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BOTANY AND FORESTRY

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Part- I, Paper- III (1st half)

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Silviculture of

Shorea robusta, Tectona grandis

Eucalyptus sp., Leucaena Sp.

PAPER III

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Chapter - I

GENERAL SILVICULTURE PRINCIPLES

Silviculture is that branch of forestry which deals with the establishment, development care and reproduction of stands of timber. This is also defined as the art and science of cultivating forest crops. Silviculture, is practical application of Silvics and Silvics is defined as 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.

Silviculture is not a purely biological science. Silviculture in principal as relevant to the environment at one hand and the supply of multivarious requirements of the people on the other hand. In short knowledge of Silviculture help to develop a forest which otherwise may develop into a "JUNGLE".

THE STUDY OF SILVICULTURE HELPS IN

1) Production of species of economic value
2) Production of larger volume per unit area
3) Production of quality timber
4) Reduction of rotation
5) Raising forests in blank areas
6) Creation of man-made forests in place of natural forests.
7) Introduction of exotics.

FACTORS OF LOCALITY

It is our common observation that the vegetation of hills, valleys, plains, coastal areas deserts etc., varies distinctly. This happens because of locality are also referred to as environment, which is defined as

"all the biotics and abiotic factors of a site". Therefore the factors of locality may be defined as the effective climatic, edaphic, topographic and biotic conditions of a site. which influence of vegetation of the locality.

Factors of locality are classified into the following four broad Categories.

1) Climatic Factors
2) Topographic Factors
3) Edaphic Factors
4) Biotic Factors

1. CLIMATIC FACTORS

Climate is defined as the average weather conditions prevalent in any locality. Climatic Factors are defined as light, atmospheric temperature, pressure and humiditys. Wind and other factors of a climate-- regional, local and seasonal that influence vegetation.

Climate Factors may be classified broadly as follows :

1. Solar Radiation - a) Light b) Heat and Temperature
2. Moisture
3. Wind

SOLAR RADIATION

(a) Light : The most important effect of solar radiation is that it provides both light and heat and both are important for the growth of a tree or any plant. The light plays most important role in the life cycle of a plant such as :-

i) **Chlorophyll Formation**

ii) **Stomatal Functioning**

iii) **Photosynthesis :** It has been estimated that light used in photosynthesis is less than 2% of the light energy incident well illuminated leaves. Therefore generally even feeble light in dense forest is sufficient for photosynthesis.

iv) **Growth :-** Light influences the growth of plants and trees through its effect on photosynthesis. The influence of light varies with its quality duration and intensity. Quality refers to wavelengths

or colour of light also. Duration of light in otherwords is photoperiodism. Photoperiod also varies with a altitude and latitude. Similarly excessive high and low intensity of light is not good for the growth of a plant.

v) **Form and quality of trees** :- Regulation of light by close spacing or wide spacing or allowing shade is exploited to regulated the form of trees and quality of timber produced in the forest. Light also results in the formation of relatively large crown and consequently rapid growth. Often towards the end of rotation, crops are opened up heavily to take advantage of this fact to allow the selected remaining trees to pun on rapid diameter increment.

vi) **Species stratification and size and structure of leaves** :- As the light available to the top canopy is maximum and gradually, it diminishes below the top canopy to the different storeys and finally to the ground floor. This result in the stratification of a species in different canopies according to the requirement of light. Light also affects the arrangement of leaves. In temperate climate leaf mosaic is often formed by the juxtaposition of large and small leaves in such a manner that interspaces are reduced to minimum and maximum light is intercepted. Acer provides a good example of leaf mosaic.

v) **Light requirement of Species** : According to the requirement of light the species are categorised as light demander, shade bearers and shade demanders.

b) Temperature : As the source of heat is solar radiation, the temperature of a place is governed by it. The factors infuencing the temperature are as follows :-

i) **Latitude** :- In general as the latitude increases the temperature decreases. In the indogangetic plain, the normal fall in the mean temperature is estimated roughly 0.55°C for increase of each degree in latitude. However, it is further modified by atitude, distance from sea, wind etc.

ii) **Altitude** :- It has been observed that there is a fall of 1°C in mean temperature in the hills for every 270 m rise in altitude upto about 1500m, after which the fall is more rapid.

iii) **Distance from Sea** :- Evident in coastal are as and non coastal areas.

iv) **Winds**

v) **Mountains**

vi) **Cloudiness**

vii) **Presence or absence of forest Vegetation**:- All influence the temperature of a locality. Air temperature as well as the soil temperature affects the growth of the species in various way, directly or indirectly.

Frost :- In tropical zone fall of temperature even before 5C may result in chilling injury to plants. Further fall in temperature causes frosts which means chilling of air below the freezing point depending on the mode of occurrence in the frost is classified into, (1) Radiation frost, (2) Pool Frost and (3) Advective Frost.

1. **Radiation Frost :-** The frost occurring on nights with a clear sky, produced by loss of heat by radiation. Plant areas of the country are affected by this types of frost and results in killing back young plants.

2. **Pool Frost :-** The accumulation of heavy cold air flowing down in depressions from adjoining areas is known as pool frost. This has more deleterious effect on vegetation as the freezing effect extends to a considerable height Pool Frost is the characteristic of all hill and valleys.

3. **Advective Frost :-** This type of frost is produced by the cold air brought from elsewhere.

Frost injuries : Frost causes the following injuries :-

i) Killing of yound plants or their parts.

ii) Death of plants due to damage to cells

iii) Injuries to the crowns of poles and saplings

iv) Frost cracks

v) Formation of canker.

To avoid the damage of frost the tree species selected for plantation in frosty localities should be frost hardy.

Snow :- Precipitation at higher altitude is in the form of Snow. Snow is beneficial in some cases and harmful is other.

Beneficial effects of Snow :-

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

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

Harmful effects of Snow :-

i) Snow fall results in the mechanical bending of stems of trees causing loss of volume in the maximum diameter portion of a tree.

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

iii) Sliding snow causes erosion and uprooling of trees.

iv) Snow shortens the period of vegetative growth.

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

2. **Moisture :-** The importance of moisture in forestry is well known. It influences the physiological processes in plants, the soil information and also the vegetation of a locality sources of moisture are

i) Precipitation in the form of rain, snow or hail
ii) Dew and Frost
iii) Invisible condensation of moisture.

All these sources of moisture influence the vegetation but the major source of moisture is the rain and snow. In India, the rainfall occurs under the influence of

a) Advancing Southwest monsoon
b) Retreating northeast monsoon.
c) Cyclonic depressions.
d) Westerly depressions and thunder storms etc.

Influence of Rain fall in Vegetation of India

In our country, the rainfall is very distinct in variation. There are places where average annual rainfall exceeds 2500 mm such as west coast and windward side of westernghat, North Bengal, upper Assam above Dibrugarh and Khasi hill tract of Assam. On account of tropical temperatures and heavy rainfall these areas carry a very lucuriant vegetation known as tropical wet evergreen forest. On the other hand there are areas in western part of the country where the rainfall is less than 250 mm with only desert scrub vegetation which can hardly be called a forest.

On the basis of total annual rainfall, India can be divided into following 3 Bread Zones:-

Name of Zone	Total annual rainfall in mm	Nature of Vegetaion
Wet	2500 or more	Wet Evergreen
Intermediate	<2500 to >900	i) Wet Semi evergreen
		ii) Moist deciduous
		iii) Dry deciduous
Dry	<900	i) Dry deciduous Forest of poor quality
		ii) Desert and Semi desert thorn Forest and Scrub.

Seasonal distribution of rainfall also influence the vegetation. Similarly snow, Hail, Dew. invisible condensation of moistrue and humidity also are the sources of moisture and they also influence forest in some way or other.

3. **Wind** :- Favourable effects of wind are as follows :-

i) Wind brings fresh supplies of carbon dioxide to the foliage of trees and thus helps in photo synthesis.

ii) Wind helps in pollination of anemophilous Fowers.

iii) Winds helps in the dispersal of seed of many forest trees i.e. **Holoptelia, Bomibax, Hymenodictyon, Toong** etc.

Apart from these, the shape and size of trees are also influenced by the direction of wind and its intensity. Trees are often uprooted or their stem or branches get damaged. The trees which with stand strong winds without being over thrown or broken are called "wind firm". But the trees which are uprooted are referred as "wind fall" or "wind throw". In case only the stem is snapped from some place or the branches are damaged, it is referred to as "windbreak".

2. **Topographic Factors** : Topography deals with the physical features of a place and the topographic factors may be defined as factors "pertaining to the configuration of land surface viz. altitude slope, aspect and exposure. We can well understand this factor under the following sub-heading:-

(i) Configuration of land Surface, (ii) Altitude, (iii) Slope (iv) Aspect and exposure

i) **Configuration of land surface** :- Hills, valleys and plain located at same latitude have variable climat because of topography Valleys, due to promixity of hills also results in collection of cold air in the land-locked valleys and therefore pool frost affects the vegetation. Similarly hills which experience greater humidity and reduced temperature variation have a climate very different from a plain area with the same mean actual temperatures. Because of these the vegetations of plan, hills and valleys are greatly influenced.

ii) **Altitude** :- It has already been discussed under climate factors that the increasing altitude causes decrease in temperature. Contrary to that solar radiation increases with the increase in altitude. As temperature requirement of various species is different, each species grwos in certain temperature range above and below which it is replace by other species. This results into altitudinal Zonation in vegetation in hills.

Altitude also influence rainfall. It has been estimated that about half the water vapour in the air lies below 2000 in which there quarters his below 4000m. Therefore a high mountain range is a

very effective barrier for the monsoon. As the water vapur containing monsoon winds rise along the altitude, they get cooled resulting in condenstation of water vapour and heavy precipitation in the form of rain.

iii) **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 modifies the intensity of the insulation and thus affects the temperature and moisture of the surface soil. Slope also affects erosion as well as depth of soil.

iv) **Aspect and Exposure** :- Aspect is defined as the direction towards which a slope faces. Exposure is defined as the relation of a site to weather conditions, especially sun and wind. Thus both of them have the same effect.

In India, all southern aspects are comparatively warmer than the northern slopes. This difference in temperature on the Southern and Northern aspects often results in their having different vegetation on higher altitudes. Thus the two slope of the same valley running east of west may have deodar forest on slope having southern aspect and fir and spruce forest on the slope having northern aspect even when the altitude is the same.. Generally, northern slopes in Himalayas have better forests than the southern slopes, which in extreme cases are completely bare.

EDAPHIC FACTORS

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

Forest Soil :- Forest soil is defined as a portion of earth's surface which serves as a medium for the sustenance of forest vegetation, it consists of minerals and organic matter, permeated by varying amounts of water and air and inhabited by organisms; it exhibitspeculiar Characteristics impressed by the physical and chemical action of roots and forest debris.

Soil Information :- The factors responsible for soil formation and development are (i) Climate (ii) Biological agencies including vegetation and (iii) animals; (iv) parent rocks, (v) Topography and time.

Details may be read from the **Silviculture book or any other Soil Science book.**

Influence of Parent rock or Forest :- The occurrence of a tree and its distribution sometimes verymuch influenced by the parent rock. The tree draws nutrition not only from the soil formed from parent rock but also from the paritally weathered parent material. Therefore, the parent rock affects the growth

and distribution of trees species. Though, most of the species grow on a variety of geological formations, yet there is in certain cases a characteristic correlation between the under lying rock and the occurrence of a particular species. A few examples are given below :-

1. In western Himalayas, chirpine occurs mostly on quartzite rock, while blue pine occurs on micaschist. As the Kashmir and Kulu valleys have practically no quartzite formations, chir is conspicuously absent in there valleys. If quartzite occurs at higher altitude, chir appears there changing the common altitudes zonation of conifers as seen in the following two cases :-

a) In parbatti valley (H.P.), Deodar occurs at lower altitude on old and fresh alluvium where as chir occurs above deodar at higher altitude on quartizite.

b) In Tirthan valley (H.P.), a dry quartzite formation occurs at a higher altitude than mica schist is monopolized by blue pine while chir pine occurs on quartzite at higher altitude above blue pine.

Similarly there are many examples which prove that the rocks sometimes decide the fate of the occurdences of many tree species.

Soil profile special features of soil profiles such as :

(I) Accumulation of Salts :- Saline soils, Non-Saline alkali soils and Saline soils.

(II) Pan formation - Lateritic iron pan, Podosolic iron pan, silican pan, Kankar pan and clay pan. Physical properties and chemical properties of soil may be read from the book :-

Importance of Edaphic Factors :- Soil provide water and nutrients for trees, all their physiological processes are controlled by it. It affects the size as well as rate of growth of trees natural regeneration and establishment of crops. Under prevailing climate occurrence of various places species at various are governed by soil or edaphic factor. For example in more or less pure sal forests occurrences of pure patches of **"Ougeaia"** or **"Anogeissus"** is due to change in soil condition. In another words with more or less uniform climate, one type of vegetation gives place to another only because of the change in edaphic factor : Unlike climate and topographic factors Edaphic factors can be managed by the foresters in favour of growing tree.

BIOTIC FACTORS

In a forest besides trees various other living organisms such as weeds epiphytes parasites insects and animals also survive and thus influence each other. Thus Biotic factors are defined as "the influence of living organisms". Biotic factors can be studied under the following headings :-

1. Influence of plants.

2. Influence of insects

3. Influence of wild animals.

4. Influence of man and his animals.

1. Influence of plants :- When we grow a desired species of tree it faces competition with the plants of the same species as well as others growing in the vicinity. This competitioin is for food and light. Besides, the plants also complete with harmful group of plants such as :-

i) **Parasites :-** **Cuscuita reflexa, Cassytha filiformis, Loranthus viscum** etc. Even the Sandal tree is a root parasite.

ii) **Epiphyles :-** **Ficus** bengalensis, **F. religiosa, Tinospora, Orchids** etc.

iii) **Climbers :-** Lianas are large woody climbers. Some common climbers are **Dioscorea, Muccina, Ipomaea, Bauhinia vahlii** etc.

iv) **Abnoxious weeds :-** **Lantana camara** is large parts of our country, **Eupatorium odoratum** in the forests of Assam, West Bengal, aparts of Bihar and the Deocan.

v) **Fungi :-** Various fungi causes diseases because of their parasite and saprophytic nature :- **Damping of** in seedlings and wood rot and root rot in trees are caused by Fungi.

2. Influence of insects :- Insects are beneficial and harmful both. The important harmful insects are

a) **Hoplocerambyx Spinicornis** :- Sal borer

b) Hapalia machcacralis :- Defoliator of Teak.

c) **Hylaea Puera** :- Skeleforizer of teak there are so many insects which are harmful to the desired three crops.

3. Influence of wild animals :- The wild animals in the process of procuring their food damage the forests a lot.

Example :-

i) Incresing herbivoras population such as deers Cheetals, Smabhars and nilgai sometime interface with the establishment or crops such as sal.

ii) Monkeys destroy Fruits and However where as porcupines destroy innumerable seedlings of bamboo khair and semal every year :

iii) Bisons and Elephants also damage the forests. Bisons rapeatedly brouse seedling of **Artocarpus hirsuta, Dalbergia latifolia, Pterocarpus marsupiumetc.** Eliphants feed on, Bamboos, **morus laivigata Ficus** spp. etc.

4. **Influence of man and his animals :-** Man and his animals are the most important factors affecting vegetation.

Increase in human population and consequent increase in cattle population has ultimately affected the forests only and as a result the area of the forests has decreased and because of heavy grazing the regeneration and growth of the forest crops has been badly affected. The various influence of man and his animals can be studied under the following headings :-

i) **Deforestation and enudation**

ii) **Fire :-** Fire if controlled is many times used in favour of desired crop. The advantages of fire are as follows :

a) Improvement in soil and undergrown conditions for including natural regeneration.
b) Clearance of site for artificial regeneration.
c) Hazard reduction : removel of dry inflammable material (Leaves, twigs weedsck). On the other hand uncontrolled fire causes damage such as :

a) Damage to trees
b) Damage to regeneration
c) Damage to Soil
d) Damage to the productivity of the forest
e) Damage to fauna.

iii) **Lopping :-** Trees are lopped by local people to feed the leaves to the cattle and it results into stunted growth of the trees as well as attack by various insects and pests and pathogen.

iv) **Removal of dry leaves :-** Dry leaves on the forest floor forms organic matter and increase the water retention capacity of the soil. Its removel by local people repeatedly reduces the productivity of the soil.

v) **Collection of flowers and fruits :-** Flowers are future fruits and seed and they are directly responsible for natural regeneration. If they are collected for human consumption indiscriminately it affects the forests.

vi) Grazing:- The damage caused by grazing which is unregulated is damaging to forests. Like fire "Grazing is also a good servant but bad master".

Chapter - II

FOREST TYPES OF INDIA

India's forest are complex both in numbers and variety. Various attenupts have been made to classify them. The most accepted classification was advanced by champion and seth (1968). This is based mainly on Eco-system which gives weightage to both vegetation and climate. According to this classification there are 5 major groups, which are further divided into 6 types groups or simple groups :-

Major Groups :

i. Tropical Forest.

ii. Montane Sub-Tropical Forests.

iii. Montane Temperate Forests.

iv. Sub-Alpine Forests.

v. Alpine - Scrub Forests.

Type Groups :-

i. Tropical Forests have been differentiated into 7 type groups or groups as follows :-

1. Wet evergreen forest.
2. Semi-evergreen forest.
3. Moist - Deciduous forest.
4. Littoral add Swamp forest.
5. Dry - Deciduous forest.
6. Thom forest.
7. Dry Evergreen forest.

ii. Montane Sub-Tropical forest:- Have been differntiated into 3 groups as follows :-

8. Broad leaved Hill forest.
9. Pine forests

10. Dry Evergreen forests.

iii. **Montane Temperate Forests :** Have been differentiated into 3 groups as follows -

11. Montane Wet Temperate Forest.

12. Himalayan Temperate Forest.

13. Himalayan Dry Temperate Forest.

iv. **Sub-Alpine Forests :-** Has only one group as 14 Sub-Alpine Forest.

v. **Alpine Scrub Forests :** Have been differentiated into 2 groups :-

15. Moist Alpine Scrub.

16. Dry Alpine Scrub.

Therefore, under 5 major groups of the Indian Forests types, all together 16 groups of the forests have been recognised. Details of the groups is not possible to describe in few pages but the major sub-groups and types is brief are as follows:

Group 1

Tropical Wet Evergreen Forests: This is divided into 1A and 1B Sub groups.

1A stands for Southern Tropical Wet Evergreen Forests.

1B stands for Northern Tropical Wet Evergreen Forests

Sub-Group 1A : Prominently developed in tropical parts of southern India. The mean annual rainfall ranges between 2000 mm. to 3300 mm. and the number of rainy days from 118 to 150 means annual Temperature is about 27°C. These forests are mainly situated in Anadaman. Nicobar islands and Western ghats.

Type $1A/C_1$ - Gaint Evergreen Forest (Andaman Western ghats)

Type $1A/C_2$ - Andamans Tropical Evergreen Forests.

Type $1A/C_3$ - Southern Hill top Tropical Evergreen Forests.

Type $1A/C_4$ - West coast Tropical Evergreen Forests.

Sub-Group 1B:- This is found in the eastern and north-eastern parts of the country, viz. Assam, West Bengal, Orissa etc. The average annual rainfall is over 2500 mm.

The number of rainy days in a year is 122 to 137 and the annual temperature coverage is 22°C to 26°C.

The main species of this sub-group are **Dipterocarpus, Mesua, Michelia, Shorea** in the overwood, bambusa, Vatica in the middle story.

This has the following type :-

Type $1B/C_1$ - Assam vally Tropical Evergreen forest.

Type $1B/C_2$ - ($1B/C_{2a}$ -and $1B/C_{2b}$) Upper Assam Valley Tropical Evergreen forest.

Type $1B/C_3$ - Cachar Tropical Evergreen forest.

Group 2

Tropical Semi-Evergreen Forests : This is also divided into two groups i.e.2A and 2B.

Sub-Group 2A: Southern Tropical Semi-Evergreen Forests :- This type of forests occur in moister localities of the southern tropical part of the country, mainly adjoinir g the evergreen forests. Prominent along the westernghats. The mean annual rainfall is between 2000 mm and 3000mm, and the total number of rainy days in a year is between 98 and 110. The main annual temperature is about 26°C.

The following are the type of forests :-

Type $2A/C_1$ - Andamans Semi-evergreen Forest

Type $2A/C_2$ - West Coast Semi-evergreen Forest

Type $2A/C_3$ - Terunalvali Semi-evergreen Forest

Sub-Group 2B : Northern Tropical Semi-evergreen forest : This sub-group occurs is the heavy rainfall tracts of Assam. Bengal and Orissa. The mean annual temperature is about 24°C and the mean annual rainfall varies form 1500 mm to 3000 mm.

Further divisions are as follows :

Type $2B/C_1$ - ($2B/C_{1a}$ and $2B/C_{1b}$) Assam valley Semi-evergreen forest.

Type $2B/C_2$ - Cachar Tropical Semi-evergreen forest.

Type $2B/C_3$ - Orissa Tropical Semi-evergreen forest.

Group 3 : Tropical Moist Deciduous Forests :-

This group is divided into 3 sub group :-

Sub group - 3A - Andamans Moist Deciduous Forests.

Sub group - 3B - South Indian Moist Deciduous Forests.

Sub group - 3C- North Indian Tropical Moist Deciduous Forests.

Sub Group 3A : Andamans Moist Deciduous Forests:

They are well developed in Andamans and Nicobar Islands Main overwood special are **Pterocarpus dalbergioides, Dillenia, Salmalia insignis, Terminalia spp. Diospyros etc.**

Sub Group 3B : South Indian Moist Deciduous Forests

This is found in parts of Mandla and Raipur (M.P.), Dangs (Gujarat), Thana (Maharashtra), Mangalore (Karnataka)

Type 3B/C_1 : Moist Teak Bearing Forests :

This has the following sub-types

3B/C_{1a} - Very moist Teak Forest.

3B/C_{1b} - Moist Teak forest.

3B/C_{1c} - Slightly moist teak Forest.

3B/C_2 - Southern Moist Mixed Deciduous Forest.

Sub-Group -3C : North Indian Tropical Moist Deciduous Forest :

This sub-group occurs throughout northern India, except in the day north-west and very Wet north-east. It is well distributed in Bihar, Bengal and Assam. The mean annual temperature ranges between 21°C and 26°C, the the mean annual rainfall between 1000mm and 2000mm., number of Rainy days varies from 48 to 112. This sub-group is sub-divided into folloowing 3 types :

Type 3C/C_1 - Very moist sal bearing forest. This is further divided into sub-types & Varieties.

Type 3C/C_2 - Moist Sal bearing forest. This is also divided into sub-types and varieties.

Type 3C/C_3 - Moist Mixed Deciduous Forest. With two sub types 3C/C_{3a} and 3C/C_{3b}

Group 4 - Littoral and Swamp Forests - (5 Sub-groups)

Sub group : 4A - Littoral Forests : This sub group has only a single type viz. - Type $4A/L_1$ - Littoral forests, which is found all along the coastal region. Mean annual temperature various from 26°C to 29°C. The mean annual rainfall varies from 760 mm to 500 mm and the number of rainy days in a year is from 24 to 104.

Main Species : **Casuarina equisetifolia, Manilkara Littoralis, Callophyllum, Pongamia pinnata etc.**

Sub-group 4B - Tidal Swamp Forest : (3 types)

Type $4B/TS_1$ - Mangrone Scrub - species - **Avicennia, ceriops etc.**

Type $4B/TS_2$ - **Mangrove Forest** - Along deltic tract of South Indian rivers as well as in sunderbans species - **Rhizophora, ceriops, Avicennia** etc.

Type $4B/TS_3$ - Brackish water Mixed Fornt - occurs in Sunderbans delta and Andaman & Nicobar islands. species -**Heriteria, ceriops etc.**

Sub-group -4C - Tropical Fresh water Swamp Forests.

Distributed along the Himalayan foot hill tract and in tropical hill valleys. Principal species **Ficus glonurata, Trewia nudiflora, Salix, Syzyginus etc.**

This sub group has three types :

Type - $4c/FS_1$

Type - $4c/FS_2$

Type - $4c/FS_3$

Sub-group 4D-Tropical seasonal Swamp Forest : This has 5 types.

Type $4D/SS_1$ - Eastern Seasonal Swamp Forest

Type $4D/SS_2$ - **Barringtonia** Swamp Forest.

