aged Forest.

DE LIOCOURT'S LAW: A very important fact was discovered by F. De. Liocourt that in a fully stocked selection forest, the number of stems falls off from one diameter class to the next in geometrical progression, which means that the percentage reduction in the stem number from one diameter class to the next is constant. This is referred to as De Liocourt's Law. If the quotient of the series is known and the number of stems in any class is given, the whole series can be worked out and this should give the proportionate distribution in an Ideal Selection forest or its balanced composition. This series is represented by the geometrical progression: $a, aq^{-1}, aq^{-2}, aq^{-3}, \dots, aq^{-(n-1)}$ where a = number of stems in the lowest dia class. q = Co-efficient of reduction in the number of stems; the quotient. By itself, it is a very important discovery, but it does not readily lead us to the ideal selection forest. Firstly, it is not known what the ideal number in known class should be and, secondly, what the quotient should be. Later researches found that the normal stem number distribution for different site qualities varies. It was still in geometrical progression but the quotient was different for different qualities. For example, this quotient q for silver fir Q.I is reported as 1.30, 1.35 for Q.II, and 1.40 for Q.III and 1.50 for Q.IV. In India, it was only in 1952 that some studies were made in this regard, in the plots laid out in 1939. Some of the conclusions reported by S.K. Seth and G.S. Mathauda at the Ninth Silvicultural Conference at the F.R.I., Dehra Dun, in 1956 are:

- (1) The number of stems in successive diameter classes of true selection forest of tropical wet ever-green, southern moist deciduous or hill sal type follows De liocourt's law, which was hitherto known to hold well for temperate forest.
- (2) A set of 'empirical yield Tables' for selection Sal forest in one locality, and 'empirical stand Tables' for true selection sal forest for various qualities have been prepared. It is felt that there is urgent need for a study of the rate of growth and the composition in a selection forest and for the preparation of stand tables for different types of forest.

The problem of a normal forest, for the irregular and / or mixed forest, continues to be a complex one: management of Indian irregular forest would remain unscientific till the problems of composition and growth solved. Meyer (1933) simplified De Liocourt's law in the form of an exponential function: $y = Ke^{-ax}$ Where y

= number of stems in the dia, interval; x = diameter at breast height. A = percentage reduction in number of stems for each dia. K = relative stand density which is dependant on site conditions. $e = 2.71828$, the base of Napierian logarithms. By plotting the log, numbers of stems against their mid-diameter values on an ordinary graph paper, if the resulting points are in a straight line, it would indicate a balanced crop. The abnormality in number in any dia-class can be readily detected and silvicultural treatment can be given to obtain ideal distribution in course of time. For example, if there is preponderance of smaller trees, mid-sized or larger-sized tree, the position can be rectified by thinnings, heavy thinnings or regeneration fellings, respectively.

DISTRIBUTION OF TREES IN DIFFERENT DIAMETER CLASSES IN UNEVEN- AGED SAL FORESTS

Theoretical selection forest is supposed to have all diameter classes intermingled in balanced proportion. Uneven-aged crops are continuous in nature and have no point of termination; when mature trees are removed a new crop of the next order is started. Growth data of unevenaged forests cannot be presented in the form of yield tables. Age of the crop is usually difficult to determine. Mathauda studied the distribution of number of stems in different dia. classes in uneven-aged sal forests in Ram Nagar forest division (U.P.). Application of De Liocourt's law to enumeration results of spruce and silver fir forests of Mandi and Nachan forests of Himachal Pradesh yields the ideal stocking of fir forests as given in the following table (source: article "Ideal stocking and normal growing stock of selection forests of fir and spruce", by R.V.Singh, Indian Forester, January, 1975).

Chapter-1

Concepts of Agroforestry

Agroforestry - objectives, components, different terminologies for describing tree cultivation on non- forest areas - accepted terminologies - distinction between agroforestry and social forestry.

Concepts of Agroforestry

Agroforestry is a collective name for land-use systems involving trees combined with crops and/or animals on the same unit of land. It combines i) production of multiple outputs with protection of resource base; ii) places emphasis on the use of multiple indigenous trees and shrubs; iii) particularly suitable for low-input conditions and fragile environments ;iv) It involves the interplay of socio-cultural values more than in most other land-use systems; and v)It is structurally and functionally more complex than monoculture.

Definition

Agroforestry is any sustainable land-use system that maintains or increases total yields by combining food crops (annuals) with tree crops (perennials) and/or livestock on the same unit of land, either alternately or at the same time, using management practices that suit the social and cultural characteristics of the local people and the economic and ecological conditions of the area.

Difference between Social forestry and Agroforestry

Social forestry is defined as “Forestry outside the conventional forests which primarily aims at providing continuous flow of goods and services for the benefit of people. This definition implies that the production of forest goods for the needs of the local people is Social forestry. Thus, social forestry aims at growing forests of the choice of the local population.

Shah (1985) stated that Conceptually Social forestry deals with poor people to produce goods such as fuel, fodder etc. to meet the needs of the local community particularly underprivileged section.

Different terminologies for describing tree cultivation in nonforest areas

1. Farm Forestry

Farm forestry is the name given to programmes which promote commercial tree growing by farmers on their own land

Farm forestry was defined by NCA (1976) as the practice of forestry in all its aspects in and the around the farms or village lands integrated with other farm operations.

2. Extension Forestry

Extension forestry is the practice of forestry in areas devoid of tree growth and other vegetation situated in places away from the conventional forest areas with the object of increasing the area under tree growth .

It includes the following.

i) Mixed forestry

Mixed forestry is the practice of forestry for raising fodder grass with scattered fodder trees, fruit trees and fuel wood trees on suitable wastelands, panchayat lands and village commons

ii) Shelterbelts

Shelterbelt is defined as a belt of trees and or shrubs maintained for the purpose of shelter from wind, sun, snow drift, etc.

iii) Linear Strip plantations

These are the plantations of fast growing species on linear strips of land

3. Rehabilitation of Degraded forests

The degraded area under forests needs immediate attention for ecological restoration and for meeting the socio economic needs of the communities living in and around such areas.

4. Recreation Forestry

Recreation forestry is the practice of forestry with the object of raising flowering trees and shrubs mainly to serve as recreation forests for the urban and rural population. This type of forestry is also known as **Aesthetic forestry** which is defined as the practice of forestry with the object of developing or maintaining a forest of high scenic value.

Benefits of agroforestry

Environmental benefits

- i) Reduction of pressure on forest
- (ii) More efficient recycling of nutrients by deep-rooted trees on the site
- (iii) Better protection of ecological systems

iv) Reduction of surface run-off, nutrient leaching and soil erosion through impeding effect of tree roots and stems on these processes

v) Improvement of microclimate, such as lowering of soil surface temperature and reduction of evaporation of soil moisture through a combination of mulching and shading

vi) Increment in soil nutrients through addition and decomposition of litter-fall.

(vii) Improvement of soil structure through the constant addition of organic matter from decomposed litter.

Economic benefits

(i) Increment in an outputs of food, fuel wood ,fodder,fertiliser and timber;

ii) Reduction in incidence of total crop failure ,which is common to single cropping or monoculture systems

iii) Increase in levels of farm income due to improved and sustained productivity

Social benefits

(i) Improvement in rural living standards from sustained employment and higher income

ii) Improvement in nutrition and health due to increased quality and diversity of food outputs

iii) Stabilisation and improvement of communities through elimination of the need to shift sites of farm activities.

Chapter-2

Classification of Agroforestry systems

Nair (1987) has classified the agroforestry systems based on the following four criteria.

1. Structural Basis
2. Functional basis
3. Socio economic Basis
4. Ecological basis

1. STRUCTURAL BASIS

- a) Nature of Components
- b) Arrangements of Components

a) Nature of Components

1. Agricultural systems
2. Silvopastoral systems
3. Agrosilvopastoral systems
4. Other systems

1. Agricultural systems

- i. Improved fallow species in shifting cultivation
- ii. The taungia system
- iii. Multispecies tree gardens
- iv. Alley cropping
- v. Multipurpose trees and shrubs on farmlands
- vi. Crop combinations with plantation crops
- vii. Agroforestry fuel wood plantations
- viii. Shelter belt s
- ix. Wind breaks
- x. Soil conservation hedges

2. Silvopastoral systems

- i) Protein bank
- ii) Live fence of fodder trees and hedges
- iii) Trees and shrubs on pastures

3. Agrosilvopastoral systems

- i) Home gardens
- ii) Woody perennials for browse, mulch, green manure, soil conservation

4. Other systems

- i) Apiculture with trees
- ii) Aquaforestry

iii) Multipurpose wood lots

b) Arrangement of components

1. Spatial arrangement
2. Temporal arrangement

2. FUNCTIONAL BASIS

- i) Productive functions
- ii) Protective functions

i) Productive functions

Food, Fodder , Fuel wood, Cloths, Shelter, NTFPs

Protective functions

Wind breaks, Shelterbelts, Soil conservation, Soil improvement, Shade

3. SOCIO ECONOMIC CLASSIFICATION

- i) Commercial systems
- ii) Intermediate systems
- iii) Subsistence systems

4. ECOLOGICAL CLASSIFICATION

- i. Humid / sub humid
- ii. Semiarid / arid
- iii. Highlands

SUB SYSTEMS OF AGRISILVICULTURAL SYSTEM

AGRISILVICULTURAL SYSTEM involves the conscious and deliberate use of land for the concurrent production of agricultural crops including tree crops.