Type $4D/SS_3$ - **Syzygium cumini** Swamp forest.

Type $4D/SS_4$ - Low Swamp Forest.

Type $4D/SS_5$ - Eastern Dillenia Swamp Forest.

Sub-group-4E-Tropical Riparian Fringing Forest :-

This occurs along the beds of streams and small water channels. **Terminalia arjuna** (Centra India)

T. Myriocarpa, Lagerstroemia speciosa (Assam & Karnataka)

Group 5 - Tropical Dry Deciduous Forests

Sub-group 5A - Southern Tropical Dry Deciduous Forests.

Sub-group 5B - Northern Tropical Dry Deciduous Forests.

Sub-group-5A : The mean annual temperatures varies from 24°C to 29°C. The average annual rainfall varies from 750 mm to 1900mm and the number of rainy days in a year ranges from 40-81-Three types

Type $5A/C_1$ - Dry Teak Bearing forest.

Sub-type $5A/A_{1a}$ - very dry Teak bearing forest

Sub-type $5A/A_{1b}$ - Dry Teak forest.

Type $5A/C_2$ - Red Sanders - bearing Forest : Occurs on dry, Hilly, rocky ground in Andhra Predesh.

Type $5A/C_3$ - **Southern Dry Mixed Deciduous Forest** : Occurs through out peninsular India in Madhya Pradesh, Maharashtra, Andhra Pradesh, Gujarat, Karnataka and Tamil Nadu.

Sub-group-5B : The mean annual temperature ranges from 24C to 27C. Average annual rainfall varies from 900mm to 1150mm and the number of rainy days in a year from 35-80. It occurs throughout northern India, except in very dry western and very moist eastern part. It is found in H.P., U.P., Bihar, Orissa, West Bengal, Rajasthan and M.P.

Type :

$5B/C_1$ - Dry sal Bearing Forest : This has 3 sub types.

Sub types $5B/C_{1a}$ - Dry siwalik Sal Forest.

$5B/C_{1b}$ - Dry Plains Sal Forest.

$5B/C_{1c}$ - Dry Peninsular Sal Forest.

$5B/C_2$ - **Northern Dry Mixed deciduous Forest**

Besides there are some Edaphic Climaxes in this sub-group are given below :-

$5B/E_1$ - **Anogeissus Pendula**

E_2 - Bosweilia Forest

E_3 - Babul Forest

E_4 - **Hardwickia Forest**

E_5 - **Butea Forest**

E_6 - **Aegle Forest**

E_7 - **Laterite Forest**

E_8 - **Saline/ Alkaline Scrub - Savannah**

E_9 - **Dry Bamboo Brakes**

Group -6 - Tropical thorn Forests

Two Sub groups :

6A - Southern Tropical Thorn Forests.

6B - Northern Tropical Thron Forests.

Sub - group -6A : Occurs throughout dry peninsular India in Madhya Pradesh, Andhra Pradesh, Maharashtra, Tamil Nadu Mean annual temperature varies from 21°C to 26°C rainfall 460 mm to 900mm, number of rainy days in a year 29 to 57. This is sub divided into two types.

Type 6A/C1 - Southern thorn Forest : Found in the southern dry torpical zone - Main species are **Acacia catechu, Acacia nilotica, A. Chundra, Zizyphus jujuba, Prosopis, Anogeissuss, Capparis**

Sub-group-6B : Found in the northern dry tropical zone of M.P., Rajasthan, Gujarat, Haryana and U.P. Mean Annual temperature varies from 25°C to 27°C. Rainfall 250mm to 750mm, number of rainy days 15-38 in a year.

Type $6B/C_1$ - Desert thorn Forest.

Type $6B/C_2$ - Revine thorn Forest?

Group 7 - Tropical Dry Evergreen Forest

This group has only one forest type:

Type $7/C_1$ -Tropical Dry Evergreen Forest : Mean annual temperature 28°C to 29°C. Rainfall 870 mm to 1270mm. number of rainy days 47 to 57. The main species are **Manilkara hexandra, Conthium, discoccum, Zizyphus glaberrima, Acacia lucocephala, Albizzia amara, syzygium cumini, Azadirachta indica, Diospyros melanoxylone**

Group 8 - sub Tropical Broad Leaved Hill Forests

Sub-group 8A -Southern Sub-tropical Broad leaved Hill Forests.

Sub-group8B - Northern Sub Tropical Broad Leaved Hill Forests

Sub-group-8A-3 types

8A/C_1 - Nilgiri Sub-tropical Hill forest. Found in the tropical tract of the Nilgiri hills.

8A/C_2 - Western Sub-tropical Hill Forest.

8A/C_3 - Central Indian Sub-tropical Hill forests.

Sub-group-8B - Two types

8B/C_1 - East Himalayan Sub-tropical wet Hill Forests.

8B/C_2 - Khasi Sub-tropical wet Hill Forests.

Group 9-Sub tropical Pine Forests

This Group occurs throughout the Western (except Kashmir) and central Himalayas between a altitudes of 1000m and 1800m, though it descends down to 600m and ascends on southern aspects upto 2300m. The main species is **Pinus roxburghii**, which occurs in pure forests over extensive areas. The group also occurs on Khasi, Naga and Manipur Hills though the species in there areas is **Pinus insularis**.

Mean annual Temperature - 15°C to 20°C.

Mean annual rainfall - 1000m to 3000mm.

No. of rainy days - 67 to 122.

Types and Sub-types :

Type 9/C_1 - Himalayan Sub tropical Pine forest

Sub types 9/C_{1a} - Lower Siwalik Chirpine Forest.

9/C_{1b}- Upper or Himalayan Chir Pine Forest.

Type 9/C_2 Assam Sub-tropical Pine Forest.

Group 10-Sub Tropical Dry Evergreen Forests

Well developed on bhabar, the siwalik hills and the Himalayan foot hill tract upto about 1000m. There is only one forest type in this group.

Type -10/C_1 -Sub-tropical Evergreen Forest.

Sub-type -10/C_{1a} - Olea cupsidata scrub Forest. Well developed in the lower hills of Punjab, Haryana and M.P.

Sub-type : 10/C_{1b} Acacia modesta scrub Forest : occurs in lower hills, particularly denuded slopes in Hoshiarpur (Punjab) H.P.

Group 11 - Montana Wet Temperate Forests.

Two-Sub-groups 11A & 11B.

11A - Southern Montane Wet Temperate Forests : This sub group has only one type :

11A -C_1 - Southern Montane Wet Temperate Forest : Found mainly in Nilgiri hills in Tamil Nadu and Kerala.

11B-Northern Montane wet Temperate Forests : This occurs in eastern Himalayas from 1800mm to 3000m in West Bengal, Assam, Arunachal Pradesh.

Type : 11B/C_1 & 11B/C2

Type -11B/C_1 East Himalayan Wet Temperate Forest: Prominently developed in the temperate Zone of the eastern Himalayas - West Bengal, Sikkim, Arunachal Pradesh, Assam.

Sub -types

11B/C_{1a} - Lauraceous Forest Altd - 1800 m to 2100m.

11B/1_b - Bik-Oak- Forest - lowers hills Altd - 2100 - 2440 m.

11B/1_c - High leval Oak Forest - higher hills - Altd - 2440-2750m.

Type 11B/C_2 - Naga Hill wet Temperate Forest : In the wet temperate Naga hills.

Group 12 - Himalayan Moist Temperate Forests

This group occurs throughout the Himalayas between altitudes 1500m and 3300m, in Himachal Pradesh, U.P. Kashmir, Sikkim, West Bengal. Mean annual temperature ranges between 13°C and 16°C, rainfall. 1100mm to 2500mm.

Types 12/C_1 - Lower western Himalayan Temperate Forest.

12/C_2 - Upper West Himalayan Temperate Forest.

12/C_3 - East Himalayan Mixed Temperate Forest.

Sub types of type $12/C_1$

$12/C_{1a}$ - Ban Oak Forest -Altd-1800m to 2200m.

$12/C_{1b}$ - Moru Oak Forest - Altd - 2200m to 2400m.

$12/C_{1c}$ - Moist Deodar Forest - Altd - 1800 - 2500m.

$12/C_{1d}$ - Western Mixed coniferous Forest 2300-3000m.

$12/C_{1e}$ - Moist Temperate Deciduous Forest - 1800-2750m.

$12/C_{1f}$ - Low level Bluepine Forest - Above - 2100m.

Sub types of $12/C_2$ -

$12/C_{2a}$ - Kharsu Oak Forest.

$12/C_{2b}$ - West Himalayan Upper Oak Fir Forest.

$12/C_{2c}$ - East Himalayan Mixed Temperature Forest.

Sub type

$12/C_{3a}$ - East Himalayan Mixed Coniferous Forest.

$12/C_{3b}$ - Abics delavayi Forest - (Altd-1700m - 3500m)

Group 13 - Himalayan Dry Temperate Forest

This is by and large an open forest with the canopy closed only in favourable conditions. It is,well distributed in the inner ranges of Himalayas at altitudes of over 1500m, where percipitation is mainly in the form of snow.

Type $13/C_1$ - Dry Boradilevaed and coniferous Forest.

$13/C_2$ - Dry Temperate coniferous Forest (Sub types 13 & $13/C_{2b}$)

$13/C_3$ - West Himalayan Dry Temperate Forest.

$13/C_4$ - West Himalayan High level Dry Blue Pine Forest

$13/C_5$ - West Himalayan Dry Juniper Forest.

$13/C_6$ - East Himalayan Dry Temperate Coniferous Forest

$13/C_6/E_1$ - Larch Forest. This is an open forest. Found above 3000m alt. in Eastern Himalayas.

$13/C_7$ - East Himalayan Dry Juniper Birch Forest.

Group 14 - Sub Alpine Forests :

This group of forests represent the highest tree forest, occurring in the Himalayan region. Usually along the periphery of alpine meadows and snow blanks in the altitudinal zone of 2900m to 3500m Climate is long and severe winter and forests comprise typically of a dense growth of small crooked and stunted trees with scattered patches of coniferous word.

Type : $14/C_1$ - West Himalayan Sub-alpine Birch - Fir Forest :

Sub -type : $14/C_{1a}$ - West Himalayan Sub-alpine Fir Forest

$14/C_2/S_1$ Sub alpine pasture

Group - 15 - Moist Alpine Scrub

The forests of this group constitute the vegetation occurring at very high altitudes in the Himalayan region, usually along the Snowline. These are generally devoid of true growth.

Type : $15/C_1$ - Birch Rhododendron Scrub Forest.

$15/C_2$ - Deciduous Alpine Scrub

$15/E_1$ - Dwarf Rhododendron Scrub

$15/C_3$ - Dwarf - Sub alpine - Scrub.

Group - 16 - Dry Alpine Scrub

This group occurs in Uttar Pradesh, H.P. and Kashmir at very high altitudes in the dry zones of Himalayan region. It is Xerophytic formation with predominance of dwarf shrubs. This group consists of one type.

Type $16/C_1$ - Alpine Scrub : This scrub occurs in the desert like conditions prevailing the trans - Himalayan - Ladak, Lahaul - Spiti, Upper Kumaun.

Chapter - III

FOREST REGENERATION

Reproduction is a synonym of regeneration. In case of forests it means "revewal of a forest crop by natural or artifician means". Thus, theforest regeneration may be

(i) Natural regeneration.

(ii) Artificial regeneration.

(iii) Natural regeneration supplimented by artificial regeneration.

(I) **Natural regeneration :** "Renewal of a forest of a forest crop by self-sown seed or by coppice or root suckers" is known as natural regeneration. It may be obtained by either (A) from seed or (B) from Vegetative parts. The forest developed from seed or seedling is known as high forest and that from coppice as coppice forest.

(A) **Natural regeneratiion from Seed :** Depends upon:

(i) Seed production (ii) Seed dispersal (iii) Germination (iv) Establishment

(i) Seed production : the seed production depends upon Species, age of trees, Size of corwn, climate and other external factors. All species do not seed annually and abundantly. For instance while teak, babul, Khair, Shisham seed every year, deodar, fir Spruce seed at interval of years.

(ii) Seed dispersal : Seed dispersal agents are as follows :

By wind : Conifers, Acer, Populus, Alnus, Salix, Dalbergia, Acacia catechu, Casuarina and many others.

By water : Trewia, most mangrove species, **Delbergia, teak,** etc.

By gravity : Oaks, Juglans regia, Aesculus etc.

By birds : Prums, Mulberry, **Trema, Diospyros melanoxylon etc.**

By animals : Acacia arabica, prosopis juliflora, Zizyphus, Anthocephalus etc.

(iii) **Germination :** Germination of seeds depends upon Internal and External factors.

Internal factors may be, permeability to water, permeability to oxygen, development of embryo (dormancy) after ripening developments in seed (**Juniperus macropoda**); viability (the potential capacity seed to germinats). Size of seed, plant percent (percentage of the number of the seeds in a sample that develop into seedlings at the end of the first growing season) etc.

External factors : The external environment which affects germination are Moisture, air, temperature, and in some cases light (**Cassia fistula, Albizzia procera**). Besides, it is also necessary to prepare the forest floor i.e. seed bed for proper germination of seed and its growth.

(iv) **Seedling establishment** : Only germination of seeds does not guarantee a forest establishment, because due to various reasons, numerous seedling die out every year after germination. Establishment is defined as "development of a new crop, naturally or assisted is considered, safe from normal adverse incluences such as frost, drought or weeds and no longer needs special protection, or tending operations other than cleaning thinning and prunning".

The following factors affect establishment of seedlings :-

a) **Development of roots** : - Normally a seedling must develop longer roots in the first growing season only to become self sufficient for moisture and mineral absorption by making contact with the deeper layers of soil.

b) **Soil conditions** :- The soil should have good moisture and water holding capacity (not water logged), organic matters, nutrients good aeration etc. for better growth of seedlings.

c) **Light** :- Depending upon the species and under given climatic conditions light plays very important role in seedling establishment. For example in moist localities teak seedling must have sufficiant light from the very beginning but in dry hot localitics, a sudden flux of light on young seedlings may cause theirdeath.

d) **Other climatic factors** :- Excessive high temperature, low temperature, rainfall or long dry season etc. are the factors which govern seedling establishment.

e) **Conditions of grass and other competing weeds** :- For changing localities, the prescription changes. In the dry and arid areas a certain amount of weed growth is helpful in conserving moisture and affording certain amount of shade to the seedlings but in moister localities, needs particularly dense weeds are very harmful. Sometimes certain weed species are marked as good indicators of good regeneration of particular forest crops. For example :- **Flemingia spp** indicate favourable condition for sal regeneration where as **Imperate arundinacea, Saccharum procerum** indicate unfavourable condition for the same.

f) **Grazing, browsing and burning** :- Light grazing and browsing is not harmful to seedling establishment but uncontrolled grazing and browsing completely destroy regeneration. Similarly, where as control burning is a silviculture prescription, the uncontrolled fire is devastating.

Besides the composition of crops drips (water drops from larger leaves), also influences the regeneration.

The methods of obtaining natural regeneration vary with the silvicultural systems used and the species. The details of these may be covered under the study of Silviculture systems a separate course.

B. **Natural regeneration form vegetative parts :-** Some species have the power to regenerate themselve by vegetative parts such as root, stem, branch etc. Reproduction obtained from there parts is called vegetative reproduction which is defined as "asexual reproduction in plants from some parts of the plant body, i.e. of trees by coppice or root sucker or from root, stem or branch cutting.

Advantages of vegetative reproduction :-

(i) One plant produces several plans.

(ii) This is also possible when the plant is not capable of producing seed.

(iii) The plants obtained from vegetative reproduction grow faster than the seedlings at lesser cost.

Methods of vegetative reproduction :-

(i) Coppice (ii) Root sucker (iii) Cutting (iv) Layering (v) Grafting and Budding.

Natural regeneration by Coppice : By (1) Seedling coppice and /or (2) Stool coppice.

(i) Seedling coppies : It is defined as the "Coppice shoots arising from the base of seedlings that have been cut or burnt back. The advance growth of Sal is in the form of whippy shoots, woody shoots and sometimes, even the established regeneration, often does not progress due to adverse environmental conditions and keep on stagnating for years. If this stagnating advance growth is cut back and given proper light conditions, it progresses fast and soon developes into sapling and pole crop. This method of obtaining natural regeneration of Sal is used in several Sal divisions in U.P. (if Dehradun), M.P., Bihar and Orissa. Similarly this method is used for obtaining natural regeneration to teak in many divisions of M.P.

(2) **Stool Coppice :** Coppice arising from the Stool or living stump. The coppice shoots generally arise eitehr from near the base of the stump or from its top. Of the two, two those arising from near the base are better because they get established easily.

Factors affecting natural regeneration by coppice :

(1) Coppicing power of Species varies and all the species do not coppice well:

Strong coppicers : Acacia catechu, Albizzia spp., Butea monosperma, Cassia fistula, Eucalyptus spp., Morus alba, Prosopis juliflora, Salix Spp, Shorea robusta, Tectona grandia etc.

Fairly good coppicers : Quercus Spp., Terminalia spp., Juglans regia., Plerocarpus marsupium etc.

Bad Coppicer : Adina cardifolia, Bombax, ceiba, Casuarena equisetifolia, Madhuca latifolia Populos ciliata etc. conifers are bad coppicers.

2. **Age of the tree:-** With the age of the trees gradually coppicing power deline.

3. **Season of coppicing :-** The best season for coppicing is a little before growth starts in spring, because delay results in reducing the growing period. But in places where there may be danger of late frost in spring, coppicing should be done after the danger is over.

4. **Height of stump and method of cutting :** Usually lower the stump, the better it is for the coppice. Very near to ground stumps are sometimes attached by rots. Normal height should be 15 to 25 cm. Stump should be given a slant at top for water drainage. Sometimes, higher stumps also help in getting good coppice even with the species like **casuarina equisetifolia** which is a bad coppicer.

5. **Rotation :** Since most of the trees coppice best during the early age, coppice ratation should be short. Long ratation encourages seedling regeneration and for that reason, coppice rotation is generally shorter than the age at which trees produce good viable seeds.

6. **Silviculture System :** The coppice shoots are strong light demanders and therefore, they must be worked under systems involving clear-felling. Thus seedling coppice is used to obtain natural regeneration of Sal and Teak under clear felling system in Bihar, M.P. and parts of Maharastra and under uniform or Indian irregular shelter wood system in U.P. When natural regeneration is obtained from stool coppice, the silvicultural system may be simple coppice system, coppice with standards system or coppice with reserve system.

Simple Coppice System : In this system coupes are clearfelled on short rotation to get new coppice crops. Naturally this system is applicable to species which coppice strongly.

Coppice with Standards System : In this system, a part of the crop is retained to form an uneven-aged overwood. Thus the resultant crop is two-storeyed, the upper storey, being of standards, over the lower storey of coppice crop.

Coppice - with - reserves : In this system, well grown saplings and poles are retained in coupes to form part of the new crop and rest is felled. The reservation is done with the objective of improving the

condition of the crop, providing protection against frost and crosion, supplying seed protecting valuable species as well as species with edible fruit etc.

Natural Regeneratioin by Root Suckers : This method is not being attempted on any large scale anywhere in this country. Sissoo was the chief species in which this method of regeneration was practiced in U.P. on canal bank plantations.

II) Artificial regeneration :- Artificial regeneration is defined as the renewal of a forest crop by sowing planting or other artificial methods. Normally such a crop is called by another term 'plantation'. Plantation is defined as a forest crop raised artificially, either by sowing or planting. Planting is a far more dependable method of artificial regeneration than direct sowing.

Artificial regeneration is carried out mainly for Refoestation and Afforestation.

Reforestation: Is is defined as the "restocking of a felled or otherwise cleared woodland" by artificial means. In other words, reforestation is the raising of a forest artificially in an area which had forest vegetation before. On the other hand, afforestation is the "establishment of a forest by artificial means on an area from which forest vegetation has always or long been absent".

Objects of reforestation : Reforestation is done :-

1. to supplement natural regeneration.
2. to give up natural regeneratiion in favour of artificial regeneration. Example :- Artificial regeneration offer and spruce forests in Chanchpur (M.P.) Sal forests in parts of U.P., Bengal and Assam and teak forests in parts of M.P., Maharastra, Kerala etc.
3. to restock forests destroyed by fire and other biotic factors.
4. to change the composition of the crop.
5. introduce exotics. Example : Plantations of Eucalyptus, tropicalpines, poplars etc.

The recent trend is towards man-made forests and, during the past few years greater effort has been made to raise them with the following objects.

i) Increase the yield from forests to meet the fast increasing demand of timber for building construction, industries, defence and communications.

ii) Shorter the rotation by raising fast growing species.

iii) Location forests with relation to locations of industrie

iv) Meeting the demand of agricultural implements, housing, Fodder and firewood of the rural population.

v) Improvement of agro-ecosystem, control of erosion, and beautification of countryside.

vi) Concentration of work resulting in easier supervision, easier mechanizatioin of operation cheaper logging and extraction and

vii) increasing employment potential.

Essential considerations of Artificial regeneration (AR):-

i. Choice of species.
ii. Selection of site.
iii. Choice of methods of A.R. viz. sowing or planting etc.
iv. Spacing and
v. Arrangement of staff and labour

I. Choice of species : This depends upon the following factors :

a) Climate and microclimate
b) Soil conditions
c) Stage of succession.
d) Object of management
e) Consumers requirement
f) Growth rate
g) Availability of Suitable exotic
h) Ease of establishment
i) Cost
j) Select on site.

Before selecting a species for A.R. the above factors must be taken into account as the success is not only dependent on better growth but also other conditiions mentioned above. Further, it is also important to decide whether they will be raised as pure or mixed crop.

II. Selection of Site : Even after selection of species, the species should not be planted on large scale on any site, rather experimental trial should be given first and if the results are encoraging it should be prescribed for specific sites.

III. Choice of method of A.R. : After I and II, the method of AR is decided. This may be done either by sowing of seed directly in plantation area or by planting seedlings or cuttings obtained from some nursery. Each of the methods have merits and demerits both. Though most of the species can be raised by both the methods, some of them e.g. Sal, Khair, Chir and Kail were till recent part, raised by sowing as their planting was considered difficult. But none even these species are raised by planting in many states. As a general rule, slow growing species or the species having seed enclosed in a hard coat are raised by planting Ailanthus, Albizzia etc. however, continue to br raised by sowing.

IV. Spacing : Spacing is defined as "the distance between the plants put out in plantation or standing in a crop". It is also referred "espacement". Spacing is expressed by distance between the lines multiple by the distance between the plants in the same line in meter.s

Exp. : 4m x 2m means that lines are 4m in apart and the plants are 2m aprat. Based upon this spacing is referred as close spacing or wide spacing.

Usual spacing of some important species :-

i) **Teak (Tectona grandis) :-** 1.8m x1.8m in lower quality classes area and 2.6mx 2.6m in higher quality class areas.

ii) **Sal (Shorea robusta):-** Usually raised by line or strip sowing. In the lines, the seeds are spaced at 8c.m. (West Bengal) to 10c.m. (U.P.) apart. The lines or strips are spaced 1.8m in West Bengal to 3 or 3.6m in U.P.

iii) **Semal (Bombax ceiba) :-** There is no recognised spacing for semal. It is raised at a spacing from about 4.6m x 4.6m to 11m x 11m.

iv) **Eucalyptus Spp. :-** The usual spacing varies from 2.4m x 2.4m to 3.3m x 3.3m but where tractors are used for soil working and suppression of thick grass, its spacing is 1.2m to 1.8m from plant to plant in the same line, while the lines are spaced from 3.6m to 4.5m apart.

v) **Arrangement of Staff and Labour :-** In case of A.R. done by forest department if the area is small say, 10 to 20 hectares, the existing range staff can do it. When it is 25 to 80 ha, additional staff is posted for A.R. If however, the area to be taken up for A.R. in one, division is as large as 600 to 800 ha or more, it is better to create a new plantation division with full complement of stuff and do the work in two or three centras for the sake of concentration of work.