Based on the nature of the components this system can be grouped into various forms.

- (i) Improved fallow species in shifting cultivation
- (ii) The Taungya system
- (iii) Multispecies tree gardens
- (iv) Alley cropping (Hedgerow intercropping)
- (v) Multipurpose trees and shrubs on farmlands
- (vi) Crop combinations with plantation crops
- (vii) Agroforestry fuelwood production

- (viii) Shelterbelts
- (ix) Windbreaks
- (x) Soil Conservation hedges

i) Improved Fallow Species in Shifting Cultivation

Fallows are cropland left without crops for periods ranging from one season to several years. The objective of improved fallow species in shifting cultivation is to recover depleted soil nutrients. Once the soil has recovered, crops are reintroduced for one or more seasons.

Shifting cultivation is a pattern of land use and a system of production of crops under which plots of land are cleared, cultivated for a short period for raising one, two or three crops, after which the land is allowed to rest longer than the period of cultivation. However, during the period of rest the land reverts to some modified form of its original cover

This system is practised extensively in the north-eastern hill region comprising the states of Assam, Meghalaya, Manipur, Nagaland and Tripura and the two Union territories of Arunachal Pradesh and Mizoram and to some extent Andhra Pradesh, Bihar, Madhya Pradesh, Orissa and Karnataka states. It is called '**jhum**' in the north-eastern hill region and '**podu**' in AP and Orissa states and considered most destructive for forest areas.

The main feature of the improved fallow system of agroforestry is that trees and shrubs are not grown with crops on the same plot at the same time. The fallow periods vary from region to region but are presently becoming shorter due to an increasingly acute land shortage. The best species for the fallow system should induce good nitrogen fixation in the soil.

(ii) Taungya System:

The taungya (taung = hill, ya = cultivation) is a Burmese word coined in Burma in 1850s. The taungya system was introduced into India by Brandis in 1890 and the first taungya plantations were raised in 1896 in North Bengal. It is practised in the states of Kerala, West Bengal and Uttar Pradesh and to a lesser extent in Tamil Nadu, Andhra Pradesh, Orissa, Karnataka and the north-eastern hill region. In southern India, the system is called '**kumri**'. It is practised in areas with an assured annual rainfall of over 1200-1500 mm.

This is a modified form of shifting cultivation in which the labour is permitted to raise crops in an area but only side by side with the forest species planted by it. This labour is responsible for the upkeep of a plantation. The practice consists of land preparation, tree planting, growing agricultural crops for 1-3 years, until shade becomes too dense, and then moving on to repeat the cycle in a different area. In some cases crops may be grown one year before the trees are planted. A large variety of crops and trees, depending on the soil and climatic conditions.

Types of Taungya systems

Taungya systems are of three types:

(a) **Departmental Taungya:** Under this, agricultural crops and plantation are raised by the forest department by employing a number of labourers on daily wages. The main aim of raising crops along with the plantation is to keep down weed growth.

(b) **Leased Taungya:** The plantation land is given on lease to the person who offers the highest money for raising crops for a specified number of years and ensures care of tree plantation.

(c) **Village Taungya:** This is the most successful of the three taungya systems. In this, crops are raised by the people who have settled down in a village inside the forest for this purpose. Usually each family has about 0.8 to 1.7 ha of land to raise trees and cultivate crops for 3 to 4 years.

iii) **Multispecies Tree Gardens:**

In this system of agroforestry, various kinds of tree species are grown mixed. The major function of this system is production of food, fodder and wood products for home consumption and sale for cash. Major woody species involved in this system are: *Acacia catechu*, *Areca catechu*, *Phoenix dactylifera*, *Artocarpus* spp., *Cocos nucifera*, *Mangifera indica*, *Syzygium aromaticum* etc

(iv) **Alley Cropping (Hedgerow Intercropping):**

Alley cropping, also known as hedgerow intercropping, involves managing rows of closely planted (within row) woody plants with annual crops planted in alleys in between hedges. The woody plants are cut regularly and leaves and twigs are used as mulch on the cropped alleys in order to reduce evaporation from the soil surface, suppress weeds and/or add nutrients and organic matter to the top soil. Where nitrogen is required for crop production, nitrogen-fixing plants are the main components of the hedgerows.

The primary purpose of alley cropping is to maintain or increase crop yields by improvement of the soil and microclimate and weed control. Farmers may also obtain tree products from the hedgerows, including fuelwood, building poles, food, medicine and fodder and on sloping land, the hedgerows and prunings may help to control erosion. Alley cropping usually works best in places where people feel a need to intensify crop production but face soil fertility problems. This situation is often characteristic of crowded, densely populated areas, but may also occur wherever some farmers wish or forced to increase production on a plot of limited size.

Eg. Cassia siamea, Leucaena leucocephala, Gliricidia sepium, Calliandacalothyrsus and Sesbania sesban are commonly used tree species for alley cropping.

v) **Multipurpose Trees and Shrubs on Farmlands:**

In this system, various multipurpose tree species are scattered haphazardly or according to some systematic patterns on bunds, terraces or plot/field boundaries. The major components of this system are multipurpose trees and other fruit trees and common agricultural crops. The primary role of this system is production of various tree products and the protective function is fencing, social values and plot demarcation. Examples of multipurpose trees employed in agro forestry are: *Leucaena leucocephala*, *Acacia albida*, *Cassia siamea*, *Casuarina equisetifolia*, *Azadirachta indica*, *Acacia senegal*, *Cocos nucifera* etc.

(vi) Crop Combinations with Plantation Crops:

Perennial trees and shrub crops, such as coffee, tea, coconut and cocoa, are combined into intercropping systems in numerous ways, including:

- (a) Integrated multistorey (mixed dense) mixture of plantation crops;
- b) Mixture of plantation crops in alternate or other regular arrangement
- (c) Shade trees for plantation crops, shade trees scattered; and
- (d) Intercropping with agricultural crops.

(vii) Agroforestry Fuel wood Production:

In this system, various multipurpose fuelwood/firewood species are interplanted on or around agricultural lands. The primary productive role of this system is to produce firewood; the protective role is to act as fencing, shelter-belts and boundary demarcation. Tree species commonly used as fuelwood are: *Acacia nilotica*, *Albizia lebbek*, *Cassia siamea*, *Casuarina equisetifolia*, *Dalbergiasissoo*, *Prosopis juliflora*, *Eucalyptus tereticornis* etc.

(viii) Shelter-belt:

These are belts/blocks consisting of several rows of trees established at right angles to the prevailing wind. The purposes are:

- a) to deflect air currents,
- b) to reduce the velocity of prevailing winds,
- c) to provide general protection to the leeward areas against the effects of wind erosion,
- d) to protect the leeward areas from the desiccating effects of hot wind,
- e) to provide food, fodder, timber etc.

ix) Wind-break:

Wind-breaks are strips of trees and/or shrubs planted to protect fields, homes, canals or other areas from wind and blowing soil or sand.

The important reasons for which wind-breaks are planted include:

- ✓ to protect livestock from cold winds
- ✓ to protect crops and pastures from hot, drying winds
- ✓ to reduce/prevent soil erosion
- ✓ to provide habitat for wildlife
- ✓ to reduce evaporation from farmlands
- ✓ to improve the microclimate for growing crops and to shelter people and livestock,
- ✓ to retard grass fire
- ✓ for fencing and boundary demarcation

Some of the tree species used for wind-breaks are *Eucalyptus*, *Cassia*, *Prosopis*, *Leucaena*, *Casuarina*, *Acacia*, *Grevillea*, *Syzygium*, *Dalbergia* etc.

(x) Soil Conservation Hedges: Trees can be planted on physical soil conservation works (grass strips, bunds, risers and terraces) wherein they play two roles: **ie.**, to stabilise the structure and to make productive use of the land they occupy. Stabilisation is through the root system. In some of sloping landscapes of the country, the risers or terraces are densely planted with trees, with multiple use being made of them for fruit, fodder and fuel wood
Eg: *Grevillea robusta*, *Acacia catechu*, *Pinus roxburghii*, *Acacia modesta*, *Prosopis juliflora*, *Alnus nepalensis*, *Leucaena leucocephala* etc.

SILVIPASTURE SYSTEM

The production of woody plants combined with pasture is referred to Silvipasture system. The trees and shrubs may be used primarily to produce fodder for livestock or they may be grown for timber, fuelwood, fruit or to improve the soil.