The labour engaged for the work are either daily wages labours or sometimes the work is done through contractros. **Taungya** System is also followed where labour are permitted to raise agricultural crops in between trees in lieue of their labour. Taungya is a Burmise word which

means cultivation in the hills. This cultivation is shifting cultivation which is defined as a "a method of cyclic cultivatiion, ciefly in vogue in the tropics, where moving on to another site and repeating the process". This is also known as "Jhum" (Assamese). This distructive method of cultivation has been changes by Indian forests into a cheap and production method of raising forest crops conjunction with agricultural crops. In this method, the area to be regenerated is handed over to tanngya cultivators after clearfelling. They burn, the felling refuse and raise agricultural crops for themselves. Along with cultivation of agricultural crops, they also raise forest plantation in lines and continue to cultivate the area for 2 or 3 years, after which they move to the next area. Thus the term "taungya" is now applied to the method of raising forest plantations in combinatioin with field crops otherwise known as Agri-silvi method or Agrislviculture.

The taungyas as per its method of operations may be Departmental taungyas, Leased taungyas or village tanungyas.

Nursery :- As seedling are planted in the field in case of plantations or artificial regeneration, it is important to develop nursery to raise required seedlings for plantation. A nursery is define as "an area where plants are raised for eventual planting out". A nursery may be (a) Temporary or (b) Permanent Temporary nursery is also referred as field nursery and "as the name suggest it is formed in adjoining the planting area. It is intended to meet the requirements of a limited area, it is usually small in extent. On the other hand a permanent nursery is maintained for supplying nursery stock for a long time on a permanent basis. As it is intended to meet the requirements of one or more ranges, it is relatively larger in extent.

Site of a nursery :- It should be centrally located preferably near Ranger's or Forester's quarter for proper supervision. The soil should be well drained the labour supply should be smooth and also adequate water source for irrigation.

Area of nursery :- It depends upon the species to be raised, age of seedlings or transplants at the time of planting out, number of transplantings required, area of plantation and spacing in plantation. The areacalculated on the basis of these considerations should be increased by 50% to allow for paths, roads, irrigation channels etc. For example in Bengal for 1.8m x 1.8m planting of one year old nursery stock, one hectare nursery is considered sufficient for plantation of 200 ha i.e. 0.5% of plantation area.

Details of the nursery fencing, layout and preparations of bed may be read in books.

Paper III

1st Half

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   Publisher : Khanna Bandhu

   7 Tilak Marg, Dehradun, U.P.

2. **The Practice of Silviculture by David M. Smith**

   Publisher : E.D.B. Educational Pvt. Ltd.

   15, Rajpur Road, Dehradun - 248 001.

MODULE -20 (A),21.22

Questions :-

1. What are the major forest types of India? Write the important considerations on which these forest types are classified.

2. Write short notes on following :
   - i) Rainfall and its influence on vegetation on India.
   - ii) Influence of Parent rock on species distribution in forests.
   - iii) Man and his animals - as biotic factor.

3. What is coppice? What is the difference between seedling coppice and stool coppice? Explain briefly the factors which affects the regeneration by coppice.

4. What is artificial regeneration? What are its objectives? What are essential considerations in favour of artificial regeneration ?
   - a) Nursery
   - b) Frost injuries.
   - c) Importance of Edaphic factors
   - d) Effect of Altitude on the climate of a locality.

Chapter- IV

Silviculture of

SHOREA ROBUSTA

Family : Dipterocarpaceae

Local name : Sal, Shal, Sakhu, Sakwa

DISTRIBUTION :

Sal forests occupy about 1,16,000 sq. km. or about 14.2% of the total forest area in India. It occupies two main regions, the northern and central Indian region. In the northern region it commences from kalesar forest in Ambala (Haryana and stretches eastwards along the sub-Himalayan tract as far as Darang (Assam), through U.P., Bihar, Assam, Mehalaya and Tripura. In the central regions, Sal occurs in Bihar, West Bengal, Orissa, M.P. with isolated pockets in Andhra Pradesh.

Flowering and Seeding : Flowers appears from late February to April depending on locality and season. Fruits ripen in May to July and fell soon after.

Fruit weight : 575 to 1000 per kg. Average seed year almost every two years but good seed year after every 3-5 years.

Germinative capacity – 80-96% of sound – fresh seeds and plant percent upto 86.

Viability : Seed loses viability rapidly it may be stored for about 7 days only. Seeds germinate soon after falling; in some cases even on trees.

PROPAGATION:

Natural regenerations: Natural regeneration of Sal is not satisfactory, particularly in moist and dry deciduous Sal forest types. The problem is not the recruitment of regeneration but its establishment. However, there is no problem of regeration in moist peninsular low level and valley Sal forests of M.P. (South Raipur), Bihar (Singhbhum) and Orissa, which are successfully worked under vitual clear felling, followed by natural regeneration from tended advance growth. Early and well distributed rains synchronising with seed fall, absence of frost and suitable soil conditions are the main favourable factors of germination

Artificial regeneration: The method largely used in the filed is by direct sowing. Sal has been successfully raised by sowing in clerfelled areas by departmental plantations in Tripura by taungya in U.P., Assam and W.B.

PLANTING: -

Planting of 22 or 34 months old basket plants in 60 cm^3 pits, 3m apart in continuous strips, 6m apart, both in clear felled areas and under shelterwood gave 80% survival, in Haldwani Division on U.P.

Transplants in dona containers have proved successful in dry Sal forests of southern West Bengal, more successful than sowings in heavy clayey and lateritic soil, Dona planting is dine in partly filled trenches at a spacing of 1 to 1.25 m throughout to supplement sowings in plantations. It has give 75% survival at reasonable cost in W.B. This technique has also been adopted in Bihar. Even polythene bags have been used as containers with cent percent success.

Stump planting: Stumps prepared from one year or two year old nursery stock were successfully planted in W.B. & U.P. Pre-sprouted stumps in polythene have also been found successful.

Nursery Practice:-

In Southern West Bengal and Bihar, Sal is raised in donas (leaf cups), made up of Sal Leaves, 6-8cm diameter and 22-23 cm deep. These are filled with silt, earth and cowdung mixed in 2:4:1 proportion. Two fresh seeds are sown in each and watered regularly. In summer they are kept in shade. At the onset of monsoon, dona seedlings with 4 leaves and 12-15 cm in height are fit for planting out with containers.

Tending : Intensive tending of young crops of sal, whether natural or artificial, is very important, for establishment of seedlings. These operations involve weedlings, hoeing, selective shrub cutting, fencing fire protection and manipulation of cover at various levels and various stages.

General characteristics:

i) Sal is a large deciduous tree, seldom quite leafless and one of the most important timber trees of India. It is a light demander, sensitive to drought and frost, fire resistant. It is a good coppicer. It is a very slow growing species.

ii) Sal wood is very hard, tough and heavy. Heart wood is naturally very durable. Timber is difficult to saw and work with, due to interlocked fibres.

iii) Main use of Sal timber is for railway sleepers. It is used as poles, ballies, overhead electric transmission lines and in various other works. This is also an excellent fire wood.

iv) Bark of Sal is useful as tanning material.

v) Sal seed yields vegetable oil.

vi) **Management :** Sal forests are being worked in various states under a variety of Silvicultural systems. In Saranda (Bihar) and in South Raipur (M.P.). It is worked under clear felling with natural regeneration. Clear felling with artificial regeneration is followed in the taungyas of West Bengal, Assam And U.P. Besides uniform, Irregular Shelter wood, selectiion, systems are also followed according to the factors of locality. Under coppice system. Sal is worked as simple coppice, coppice with standards and coppice with reserves.

Tectona grandis (Teak)

Family- verbanceae

Vommon name : Teak- Eng. Segun-Bengal, Sagun, Sangun-Hindi

1. General distribution and habitat

Teak is indigenous to Baruma, Indian peninsula, siam, Java, Indonasia, Malaya, Thailand and other islands adjoining India.

The localities where the most important teak forests are found are M.P., Mysore, Bombay, Coorg, Tavancore, Cochin. Out side its natural habitat, it is planted in Uttar Pradesh, Bengali, Bihar, Orissa, Assam and Andamans.

Climate : Teak thrives best in fairly moist, worm, tropical climate.

Rainfall: Max : 200"

Opt : 100"

Min : 25"

Temperature : Max : 118°F

Min : 40°F

Altitude : Extends upto 4000" in western ghats. Best growth is obtained at about 2000" and below.

Topography: Thrives equally well in undulating as well as flat alluvial country provided subsoil drainage is satisfactory. Given this, the growth can be equated in terms of the depth of soil. In Madras, all India Super quality is met with along river banks, on ridges and upper slopes, the growth is poor.

Geology, rock and Soil:

Teak occurs on a variety of geological formations varying from sandstones to lime stones to geneisses and schists.

It thrives in soils ranging from sandy to clayey loam. It thrives best in sandy loams along river and stream banks. It requires deepest, well drained soils of moderately high fertility.

Teak occurs in soils with a pH range of 6.5 to 7.5. Good teak forests are found in soils which have a higher pH value of sub-soils. In other words, teak prefers basic soils.

Teak is intolerest of shallow soils, keep sands heavy clays and water logging.

II. Phenology:

1. **General description:** A large deciduous tree with a rounded crown and under favourable conditions a fall clean cylindrical bole which is often buttressed at the base sometimes flutted. Branches quadri-angular, channelled with a large quadrangular pith. Bark thin grey, exfoliating in long, thin grey, exfoliating in long narrow flakes.

When leafless, the ashy colour of the bark readily leads to its identification. When in leaf, the large, shinning leaves and a very large inflorescence provide distinguishing characters of identification.

2. **Leafless :** November – January (Any area) March (Moist areas); in very moist localities, almost evergreen.

3. **Leaf renewal:** April to June according to locality. Leafless during the hot weather in dry localities.

4. **Flowering:** June – September.

5. **Fruiting :** November-January. Seed collected in January – February. Fruit hard ibony, regularly globose nut, somewhat pointed at the apex enclosed thick folty light brown covering, usually 4" to 6" in diameter containing 1 to 3 rarely 4 seeds. One fruit may produce two or three seedlings. Weight of the seed is about 1430 seeds/kg.

III. Silvicultural Characters:

Light : Very strong light demander. Can not tolerate suppressiion at any stage. Under light shade of bamboo the leading shoot has the capacity to make head way and rise above the culms.

Wind: Moderately wind firm.

Drought : Seedling extremely sensitive particularly in the first years; dies completely. Later on, stem portion may die while at the same time building up root stock until it attains sufficient vigour to produce a permanent stem.

Trees: Severe draught may have an adverse effect on even bigfully established trees.

Fire: Teak has greater power of resistance than majority of its associates.

Frost: Frost tender of :

Browsing and animal injury – Not browsed. Injured by wild animal.

Insect attack: Defoliators – most common (1) Hyblea poucea and (2) Hopalea machaeralis.

Borers: Dihammus earvinus attacks young plantations in West Bengal.

Coppicing and pollarding: Coppice vigorously.

IV. Natural regeration:

V. Artificial Regeneration

Teak is the first to be artificially regenerated (1842). Artificial regeneration is the frequently adopted for its propagation.

After proper collection seed should be dried in the sun for 6 to 7 days. There are several methods for Preparation of seeds before sowing i.e. pre-treatment.

1. **Pre-treatment :** (a) Seeds are soaked for 48 hrs. in water and the dried in the sun for 48 hrs. This process of alternate soaking and baking is continued for 12 to 15 days.

Are generally raise. Their size may be 10mt x 1mt.

Germination takes place within 7 to 10 days of sowing. Germination percent is 90-99 and the seedling survival percent from 80 to 90.

Pricking out process is not recommended as it leads to the development of a bushy root system.

3. **Planting :** The following points are to be kept in mind while selecting a planting site.

(a) Poorly drained sites should not be selected as teak dies off under such conditions.

(b) Late ritic soil is not suitable.

(c) Quartizite soil should be avoided.

(d) Clayey cotton soils, stony tops etc. are also unsuitaeste for raising teak Plantations.

(e) Areas having steep stops should also be avoided.

Seedlings are transplanted immediately after the break of the rains (June – July) entire with balls of earth or with a handful of earth round the roots when they have 4 leaves berides the colyledons.

Pre-monsoon stump Planting after the first showers in April is by for the best method of raising teak in plantations Experiments carried out show that the rate of growth and percentage of survivals from pre-monsoon stump planting in April far exceeds that of either rains stump planting, transplanting or direct sowing. About 18 mm diameter at the collar is the most.

(b) Pit treatment: This method is the one most commonly used in Bengal. A pit is dug 60cm to 90 cm deep and 90cm to 1.20 cm square and filled with water. When this has been done the out line, the bottom and sides of the pit are covered with teak leaves. Soak the seeds for 48 hours in water in a tubs warmed by the sun during the day and then put them in the pit with a layer of teak leaves between the layers of seeds and a final cover of 15 cm of earth. Before filling up the pit in this manner 5 bamboo pipes, one in the middle and one at each corner, the latter laid at a Hant are put into position and holes cut in then; So that when the pit has been filled up water an reach all layers. The seeds are kept in the pit for about 10 days and watering is done every alternate day. The pit is then opened and normally about 80 percent of seeds are expected to have germinate.

© Scorching the seed in a light fire.

(d) Burying the seed near an anthill.

(e) Placing the seed in paste of cowdung and water.

(f) Weathering the seed by exposing it to the sun and rain on leaving it in the open for 2 ro 3 weaks.

(g) Acid treatment.

2. **Nursery Technique :** Broad costing of seeds at the rate of about 5 to 7 kg per bed. Sowing are generally carried out from Feb; to May. The beds prepared.

Management of Teak:

(a) Clearfelling with natural or artificial degeneration or a combination of both.

(b) Coppice and modification of coppice.

(c) Selection cum improvement felling.

General remarks : Timber with golden brown to dark brown heartwood, medium weight (401b/cft) tenture uneven coarse grained, grain variable, often straight, medium bending strength, medium bending strength, higher crushing strength, stiffness, low toughness, moderately hard, very durable, very resistent to

impregnation fairly easy to work, seasons well but slowly. Natural resistance to termites due to oil (Sesquiterpine),.

Used for ship building, Coach building, furniture cabinet, Carpentry, Joinery vats etc.

TELI VARIETY OF TECTONA GRANDIS

A new Variety of teak, which is a prominent variation grom the normal has been revealed by observations on a teak plantation raised in 1923 in Hudsa Block of vimoli Range, Kanara North Divisons, Bombay state. It appears to be distinctly superior in more than one character. This distinct form of teak occurs sporadically mixed with the normal variety in the natural forests and the plantations in Kanara. It is Called 'Teli' Teak because the wood is said to contain more oil. It is considered to be stronger and more durable.

Suitable size for stumps, one year old seedlings stumps. Stun p Planting should be carried out as follows : A hole equal in the exact depth of the stump is made in the centre of the thali with on iron crowbar about 60 ml long. The stump is then inserted and the soil firmly pressed in against it by thrushing the crowbar in the ground at an angle close to the stump and levelling the soil fight against the root. Damp soil is necessary for each and successful stump planting. The essential points are –

(a) the stump should be planted exactly up to the collar.

(b) The depth of the hole should exactly be equal to the length of the root.

(c) When driving the crowbar slantwise and closing the hole, care must be taken that no air spaces are left below or around the root.

(d) The stump must be very firmly planted, and

(e) Every stump should be tested before it is left, and only if it is resident to a fairly hard pull should it be considered as satisfactorily planted.

Spacement: It depends up on the site quality and as well as objective of plantations. It may be 2mtx2mt or 2.5mtx2.5mt or even 1mtx1mt.

Thinning: Thinning should not be delayed and must be a heavy D grade. Teak must never be allowed to become suppressed as it has definitely been proved that teak has once, been suppressed does not respond to a thinning for 3 or 4 years and so much increment is lost.

Eucalyptus Spp.

Family Myrtaceae

1. **Distribution:** Eucalyptus is a genus of Australian origin, most of which are found in Australia, Tasmania, New guinea and other islands.

   Eucalyptus is an exotic in India. It does not occur in native form in India. Eucalyptus trees were first introduced in India, as early as 1790 at Nandi hills in Karnataka. In 1843, it was successfully introduced in Nilgiri Hills. However, regular plantations were taken up only in 1851. Later on extensive plantations were undertaken in Punjab and Haryana, where the forest are is very small to meet the demands of fuelwood, small timber and pulpwood. The species which have small, ti mmet the demands of fuelwood, small timber and pulpwood. The species which have received country wide acceptance are E. tereticornis, E. Cameldulensis. E. grandis. E.citridora, E. globulus.

Natural Habitat: It is a versatite tree, adopted to a variety of edaphic and claimatic conditions. It flourishes from coastal areas to area situated at an attitude of 200m, climate varying from tropical to warm temperate and annual –rainfall ranging from 400 to 4000 mm.

It can grow in a wide variety of soil conditions but requires deep, fertile, well drained loamy soil with adequate moisture for best growth.

II. Silvicultural characters:

(1) Eucalyputs, as a rute, are intolerant of shade, though many species tend to branch low if grown in isolated positions. Also, in early youth seedlings endure a little shade for a time.

(2) Many species coppice well, the most vigorous probably being in globules.

(3) Root system – spreading.

(4) Generally wind firm, but many species are liable to become bent, gnarled and stunted in exposed situations.

(5) The more aromatic eucalyptus are not readily browsed by cattle;. Two species E. corynocalyx where leaves are sweetish and E. gunnji whose elevates are not strongly aromatic are browsed by cattle.

(6) Thick –barked trees do not suffer much from fire but thin barked ones and young trees suffer

badly. Those with barks exfoliating in long, dry strips, like Bluegum suffer much as the fire as ceands through the strips to the crown. Most species have high power of recovery from fire damage. Injured and climate for various species vary considerably leaves.

(7) The requirements of soil and climate for various species vary considerably. generally speaking, most if not all eucalyptus grow best on deep fresh soil with a fair amount of sub soil-moisture. Many however accommodate themselves to unfavourable conditions and in such cases their growth affected.

III. Natural Regeneration: In Australia it is recognized that natural reproduction can be secured, by cutting the under growth in Eucalyptus areas, passing fire over the area, and thereafter strictly protecting from fire and in the first few years from grazing. These methods usually result in a good crop if natural seedlings form seed lying dormant or falling subsequent to the fire, where over, there is sufficient light for their development. In India, to a limited extend natural seedligns have been springing up in and around the blue gum plantations of the Nilgiri for some years past, and the essential conditions appear to be bares oil tree of woods and sufficient light.

IV. Artificial Regeneration:

Artificial regeneraion of eucalyptus are preferred in place of natural regeneration

Seeding time varies from species e.g. F. globulus May-June and 1,48,000-1,50,000 clean seeds/kg. in E. tereticuornis once in October and next in May-No. of seeds per is about 3,50,000. The possible method of seed collection include climbing, shooting, felling the fruiting branches and the use of tree shakers. extension platform ropes etc. The capsules should be spread in a thin layer to permit rapid drying and to prevent mold-formation. After drying, the fruits must be vigorously shaken, particularly if they are not fully mature, other wise abscission of the seed from the placenta may be only partially affected.

Extracted 'seed' usually consists of a mixture of fertile seed and chaff, plus large particles such as fruit, twisg and leaf debris. The fertile seed and the chaff can usually eb separated from other matter by sieving moving or by specific gravity sepeartions.

Viability of seed is 5-20 yrs. if stored at a low moisture content (4-6%) in sealed containers at 3.5°C. Eucalyptus seeds should be fumigated before storage to kill inseet pests.

Seed germination: Most Eucalyputs sedds need no pre-treatment to ensure adequate germination if fresh seeds are used. A few species which are normally dormant at the time of collection will require cold

stratification. In few cases (GA) have been employed to over come dormancy.

Nursery Practices:

The methods of raising eucalyptus seedlings in the nursery vary considerably and local experience alone can decide which method to adopt in any particular case. The best time for sowing the seed in most parts of India both in hills and on the plains is early spring, about February – March or even as early as January in the hills.

Seed beds should be well raised and should consist of a mixture of fine leaf moulds/ farmyard masure and sand. The seed is sown broadcast on the surface mixing with fine earth or sand and covered with a fine earth. The seed bed should be kept moist with a fine spray until germination begins. The beds should be protected by a Covering, raised about 30 to 50 cms above them. Germination of seeds commences in about a week and is completed in about 2-5 weeks.

When the seedlings show second pair of leaves above the cotyledons, they are ready for pricking out. Pricking out of seedlings is generally done into polythene bags. The poly bag size is generally 10-22 cm or 15-22 cm E. globulus and E. grandis are generally planted out using planting stock 20-30 cm tall. The soil mix used to fill the bags consists of garden soil. sand and compost in the ratio 1:1:1. The mixture is thoroughly pulverised and served. Insecticide like Aldren 5% or B.H.C. is also mixed in the planting media. Aldren (5% dust, about 800 gms) is mixed in 1 cum of soil mixture.

The bags after filing are kept in Sunken beds. White carrying out pricking of seedlings into Polythene bags, the planting media is well drenched prior to pricking. After pricking the bags are continuously watered by atomisers or fine rosecan twice daily. As the seedling plated in polythene bags grow rapidly, prevention of penetration of roots from the bags into the soil is essential. It is a general practice that the bags are shifted from their original place in a period of 30-40 days. The last shifting is done about the days before planting.

Regular weeding is necessary for raising successful seedling. Basaline is a promising weedicide for effective control & weeds in the Nursery.

Vegetative Propagation: The mass production of genetically improved and desirable individuals of eucalyptus is mainly through vegetative propagation. It may be by clonal propation (cutting) grafting, or tissue Culture. Most commonly used clonal propagation is given here.

Planting:

Site preparation: Clearing and burning the area. Then ploughing, harrowing, ridging, levelling etc. are done from February to June.

Pit digging

Pit size 30 cm x 30 cm x 30. The soil of the crop half of the pits is to be kept seperately. When the pit is filled up, this half of the soil shall be put at the bottom of the pit and the rest of the soil at the top.

Row and line planting: This is the simplest method of the farming in combination with agriculture. 30 cubic cim pits be dug with the spacement of 2m. The dug out earth is mixed with FYM and again filled back in the pits after it is thoroughly mixed with 20 gms 10% BHC powder. As root system of trees and agriculture crops tap soil moisture from different horizon, the root competition does not affect the agriculture yields adversely.

Block planting : Nursery raised transplants are planted in the pits. The inter spaces between trees are used as intercropping purposes. In such cases the ridges of 20-30 cm ht. are made at 4mt. interval. Planting is done at the distance of 1.25 to 1.5 m along the ridge, spacing of plantation into blocks varies from 0.6mx0.6m to 3mx 2m. However, ideal spacing is 2m x 2m.

Spacing: Sufficient spacing between plants is required to ensure adequate crown space when the plants grow up. In India various spacing has been adopted depending upon the species and site. Normal spacing 1mx x 1mt. 2mt x 2mt x2.5mtx2.5mt etc.

Planting time: Seedling should be planted soon after the regular monsoons have set in planting should be completed within 3rd week of July.

Eucalyptus may be raised in menocultures or in an mixture of Ailanthus, Grivellea, Bombax, Anacardiu,, Santalum, Albilzia etc. spp.

Management System: Usually simple coppice 10-15 yrs. rotation or less.

Thinnings are made from 6th to 10th year and the effect of regular thinning on the yield and on the subsequent development of the crop is quite significant. Thinning may be carried out after the 1st year so as to reduce competition by cutting the undesirable /weak/ poor seedlings. This operation helps the selected seedlings to grow more vigorously.

Diseases and Post : Eucalyptus are susceptible to many diseases.

Nursery Diseasa: Danping off, Seedling wilt, Root rot, Collar rot, Leef spot and blight etc.

Plantation Disease: Pink disease, stem Canker, Ganoderma root rot etc.

Insect pest: Root feeders, xylophagus insect, Polyphagous insect.

Uses : (1) It yields fencing post, mine props, and very good quality pulp wood.

(2) Leaves of Eucalyptus sps contain essential oil, which is obtained by distillation. The oil is

used for medicisal, industrial and perfumery perposes.

(3) Honey and pollen : Among the forest plants, a few species of Eucalyptus provide be pasture.

(4) Tannin materials : Tannin for feather production are extracted from many barks.

Leucaena leucocephala (Lamk) de wit

(Syn. L.glauta)

Family - Mimosaceae

Common name - Subadul, Lead tree

1. General distribution and habitat : An unarmed evergreen large shrub or small tree, a native of tropical America and naturalized in other tropical regions of the world. It is planted in the plaints of India, often as a hedge plant, and regenerates freely from self sown seed.

Grows in areas with warm summer, followed by rain and cold winters with one or two showers. Dry sand or gravelly soils, grows best on well drained loamy sands, with water table in summer not below 5-7 m from surface soils with pH 6.0 to 7.5 best.

II. Phenology:

1. General description: Large erect shrub or a small tree 2-6 mt ht. Evergree thornless or with grey yellow bank with white spots roots with nodules. Flowers small whitish. Several varieties and strains of Leucaena have been isolated. Brodly these can be classified into three main types.

i. Hawaiin type: It is a short tree upto 5 mmiht, flowers all the year round. The yield of wooe\d and foliage is low.

ii. Salvador type: It is tall variety attaining upto 20mt ht. fast growing and high yielding.

iii. Perutype: Tall tree upto 15cm develops extensive branch system, produces high quantities of foliage.

2. Flowering and Fruiting : Fruiting of this species occurs twice a year once in July - August and next in November to Februay. Ripe pods are collected and dried in sun for 3-4 days, and after they dehisce. Pods 12-15 cm long, fruits at 2-3 years age. Seed 20-25 per pod, flat, polished brown seeds are collected. Viability remains for 3 to 4 years. No of seeds per kg in 20,000 to 30,000.

III. Silvicultural characters:

1. A moderate light demander ean withstand shade in seedling stage.
2. Vigorous coppicer, Pollards well, stand heavy lopping.
3. Drought hardy.
4. Stands frost.
5. Does not luke water logging and Kanker pans.
6. Fast growing species.

IV. Artificial Regeneration:

Fruiting occurs twice a year, once in July - August and next in November to February Ripe pods are collected and dried in sun fro 3-4 days and after they dehisce seeds are collected. Viability remains for 3 to 4 days. No of seed /kg is 20,000 to 30,000. Germination percentage 85 and germinationn period 10 days.

Pretreatment of seed: Either the seeds are soaked in hot water (90^{0}C) for 2-3 minutes or soaked in cold water for 2-3 days or soaked in cone. H_2SO_4 for 15 minutes.

Pre-treated seeds are sown in mother beds in February - March and the seedlings are pricked out in the poly post. Rhizobium in oculum may be done by mixing of 250 gm of Rhizobium with 20 kg of seeds.

Nursury technique : The nursery soil should be neutral to midly alkaline. If the soil has a nH of less than 6 then adequate lime should be added to raise the pH 6.0 or above.

Two pretreated seeds are planted on polythene bag. The poly pot should have good aoil having a pH near neutral. If both seeds sprout, one seedling is transferred to another polypot.

Seeds are sown 4 cm apart by drills in parallel rows, spaced 25 cm apart, 10gms/sqm. The seed beds should be trenched and filled with sand or humus.

Planting out: The seedlings may be transferred to planting site at an age of 2-4 months. No pruning is necessary if planted out from bags or pots, however. if they are planted out bare-root. the top stem should be pruned to a point where the bark has turned brown. Long tap roots should be pruned to a length of 12-15 cm.

Direct Sowing: Succesful plantation of leucaena have been raised by simply ploughing a furrow and sowing the seed directly.

V. **Uses:**

(1) Very good protein rich fodder firewood enriches soil quickly.

(2) It yields 1250 quintants/ha green fodder/yr. in 2 to 3 harvest.

(3) 90-100 cum/har fuel wood/yr from coppice after 2nd year.

(4) Fencing post, and timber of medium quality is obtained from oder crop.

(5) It contains alkaloid "Mimosine" harmful to cattle (and man) so it is good wise to controlled feed.

BOTANY AND FORESTRY

Module- 20 (B)

Part- I, Paper- III (1st Half)

CONTENTS

SOCIAL FORESTRY

Forest and Forestry

Legally, an area of land declared to be a forest under a forest act or ordinance is termed as forest and accordingly our country has about 22°8% of area under forests. But if actual wood coverage is considered, the forests constitute hardly 12% of the land area. Undoubtedly, this is an outcome of over exploitation of the forests by the mankind to fulfil their various demands. But the three basic resources, the land, air and water could only be protected, conserved and developed by forests. A forest is a complex system of Abioti. and Biotic components in constant dynamic equilibrium. Superficially, it may be known by the presence of trees, shrubs, herbs, grasses climbers and animal life. The function of a forest is to create, conserve and develop life. Here life includes all forms of life. If these functions are funfilled, then only an area is fit to be called as forest. All operations to create, conserve and develop forest for discharging prescribed functions can be termed as Forestry.

Tree planting activities in nonforest areas:

The shrinkage of area in forest due to diversion for non-forest use, the degradation of forests due to over exploitation, the widerring gap in supply demand of several forest produce, the ecological and environmental imbalance have initiated a concerted and multipronged drive to plant more number of trees and create more forests both within and outside recorded forests.

Various terms of activities under Social Forestry

The various terms have been used for various programmes of extending tree cover to nonforest areas viz. Social Forestry, Community forestry, Mixed forestry, extension forestry, Rural forestry, village forestry, Farm forestry, Van Mahat Sava, Urban forestry, Recreation forestry Environmental forestry Tree farming, Village wood lot, three dimensional forestry, Live stock forestry etc.

The National commission on Agriculture in its report on Social Forestry published in 1973, gave to it a broad base to include all tree planing activities outside recognised forest area, such as farm forestry, urban forestry, Homestead forestry, Land-scape forestry etc. F.A.O. has coined the word community forestry to mean the same thing as Social forestry. But Society is a broader term than community and hence it is reasonable to treat Social Forestry as generic term with community forestry at least a synonym.

Definition

It may be simply expressed that Social Forestry is Forestry with social objectives. No tree planting activity can be termed Social Forestry, unless local improvement in the activity is percived, unless benefit to and participation by village peoples are ensured. Thus Social Forestry has a great social over tone and is intemately connected with rural welfare. Hence, Social Forestry can be defined as forestry of the people, by the people and for the people.

It involved poor land and poor people. It is entirely related with rural welfare. It aims at a social change and it requires, thus, special aptitude and approaches.

Unique features of Social Forestry

They are :

1. It is extremely sensitive to the local Socio-Economic profile.
2. It creates resources to meet the local need on sustained basis.
3. It depends more on multiple use trees.
4. It requires involvement and participation by rural population.
5. It adopts short rotation for its crop for early return of benefit.
6. It demands for such technology which can be easily understood and implemented.
7. It directs for decentralised activity.
8. It desired equitable distribution of benefit to the economically and socially backward people.

Objectives

The National Commission an Agriculture recommended the following objectives of Social Forestry

1. To meet the needs for firewood, small timber, bamboo, fodder and other minor forest produce.
2. To release cowdung as manure for increasing agricultural production.
3. To provide employment opportunities to the rural poor.
4. To develop cottage industries in local areas.

5. To utilise the available land to the best advantage according to its production capacity.
6. To provide efficient soil and water conservation.
7. To improve the aesthetic value of the area and to meet the recreational need of the population.
8. To bring out all round development of rural areas as part of integrated rural development.

Social Forestry Vis-a-vis Traditional Forestry

The salient features of Social Forestry and traditional forestry may be compared under the following broad heads :

Social Forestry	**Traditional Forestry**
1. Type of land used	
various types of unused underused and mis-used land generally in small scale and spatially diffused in strips or blocks	Govt. Reserved, protected and unclassed forests often in large compact blocks.
2. Ownership	
Individual, community, government (Forest and non-forest) lands	Government lands
3. Objective of Management	
To meet the local demand and export if surplus	To meet demands of industries and defence
4. Species used	
Large number of species used with emphasis on species ensuring benefit on a short rotation, generally preferring fuelwood, foddere fruit and small timber	Usually species capable of producing round timber with emphasis generally on mono culture of few elite species like sal, teak, sissoo, roscwood, deodar etc.
5. Management practice adopted	

Through several production and management systems to meet perceived needs of the local communities general preference on manmade forests though naturally regenerated forests are not excluded	Through established silvicultural systems. Convert shifting from natural regeneration to artificial regeneration (man made forests)
6. Local involvement in forestry activities	
Local involvement is the Key element. The local communities act independently with Government assistance or as partners with Forest department in planning implement action and benefit sharing	Planning, implementation benefits etc. to Forest department or private owner (where Private Forestry is still in vogue)
7. Benefits to Local communities	
Benefits of forest based resources to local communities which on promotion, protection and diversification assist local development.	.Well income and fringe benefits usually comprising of low price commodity.
8. Role of forestry professionals	
As development workers and extension workers concern with various socio economic used to integrated forest activities with the local way of life as a vehicle of community development specially in places where physical and social conditions preclude other developmental works.	Mainly as resource manager to increase corporate profit concern mainly with various technical and financial works to improve performance for higher yield and higher corporate earning.

Scope

The scope of the programme includes

(i) **Farm Forestry**

(a) Raising rows of trees on the bunds and boundaries of fields and individual trees in private agricultural lands, agro forestry on marginal and sub marginal lands.

(b) Wind breaks.

(ii) **Extension Forestry**

(a) Mixed forestry comprising raising of grass and leaf fodder, fruit trees and fuel wood trees on suitable waste lands, panchayet lands and village commons.

(b) Shelter belts.

(iii)**Raising of plantations of different quick growing species on**

(a) Lands on sides of roads, canal banks, and railway lines.

(b) Foreshore lands and tankbeds.

(c) Bank yard of rural homes.

(iv)**Reforestation of degraded forests**

Necessity

India today forces of dull crisis of environmental degradation, rural poverty and unemployment of 74°74 million ha of forest area only 35 million ha is wellwooded, whereas 25 million ha contain sparse growth and 14.74 million ha is unproductive. Nearly 100 million ha land in the country is crying for afforestation which includes degraded forest areas, revenue lands and barren unculturable waste or fallow lands.

The treeless lands have been the greatest eyesore in the country's landscape. A massive programme of tree plantations is necessary on community land, along the roads, canals, tanks, railway tracks and on private waste land, old fallows and on the bunds of agricultural farms. In addition to inviting massive social forestry, agroforestry etc. it is also necessary to regulate tree felling in these areas.

Moreover, the principle underlying the plantation programme of social forestry is not only to utilise every piece of vacant land for growing trees but also to let the people participate and fell at home on their own land. The programme meets the immediate requirement of the society. The programme is actually an instrument for rural development. Nevertheless, large, landless population is the major beneficiary. A need for the poor land and the poor people.

Social forestry as a tool for community development

Poverty in India largely concentrated in rural areas as compared with the urban areas. The majority of the victims are landless labour, poor artisans and small cultivators whose holdings are very small varying from 0.1 ha to 0.5 ha in spite of various development plans meant for improving the economic condition of rural population, the beneficiaries of development works have mostly been persons who were relatively well off. The poor main has continued to be neglected. In most cases, no alternative scheme was prepared to absorb the poor man, before taking up any development work which was likely to affect him adversely. The economy of the landless and other cultivators was further eroded and they were made unemployed due to gradual disappearance of small patches of forests which were dotted all over the country side. These satchy forests were once source of raw materials like leaf for platemaking, seeds for extraction of oil, smallwood for fuel, small timber for toys and furniture bamboo for basket making, leaf for fodder and roots and fruits for various purposes and these products used to be utilised by those poor landless labour, poor artisans and small cultivators. The cattle population also lost their grazing ground and were deprived of their important source of nutrition and thus they became further impoverished to add a storm to the poverty of the poor people. Their small holdings were also subjected to loss of top fertile topsoil by surface erosion unchecked due to disappearance of nearby patchy village forests and they were not in a position to bring back the productivity by applying fertilizer or better village practice or improved seeds etc. like other efficient members of the village population. Thus, they were forced to become poorer due to declining yield of there holdings.

The creation of fuelwood plantations and small village forests on individual or community land under social forestry has thus opened up new coverage for the upliftment of economical level of village communities. Social forestry is labour intensive in which approximately 80% expenditure is towards employment opportunity to the landless people. With the higher allocation of fund for social forestry under various rural development programmes, the employment opportunity has been increased enormously and each poor family has found opportunity of work and earn their livelihood.

The projects will yield raw material for various cottage industries in villages for the benefit of the individuals and community as a whole. The trees raised on individual land or community lands stand assets, may be used as savings or source of cash to meet up the unforeseen contingencies like social conventions, disaster, physical incapability essential but unproductive expenditure. Again there is opportunity to share the benefits of all projects in kinds and cash, at maturity, through equitable distribution amongst the participants. However, at the very onset, the schemes should be devised that the maximum benefits go to the landless class and then to small farmers and poor artisan. The schemes should be meant for the poorest upwards. Economically, better off people should be in a position to look to their improvements

themselves. If, therefore, transpires that Social Forestry is a boon to the society for the socio-economic development of the community at large.

AGRO-FORESTRY

Definition

Agro-forestry has been defined as a sustainable land management system which increases the use of land, combines the production of crop (including tree crops) and forest crops and/or animals simultaneously or sequentially, on the same unit of land and applies management practices that are compatible with the cultural practice of the local population.

Concept

Agroforestry is only a part of the Social Forestry. In fact, agroforestry as distinct from conventional agriculture and forest is an inter face between these two traditional land use systems, where emphasis is on integrated production of wood perenials with agricultural components (crops, live stock) in a sustainable manner.

Objectives

The following are the broad objectives of agroforestry.

(1) To use farm resources properly.

(2) To maximise per unit production of food, fuel, fodder, live stock and other forest products. Besides, it should be raised with a view to optimise the productivity of natural biological and physical resources viz. Land, labour, livestock, soil moisture, solar radiation and the like.

(3) Reduction of pressure on protective and productive forest to meet the local demands for fuelwood, fodder building material, industrial timber etc. so that the existing forests can fully be spared for the protective and productive roles.

(4) To maintain/restore ecological balance.

(5) To check soil erosion, conserve soil moisture and increase soil fertility.

Agro forestry production system

Agroforestry has been defined as a sustainable land management system and it includes

(i) Agri-silviculture

(ii) Silvo-pastural system

(iii)Agro-silvo-pastureal system

(iv)Multi purpose forest tree production system.

In all agroforestry land management systems there are two essential and related aims : the systems should conserve and improve the site, and at the same time optimise the combined production of a forest crop and an agricultural crop.

Agroforestry can be compared in concept with the multiple cropping system of agriculturists. Thus, the term multiple cropping can be compared to the term agro-forestry. In the same way the term mixed cropping might be considered to be similar to that of Agri-silviculture. The spatial arrangements of crops in mixed cropping system or in Agri-Silvicultural system might be haphazard or might be organised. In haphazard systems, there is multiplicity of species grown in mixture, whereas the organised systems correspond to intercropping or row intercropping where the different species are grown in rows and the populations of each are fixed.

Agroforestry systems of developing countries:

Agroforestry encompasses many well known land use systems practised since long time in the entire humid tropics. Shifting cultivation or bushfallow system where woody fallow is a deliberate and important part of the system, interacting ecologically and economically with cropping phase. Systems with natural fallows can be classified as primitive agroforestry since no deliberate choice of planting woody species takes place. Taungya system which originally started from Burma with prime objective of raising. Teak along with the mixed cropping can be considered one step further in the process of transformation from shifting cultivation to Agroforestry other systems such as raising of economically important tree crops such as rubber, coconut, oil palms, citrus, prunas etc. mixed with annual crops or fodder and fruit trees mixed in the pastures or raising of fodder and fruit tree on the bunds of agricultural field as is in common practice in the Himalayas or use of woody species as wind breaks, fence etc. are included in the scope of agrogorestry.

Different species of parennial plants with different growth habits can also be combined: an interesting example exists at Costa Rica where the combination of Coffee in lower level. species of Erythrina at the middle level occurs. Erythrina species enriches the soil by the fixing nitrogen in the soil and also increases the quality of coffee by partial shading. Whereas a timber tree cordia alliodora is raised at the top level. An artificial system of this type is quite similar to forest ecosystem and should be rated very high for conservation of nutrients and soil and for increasing productivity.

It will be evident that agroforestry is primarily a system where agriculture and forestry are practised either simultaneously or separately on the same unit of land. In fact in forestry, we have a system known as taungya system of regenerating one of our most valuable forest i.e. deciduous sal forest in West Bengal and in Uttar Pradesh. In West Bengal this system is being practised from the beginning of the 20th Century and in Uttar Pradesh from 1923. This system has worked very successfully. It is evident that foresters are well aware of this type of agroforestry system for the regeneration of the forests themselves.

A detailed summary of various Agroforestry system, and practices by location is recovered in the following table :-

	Practices	Regions where used
1.	**Agro Silvicultural system**	
1)	Improved fallow (in shifting cultivation areas)	S.E. Asia, East and central Africa, American tropics
2)	Taungya	South pacific, S.E. Asia South Asia, East and Central Africa, West Africa.
3)	Tree gardens (primariiy fruit and nut trees and also for firewood	South Pacific. S.E. Asia middle east Mediterranean American tropics.
4)	Hedge grow inter cropping (Alley cropping	S.E. Asia, East and Central Africa, West Africa
5)	Multipurpose trees and shrubs on farm lands	Through out developing world
6)	Crop combination with plantation crop	- do -

7)	Multipurpose fuelwood trees	South Pacific, S.E. Asia, East & Central Africa, American tropics
8)	Shelterbelts, wind breaks soil conservation hedges	Through out developing world
II.	**Silver pastoral system**	
1)	Protein bank (cut and carry fodder production)	S.E. Asia, South Asia, East and Central Africa, West Africa, American tropics
2)	Living fance of fodder trees and hedges	S.E. Asia, South Asia, East and Central Africa American tropics
3)	Trees & Shrubs on Quartures	Through out developing world
III	**Agro Silvo-Pastoral**	
1)	Woody hedges for browse, mulch, green manure, soil conservation etc.	South Pacific, S.E. Asia, South Asia, East & Central Africa, W. Africa, American tropics
2)	Home gardens (with harbaceous and woody plants)	Throughout developing world
IV	**Others**	
1)	Agro forestry (Silviculture in mangrove swamps, trees in bunds of fish breeding ponds)	South East Asia
2)	Shifting cultivation	South pacific, South Asia, East and Central Africa, West Africa, American tropics
3)	Beekeeping with trees	South pacific, S.E. Asia, South Asia, Middle East and mediterranean, East and central Africa, West Africa.

Problems in Agroforestry managment

The purpose of agroforestry researches to help clients achieve their goals. The most obvious clients are farmers, especially resource poor farm families in the tropical uplands and humid lowlands other clients include forestry and natural resource agencies rural development authorities, village associations and other group that want to use agroforestry techniques to further organisational goals. Clients also include extension agencies and non government organisation that help farmers and organisations obtain new information and apply it.

Those who prescribe agroforestry interventions and those who perform agroforestry activities are motivated by both social and economic goals, but prescribers are more often motivated by social motives, while farmers are more concerned with direct economic and financial goals.

Social goals

Social goals include

(i) Rural development

(ii) Site productivity

(iii)Watershed improvement and environment protection.

Economic goals

Farmers are particularly motivated by economic incentives, and the economic condition of farmers has wellknown social effects on those around them and those dependent upon them.

Economic goals include

(i) Increasing net income

(ii) Reducing risks

(iii)Improving environmental services

(iv)Accumulation of wealth and savings.

Applied research problems are best defined according to the clients needs for information. This requires the researchers to understand the clients problems. A problem has five elements. All five must be specially described if the problem so defined is to be the basis for an agroforestry preservation or research projects.

Five elements of a problem

(1) The Client

The client is one or more people who must make one or more decisions involving agroforestry.

(2) The Clients objective

The client must wish to achieve an explicit objective as a result of decision made.

(3) Alternatives to reach the objectives

Helping clients by giving them better information as they choose among alternatives is a primary role of Agroforestry research.

(4) Doubt

The development of new and better alternatives is major research role. Another role of research is to reduce uncertainty and risks associated with the predicted responses to inputs.

(5) Context

The client, the clients objectives and the pursuit of these objectives occur in a specific location and social context. There must be described in a completely defined problem statement..

Constraints with respect to land tenure

To grow trees, people must have access to some land. Unless this can be secured, selfhelp forestry cannot help the landless. Nor are very small farmers needing to devote all their inadequate allocation of land to staple food crops, likely to be able to participate in tree growing.

In most countries of the developing world land is the most valuable possession, wealth and status are measured by land ownership. When farmers are given temporary base to develop government land, it is difficult for them to be committed to longterm cultivation practices that produce no immediate or obvious benefit. Shifting cultivators also are not interested in planting trees with crops because they are illegal occupants - they have no security of land ownership.

So, we would like to activate unutilized wastelands where no viable agricultural activities other than forestry are possible. Such unutilized waste land can be broadly divided into two categories, government and non-government. On the Government side there are wastelands belonging to revenue departments and vast areas of denuded forest lands belonging to the forest department on the non-government side, there are wastelands under individual ownership and waste lands under common ownership.

However, after the abolition of Zamindary various legislations to limit tree land holdings were also enacted and arrangements were done to distribute the surplus land to the landless. Furthermore in W. Bengal and the philippines projects are based on groups or landless given access to public land on which to grow trees. These schemes are too young to permit an assessment of their success, but early indications from some of them are encouraging.

Agroforestry research

Considering the importance of Agroforestry, approach, a seminar on agroforestry was organised by the ICAR at Imphal in the year, 1979. The seminar constitute a task force headed by Dr. K.F.S. King as its chairman to suggest the research directions and organisational pattern for making such studies in the country. Establishment of an ALL INDIA COORDINATED RESEARCH PROJECT with centres in States and union territories for comprehensive study on the various aspects of agro forestry was recommended.

As a consequence of the task force recommendations, the ICAR sanctioned an ALL INDIA COORDINATED RESEARCH PROJECT on Agroforestry with the coordination call in Krishi bhavan and centres at 20 places in different agro-ecological regions of the country during the 6th plan.

Proposed lines of research in Agroforestry

1. **Survey, diagnosis and design**

   (i) Survey and evaluation of existing agroforestry systems.

   (ii) Diagnosis of land management system suitable for Agro forestry.

   (iii)Design of appropriate system of Agroforestry with particular reference to combination of various components.

2. **Introduction, screening and improvement (plant breeding)**

   (i) Introduction and screening of plant species both woody perennial and less known economic plants from analogons climatic regions for various farming systems.

   (ii) Breeding and genetic improvement of trees for agroforestry systems to evolve ideo types for compatible associations in consonance with the cultural practices of local population.

3. **System management Studies**

   (Agronomy and soil science)

   (i) Ecological and silvicultural studies with regard to woody perennial species compatible with inter cropping.

(ii) Root distribution. root growth and root activity with reference to Agroforestry system.

(iii)Dry matter production as affected by the form and nature of crop system especially in mined herbaceous/woody perennial crop systems.

(iv)Influence of genotype and environment (especially intercrop environment) dry matter distribution in herbaceous and woody plants.

(v) Effect of plant management on plant growth, dry matter distribution and plant development.

(vi)Plant stress factors and there influence on production with species reference to plant associations in Agroforestry.

(vii) Seed morphology and germination physiology of woody perennial species suitable for Agroforestry.

(viii) Primary and secondary production in Silvi-pastoral systems with fodder production and its utilisation by animals and determination of the nutrient supply and demand profile through out the year in different grazing systems.

(ix)Crop water use with special reference to mixed cropping situations in Agroforestry. Ecoclimatic influence of perennial woody species in mixed cropping systems. Ecoclimate and crop tree mixtures and soil erosion studies under different agroforestry systems and crop management practices.

(x) Collection and collection of data in Agroforestry practices and systems and simulation models of production from Agroforestry as compared to single crop/ forestry practices. Environmental impact analysis studies with regard to systems affected as a result of Agro-forestry management.

(xi)Plant nutrient needs as affected by soil and intercroppin in agroforestry systems.

(xii) Nodulation ecology and nitrogen fixing ability of leguminous species in agroforestry systems.

(xiii) Microbial and mycological studies in rhizosphere of perrenial woody species for agroforestry with reference to cultural practices.

l. Economics and extension

(i) Evaluation of the cost benefit analysis of various agroforestry systems, socio-economic impact study and analysis of existing agroforestry systems on marketing of plant products both for woody perennial vegetation and cropping systems.

(ii) Research methods in extension and training for Agroforestry along with production of suitable literature for agroforestry system adoptable to different soil climate regions of the country.

Cost and benefit ratio in Agroforestry

It has been widely argued that to be attractive to rural people tree growing must produce trangible short term economic benefits. For the poor, the need to give priority to meeting present rather than future need is very urgent. \that this is an important factor is borne out by the fact that nearly everywhere the trees people choose to grow are those that start to produce fruits, fodder, gums and other outputs of saleable o: ownuse value early after planting in addition to the wood produced later on in the production cycle wood in fact is usually a co-product, and often only a by-product of other products of trees on a farm or in a village.