This system is classified in to three categories

Protein bank, Livefence of fodder trees and hedges, Trees and shrubs on pasture

i) Protein bank

In this Silvipastural system, various multipurpose trees(protein rich trees) are planted on or around farmlands and range lands for cut and carry fodder production to meet the feed requirement of livestock during the fodder deficit period in winter

Example: *Acacia nilotica*, *Albizia lebbeck*, *Azadirachta indica*, *Leucaena leucocephala*, *Gliricidia sepium*, *Sesbania grandiflora*

ii) Livefence of fodder trees and hedges

In this system, various fodder trees and hedges are planted as live fence to protect the property from stray animals or other biotic influences.

Example: *Gliricidia sepium*, *Sesbania grandiflora*, *Erythrina sp* , *Acacia sp*.

iii) Trees and shrubs on pasture

In this system, various tree and shrub species are scattered irregularly or arranged according to some systemic pattern to supplement forage production. **Example:** *Acacia nilotica*, *Acacia leucophloea* , *Tamarindus indica*, *Azadirachta indica*.

AGRISILVOPASTURAL SYSTEM

The production of woody perennial combined with annuals and pastures is referred Agrisilvopastural system. This system is grouped into two categories.

i) Home gardens

This system is found extensively in high rainfall areas in tropical South and South east Asia. This practice finds expression in the states of Kerala and Tamil Nadu with humid tropical climates and where coconut is the main crop. Many species of trees, bushes , vegetables and other herbaceous plants are grown in dense and in random or spatial and temporal arrangements. Most home gardens also support a variety of animals. Fodder grass and legumes are also grown to meet the fodder requirement of cattle. In India, every homestead has around 0.20 to 0.50 ha land for personal production.

Home gardens represent land use systems involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and livestock within the compounds of individual houses. The whole tree- crop- animal units are being intensively managed by family labour. Home gardens can also be called as **Multitier system** or **Multitier cropping**

Choice of species:

a) **Woody species** : *Anacardium occidentale*, *Artocarpus heterophyllus*, *Citrus sp*,
Psidium guajava, *Mangifera indica*, *Azadirachta indica*, *Cocos nucifera*,

b) **Herbaceous species**: Bhendi, Onion, cabbage, Pumpkin, Sweet potato, Banana, Beans, etc.

ii) Woody Hedgerows:

In this system various woody hedges , especially fast growing and coppicing fodder shrubs and trees are planted for the purpose of browse, mulch, green manure soil conservation etc. The following species viz., *Erythrina sp*, *Leucaena luecocephala* , *Sesbania grandiflora* are generally used.

OTHER SYSTEMS

i) **Apiculture with trees:** In this system various honey (nector) producing trees frequently visited by honeybees are planted on the boundary of the agricultural field.

ii) **Aquaforestry:** In this system various trees and shrubs preferred by fish are planted on the boundary and around fish ponds. Tree leaves are used as forage for fish. The main role of this system is fish production and bund stabilization around fish ponds

iii) **Mixed wood lots:** In this system special location specific multipurpose trees (MPTs) are grown mixed or separately planted for various purposes such as wood, fodder, soil conservation , soil reclamation etc.

B. Arrangement of Components:

1. Spatial arrangement
2. Temporal arrangement

1. Spatial Arrangement: Spatial arrangement of plants in an agroforestry mixture may result in dense mixed stands (as in home gardens) or in sparse mixed stands (as in most systems of trees in pastures).

2. Temporal Arrangement: Temporal arrangements of plants in Agroforestry may also take various forms. An extreme example is the conventional shifting cultivation cycles involving 2-4 years of cropping and more than 15 years of fallow cycle, when a selected woody species or mixtures of species may be planted. Similarly , some silvipastoral systems may involve grass leys in rotation with some species of grass remaining on the land for several years. These temporal arrangements of components in agroforestry are termed coincident, concomitant, overlapping, separate and interpolated.

2. Functional Basis

All agroforestry systems have two functions.

- i) Productive functions ii) Protective functions

i) Productive functions

Food, Fodder, Fuel wood, Cloths, Shelter, NTFPs

Protective functions

Wind breaks, Shelterbelts, Soil conservation, Soil improvement

3. Socio economic Classification

Based on socioeconomic criteria as scale of production and level of technology input and management, agroforestry systems have been grouped in to three categories.

i) Commercial AF systems: The term commercial is used whenever the sale of the production of the output is the major aim of the system. **Examples:** 1) Commercial production of plantation crops such as rubber, oil palm, and coconut with permanent underplanting of food crops, pastures 2) Commercial production shade tolerating plantation crops such as coffee, tea and cocoa under overstorey shade trees

ii) Intermediate AF systems: Intermediate systems are those between commercial and subsistence scales of production and management. **Examples :** Production of perennial cash crops and subsistence food crops undertaken on farms wherein the cash crops fulfill the cash needs the food crops meet the family's food needs.

iii) Subsistence AF systems: Subsistence AF systems are those wherein the use of land is directed towards satisfying basic needs and is managed mostly by the owner and his family .

4. Ecological classifications

- i. Humid / sub humid
- ii. Semiarid / arid
- iii. Highlands

i) Agroforestry systems in Humid / Subhumid lowlands

Examples : Homegardens, Trees on rangelands and pastures ,Improved fallow in shifting cultivation and Multipurpose woodlots.

ii) Agroforestry systems in Semiarid and arid lands

Examples : Various forms of silvopastoral systems Wind breaks and shelterbelts

iii) Agroforestry systems in Tropical High lands

Examples : Production systems involving plantation crops such as coffee, tea Use of woody perennials in soil conservation Improved fallow.

CONSTRAINTS IN AGROFORESTRY

The following are the major constraints in agroforestry

1. Depression in crop yields due to interference effects caused by the tree
2. Delayed liquidation of planting investments due to long gestation period
3. Increased damage to crops due to birds which the tree attract
4. Increased damage to crops due to pests for which the tree serve as alternate hosts
5. Allelopathy

1. Interference effects

In an agroforestry system, trees being the dominant partners, will compete with the herbaceous substratum for resource pools of light, water and nutrients. When the immediate supply of a single necessary factor falls below the combined demands of the plant, then the competition begins. The competition is also referred as Allelopathy.

a) Competition for Light

b) Competition for moisture

c) Competition for nutrients

2. Allelopathy

Muller(1969) emphasized that allelopathy, the direct or indirect effect of one plant upon another through the production of chemical inhibitors that are released in to the environment , should also be recognized as another factor in analyzing mechanisms of plant interactions.

The species interaction due to chemical influences is also designated as **Allelochemistry, Phytochemical ecology or Ecological biochemistry** and **Allelobiology**.

Most of the chemical substances involved in allelopathic reactions are secondary compounds. Though the toxic metabolites are distributed in other plant parts also, leaves are the potent source of allelochemicals. Summer materials are more toxic than those of rainy and winter season. Toxins released from plant litter are the primary causes of allelopathy.

3. Damage due to Birds

It is generally believed that planting of trees in the farm will attract the birds and thereby enhance the risk of damage for agricultural crops.

4. Trees as a alternate hosts to Agricultural crops

Some trees act as alternate hosts for insect pests. For instance, the jowar hopper migrates to neem tree after harvest of crop and returns to the crop after completing its life cycle on the woody perennial.

Silvicultural options for minimizing the negative interactions

1. Manipulation of Densities and Arrangement of Trees

The negative effects of trees can be minimized by increasing the spacing between the trees. The studies carried out in the semi arid regions of India showed that as the distance between the hedgerows of *Luecaena luecocephala* increased, the percent reduction in crop yield decreased. The reduction in the yield of sorghum, cowpea and castor was relatively less in wider spacing (7.2m) compared to narrow spacing (3.6m). Tree orientation is also important to reduce the negative effect of trees on crops. Planting in east–West direction may reduce the shading effect of trees on the crops.

2. Manipulation of Tree crown and roots

The negative effects of trees can be further reduced by pruning of tree crown and roots. In alley cropping system, pruning of trees and applying the biomass to the soil will reduce the trees competitive ability and increase the growth yield of the associated intercrops by providing green manure and by allowing more light to the intercrops.

3. Choice of Agricultural crops

There is a great need to identify the suitable agricultural crops which can grow well under trees with limited solar energy available.

Example

1. Vegetables : Ginger, turmeric, potato, cucurbit
2. Agricultural crops : Oats, maize, soybean, groundnut
3. Grasses : Cenchrus spp, panicum

NON COMPETITIVE COHABITATION

Not all the tree- crop association need be competitive or allelopathic. Under natural ecosystems, disparate groups coexist through spatial or temporal sharing of resource pools (utilizing different parts of it or utilizing it at different times) and through non-competitive adaptation. Such complementary use of resources is called. Using a bioeconomic perspective, Raintree describes two positive plant associations of supplementarity and complementarity wherein environmental resources are partitioned or maximized resulting in higher productivity.

Supplementarity: This is a relationship wherein the production of one component can be increased independent of the production of the other. Nair (1979) cited multistory intercropping with coconuts as an example of this relationship.