It is important to recognize in what form costs have to be borne by a small farmer, and that particular costs may weight much heavily in his economic calculations than in these of a forester or enterprencur. Many of his costs and benefits take forms other than cash outlays and incomings. For example, prominent among his implant calculations in usually consideration of risk; the need when living in the margins of existence to avoid any change which, though it might improve his situation if it functions expected, could leave him even worse off than he is now if it does not an assessment of the options open to the farmer must therefore reflect these and other realities which shape his economic decisions, and not be continued simply to monetary assessment of cost and profitability.

Marketing

The emerging importance and magnitude of the growing of trees as a cash crop is focussing attention on a member of issue. First, there is the matter of access to markets and on prices. Much of on firm forestation has grown up spontaneously in respect to market factors, notably rising prices. In some places, such as Gujrat, the expansion of tree growing has been so rapid, and now so large, that concerns have begin to arise that supplies could soon excced demand, leading to fall in prices. Attention is, therefore, being given to developing a market intelligence system so that farmers are not encouraged to build up production beyond levels, which would yield then accceptable return shifts in land-use practices towards tree growing on the scale being witnessed in Gujrat are also raising issues of crop and labour displacement.

In most places it is still the opposite problem of producing the necessary support to enable farmers to take advantage of market opportunities that require attention. This may entail no more than extension advice on what to grow and how to grow it and access to planting stock. In some cases, it could also involve

access to markets and price levels. Small holder production of pulpwood in the phillippines, for example, rests on contractual assurances about prices and about the willingness of the pulp company to purchase farmer production.

The process of commercialization of previously predominantly substance tree out put such as firewood is clearly spreading from the towns into the rural areas. As local wood resources continue to demenish, rural as well as urban people will increasingly have to purchase at least part of their needs.

The stimulus of an accessible cash market for tree products is becoming available to farmers in more and more situations. The growing of trees in response to market forces is therefore becoming and increasingly large component of overall community level forestation. The need to understand commercialization process is consequently becoming important. As yet, it has been little studied.

Extension education strategy

A planned extension education strategy has to be developed to overcome vital problems inhabiting people's involvement in social forestry or agroforestry operations like :

(1) **Personal** : Socio-economic status, economic motivation, risk orientation and attitude towards forests.

(2) **Social** : Social participation, mass media exposure, extension contacts, illicit filling of trees.

(3) **Infrastructure and support activities:** Forest policy, institutional support in terms of training in silviculture and managment practices, extension programme for afforestations.

For optimum harnessing of forest wealth all factors capable of inducing the scope of extension education in Agroforestry should be given due attention and a planned or system approach of different stage development is adopted for various problems inhibiting people's participation.

EXTENSION FORESTRY

Extension forestry programmes cover:

(i) Mixed forestry wastelands, Panchayat lands, village commons.

(ii) Raising shelter belts in arid regions.

(iii)Raising of plantations of quick growing species on lands on the sides of roads, canal banks, railway lands.

The National commission on Agriculture (NCA) has suggested the following important steps in regards to mixed forestry and shelter belts :-

(1) Any programme of mixed forestry in village wastelands and panchayet lands should be such as is acceptable to the village population.

(2) The programme should be undertaken only in those areas where the incidence of wasteland is sufficiently high, so that a part of them can always be kept for the satisfaction of the villagers.

(3) The programme should be take into consideration the need for a yield of such products are the villagers' immediate concern fodder and grass should form an important component of mixed forestry.

(4) Income from mixed forestry should be divided equally between the Panchayat and the State Government.

(5) Co-ordinated efforts by the Agriculture and Forest departments of State governments should be made for the planning and creation of shelter belts.

(6) Research should be carried out on a priority basis by the concerned institutions to determine the regions where shelter belts should be planted their effect on hydrology and crop yield and their composition and management.

(7) There should be an element of subsidy to be shared between the Central and State Governments that has to be built into shelter belts programmes during the first 15 to 20 years.

These programmes should be implemented by villagers under the supervision of village panchayats and in close co-operation with the State Governments Forest department.

RECREATION FORESTRY

Recreation forestry contributes both to social development and education in environmental matters. Better landscape effects are achieved by easing out the edge of coppices and adding a few ornamental species in a more fragmented or frequently viewed sites. With planting up pipul and simul the landscaps brighten up. The trees are not only ornamental but attract birds and colour and life to the environment. In urban areas, parks and gardens are city's lungs; but they lend colour and life and bring recreation to urban people since the maintenance of parks and gardens are expensive, larger areas may be planted with suitable trees and shrubs to provide a forest atmosphere such forest parks and gardens are very popular and contribute to the general uplift of the health of the urban population. The development of wild life should be much for recreational forestry as far its scientific importance.

It is generally agreed that any tree planting programme especially those on congested city slum areas close to habitants, industrial and business areas, constitute an exercise which leads to considerable ecological gains. It is also an established fact that tree planting not only adds to the aesthetics, but also provide a pollution free zone congenial to healthy living of the city dwellers.

Hence, in order to enhance the quality of life and to ensure a healthy body and spirit to the future progeny it is imperative that the threatened environmental balance be re-established to the extent possible in a systematic way within a given time frame.

PEOPLE'S PARTICIPATION

Concept of development

The concept of development is concerned as an integrated process of economic and social development with social justice. It is an integrated process of change involving not only economic and social, but also cultural and human factors.

Concept of Participation/Involvement

Involvement

Involvement in the development process requires identification with the movement itself. This means that people involve themselves in all aspects of the process :-

— in thinking

— in need identification

— fixing priorities of the need

— planning

— decision making

— implementing

— evaluating.

This is a mental process as well as physical. There is an element of initiative in the process.

Participation

It is defined as an individual's mental and emotional involvement in group situations that encourage

him to contribute to group goals and to share responsibility for them. The definition has three important aspects:

The first aspect is mental and emotion involvement rather than more muscular activity. The participants characterized to have egoinvolvement rather than task involvement.

The Second aspect is to motivate contribution. There is opportunity for initiative and creativity. Participation is more than mere approval of something already decided.

The Third aspect is that it encourages people to accept responsibility for group activities. An individual who is actively involved in some activity is more committed to finishing that activity.

Differentiation and interchangeability of the terms.

It is evident that participation and involvement could be differentiated. The former means sharing and latter is characterized by wrap oneself with the activity. In spite of this differentiation, these two terms are often used interchangeably.

Interaction with the participants

However, participation or involvement in whatever way they are defined, there is need to involve the participants (people) of the people right from the designing stage. It is man who is to be understood since he is to be involved in the process of his own change. The understanding should be in terms of his needs, motivation, perception, attitudes and the social milieu which would facilitate the planner to draw out schemes in such a way as to facilitate people to organise themselves in order to achieve the goal.

Psychology of participation

People spend a great deal of their time in the company of other people. Pursuit of satisfaction of even basic needs is carried out in groups. Whether it is an instinctive need or a learned behaviour, the fact remains that a social contact becomes the most important and necessary part of existence. People do mediate goals for one another and it may be necessary to associate with other people or belong to particular group in order to obtain specificable individual goal. People representing goals for one another do have needs like approval, support, friendship, prestige etc. that can only be satisfied in interpersonal relation.

Thus must be certain factors which impel people form into groups. Groups form as individuals interact in definite location and performs tasks or cope with problems that can not be handled individually. In the interaction process, the group influences individual members and expects them to believe and act as others do. Very often, the members of the group would like to confirm the norms and values of the group. The types of conformity behaviour have been identified one is the compliance behaviour and the other personal acceptance. In the former case, it is primarily compliance without believing in it, whereas in latter

case, there is change in one's attitudes in the direction of group's attitudes. In this process, psychological functions such as perception, attitudes, emotions, motivation and personality are affected depending on the properties of the groups.

Characteristics of group behaviour

(i) A motivated base common and conducive to recurrent personal behaviour over times.

(ii) Formation of a group structure with certain defined and differentiated role and statuses from non members.

(iii)Formation of a set of norms in terms of values, rules, standard or behaviour, goals etc.

(iv)Comparatively consistent differential effects in the attitude and behaviour of individual members produced by the group properties.

Criteria of effectiveness of participation

(i) Personal-Social

Personal-social characteristics of members such as age, sex, educational level, occupational and social status, cultural and traditional values, personality characteristics form some of the important criteria. The homogenity and heterogenity too affect interpersonal behaviour.

(ii) Task oriented

Task oriented factors pertaining to the characteristics of the activity problems, task or occasion that form the objective or aim of group formation, affect the performance of the members in a group.

(iii)Infrastructure and locational facilities

The social milieu like the location place of incidence, cultural, environmental values, taboos etc. also affect interpersonal behaviour of the members in a group.

The importance of the individual and his personality cannot be neglected as it is the individual who acts in a certain social environment in order to bring about an effective participation for a social cause. The participation will be more effective when the participants motives, needs, attitudes, values and ability with regard to the task in hand, the fact to make use of locational facilities are consonance with each other.

Approach for organising the rural poor

People should be involved fully and consciously without the socio-economic barrier. To achieve this, the following approaches are suggested :-

1. **Bottom-up approach**

The whole planning process should be bottomup approach. The user of the programme should also be decisionmaker of the programme may be, the existing setup does not persist sudden change from topdown to bottomup approach. Hence, an attempt needs be made to merge the topdown and bottomup approaches where both the givers and receivers of programme play a mutually supported role in evolving a programme.

2. **Sound information desimination desimination approach**

In order to participate meaningful in the policies and plans, the people need to be given sufficient and objective information. Hence a sound information desimination approach needs to be developed. Formal and informal education to people should be made available, to enhance their capacity to plan, initiate and follow up the scheme.

3. **Conscientisation approach**

(i) To bring about people involvement, the people should be conscientised carefully and effectively so that they become aware of the rights and privileges and organise themselves into groups for production activities.

(ii) People should be given emotional support to accept the newer values.

(iii)The hierarchical nature of the existing social structure to create a depending relationship. A break through in this could be achieved through a process of conscientisation.

4. **Identification of groups having identical needs**

Certain groups exist in all the communities i.e. religious, political etc. These groups all formed on the basis of certain characteristics and affiliations. It is also found that groups spring up when a need arises. The development worker should be conscious of identifying these informal groups and brings them together for development activities. Attempts should be made to identify the felt needs of the people and bring together those having identical needs.

5. **Individual approach**

Approach to the person should be based on the concept of the total man. This requires and integrated approach of development and welfare oriented programme. In this respect, the role of the external agency should be one of catalyst and the change should occur within the individual so that the self is developed over a period of time. Selfhelp activities should be encourage substantial help if demand necessary shall be provided in time. Subsidies should be given to serve as a supplement and is more effective if it is given in ...tion of the efforts.

6. **Development of a sense of ownership and responsibility**

The outside agency should be sensitive to the opportunity which arise from the community to assure more and more responsibility for the implementation of the programme. The outside agency should be prepared to withdraw gradually, delegating responsibilities and functions to the community.

A programme which does not achieve tangible and meaningful results within a relatively short period is less attractive to a community. Therefore, activities particularly in the initial stages of programme development should meet the needs felt by a significant section of the community involved in the programmes.

Lastly, the approaches should be extensive and intensive to the extent being redundnt. This in communication terms means densification. The main task here would be to expose the people to a wide information environment. The audience will not always be available. But omnipresence of programme messages will ensure that they will be noticed when the audience is receptive and available.

Peoples' participation in Social Forestry projects with reference to West Bengal

Peoples' participation

A modern management pattern envisages involvement of all people for all time, participation at all stages and social accountability at every stage.

One way that forestry development planners and policy makers are attempting to re-establish the traditional people forest resource balance is through social Forestry - a genetic name embracing large number of the growing and management practices involving the rural people who are agents as well as victims of forest degradation.

The requisites for successful approach would include the following :-

(1) The objective should be clearly laid out.

(2) The objectives and the means of reaching the same should be such to meet the needs of the people actual as well as prescribed.

(3) The community should fully be empowered and be independent of outside negative intervention.

(4) The community capability should be adequate to reinforce the existing structure authority.

Benefit sharing mechanism in participatory management of forests

1. The conventional definition of common property resources is those resources in which a group of people have got equal use rights. In the content of Indians villages the resources falling in the category included community pastures, community forests, wastelands, drainages, village ponds, common dumping/threshing grounds, watershed rivers as well as their banks and bed's. Even when local ownership of some of these resources with another agency (eg. Wastelands belonging to the revenue department of the state), in a defacto sense they belong to the village communities.

2. Various components of social forestry project like strip plantations, rehabilitation of degraded forests through planting and coppicing etc. envisaged sharing of benefits from the common property resources and government lands with beneficiaries to the identified from amongst the fringe population.

3. With progress of social forestry project and after creation of assets in the form of plantation etc. Forest department felt the need of management of these plantations with the help of local panchayat institutions and the identified beneficiaries. Accordingly **"Bon-o-Bhumi Sanskar Sthayee Samity"** was created and it was assigned with the duties and responsibilities for looking after the forest matters in addition to the identification of the beneficiaries from amongst S.C. and S.T. to reap the benefits from the plantation created under Social Forest Project and I.T.D.P.

4. It was also decided that the usefruits from the plantations created by the Forest department on the vested wastelands and other public lands under RLEGP scheme would be distributed to the extent of 50% to the rural poor persons as identified by the "Bon-o-Bhumi Sanskar Sthayee Samity" of the Panchayat Samity.

5. The department of forest also granted that 25% of the usefruits from the plantations created under the R.D.F. programme of the Social Forestry project will be distributed to the local people as identified by Gram Panchayat concerned and the beneficiaries will be selected by the said sthayee samity of the Panchayat Samity concerned.

6. The department of Forest also arranged to hand over the strip plantations created under the Social Forestry Project to the Gram Panchayat after third year of creation for maintenance and protection. The Gram Panchayats are to identify the beneficiaries from the poor people in the localities to get use fruits from the said plantations. So far, about five thousands hectares strip plantations have been handed over.

7. Meanwhile an equipment initiated by silvicultural (South) Division near Arabari of Midnapore district for resuscitation of nearby 1271 hectares of degraded sal forests with the help of 618 families living in the forest fringes, resulted in restocking of the degraded forest land with beautiful regeneration of sal crop and plantation. Here also, the department of forest granted 25% of the net return from forest

harvesting of sal coppice and fast growing species to be distributed among the identified beneficiaries as unifructory benefits subject to some terms and condition. In the year 1987-88, the total income calculated for 618 families from 97 ha. turned out to Rs. 6,04, 887/- i.e. Rs. 1,028/- per family per annum.

8. The experience of social forestry Project Arabari socio-economic experiments as well as the extension motivation campaign by forest department personnels jointly with the members of Panchayet Raj institutions led to spread of **Peoples Participatory Management**. Like wild fire in whole of South Bengal in the name of Forest Protection Committees. The department of forests granted recognition of these committees allowing the members of such committees 25% of the usefruits free of cost, from the Sal coppice forests and plantations to be protected by such committees. The Govt. also allowed free collection of certain minor forest produce as well as 25% of the firewood obtained as intermediate thinning yield.

Individual benefits : Short term return from N.W.F.P.

Activities are aimed at the short term yields to sustain the interest of adjoining villagers. These are silvi-pasture, Agroforestry kishan nurseries, Sciviculture Mushroom cultivation, Sabai rope making etc. There is considerable potential income from non-wood forest products (N.W.F.P.) obtainable from vigorously regenerating forest land. Case studies reveal that N.W.F.P.S. - Sal seed, pal leaf, kend leaf, mushroom, natural tussar coccons, edible fruits medicinal plants enable a villager to earn on an average Rs. 9.60 per day.

Social justice

So far forest management is concerned the experience in Bengal in unique. The success stems from the advancement of democracy which has by now taken a deep root in the fibres of social ramification. A propeople land reform policy, involvement of the threetier Panchayet Raj and planning process from grassroot level, blending with as institution ailed propeople forest management have made this possible. A break through has been achieved by ensuing a distributive social justice and by foresting a conservation culture.

Species suitable for different difficult sites afforestation

Afforestation means creating forest crops on lands not originally forested and includes mainly extension forestry for production or protective purpose.

In undertaking afforestation works we should keep in mind open and be prepared to do anything new. We may have to tide over numerous difficulties like drought, white out, mycological and bacterial diseases forest, grazing by animals including camels and goats and danger of locust invasion.

1. **Fixation of Shifting sand**

(A) Inland sand

(i) **Tirunelvelly and Ballary districts of Tamilnadu** : Plantations of casuarina, prosopis inga dulies and Albizzia lebbek successfully established on the **river banks.** Natural regeneration of Acacia arabia and A auriculata come up and the danger of **shifting sand vanished.**

(ii) **Stream bed fixation or 'cho' training work** : Branch cuttings of Sissoo, vitex, Ipomea, Osqly as well as Arundo donax are planted in lines along the banks and spurs of the same species are constructed in such a way that they are inclined at an angle of 30° tc main bank. There is deposition of the fine silt behind the live nedge line. The 'Bela' area is next taken up for planting works. It is first planted up with tufts of saccharum munja grass and when the san has been stabilized, the Sissoo is raised by sowing or planting.

(B) Coastal pond

W. Bengal, Orissa, Tamilnadu, Maharastra etc.

The sandy wastes are planted with two year old seedlings of casuarina equisetifolia grown in bottomless pots. Spacement 6' x 6' in W. Bengal, 8 ½' x 8 ½' in Orissa and 12' x 12' in Maharastra. The casuarina planting is done on the inner dunes and protected by barbed wire fencing against in roads by cattle. Rotation period is 10-20 years. Along with casuarina. Anacardium occidentalis, callophyllum inophyllum and Acacia moniliformis have also been successfully tried. Low tracts near the sea may be waterlogged. In such areas, good results have been obtained by harnessing the wind to bank up sand against the baffles and planting casuarina on the banks to raised.

2. **Afforestation of dry and arid areas**

Such area occupy about 7% of the total land area in India distributed mostly in western India. The success of afforestation works depends upon :

(i) **Proper selection of Species Rajasthan and Punjab**

Acacia general, A. modests, Prosopis Spicigera, P. zinlifera, Zizyphus zujuba, Dodonea viscosa, Callotropis procera, Aristida Spp., Cenchrus spp., Saccharum munja and Cyperus and narious.

U.P.

Acacia arabica, A. lencophboea, Prosophis julifera, P. spicigera, Alilanthus excelpa Siessu, Pongamia

pimata, Azadirachta indica, Bauhinia variegata and cassia fistula.

(ii) **Proper nursery technique**

In sunken beds - irrigation by flooding.

(iii)**Strict clasure of the planting area**

(iv)Application of **moisture conservation** methods such as contour trenching, cross bending terracing, subsoiling and application of agrisilviculture technique.

(v) Planting of seedling. Transplants and stumps should be preferred to sowing. Planting early in the season. Sowing of planting may be done in depressions or pits to facilitate moisture conservation.

(vi)**During weeding** weed growth not interfering with the plants are retained for moisture conservation.

(vii) **Soil working** done in between lines or plants after each shower or rain and the soil is not allowed to cake.

(viii) Plants should be **thinned and spaced out** early as the soil moisture is the limiting factor.

(ix)The sodium soils are **reclaimed** before undertaking afforestation.

3. **Irrigated plantations**

The siling of an irrigated plantation involves consideration of accessibility, size and shape of the area. Shallow soil should be avoided as also ground with uneven surface. The site should be as near as possible to the head work of a canal system. The command should be good for rapid distribution of water.

On Kallar or Sandy soils sissoo makes a heavy demand for water but little headway in growth and the resulting crop is patchy and open. Kallar soils should be planted with Tamarix articulata and drier soils with Melia azadarach and prosopis. In view of the fact that pure sissoo crops are liable to attach by Fungus Fomus lucidus and insect (Plecoptera ruflexa) the sissoo crop is underplanted with melia azadarach and Tamarix articulata.

4. **Afforestation of denuded hill slopes**

Denuded hill slopes are found throughout the country. The soil is generally shallow and subject to erosion. The hot southerly aspects present extreme conditions and limit the choice of spices for afforestation purpose. Grazing as generally heavy and no attempt to re-vegetation can be attempted unless the area is rigidly closed to grazing, browsing and other destructive activities. Sowing or planting at stake is confirmed

to worked up patches, little tried being paid to regular spacement. Contour tranching and brushwood spars may be helpful in arresting the process of soil erosion and in conservation of moisture, sowing or planting being confined in the barriers of Trenches or in the deposited soil behind the spurs.

Choice of spices

In all afforestation works a start should be made with pioneer species, quickgrowing nonpalatable species capable of surviving the adverse conditions should be selected.

For **moist subtropical zone** - chir pine.

For **the dry subtropical zone** - Olco, Acacia modestor. A catechu and prospis julifera.

Higher hills in the temperature regions - Pinus excelsa.

5. **Afforestation of inundated and waterlogged areas**

Treatment of waterlogged areas

(1) Digging's storm water and seepage drains depressed below the water table.

(2) Lining of canals.

(3) Afforestation or creation of permanent tree belts along canals, tarents or dration making use of species with high transpiration rate. The planting should be done on moinds or ridges which should be set high enough to enable the plants to remain above the level of stagnant water

Species suggested

(1) Eucalyptus robusta, E. redio, Lagerotroemia flosriginae, Casuarina equisetifolia, Barringtonia acutamgula and Bischoetia javonica in **marshy places.**

(2) Areendu conan and sapium sebiferum for **Swamp areas.**

(3) Tamarix articulata raised by branch cutting. It is useful for **semiwaterlogged and saline areas.** The species roterates fairly a high degree of alkalijation.

(4) Butea frondosa raised by sowing or planting useful for **salini and swampy soils.**

(5) Acacia arabica is suitable for **moist saline soils.**

(6) Salix alba, S. fragitus, S. babylonica are suitable for **marsly lands** and raised by branched cuttings.

(7) Toxidium distichans, an exotic timber trees is useful for **heavy waterlogged area.**

(8) Eugenia jambolna is useful for **Semi waterlogged area.**

(9) Diospyros embryopteris Pterospermum acerifolium, Bischoetia javonica and canes in **freshwater swamps.**

6. **Farm Forestry**

It is the practice of forestry in farm lands, generally more or less integrated with other farm practices with the idea to make every farm more or less self supporting in respect of timber, fuel, grazing and other requirements of the cultivator and also to exercise as protective measure against erosion by wind and water and to help in maintaining the facility of the agricultural field included in the social forestry programme.

Targets

(1) 10-15% other farm to farm forestry.

(2) The final forest - one acre for every 200 heads of population for a fast growing fuel spices.

(3) The grazing requirement - about 3 acre per head of cattle.

(4) Each area to yield 600 lbs of gross annually while the daily requirement per head of cattle is about 5 lbs.

7. **Afforestation of canal banks, Road sides and Railway lands**

Mostly undertaken under Social Forestry programmes. Mostly, **Strip plantations** are raised as only narrow linear strips are available mostly located in government owned non forest lands viz.

(1) Road side

(2) Canal banks

(3) Irrigation embankments and tank embankments.

(4) River bank

(5) Railway land.

All these plantations have their own distinctive features in respect of species comparison, management procedure, financial pattern etc. The plantations are raised on a large variety of lands spreads over a number of Agro climatic zones with varying ecological conditions. The models followed in the state of West Bengal are described herewith :

Model I - wider national Highway.

II - Narrower N.H.

III - other roads

IV (a) - Canal banks

(b) - Irrigation embankments and tank embankments

(c) - River banks

(d) - Railway land, railway track side.

Common characteristics of the plantations

(i) Species selected are generally fast growing.

(ii) Emphasis is on strong copping species but valuable timber species may be planted.

(iii)Plantations are proposed to be worked out on short rotations to ensure repeated flow of benefits within a comparatively short period of time.

(iv)A general preference exists for multipurpose species, i.e. species which can produce more than one product such as finalwood, poles, small timber, half fodder, fruits etc.

(v) Fodder species included are capable of producing a large mass of fodder of reasonably good nutritional value.

(vi)Species are all easy to raise.

(vii) Seeds of most species are easily available and can be stored conveniently.

Module - I Strip plantations under National Highways

Objective : To raise Avenue trees

Shade trees 15%

Fruit trees 5%

Fuelwood and small wood leaving trees 80%.

Design Width of strip to be planted is 6m. on each side. Three rows will be planted on each side. Avenue trees will occupy the front row at 5m. intervals and others will be planted at 2.5m intervals. Each row will be special 3m. apart.

Species		(i) Avenue trees like Krishnachura, Aam, Jam, Radhachura etc. in the 1st row.
		(ii) Fuel wood trees like Eucalyptus A leasmone, munjri etc. is the 2nd & 3rd rows.
Spacing	:	Avenue trees 5m. apart.
		Fuel and small wood 2.5 m apart.
Percentage	:	Avenue trees 15%
		Fruit trees 5%
Stems per ha	:	Avenue trees = 333 nos.
		Fuel & small wood =1333 nos.
Management	:	1st row to be preserved.
		2nd & 3rd row - Fuel and small wood cut at 7th and 13th years. Thinning at 9th and 11th year.

Model II - Road side stripplantation (Narrow) highways

Objective	:	To raise Avenue trees
		Shade trees 15%
		Fruit trees 10%
		Fuel and small wood bearing being trees 75%
Design	:	Width of strip to be planted is 4m on each side. Two rows will be planted on each side. Avenue trees will occupy the front row at 5m intervals, and others will be planted at 2.5m intervals. Each row will be spaced 3m apart.
Species	:	
1st row	:	(i) Avenue trees (Krishnachura, Radhachura, Rain tree, jackfruit, Mango, Jam etc.)
		(ii) Fuel and small wood trees (Eucalyptus, Akasmoni, Minjiri, Jarul etc.)
2nd row	:	Fuel and small wood trees (Eucalyptus, Akashmani, Minjiri, Jarul etc.)
Spacing	:	
1st row	:	Avenue trees = 5 m.

Fuel and smallwood trees = 2.5 m.

Stems

Per ha : (i) Avenue trees = 500 nos.

(ii) Fuel & smallwood = 1500 nos.

Management : (i) Avenue trees to be preserved.

(ii) Fuel and smallwood trees cut at 7th and 13th years. Thinning at 9th and 11th years.

Model III - Roadside strip plantations on state Highways and other roads

Objective : To raise Fruit and shade trees 10%.

Fuel and smallwood bearing trees 90%.

Design : Width of strip to be planted at 2m on each side.

Species : (i) Fruit and shade trees (Krishnachura, Radhachura, Rain tree, Jack fruit, Mango, Jam etc.)

(ii) Fuel and smallwood trees Eucalyptus, Akasmoni, Minjuri, Jarul etc.

Spacing : Fruit and shade trees = 25 m.

Fuel and small wood = 2.5m

Percentage : Fruit and shade trees = 10%

Fuel and small wood = 90%

Stems per ha : Fruit and shade trees = 200 nos.

Fuel and small wood = 1800 nos.

Management : Fruit and shade trees to be preserved. Fuel and small wood cut a 7th and 13th years. Thinning at 9th and 11th years.

Model IV - Type : Plantations on

(a) Canal bank

(b) Irrigation embankment and Tank embankment.

(c) Riverbank and

(d) Railway lands

Objective	: To raise fuel and small wood trees	= 75%
	Fruit bearing trees	= 20%
	Bamboo	= 5%
Design	: Width of strip to be planted is 6m on either side. Three rows will be planted on each side. General spacing will be 3m or 2m in rows. For bamboo spacing will be 10 m.	
Species	: Fuel and smallwood (Eucalyptus, Akasmani, Subabul, Minjuri, Jarul etc.)	
	Fruit trees (in two rows - Jam Aam etc.) and Bamboo (in single row).	
Spacing	: Fruit and small wood	= 3 or 2m
	Fruit trees	= 15m.
	Bamboo	= 10m.
Percentage	: Fuel & small wood	= 75%
	Fruit trees	= 20%
	Bamboo	= 5%
Management	: Fuel and smallwood cut at 7th and 13th years and thinning at 9th and 11th years.	
	Fruit trees = to be preserved.	
	Bamboo = cut at 6th year onwards.	

Fruit and minor forest produce can be harvested free from payment by local people.

Bamboo : 160 nos. bamboos in each year from the 6th years onwards.

8. Afforestation of grasslands

The grasslands of Northern India are met with in the moisture parts of the sal areas. Extensive areas occur in Terai region as sovanah forest in biotic subclimax. In the Southern India a different type of grassland occurs in the sub-tropical and montane regions.

The treatment of the planting area consists of deep sailworking, preferably mechanical ploughing either in strips or all over the area. Ship sowing or planting is the general practice. A 3' wide strip generally common in the Terai areas with a spacement of 12 feet between the strips. The afforestation of grasslands of South India is comparatively simple the treatment consisting of simple ploughing and introduction of

Eucalyptus and wattlers. The species recommended for afforesting grasslands in the indogangetic plains are :- Sissoo, Khair, Simul, Terminalia belerica, lagerstromia parviflora, Pterospermum suaveolens, Trewia nudiflora and Albizzia spp.

9. Afforestation of cultivated lands

A patch of cultivation lying inside or on the bounding of a reserved forest may have to be acquired and included is a reserved forest for the facility of management and simplification of boundary. The soil condition are usefully adverse.

The treatment of the planting area consists of intensive soil working. Mechanical ploughing is preferable to other methods of soil working. The soil working should be done before the hot weather and the grass and weed roots thrown out before sowing or planting.

Strip sowing or planting is the most successful methods of afforesting such lands, the width of strips and the spacement between them depending upon the condition of wood and grass growth and rate of growth of the species.

On suitable soils, sal may be introduced but on younger or lighter soils a mixture of sissoo and khair should be preferred soil with impeded drainage should be sown with terminalia tomentosa.

In afforesting old cultivated lands and grasslands, the chances of success improve if adequate soil drainage is ensured.

10. Afforestation of other types of lands

(1) Afforestation of landslips

The treatment consists of :-

(i) Rigid closure of the area preferably with barbed wire against grazing.

(ii) Gullypugging and checkdaming.

(iii)Construction of brushwood spurs using branch cutting of poplar, willow etc.

(iv)Sowing and planting of suitable species viz. Populus, Alnus, Salix, Juglans, Tiba, Morus, Celtis and Robinia etc.

(2) Afforestation of black cotton soils

Impermeability and the presence of deep cracks render afforestation of black cotton soils difficult. Taungya cultivation is the best means of afforesting these lands and has proved

highly successful in Berar. Suitable species an Acacia arabica, Azadirachta indica and prosopis juliflora. Intensive weeding is necessary to keep in check the Kundra grass (Ischoemum filostum).

(3) **Aforestation of laterite**

Soils which are laterized should be planted with xylia, swietenia, Anacardium occidentale, cleistanthus cullinus, Emblica officinate and chloroxylon.

(4) **Afforestation of Ravine soil**

Ravine lands are found in areas subject gully erosion, brought about by uncontrolled grazing, burning and destruction of the vegetal growth, Typical examples of ravine formation are met with in the Hossiarpur Division of Punjab and Etawh division of U.P.

Preliminary treatment of the area consist of :-

(i) Rigid closure against grazing, barning and felling of trees.

(ii) Construction of interrupted contour trenches such as in Hossiarpur Division. This is combined with checkdamming and gully plugging. No contour trenching is done on slops exceeding 20 degrees.

In the Etawh Division the flat high level lands are ploughed upto a depth of about 9" and the crust is throughly broken up. Small parallel ridges are then made with a shallow ditch on the upper side to catch rain water on steep slopes upto 60° shallow platforms or ridges are prepared contourwise. The ridges act as seed beds and the ditches trap soil and moisture.

Species selected for sowing

In Hossiarpur Division (Punjab)

Acacia arabica, A. catechu, A. moderta and tuft planting of eulatiopsis binata on the berms of contour trenches. To prevent the headwater cutting of the gullies. Agave, Enlabiopsis binata are planted. Agave is a good soil stabilizer for steep slopes. Vegetative checkdams are prepared from Ipomea and Vitex branch cuttings.

In Etwah ravines (U.P.)

The following species are sown on the ridges : Babul, Sissoo, Cassia auriculata, Teak, Gamar, Adnia cordifolia, Holoptelia, Integrifolia, Poropis spicegera, Bombax etc.

CHOICE OF SPECIES

The selection of species must be done judiciously and carefully giving performance to the indigenous species.

Factors governing the choice of species

(1) Habitat conditions and the Silvicultural requirements of the species.

(a) Climate

Rainfall temperature, snow and forest, humidity factor, N/S quotient etc.

(b) Microclimate

Altitude, Aspect, Type of the forest.

(c) Soil condition

Nature or in nature soil, stages of succession, seal or climax species, indicator value of undergrowth - e.g. Jarul indicates swampy condition not fit for teak.

Species suitable for special sites

(i) **Sandy soil** - Dalbergia Sissoo, Acacia catechu, Tamarix dioca, Acacia arabica, Anacardium occidentales, Casuarina, Vitex negundo, Pongamia glabra.

(ii) **Saline soil** - Acacia arabica, Butea frondosa, Prosopis julifera, Casuarina, Tamarix articulata.

(iii) **Swampy soil** - Eugenia jambolana, Treuria nudiflora, Alstonia scholaris lagers troemia flossregine, Barringtonia acutangulata, Eucalyptus, Robusta, E. saligna.

(iv) **Highly calcareous soils** - Cupressus spp Acacia catechu, clistanthus collinus.

(v) **Forest localities** - Dalbergia sissoo, Morus alba, Acacia catechu, Aegle marmels, casuarina.

(vi) **Denuded hill slopes** - Acacia, Eucalyptus spp., Ailanthus glandulosa, Prosopis juliflora, Cupressus spp.

(2) Suitability of the particular object

(a) Protective purpose

(i) Afforestation of catchment areas

(ii) Fixation of sand dunes

(iii)Creation of shelter belts

(iv)Wind breaks

(v) Reclamation of degraded soil

(b) Productive purposes

(i) Local demand

(ii) Timber for strategy importance

(iii)Species for industrialization

(3) The Silviculture systems

(a) For clear felling systems - strong light demanders.

(b) For selection system - Shade leaving spp.

(c) For multistoried forests - shade bearer under light demander e.g. Mulberry under sissoo.

(4) Effect of species on site factors

Pure conifers, Pure Teak - Adverse effects.

(5) Growth rate

As the gap between the demand and supply of timber is fast increasing, the present tendency is to raise fast growing species.

(6) Resistance to injury

Pure toon and other Meliaceae. Attack of shoot borer.

Pure Teak - Attack of Defoliator

Pure Samar - Loranthus attack.

(7) Ease of establishment

The ease with which a species can be raised also effects the choice of species.

(8) Availability of suitable exotics

If indigenous species cannot meet the fast growing requirement of industrial timber, there should

be no hitch in selecting an exotic which as a result of experiment has proved its suitability to local conditions as well as requirement of industry.

(9) Ease of establishment

Only those species which are easy to raise and which meet the object of plantation should be selected.

(10) Cost

The cost of raising a species also effects the choice.

Species recommended for different parts of West Bengal

1. Hill areas (Darjeeling district except Siliguri subdivision)

1. The lower hill Region in altitudinal zone upto 1000 meters

Timber : Teak, champ, Gamar, Panisaj, Bahera, Mandane, Simul, Lampati, Chikrassi, Toon, Lali, Kimbhu, Siris, Odal, Maina etc.

Forestwood and fodder : Subabul, Glincide, Bauhinia, Siris, Akasmoni, Sesbanea, Phaledo etc.

Fruit : Arecanut, jackfruit, Jam, Mango, Sajina, Guava, Citrus etc.

Bamboo : Bambusa nutans, B. vulgaris, B. balcooa, Dendrocalamus spp.

2. Middle hill areas (1000-2000) meters

Timber : Panisar, Sour, Titechamp (upto 1500 m) Pipli (in the upper zones 1500-2000m) at lower altitudes in the cooler aspects. Dhupi (upper regions 1500m above).

Fruit : Orange, Pear, Apricot etc. Guava, Banana, Papaya.

Fruit and Fodder : Utis, Ratosiris, Eucalyptus saligna, Malata, Subabul (upto 1000m) Mona (on the warner aspect upto 1200m), Phaledo, narkat Artocarpus intigrifolia, A: chaplasha, Amliso, Nevaro, Dudhilo, Khanijam.

Bamboo : Bambusa, nutans, Dendrocalamus Sikkimensis, Gope, Pheling etc.

Cashcrop : Underplanting of Jejpata, Darchini, turmeric, Ginger and Cardamom.

3. Upper hill areas (2000m and above)

Timber : Dhupi, Paris petula, Mithe champ, Pipli, Sour (Betnla), Kapasi.

Fruit : Pear, orange (upto 2100 m) Apple

Fooder and fuel : Phutta, Gogun, Nabaro, Duhila, Khanijam, Narkal, uties.

Bamboo : Bambusa, Nutans (upto 2000m) Philing, Gope, Dendrocalamus, Sikkemensis.

II. **Northe Bengal foothills and plains**

(Duars, Terai and plains) (Darjeeling) (Part), Jalpaiguri and Coochbehar districts).

1. Bhabar Tract

Timber : Teak, Champ, Mandane, gamar, Chikrasi, Gobenl, Sissu, Toon, Bahera, Simul, Arjun, Siris, Kadam.

Fruit : Arecanut, Cooconut, Jackfruit, Jam, Mango, Guava, Sajina, Banana.

Fodder and fuel : Subabul, Kimbhu, Mulbery, Faledo, Gliricida, Gamar, Akasmoni, Khair, Murijin, Siris, (A. Falcataria).

Bamboo: Bambusa, balcon, B.Tulda, B. Vulgaris, D. hamiltonic, Melocana, Banabusodies.

2. Riverian areas

Timber : Khair, Sissu, Simul, Maina, Odal, Kadam.

Fruit: Khezur, Kul, Tamarind, jackfruit, Sajina.

Fodder and Fruit : Sabubul, Jhan, Minjiri, Akasmoni, Siris.

III. **Alluvial zone**

(Distficts of Nadia, Murshidabad, Malda, W.Dinajpur, Howrah, Hooghly and 24 Parganas)

Timber : Sissu, teak, Mahogoni, Arjun, Kada, Jarul, Siris.

Fruit: Aam, Jam, Kanthal, Sajina, Guava, Citrus, Coconut, Arccanut, Sapota.

Fruit and fodder: Subabul, Babla, Gliricida, Gaman, Siris.

Bamboo : Several spices of bamboo.

IV. **Lateritic South West Bengal**

(Midnapur West Bankura, Birbhum & Purulia District).

(i) On rocky outcrop and strong soils

(Purulia, Bankura and Birbhum Districts)

Timber : Neem, Kusum, Mahul, Tal, Haldu, Chhatim, Akasmoni, Simul, Sissu, Peasal.

Fruit oil etc. : Kusum (oil & lac), Arjun (Tussan) Mahul (Fruit and oil), Neem (oil) Karanj (oil), Kul (Lac & fruit), Am, Tal, Khezur.

Bamboo : Bambusa balcooa, Dendrocalamus, strictus etc.

Fodder : Gamae, Amlaki, Bahera, Stylocanthes.

(ii) **On Laterite morrum soil**

On semiarid waste lands where plantation of quicugrowing species is not ecologycally c: culturally possible rows of Khezer on lines 1 m apart and row of Tal on ridges 12m ap art may be adopted. Spacing of Khezur in lines may be 2 m and that of Tal 4 m. Intercopaces may be used for vaising leguimenous agricultural crops or fodder grasses, pulses, gram as is feasible.

(iii) **On pure laterate : (Midnapore, Purulia, Bankura, Birbhum and Bankura Districts)**

Species composition is same as in V (i), In Addition Eucalyptus may be used for pulpwood productiion if feasible and viable.

(iv) **Red morrmy soil: (Birbhum, Burdwan and Bankura district and also parts of Purulia and Midnapore District).**

Fuelwood Species : Akasmoni, Miinjuri, Subabul, Black siris, Sissu.

Fruits : Mango, jackfruit, Guava, Ata, Lemon, Sapota, Tal, Khezur, Arecannut.

Fodder : Grasses (This Napier) and Legumes (Cowpea, style etc.)

(v) **Coastal areas: (Midnapore and 24 Parganas)**

(i) Coastal belt (Saline)

Fruit, Coconut, Tal, Jam, Sapota, Cashew.

Small timber Fuel & Fodder

Babla, Subabul, Akasmoni, Thespesia, Cashew.

(ii) Coastal area near the seashore

The first row is the seaside consist of low height species like Akanda followed by Imomea, Babla and Keora. The next row away from the shore may consist of mediumsized trees like Kararja nd Subabul. The next row may consist of Jham and the last line may consist of Akasmoni and Cashew.

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QUESTIONS:

1. Define social Forestry What are the objectives? Compare social forestry with traditional Forestry.
2. Define Agroforestry. What are a agroforestry production systems. Narate briefly the Agroforestry systems of developing countries.
3. Write short notes on
   1. Entenrian forestry.
   2. Recreation forestry.
   3. Farm Forestry.
4. (i) What is concept of participation? What are the criteria of effectiveness of participation?

   (ii) Describe how far the participation in social forestry has been achieved in West Bengal
5. What is afforestation? What should be the afforestation techniques for the following situations.

   (i) Fivation of Shefting sand.
   (ii) Afforestation of inundated and waterlogged areas.
   (iii) Affortation of land slips.
   (iv) Affortation of dennuded hill slopes.
6. What are the factors governing the choice of speces. Mention the species suitable for the following special sites:-

   (i) Sandy soil, (ii) Saline soil, (iii) Forest localities, (iv) Highly Calcareous soil, (v) Swampy soil.

BOTANY AND FORESTRY

Module No. 23,24

Part-I, Paper -III (1st half)

Silviculture System

INTRODUCTION

We knew the Silviculture is "the art and science of cultivating forest crops". Silvicultural System is the process by which the crops constituting a forest are tended, removed, and replaced by new crops. resulting in the production of woods of a distinctive form. A silvicultural system embodies three ideas: (1) the method of regeneration of the individual crops constituting the forests (2) the form of crop produced and (3) the orderly arrangement of the crops over the forest as a whole, with special reference to silviculture and protective considerations and the economic utilization of the produce.

As the technique of regenerating forest crops vary with types and sub-types of forests and physical conditions in which they exist, it becomes necessary to identify different methods or techniques for different sub-types in different localities.

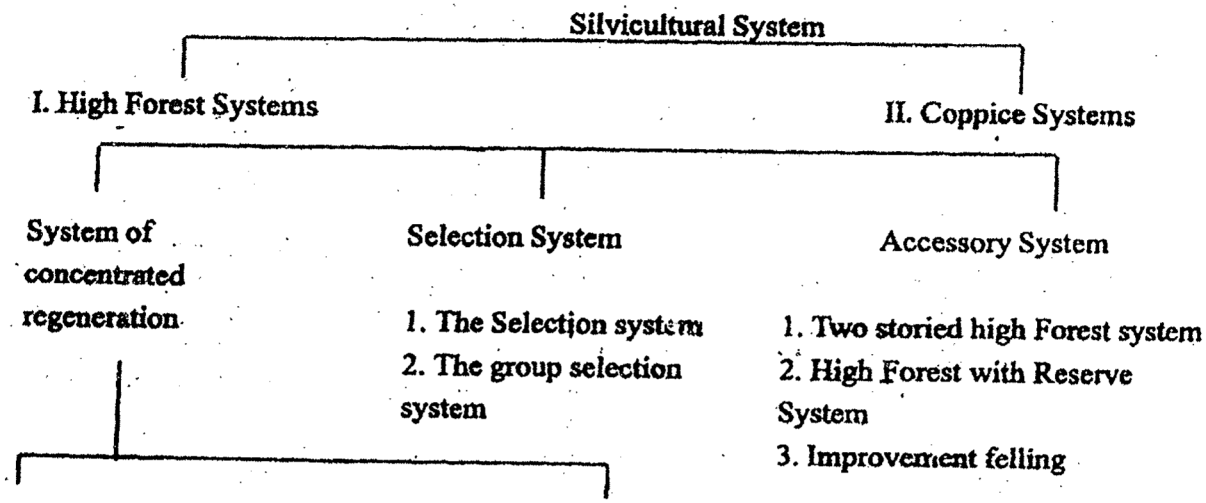
The practical application of silvicultural systems is closely related with the requirements of forest management or in other words it is a specialised tool or technique for achieving the objects of forest management.

Classification

In India, silvicultural systems have been classified according to (a) the mode of regeneration and the type of crop produced thereby (b) and the pattern of felling carried out to remove the mature crop with a view to regeneration.

Each system produces a crop of distinctive form in the young stages, though after some years have elapsed it is usually possible to treat the crop as either even-aged (uniform) or uneven-aged (irregular) for the purposes of management.

Index to the Silvicultural systems



II. Coppice Systems:

1. The Simple coppice system
2. The coppice of two rotations system
3. The shelterwood coppice system
4. The selection coppice system
5. The coppice with standard system
6. The coppice with Reserve system
7. The Pollard system

I. High Forest System : Here the regeneration of crop is normally of seedling origin, either natural or artificial or a combination of both and the rotation of crop is generally long.

Systems of concentrated regeneration : Here the regeneration fellings are for the time beings concentrated on part of the felling series.

Clear felling system : Where the mature crop removed in one operation.

Shelterwood systems : Where the mature crop is removed in a series of operations the first of which is the seeding felling and the last is the final felling. Other fellings, if necessary, are called secondary felling. The interval between the seeding felling and the final felling on a particular area such as a compartment, is the regeneration interval and determines the degree of uniformity of the resulting crop.

Selection systems : Where regeneration felling are distributed over the whole felling series (except in so far as a felling cycle introduces a modification), and the crop is always irregular.

Accessory system : Resulting in irregular or Two-storied, high Forest.

II. Coppice system : Where the crop originated mainly from coppice and where the rotation of the coppice is short.

The Clear-Felling System

GENERAL DESCRIPTION:

Under this system successive equal or equiproductive areas are clear felled in one operation and regenerated, most frequently by artificial means but sometimes naturally also. In its ideal form the clear felling system involves felling and regenerating each year equal areas (i.e. called annual coupe) on which the stands have reached the Pre determined age of maturity (i.e. rotation). If this process is repeated each year for the whole rotation and no disturb occur to interrupt the continuity, a normal series of age gradation, aged 1.2.3.4 ... n years (n is the no. of years in rotation) will have been established. So the area to be clear-felled each year (in uniformly productive sites) is $1/_n$ of the total area allotted to this system :

Example : Say total area of a Forest is 500 Ha

Rotation of the crop in that forest is 50 years.

So, total area to be felled in each year = $1/_n$ of the total area.

= $1/_{50}$ x 500 = 10 Ha.

Where the quality of the soil varies considerably from place to place, coupes not equal in area but equiproductive are formed, those on the poorer soils being larger than those on the more fertile soils.

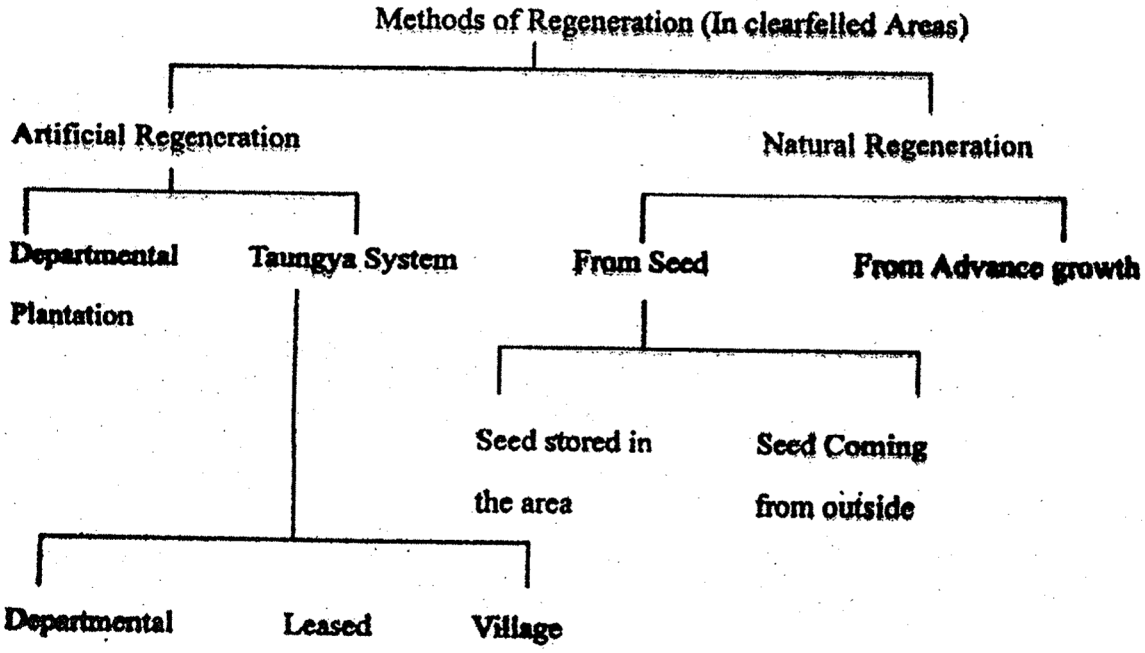
As a general rule, the entire crop should be removed in one operation from a coupe but variations may occur in the following cases.

i) Pre-existing poles are saplings may be left if they occur in promising groups large enough to form self-contained crops. But isolated poles and saplings should be removed as these are likely to develop into branchy trees as well as to interfere with the new crop.

ii) Some mature trees are retained as forest protection measure, or as an insurance against failure or to serve as a nurse crop to facilitate the establishment of forest-tender species. But the number of these trees are very small.