Complementarity: Two components are complementary if increase in one results in a concomitant increase in the other. Example. *Acacia albida* a tree legume, sheds leaves just prior to the onset of rains. This eliminates shading effects and enables cultivation of crops like millets, sorghum and groundnut conjunct with the tree. *Acacia nilotica var. cupresiformis*, a legume tree grown in Rajasthan may also be said to promote complementarity through its canopy architecture.

Raintree (1983) stresses that most complementary associations between tree and crop are attributable to either sparse canopy, deciduousness or induced canopy reduction.

Allelopathy

Muller (1969) emphasized that allelopathy, the direct or indirect effect of one plant upon another through the production of chemical inhibitors that are released into the environment, should also be recognized as another factor in analyzing mechanisms of plant interactions.

The species interaction due to chemical influences is also designated as **Allelochemistry, Phytochemical ecology or Ecological biochemistry and Allelobiology.**

Allelochemicals secreted by different Tree species

S.No	Tree species	Allelochemicals
1	<i>Pinus ponderosa</i>	Caffeic acid, Chlorogenic acid, Quercetin, Tannin
2	<i>Acacia dealbata</i>	Hydroxy benzoic acid, Protocatechuic acid, Vanillic acid, Gentisic acid, Coumaric acid, Caffeic acid, Ferulic acid, Sinapic acid
3	<i>Leucaena leucocephala</i>	Gallic acid, Protocatechuic acid, Hydroxy phenylacetic acid, Hydroxybenzoic acid, Vanillic acid, Caffeic acid, Syringic acid, Ferulic acid
4	<i>Eucalyptus camaldulensis</i>	Cineole, phenols, gallic acid, Ferulic acid, Coumaric acid, Chlorogenic acid, Caffeic acid, Saphulenol
5	<i>Delonix regia</i>	Hydroxy benzoic acid, Dihydroxy benzoic acid, Gallic acid, Dihydroxycinnamic acid, Dinitrobenzoic acid, Azetidine, Carboxylic acid, Dihydroxy benzaldehyde,
6	<i>Gliricidia sepium</i>	Gallic acid, Protocatechuic acid, hydroxy benzoic acid, gentisic acid, Vanillic acid, Syringic acid, Coumaric acid, ferulic acid and Sinapic acid, Resorcinol

7	<i>Azadirachta indica</i>	Myristic acid, Palmitic acid, Gallic acid, stearic acid, Oleic acid, Linoleic acid acid, benzoic acid
8	<i>Eucalyptus globulus</i>	Caffeic acid, Coumaric acid, Gallic acid, Gentisic acid, Hydroxybenzoic acid, Syringic acid and Vanillic acid, Catechol
9	<i>E.citriodora</i>	Caffeic acid, Coumaric acid, Gallic acid, Gentisic acid, Hydroxybenzoic acid, Syringic acid and Vanillic acid, Catechol
10	<i>Acacia nilotica</i>	Benzoic acid, Catechol, Salicylic acid, Gentisic acid, Protocatechic acid, caffeic acid, Vanillic acid, Syringic acid, Hydroxy Cinnamic acid, palmitic acid, Pyrogallol, Tannic acid, Oxalic acid
11	<i>Gmelina arborea</i>	Benzoic acid, Catechol, Salicylic acid, Gentisic acid, Protocatechic acid, Caffeic acid, Vanillic acid, Syringic acid, Hydroxy Cinnamic acid, palmitic acid, Pyrogallol, Tannic acid, Thalic acid, Oxalic acid, Ferulic acid, Coumaric acid
12	<i>Tectona grandis</i>	Benzoic acid, Catechol, , Coumaric acid, Gentisic acid, , Vanillic acid, Syringic acid, Hydroxy Cinnamic acid, Palmitic acid, Pyrogallol, Thalic acid, Oxalic acid, Naphthol, Phenol, Ferulic acid
13	<i>Simaruba glauca</i>	Benzoic acid, Catechol, , Coumaric acid, Vanillic acid, Cinnamic acid, Oxalic acid, Ferulic acid, Caffeic acid, Salicylic acid , Resorcinol
14	<i>Ailanthus excelsa</i>	Benzoic acid, Catechol, , Coumaric acid, Ferulic acid, Salicylic acid, Protocatechu

3. Damage due to Birds

It is generally believed that planting of trees in the farm will attract the birds and thereby enhance the risk of damage for agricultural crops.

4. Trees as alternate hosts to Agricultural crops

Some trees act as alternate hosts for insect pests. For instance, the jowar hopper migrates to neem tree after harvest of crop and returns to the crop after completing its life cycle on the woody perennial.