Methods of Obtaining Regeneration:

Clear felled area are generated usually by artificially but sometimes naturally also. Artificial regeneration offers some advantage over Natural regeneration. A schematic representation of obtaining regeneration is given below ;



Departmental Plantation : The annual coupe to be clearfelled are first demarcated. Then the trees which have to be felled are marked and enumerated, and a stock map of the area is prepared. But some fruit bearing trees and trees near the road side. Nalla or jhom areas are kept as per rule. The marked trees are felled and transported to timber dopt. Usually Forest Development Corporation carried out the function. Then the timbers are auctioned for sale. Previously standing trees are auctioned but this practice usually not followed. After transportation of all timber, and fuel wood all filling refuse are cleared by burning and also all stumps are dug out as far as practical. After clearing the area a soil map as well as suitability map are prepared. The area is fenced if possible. Soil working like pit, trench etc. are done as per derived. The soil working should be completed at least about a month and a half before sowing or planting. Sowing is done before the rains start and planting is done when the rains set in. After this the plantation is kept well weeded during rainy season and protected against fire during summer.

Taunga : This is a method of raising forest plantations in combination with field crops.

In departmental taungyas, the work of raising agricultural crops as well as the forest crops is done by the department.

Leased taungyas are those taungyas in which agricultural crops are raised in the interspaces of the lines of forest plants by giving the land on lease to the persons who offers maximum lease money.

Village taungyas are those taungyas which are raised by villagers who have settled down in a village inside the forest for the purpose of helping forest department for various forestry works.

Methods of Natural Regeneration:

Under certain conditions clear-felled coupes may be followed by successful natural regeneration. This may be obtained by either (1) from seed either stored in the area or received from outside (2) or from advance growth.

i) **Seed stored in the area** : In this case the seed either falls from the trees at the time of or shortly after felling, or is already lying on the ground or stored in it; sometimes the seed may be provided from both sources.

Example : The best known case of natural regeneration following clear-felling is to be seen in Pinus **pinasten** of the Landes in South Western France. Clear-felling is here carried out over large areas and natural regeneration springs up in abundance from seed, some of which is already on the ground, but much of which escapes from the cones of the felled trees in the months of April or May. The most important condition for the success of this method is the prolonged viability of the seed or the seed ripening should

coincide with felling so that the latter may result in dispersal of seed required for regeneration of the area. In India, example can be cited, the natural regeneration of **Acacia mollissima** forests.

ii) **Seed received from outside:** This form of regeneration applies chiefly to species with light or winged seeds which are disseminated by wind. Less commonly water or animal agencies may operated.

Examples : In Sind (Pakistan) clear felled coupes are inundated by flood waters of Indus river where babul seed are brought with. Thus the area gets profuse natural regeneration.

In Chhangamanga and Chichawatni plantation of Punjab (Pakistan) the seeds of **Morus indica** is brought in clear felled coupes by irrigation water and by birds, particularly the rosy starlings, which perch on sissoo : In Mangrove forests of India, **Avi cennia sps** is regenerated by this method.

2. **Natural regeneration from advance growth :** Natural regeneration may come up in clear-felled areas by advance growth i.e. established seedlings and young poles of the desired species also. These advance growths may be present before clear felling. This method is applicable to species like sal and teak in favourable localities where abundant advance growth is present. If the advance growths are not well stocked, it is supplied by artificial regeneration also.

Character of the new crops : The crop is absolutely even-aged and if, there are no accidents or failures, the system gives a normal series of age gradations:

Advantage and Disadvantage of Clear-Felling System:

Advantage : It has the following advantages over other system :

1. It is the simplest of all high Forest Systems, since it does not require skill in carrying out operation like marking.
2. The yield per unit area is more and the cost of felling and extraction is low as it represents the utmost concentration of works.
3. It affords complete overhead light, an important consideration in the case of strong light demanders.
4. It is easy to regulate the composition of new crop by introducing valuable sps in the larger proportion and also facilitate introduction of fast growing exotics, as the regeneration can be done artificial method also.
5. There is no damage done to the young crop through the felling and extraction of timber, since this is all completed before the young crop originates.

6. Owing to the even-aged condition of the crop, this produces trees with comparatively cleaner and cylindrical bole than by the more uneven aged systems.
7. New crop is established more rapidly under this system than under system in which regeneration is established by degrees: there by reducing cost of regeneration operations, and shortening the rotation.

Disadvantages: The main disadvantages of this system are as follows:

1. The complete clearance of the forest cover may produce conditions adverse to the growth of young plants of many tree species, such conditions are the following:
    a) Dessication and general deterioration of the soil through exposure to sun and air currents.
    b) Increase of swampyness in areas which tend to be swampy.
    c) Invasion of grass and weed may interfere with regeneration of the crop.
    d) Young plants exposed to forest and cold winds.
    e) Injurious insects multiply in felling refuse, stumps etc. areas.
2. On hilly areas, it exposes the area to erosion and where the ground is unstable, to landslips and there is no safeguard against rapid run-off of the rain water.
3. It produces even-aged crop which is less registant to damage by snow and wind and when the crop is pure, it becomes susceptible to damage by insects, plant parasites and fungi.
4. From the aesthetic point of view, the clear felling system is undesirable than any other high forest system.

Conditions of Application of Clear-Felling System:

Before deciding on the application of clear-felling system in any locality it is necessary to consider various factors involved to ensure not only the success of plantation but also the closure of its canopy as soon as possible. Some of these considerations are given below:

1. **Species:** The clear-felling system is suitable for strong light demanders; but in areas subject to frost, drought, or other risks it is unsuitable for sensitive shade-bearers, which will not with stand exposure in youth, although these may be introduced on clear cut areas with the help of nurse crop.
2. **Locality:** It is unsuitable in areas like (a) unstable hill sides, (b) incatchment areas where the water supply is likely to be endangered, (c) for protection forests.

3. **Soil and soil covering :** The clear-felling system is not suitable in areas where the soil is liable to serious deterioration through temporary exposure or where clear-felling is followed by a heavy growth of weed which prevent regeneration. This system is suitable for fertile soils.

4. **Conditions for regeneration:** The areas where regeneration cannot be assured as a result of biotic interference, should not be worked under clear-felling system. Suitable labour should be available during the season of planting and sowing.

5. **Type of Forest produced :** It produces more or less even-aged crops, and this is suitable for production of large quantities of material of special dimensions, for instance mine-props or pulp-wood. But even-aged crops are more susceptible to damage by wind and snow than uneven-aged crop though the risk can be lessened by giving proper attention during thinning, by an admixture of species resistant to wind on snow, and by a suitable arrangement of coupes and cutting sections.

6. **Crop composition :** The clear-felling system is the only system by which composition of crop can even be completely changed to ensure best financial return. It is the only system by which forests composed of slow-growing species of little economic value can be replaced by new crops of fast growing and valuable species.

7. **Economic Considerations :** The economic advantage of felling and extracting the largest quantity of timber from the smallest area in the shortest time is so great, that the clear felling system has been frequently adopted. Concentration of felling facilitates the mechanization of conversion and extraction work.

The clear-strip system or Progressive clear-felling strip system or Progressive strip system: In this system, as the name implies, clear felling is done in the form of narrow strips. These strips are so narrow that the adjoining old crop, by the lateral shade or protection afforded by it, has a direct influence on the strip, and may thus, produce a marked impact on the seedling survival conditions and also on the establishment of regeneration.

The salient features of this system are :

1. The strips are progress successively in one direction usually against the prevailing direction of the wind across the regeneration area.

2. The clear felled strips are separated by unfelled strips of sufficient width which may be a multiple of the width of clear-felled strips.

3. The interval between successive adjacent fellings will depend upon the frequency of seed-years and the readiness with which regeneration appears and established itself and also the period for which protection against adverse factors is required.

4. The regeneration area is divided into as many cutting sections as the numbers of years after which felling in successive adjacent area can be done. Say, the period after which felling in adjacent are can be done is 4 years, the regenerated area will have to be divided into four cutting sections marked I to IV and successive strips arranged as shown in the figure.

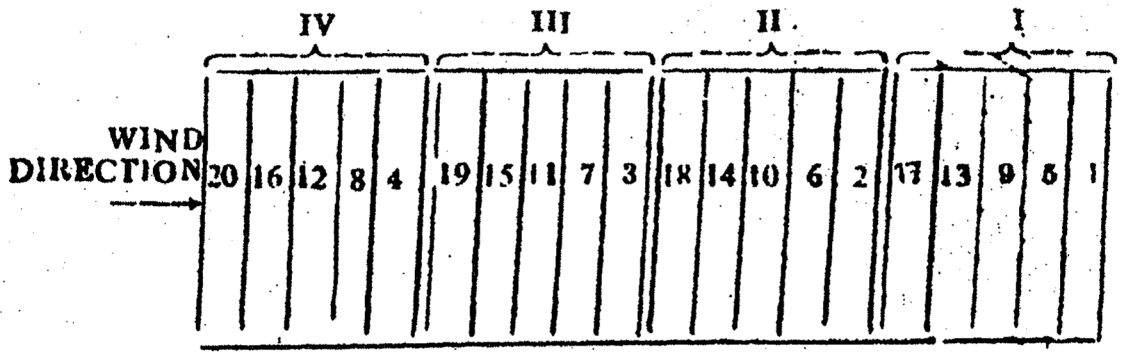


Fig. I. Arrangement of strips in Progressive Strip System.

5. The width of the strip will depend on the distance to which the seed can be disseminated by wind so that even the remotest part of the clear-felled strip gets sufficient seed for regeneration.

6. In the last coupe of each cutting section a belt of seed bearers should be left along the windward side in order to regenerate the coupe, after which the belt should be felled and the blank strip regenerated artificially.

7. The clear-strip system results in production of even-aged crop.

8. It has some advantage and disadvantage over clear-felling system.

The Alternate Strip System:

This is a modification of clear-strip System : The salient features of this system are.

1. The clear-felled strips are alternate with unfelled strips of similar width, though sometimes these may be narrower or wider also.

2. The width of the felled and unfelled strips varies from place to place e.8.

		Width of clear-felled strip	Width of unfelled strips
a)	In Normandy France	40m to 50m	15m to 20m
b)	In America	double of unfelled strip	
c)	In India	12m and 20m	36m and 80m

3. The period after which the alternate unfelled strip is felled also varies according to circumstances. According to troup unfelled strip should be felled when the crop in the initially felled strip is capable of producing seed. So that the unfelled strips when clear-felled could be regenerated naturally.
4. Crop produced is usually even-aged.
5. It has some advantages like, lesser damage to seed bearers from wind and also to young crop from and extraction of the seed bearers, it protects sensitive seedlings against forest and cold wind etc.
6. It has disadvantages like, timber extraction is difficult in hilly areas, fire protection is very difficult, etc.

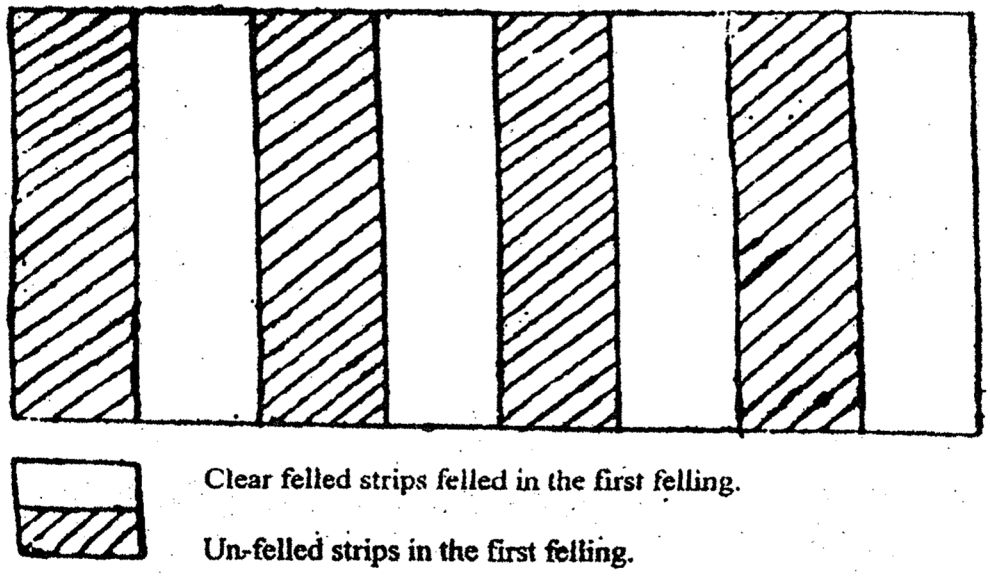


Fig. II: Arrangement of felled and un-felled strips in Alternate-strip System.

The Uniform System:

1. General Description:

The term uniform system is an abbreviation of **Shelterwood Uniform System**, which means a uniform opening of the canopy for the purpose of obtaining regeneration and also the uniform or evenaged conditions of the young crop produced subsequently. It has also been termed as the **Shelterwood Compartment System** or as **Compartment System**, implying the canopy is opened for regeneration simultaneously all over the compartment. Other terms such as Shelterwood system and system of successive regeneration fellings are also applied to the uniform system, however, the latter is preferred to any other term.

2. Kinds and Pattern of fellings:

Like any other Shelterwood system, removal of overwood in the uniform system, is carried out in two or more successive fellings in a sequence, one after the other after an interval of time, which are collectively designated as regeneration fellings and these are 1) seedling felling 2) Secondary felling, 3) and final felling.

1) **Seedling felling** : In seedling felling opening of the canopy of a mature crop is done to provide conditions for securing regeneration from the seed trees retained for the purpose. The object of the seeding felling is not to stimulate seed production, but to admit sufficient warmth from the sun to promote germination, and sufficient light to enable young seedlings to survive for two or three years, or until it is necessary to admit more light by a further opening of the canopy.

   In seedling felling keeps two considerations in view viz. (i) selection of trees to be retained and (ii) the distance between the trees and their position. Genetically superior trees should be selected as seed bearers. Hence trees with long clean, cylindrical boles and well developed crowns should be selected as seed bearers. The distance between the seed bearers or in other wards, their number per unit area, affects the light, warmth, etc. reaching the forest floor and varies accordingly to silvicultural requirement of the species, and climatic and other factors. The shade bearers species and those with heavy seed, require less opening i.e. larger no. of seed bearers than light demanders and species with light winged seeds, where the opening of the canopy is likely to result in a rank growth of weed or grass, or in the rapid drying or deterioration of the soil, the seedling felling should be carried out with caution. More cover should be retained on hot southerly and south westerely slope than on cool motherly slopes, particularly where the soil is dry or shallow, where there is a malted growth of grass, it may be necessary to hoe or plough the ground at the time of a good seed-year, to enable the

seed to reach the mineral soil. In the hills, the seed bearers should be on the ridges and not in the valleys and on a hill slope on the upper side rather than towards the bottom of the slope.

2) **Secondary Felling** : Secondary felling is carried out between the seedling felling and the final felling under a Shelterwood system in order gradually to remove the shelter and admit increasing light to the regenerated area. When the young crop has been fully established as a result of the seeding felling, the overhead cover should not be retained no longer. The number of secondary fellings depends upon the species and the progress of its regeneration. With species in which a large number of seed bearers are retained at the time of seeding felling, the number of secondary fellings would be more than with species in which the number of seed bearers retained was less. In case of a hardy light demanders the whole of the overwood may be removed in a secondary (in this case a final) felling within a few years of the seeding fellings. In case of a sensitive shade-bearer, the young crop should be uncovered more gradually by means of two or more secondary felling carried out at intervals in order that it may receive the protection from forest, drought or other risks which the overwood affords : **The state of the regeneration should be the chief guide towards the selection of trees to be felled or retained.** In practice, the number of secondary felling is kept to an absolute minimum to minimise the damage to regeneration during felling, logging and extraction of trees for secondary felling or they are not carried out at all.

3) **Final Felling** : In the final felling all remaining seed-bearers are removed and the fully established young crop remains. The condition of established regeneration, when considered to be no longer in need of Shelterwood, varies with species and climatic and biotic factor of the locality in which it grows. Though final felling means that all the Shelterwood is removed, it is usual to keep 3 to 5 seed bearers per hectre in chir even after final felling, as an insurance against devasting fires and sometimes to allow them to put on increment and met demands of the local people.

The method of obtaining regeneration is mainly natural, though often supplemented by artificial regeneration.

3. **Character of the crop** : Crop is usually even-aged though it is not so even-aged as in the clear felling system.

4. **Regeneration Period and Periodic Blocks** : In clear-felling system we have seen that theoretically one coupe is cut and regenerated each year, so that if there are r years in the rotation (i.e. age of felling) there will be r annual coupes differing in age by one year. Under the uniform system this is not possible, since it requires more than one year to regenerate any given area. Hence, in order to systemize operations and ensure that the whole forest shall be felled and regenerated during the course of a rotation, the plan

commonly followed under favourable conditions, is to divide the rotation into a number of regeneration period (i.e. the period required to regenerate the whole of a period block) and the forest into the same number of periodic blocks (abb. P.B.), each to be felled and regenerated in turn during the course of successive periods. For example, if the rotation is 100 years, and it takes 20 years to regenerate an area naturally, the rotation will be divided into 100/20 = 5 periods and the forest area will be also divided into 5 periodic blocks. If one whole rotation under the uniform system has just been completed, the normal distribution of age-classes should be as follows :

Period and Periodic Block	Age of Crop At the beginning of period (Present time)	At the end of period (20 yrs hence)
I	81 - 100	1 to 20*
II	61 - 80	81 to 100**
III	41 - 60	61 - 80
IV	21 - 40	41 - 60
V	1 to 20	21 - 40

* Old crop all removed, only young regenerated crop remains.

** To be regenerated during period II.

The area allotted to any periodic block is re-designated or allotted to the next period block at the end of the period. Thus each area moves from one periodic Block to another to complete rotation.

Length of the regeneration Period : The period is the estimated number of years required to obtain complete regeneration over a whole periodic block and to establish this regeneration upto the time when the retention of the overwood is no longer necessary, it should begin with the seeding felling and end when the last remaining seed-bearers are removed in final fellings. The chief factors which determine the length of the regeneration period are as follows.

1. **Frequency of seed year** : Where good seed-years are frequent, a shorter period is possible than for those in which they occur at longer intervals.
2. **Light requirement** : Light demander species require shorter regeneration period than that required for shade bearers as their regeneration requires shelter for a longer time.

3. **Hardiness of species** : Hardy species, which may be uncovered rapidly, require a shorter period than sensitive species, which may require the protection of the overwood for many years.

4. **Climatic conditions**: Areas with extremely variation of temperature, a longer regeneration period is required. Similarly, areas with deficient rainfall or long dry season after monsoonic rains require longer regeneration period.

5. **Soils conditions** : If soil conditions are favourable to regeneration the length of the period may be short. But where the soil is not favourable i.e. deficiency of moisture, nutrients, aeration due to water legging etc. for regeneration, the regeneration period is longer.

6. **Condition of grass and other competing weed growth** : The denser the growth of grass and weeds the longer is the regeneration period.

7. **Incidence of grazing and browsing** : Uncontrolled grazing and browsing is harmful for regeneration. So, greater the incidence of grazing and browsing, the longer is the regeneration period.

8. **Incidence of fire** : As fire damages regeneration so where the incidence of fire is more frequent, longer regeneration period usually recommended.

Allotment of areas to Periodic Blocks:

The Allotment of areas to periodic blocks may be of any one of the following two kinds. 1) Fixed or Permanent, 2) Floating.

Fixed or permanent allotment may be defined as the allotment in which the entire area being worked under uniform system is sub-divided into various periodic blocks which retain their territorial identity at each working plan revision.

The area allotted to a period block is worked out according to the formula.

$$\text{Area of P.B.} = \frac{\text{F.S.} \times P}{R}$$

where F.S. stands for area of the felling series

P = number of years in the period

R = Rotation.

Fixed periodic Block may be of two kinds (i) Self contained and (ii) Scattereo.

Floating Poriodic Block is one in which neither the area of regeneration of periodic block nor the period is fixed.

$$\text{Area of P.B.} = \frac{\text{Area of the F.S. x estimated regeneration period}}{\text{Rotation}}$$

Numbering of Periodic Blocks and works carried out therein :

If the allotment of areas to periodic blocks is fixed, it is customary to number them as I, II, III, IV and so on, depending on the number of P.Bs in the felling series or the working plan. In various PBs different silvicultural operations are carried out accordingly.

5. **Advantage & Disadvantage of Uniform System.**

Advantages:

1. As the overwood is not completely removed so, there is a little risk of soil deterioration and erosion as compared to clear felling system where the soil is exposed more or less completely.
2. The fellings are simpler in execution than in most shelterwood systems.
3. Due to overwood, the young crop is protected against adverse climatic factors like frost, cold winds, insolution etc.
4. As genetically superior seed bearers are retained, the new crop is also superior in character.
5. The selected seed bearers get rapid diameter increment after seeding felling and larger-sized trees and larger volume timber per unit area is obtained as compared to clear felling system.
6. From aesthetic point of view, it is preferable to clear felling system.
7. This system is somewhat flexible because it is used for regeneration of both light demanders as well as shade bearers.
8. As the work is somewhat concentrated, supervision and control of various operations are easy.

Disadvantages:

1. Damage of young crop by felling and extraction of overwood in more than in one operation is greater than in the case of strip or wedge fellings.
2. The isolated seed bearers are very susceptible to the thrown over by wind particularly if the species is shallow rooted. Sometimes even deed rooted plants are broken by wind at the middle of the height too.
3. In hot situations isolated seed-bearers of thin-barked species are liable to suffer from sun scorch.
4. In case of longer regeneration period, weedings, cleanings etc. have to be done for a very long

period which is costly.

5. Canopy manipulation in mixed forest require skill, and judicious judgement of the staff and labour.

6. **Application of uniform system:-**

It is application in areas where regeneration can be obtained at will during the regeneration period irrespective of hills or plain areas. It is also suitable for areas where young crop requires protection against adverse climatic factor and where clearfelling of the area is likely to result soil deterioration and erosion and invasion by thick grass and weeds.

The Group System

1. **General description:**

This system was first developed by Karl Gayer in Bavaria (Germany). It is generally known as Gayer's or the Bavarian Femelschalag, with a comparatively short regeneration period. Here regeneration fellings are done in scattered groups instead of uniformly all over the compartment. Here regeneration starts from some groups of advance growth, or from artificially created gaps and spreads centifugally to cover the entire area finally.

2. **Pattern of Felling**

a) Under the group system the first step is to go over the compartment and search for any promising groups of advance growth which may have appeared in gaps caused by wind, snow, or other agencies.

b) If these groups of advance growth require freeing, the gaps are widened by felling trees round their edges, while at the same time, or as soon as a seed-year occurs, a seeding felling is made in the form of a ring round each gap.

c) If there are not sufficient natural gaps over the compartment, further gaps are created artificially by felling trees in small groups.

In this way numerous gaps are distributed over the regeneration area, which may be a whole compartment, or more commonly only a portion of a compartment at a time.

d) As soon as regeneration has appeared in the artificially created gaps, a seedling felling is made round each gap as before. Regeneration thus spreads centrifugally round each gap. Secondary and final felling in turn follow the seeding fellings, while new seeding fellings continue outwards into the unopened old crop in ever-widening circles.