Chapter-4

AGROFORESTRY DIAGNOSIS AND DESIGN

Definition

Agroforestry D & D is a family of procedures for the diagnosis of land management problems and potentials and the design of agroforestry solutions. The ICRAF has developed an approach to assist agroforestry researchers and development fieldworkers to plan and implement effective research and development projects.

Key Features of D & D

- i) Flexibility:** D & D is a flexible discovery of procedure, which can be adopted to fit the needs and resources of different users
- ii) Speed:** D & D has been designed with the option of a 'rapid appraisal' application at the planning stage of a project with In-depth follow-up during project Implementation.
- iii) Repetition:** D & D is an open-ended learning process. Since initial designs can almost always be improved. The D & D process need not end until further Improvements are no longer necessary.

Procedures of AF Diagnosis and Design

The procedures of AF D & D are usually done of two types, 1) 'Macro' D & D and 2) 'Micro D& D '

i) MACRO D & D

An agroforestry research programme normally begins with a macro D& D exercise covering an entire ecological zone with I n a country. This consists of a rapid appraisal, based primarily on secondary information complemented by a few selected surveys in the field.

by a few selected surveys in the field.

Macro D & D includes on assessment of existing land use system constraints, agricultural policies and institutional arrangement, current agroforestry practices and the potential for improving productivity and sustainability through agroforestry interventions. The study zone is a broad region chosen for its importance at the national level. Its selection is usually based on the following factors.

- Contribution to food production and the national economy;

- Population area
- Urgency of problems or importance of unexploited potential
- Level of agricultural development and land use intensification

Typically, the D & D team comprises 5 to 10 specialists from biophysical and socioeconomic fields including soil science, agronomy, horticulture, animal science, forestry, agricultural economics and rural sociology or anthropology. All team members should have experience in both research and extension work. To ensure that the results of the D & D exercise are taken fully into account, the scientists who carry out the D & D should participate at least in the design and analysis and, better still, also in the implementation of the ensuing research programme.

ii) MICROD & D

A central aspect of macro D& D is the delineation of land-use systems within the chosen ecological zone, leading to the selection of target systems for more detailed analysis by micro D & Ds. A land-use system is defined as a distinctive combination of crops, livestock, trees and other production components.

The primary focus of analysis is the management unit that makes decisions and shares resources, objectives, labour and products. Analysis of a land-use system comprises all the characteristics that affect its management and performance. These characteristics include the following:

- Location: Administrative and political divisions
- Environmental characteristics:
- Socio-economic characteristics
- Land-use:
- Resources/supporting service
- Development activities and policies.

An important aspect of micro D& D is an analysis of the needs, objectives, and constraints of land-users. This step is based on interviews and field surveys.

One major aspect of micro D& D is the analysis of existing knowledge and agroforestry practices. What trees or shrubs are being used with what management procedures, with what objectives and obtaining what yields? Such analysis helps in defining strategies for working with target land-users.

The main objective during the initial D & D exercise is to assess how well the existing system is

performing and meeting the needs of the land-users. Any performance gap can be evaluated by comparing present resources and outputs (what the farmers are actually producing) with biophysical potentials (for instance the yields obtained from on-station or on-farm experiments). This assessment must distinguish between problems that can be alleviated and those that cannot. The emphasis is on the problems that can be addressed by agroforestry.

Potential interventions are identified and evaluated in terms of their capacity to relieve the identified constraints. In the first instance, all interventions are considered, not just those related to agroforestry. For example, low soil fertility could be addressed by applying chemical fertilizers or manure or providing mulch from multipurpose trees or other plants. Each alternative is evaluated in terms of its technical potential and its feasibility in terms of resources and capabilities of the land users.

Criteria of Good Agroforestry Design

A good agroforestry design should fulfill the following criteria:

i) Productivity: There are many different ways to improve productivity with agroforestry viz., increased output of tree products, improved yields of associated crops, reduction of cropping system inputs, increased labour efficiency, diversification of production, satisfaction of basic needs and other measures of economic efficiency or achievement of biological potential.

ii) Sustainability: By seeking improvements in the sustainability of production systems, agroforestry can achieve its conservation goals while appealing directly to the motivation of low income farmers , who may not always be interested in conservation for its own sake

iii) Adoptability: No matter how technically elegant or environmentally sound an agroforestry design may be, nothing practical is achieved unless it is adopted by its intended users. This means that the technology has to fit the social as well as environmental characteristics of the land-use system for which it is designed.