The groups of regeneration thus become larger and eventually meet, when the last remaining mother trees separating the various groups are removed and only the regenerated young crops remain.

The size of the artificially created gaps and width of the rings made round the nuclei of regeneration varies with species and their light requirement. Light demanders require bigger gaps and wider rings than shade bearers.

The places where there may be a risk of wind damage, the gaps are created only on the leeward side and when that part is regenerated, fresh gaps are made on the wind ward side of the previously regenerated area. The gaps proceed against the direction of wind.

3. **Form of crop produced** : The crop produced by this system is somewhat un-even aged with a wavy surface due to the presence of numerous thickets of different ages. If regeneration proceed slowly and the gaps are widened gradually, the uneven aged condition is more pronounced than where regeneration proceeds quickly and the gaps are widened rapidly. But unevenness generally disappears by the time the pole stage is reached, and this system may therefore be regarded as essentially an even-aged system.

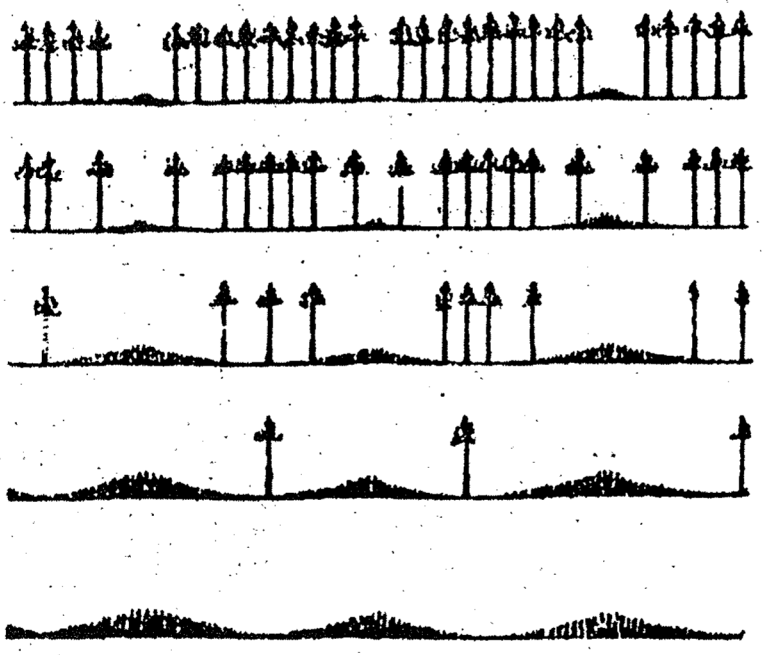


Fig. 27. Group system, showing successive stages of regeneration. a. initial gaps, with groups of advance growth; b, c, d, successive stages of enlargement of groups; e, regenerated young crop, showing wavy outline.

4. **Advantage and Disadvantage of Group System:**

Advantage :

1. As advance growth are selected for regeneration so there is a definite advantage over where seed-years are not frequent, or where regeneration is not always certain.
2. The young crop develops in a somewhat more natural way than in the case of the uniform system.
3. The young crops are protected by adgoing trees against frost and insolation.
4. As seed bearers are surrounded by unfelled forest so there is a little danger of being by wind storms of the seed bearers.
5. Damage by felling is avoided during the earlier stages of regeneration by directing the fall of the trees away from the groups of young growth, this no longer holds good when the groups being to join up.

Disadvantage:

1. As the felling, logging, conversion etc. are spread over whole compartment as patches so its supervision and control becomes difficult.
2. Before felling, the groups of existing advance growth have to be located and their extent determined. In hilly, terrain, survey and location of these groups is difficult.
3. Serious damage be wind is liable to occur as the gaps become enlarged and the seed bearers become isolated.
4. On steep hill slope much damage may be caused by the sliding of timber through groups of saplings during extraction.
5. The system requires intensive working and where this is not possible its success cannot be ensured. The system failed in Indian conditions mostly because, over extensive areas, intensive working was not possible.

The Irregular Shelterwood System

1. This system is commonly known as the Swiss or Baden Femelschlag. The term Irregular Shelterwood System is an English equivalent of two European System i.e. Swiss femelschag and Baden femelschlag. It may be defined as a system of successive regeneration fellings with a long and indefinite regeneration

period, with the object of producing young crops of a somewhat uneven-aged type. It may be regarded as a compromise between Shelterwood Group system on the one hand and selection system on the other. This system has not been used in this country but practised in Europe.

Swiss Femelschlag

2. The salient features of this system are as under :

    1. It has a long and indefinite regeneration period. This may usually extend upto 50 years and its length can vary from place to place even within the same compartment.
    2. No specific rotation is prescribed. Neither the silvicultural system nor the yield prescription by the method control require that there should be a definite period, generally none is prescribed.
    3. No periodic Block are delinected. Regeneration areas are identified and these may be scattered all over the forest. Reallotment is done after every 10 years or so and much latitude is allowed as far at the selection of areas for annual felling is concerned and also for the manner in which yield is to be obtained.
    4. Regeneration commences in small groups and is enlarged in a centrifugal manner, as in case of the group system. The basic difference between these two systems is the rate of progress. Advantage is taken of the gaps in which advance growth first appears. Such gaps may be caused by wind, or snow or other natural agencies. However, so as to avoid damage to groups of saplings during the process of extraction, it is preferred if these gaps are first in that part of the coupe or compartment, which is the furthest from the extraction areas. This helps to minimise damage to saplings due to felling and extraction operations. Regeneration should be so planned that it progress gradually towards the extraction route.

        On level ground, this may be brought about by making a line of gaps between two such routes and working gradually towards, these routes. Besides this progression from the centre towards the outside, progress of regeneration may also be along a perpendicular direction, so that the central line of gaps is gradually extended further into the coupes and the groups of regeneration advance in a v-shaped; the youngest groups being towards the apex and on the flanks, the oldest being in the centre. However, contrary to the selection system, there is a time when the crop receives regular thinnings so as to produce fine stems.

3. **Baden Femelschlag:** The broad principles of the Baden femelschlag resembles those of its Swiss counterpart. It is largely applied for the treatment of silver fir and spruce forests, where the rotation

is in the region of 120 years, but in acute practice varies considerably, the vigorous trees being left to grow and the weak and cankerous individuals being removed at an early age. The regeneration period is between 40 to 60 years; being more in cases where fir is in a higher proportion. Where the period is a fairly long one, the resultant crop is uneven aged in character. Under the Baden femelschlag, a fair degree of importance is attached to the production of wind firm trees. Height increment in the best growing individuals is considered to have a more beneficial effect than special steps to secure abundant regeneration. For this reason there are no drastic seeding fellings and more efforts are made for the best development of vigorously growing individual stems. The aim is to secure good seed bearers with a well developed crown and root system; around which when gaps are created, will put subsequently, all the remaining old and mature trees are removed in the final fellings. At this stage the regeneration is about 50 years in age.

5. In the early stages, this system resembles the group system, very often the crop may appear to be one being regenerated under the group system. During the initial stages, the crop is an even-aged one. Many crops which are being treated under this system today, were initiated either under the group system or the system of progressive strip fellings.
6. In certain cases regeneration beings with a slight opening of the canopy. However, it is very essential to make small groups or gaps. As a matter of fact, it would be very difficult to preserve regeneration in any other manner, for a period of about 40 to 50 years.
7. The gaps created for regeneration should be larger and opened with more speed when a strong light demanding species is being regenerated.
8. In certain cases, where regeneration of the favoured species is not upto the desired level, hardwood may have to be introduced in a pure of conifers.
9. As in the case of the selection system, in this system too, the best stems can be retained upto an advanced stage, so as to derive maximum benefit from its valuable increment on rapid light increment and be wind firm. Once, such trees have been developed, natural regeneration comes up in abundance around them.

Regeneration fellings are carried out with due caution.

The damage caused to the young crop is brought down to a bare minimum. Such fellings are commenced from the top of the slope, and gradually proceed down hill. Fellings are in free groups of advance growth, rather than in created gaps.

The other Shelterwood Systems like Shelterwood Strip systems, the strip and group system and the Wedge systems are not used in India. So there systems are unimportant and not discussed here.

The Indian Irregular Shelterwood System

Trevor (40) described it as a modification of the uniform system, where large quantities of advance growth of various ages and sizes, trees even upto 40 cm (16 inches) diameter, are retained as part of the future crop. According to him this system had been described earlier by Glover as the Punjab Shelterwood System in case of deodar forests. As the uniform character of the crop is lost by retention of trees upto 40 cm diameter, the uneven aged and irregular nature of the crop necessitate separate treatment of the system. This system not only a modification of uniform system but also a liberal compromise between the uniform system on the one hand and selection system on the other. Thus in this system irregular opening up of the crop is necessitated by one or a combination of the circumstances. When the crop to be regenerated irregular uniform opening of the crop leaving a few seed bearers, results in unnecessary sacrifice of immature material for a theoretical ideal of uniformity, other factors like difficulty in obtaining regeneration at will, stepness of terrain and danger of loss of soil fertility etc. govern the irregular opening of the crop.

The pattern of fellings will vary according to circumstances.

The Indian Irregular Shelterwood system is commonly applied to deodar and sal, and in certain circumstances to tropical rain forests.

The Selection System

The Selection System differs from all the systems described previously in that felling and regeneration are not confined to certain parts of the area but are distributed all over the area, the fellings consisting of the removal of single trees or small groups of trees scattered through out the Forest Fellings carried out in this manner are termed "Selection fellings"; they result in an uneven-aged type of forest in which all age-classes are mixed together over every part of the area.

1. General Description:

Felling and regeneration: Here, in this system, Scattered single trees or small groups of trees scattered all over the regeneration area are felled. Under favourable conditions, natural regeneration comes up in these gaps. Such a process continues year after year (under ideal conditions) and the whole forest is renewed at some point in time. At all times an uneven aged type of forests, in which trees of all age classes are mixed together, results. Theoretically, a forest being worked under the selection system should contain trees of all age classes, well distributed all over the area.

However, such a regular distribution is seldom found and more often than not, the age classes tend to occur in small groups as a result of regeneration, occurring in small groups. It is difficult to select and fell the trees to be removed each year. A substantial amount would required to be spent on this annualoperation. Hence, it has become customary to divide the entire area into a number of more or less, equal blocks. One block is brought under regeneration each year and the entire forest is worked during the period of a year, which is equal to the number of blocks into which the area is divided. This period is known as felling cycle.

Under the arrangement of such blocks, fellings are more concentrated and there results an accumulation of mature trees during the interval between two consecutive blocks. A larger volume per hectare is available for felling over the annual coupe, than in case of felling being carried out over the entire forest each year. At times, the term periodic selection system is applied to the former process and ideal selection system to the latter.

In their crude form selection fellings comprise of removing all trees above a certain diameter or girth limit, at times the provision is added that any trees needed as seed bearers should not be removed. However, such fellings are merely exploitation fellings, and need not provide for a yield on an sustained yield basis. Thus, if any respectability is to be given to the selection system, in the form of a silvicultural system, a more scientific basis is required to be prescribed, that the mere removal of all these trees. Furthermore, it is also necessary to provide a sustained yield for carrying out regular thinnings in the various age (and diameter) classes, so that their properties is maintained in a correct balance. It is also to be ensured that the saplings are freed from suppression under defective and malformed stems, and these are removed from time to time towards the normal; a comparison of the actual distribution of size classes with the normal curve serves as a guide, the fellings being confined as far as possible to those size-classes which are in excess.

Advantages and Disadvantages of the Selection System:

1. As Selection System maintain a constant forest cover both vertically and horizontally it affords protection against erosion, landslips and snow-slides.
2. The forest produced by this system is most resistant to injuries by insect pests and adverse climatic factors. It prevents invasion of grass and weed also.
3. Natural regeneration comes up easily as all seed years are usually used, due to abundance of seed-bearers and seedlings are well protected.
4. There is no need to maintain as high as proportion of young stems to old as in uniform forest where there must be equal areas of each age-class. Hence a much larger proportion of the growing stock and yield can be in the form of trees of large size.

5. As the lower age-class trees below the older trees, the selection system results in producing more growing stock in large sized trees per unit area than the uniform system.
6. From aesthetic point of view selection system is more considered attractive than uniform system.

Whenever, thinning of the immature stems are carried out alongwith the felling of trees which have attained the exploitable size, both these being combined together to form a single operation, cleanings are also done in the younger age classes. Certain measures to assist in the establishment of regeneration, include the removal of raw hamus from the forest floor, light soil working etc. In cases where natural regeneration is lacking, artificial means, such as sowing and/or planting has to be resorted to.

According to Troups "Fellings under the selection system generally involve the removal of the following classes of trees:

1. Dead and dying trees.
2. Trees which are diseased, misshopen or otherwise defective or lacking in vigour, or of undesirable species, particularly if interfering with better stems or promising groups of young growth.
3. Trees of exploitable size, particularly if defective or lacking in vigour.
4. In modern practice the tendency is to abandon the idea of an exploitable diameter and to leave specially vigorous well-shaped trees of any size to put on increment. In order to secure a correct distribution of size classes a plan sometimes adopted is to construct a graph representing, as nearly as can be estimated, their normal distribution, and to carry out the felling in such a way as to lead gradually.

Disadvantage:-

1. Considerable silvicultural skill is seeded for making and felling and extraction of timber.
2. The selection system is applicable chiefly to shade bearers.
3. Cost of logging and extraction is higher.
4. Where grasing is practised, the selection system is not suitable since regeneration is not confined to definite areas from which animals may be excluded.
5. As the seed is obtained from good as well as bad trees, inherent qualities of timber of the young crop may not be high.
6. It is difficult to assess the success of failure of regeneration.

Conditions of application:

1. Where clearfelling system or any Shelterwood System are not applicable like areas of hill sides and avalanches in mountainous region etc. selection system is applicable as it affords protection against erosion, landslides etc.
2. To conserve the water supply in catchment area and to prevent floods, usually selection system are adopted.
3. Where communication of forest with market is not so good and market requirement is not so high, selection system is adopted.
4. As certain species are shade bearers such species cannot be worked under systems of concentrated regeneration. As the regeneration of these species comes up well under shade, selection system is best suited for them.
5. The selection type of forest is maintained for aesthetic reasons in the immediate neighbourhood of towns and villages.

Controversy : There are some controversies regarding the merits of the selection system. The main points of controversies are (a) Quality of timber produced (b) Difficulty in supervision and higher cost of extraction (c) Damage of young crop during felling (d) Failure of regeneration (e) Higher growing stock and higher increment etc.

Coppice with Standard

The coppice system involves reproduction by stool shoots or suckers, when felled near ground-level most broad-leaved species, upto a certain age, reproduced from shoots sent up from the stump (stool). These shoots, known as stool shoots or coppice shoots, arise either from dormant buds situated on the side of the stool at or near ground-level, or from adventitious buds arising from the cambial layer round the periphery of the cut surface. As a rule several shoots arise from each stool, with the result that Coppice has a characteristically clumped appearance.

1. General Description of Coppice with standards :

Form of Crop : Coppice with standards consists of two distinct parts : (a) a lower even-aged storey treated as simple coppice and (b) an upper storey of standards forming an uneven aged crop and treated as high forest on the principle of the selection system. The Coppice is termed the underwood and the standards are

overwood. The object of standards is to provide large-sized timber, to provide seed for natural regeneration, to afford protection to the Coppice against frost, to increase revenue, enrichment of Coppice etc. The rotation of the Coppice is fixed according to requirements and the area is divided into as many annual coupes as there are years in the rotation. As each annual coupe in turn becomes due for felling, the following operations are carried out in it:

1. The coppice is clear-cut like simple coppice.
2. A certain number of the existing standards are reserved for at least one more coppice rotation, and the remaining are felled.
3. A certain number of new standards equal in age to the coppice are preferably of seedling origin are reserved.
4. Blanks caused by the death of stools or by the removal of standards are filled up by natural or artificial regeneration.

If the rotation of coppice is r years, the age of standard will be 2r, 3r, 4r ..... years. In other words, the rotation of the standards is a multiple of the coppice rotation.

Species : The standards need not be the same species as coppice. In case of mixed forest, these may be of one or more species of the forest eg. In sal forest, they may be of sal and terminalia tomentosa. In mixed deciduous forest, sissoo and teak are also good standards. The standard should be most valuable species with long clean bole and attenuated light foliage. They should be wind firm and light demander.

Classification of standards: The following terms are generally used to specify the several classes of standards.

	English
Standard of 1 rotation	Teller
Standard of 2 rotation	2nd class standard
Standard of 3 rotation	1st class standard
Standard of 4 rotation	Veteran
Standard of 5 or 6 rotation	———

Standards of the various classes can generally be distinguished by their size.

Distribution, Reservation and Removal of standards:

The number of standards varies as per object of management, climatic factors and silvicultural characteristics of the species. For example if the object is to get large sized timber then fuelwood then the number of standard is large. If the coppice crop is a shade bearer then large number of standards can be retained, if it is a light demander species then few standards are kept. The number or volume of standards to be kept reserved depends on the relative importance of the overwood and the underwood. As a general rule between 20 and 40 standards per acre of all classes are reserved. Trevor has recommended that standards should not occupy more than one third of the canopy.

Usually the standards are scattered singly over the area, but sometimes they are concentrated in groups distributed amongst the coppice or in belts with intervening belts of coppice. The selected standards are marked clearly with a ring of white paint or coaltar and serially numbered with paint Record of all standards retained giving details of species, diameter etc. for each serial number is kept in a register for reference later. The rest of the trees are all marked and clear felled.

Standards should be felled and removed immediately after the coppice is cut, in order to avoid damaging the young coppice shoots after sprouting takes place.

Tending operation:

After felling, the coupe is cleaned by slash burning. In the next year of main felling or the subsequent year, a cleaning is done to cut climber and useless species interferring with coppice and if necessary, to reduce the number of coppice shoots per stool. The first thinning is usually carried out in the 5th year and second in the 10th year. Thinning is usually done for overwood. The prunning of standards may also be done with the object of producing clean boles.

Character of Crop: The underwood is even aged while the overwood is uneven aged.

2. **Advantage and Disadvantage:**

Advantage:

1. As it produces fuel wood pole and large sized timber simultaneously so greater revenue can be obtained by this system.
2. It furnishes early returns from the coppice, which is a financial advantage.

3. The investment is small as compared with that of most of the high forest system.
4. The overwood protects the soil even when the underwood is clear felled.
5. Blanks are covered by artificial or natural regeneration so regeneration cost is less in compare to simple coppice system.
6. Aesthetically it is superior to simple coppice system.
7. It is a good system for game preserves, owing to the cover afforded by the underwood.
8. The standards serve the purpose of seed bearer and provide seedling regeneration.

Disadvantage:

1. It is a difficult system to apply correctly; the maintenance of the balance between coppice and standards and correct distribution of standards of different classes require great skill.
2. Coppice grown under standards is generally less vigorous than simple coppice.
3. Felling, conversion and extraction costs are higher in this system than in the high forest system.
4. Coppice suffers from the browsing of wild animal, smooth-barked standards, when exposed are liable to sun-scorch.

3. **Condition of the application : Coppice with standards is applicable only where there is a good local demand for firewood and other small produce as well as some demand for larger timber. Where climatic factors inhibit the use of simple coppice system.**

Example of application :

1. Dry deciduous forests (Type 5B/C_2) - This system is applied to dry deciduous forests of Kangra and Una on rotation of 30 years for coppice and 90 years for standards.
2. Sal forests part of sal forests, Champion and Seth's type 3C/C_2d, (i) and (ii) in Pilibhit (U.P.).

Rotation of Coppice 30 years.

And rotation of standards 60 years.

The sal forests of Una Division (H.P.)

where Rotation of Coppice 30 years

and rotation of standards 60 years.

The Choice of Silvicultural System

The choice of a system for adoption in any given locality involves a careful study of the conditions applying to that locality. The important factors which influence the choice of a system are (1) Conditions of regeneration (2) Conditions of growth, (3) Nature of terrain and soil (4) Protection against external dangers (5) Availability of skilled staff and labour (6) Nature of produce required (7) Economic considerations (8) Development of communications (8) Existence of rights (100 Aesthetic considerations etc.

(1) **Conditions of regeneration** : Since coppice systems are limited to those species which coppice successfully so the coppice system can not be adopted for species which do not coppice or coppice poorly. Such species in which natural regeneration by seed or seedling coppice is profuse every year, can be worked under clear-felling system followed by natural regeneration. If natural regeneration is not possible, and the species seeds profusely every year, then clear-felling followed by artificial regeneration may be the obvious choice. If natural regeneration cannot be obtained every year or large areas but can be obtained in a reasonably short period, one of the shelter-wood system with concentrated regeneration may be adopted. So choice of a particular system depends largely on condition of regeneration to be adopted.

(2) **Conditions of growth:** Light requirements, rate of growth, and other factors influence the choice of a system in relation to individual species or mixtures. The selection and irregular shelterwood systems favour shade-bearers against light demanders, strong light demanders are best adopted for clear-cutting system, the clear-strip system or some short period shelter-wood system, with very open seeding fellings.

(3) **Nature of terrain and soil** : The clear-felling system should be avoided on land subject to erosion, landslips or avalanches, in water catchment areas, and in places where the soil is liable to deterioration if exposed; the most suitable systems for such places are those which afford continuous protection to the soil like selection system, the irregular shelterwood system or two storied high forest system with a soil protective under cover. Similarly according to the condition of soil, suitable system should be adopted.

(4) **Protection against external damages:** In areas subject to occasional or seasonal storms, any silvicultural system in which heavy openings are involved, such as uniform system should not be applied, as the isolated trees will be exposed to greater danger of wind throw. Where snow damage is prevalent, uneven-aged systems, such as the selection or irregular shelterwood systems, are considered safer than even-aged systems. Damage by frost and drought is guarded against adopting some shelterwood system, or strip fellings proceeded from north to south. Thus resistance of forest crops to external dangers largely depends upon the species, the silvicultural system adopted may reduce the danger.

(5) **Nature of produce required:** If the object of management is production of fuel, small timber or even potes, any of the coppice systems may be applied with advantage for species which coppice successfully. If, the object is to produce large sized quality timber, one of the high forest systems will be the choice, depending on other factors.

(6) **Availability of skilled staff and labour:** Some system require great skill in respect of marking, felling and extraction of timber than other system. So, if skilled staff is available only that particular system can be adopted. For example in the mixed forests, application of shelterwood system requires great skill in regenerating different species in proper or desired proportion. Availability of labour in sufficient quantities also require for easy execution and timely completion of works.

(7) **Economic Considerations:** From the economic point of view concentration of work has a added advantage over diffusion of work, it cheapens the cost of felling and extraction, of cultural and tending operations, and of supervision generally. So from this point of view, the clear-felling and simple coppice systems are the most favourable and the selection system least favourable of systems. On the other hand High forest system with short regeneration periods are more advantageous than those of with long period, since they represent greater concentration of work. Consideration of early returns on the capital involved, also affects the choice of system.

(8) **Development of Communications :** Communication of Transport system also affects the choice of system. Forests with good road network, clean-felling or coppice or other even aged systems can be adopted. But the forest area with in accessible part with or less road-network system, selection system can be adopted.

(9) **Existence of rights :** If there are grazing rights of the local people like Forest villages and revenue villages, the areas cannot be closed for grazing for a long periods. The silvicultural system in which regeneration period is short should be applied. Similarly, where large quantities of small timber are required by the local population as a matter of right, coppices system is indicated.

(10) **Aesthetic Considerations:** From the aesthetic point of view those systems which maintain a continuous forest cover, and particularly the selection system, are preferably to those in which periodical clearings are made, such as clearfelling and simple coppice systems.

Conversion

Conversion is defined as a method of silvicultural procedure designed to change forest crops from one system or one (set of) species to another, e.g. coppice to high forest, selection forest to uniform, or hardwood to conifer (BCET). The concept of conversion involves a change in crop composition and/or the silvicultural system by which the crops are regenerated and replaced by new crops.

The species growing naturally in an area may not be the best in respect of usefulness, rate of growth, total yield per unit area etc. It has been seen that the growing stock of our forest is only 32m^3 per hectare where as, the world's average is about 110 m^3 per hectare. The mean annual increment (M.A.I.) is only 0.5 m^3 per hectare against world's average of 2m^3 per hectare. Therefore, to compensate as well as to meet the demand of increasing population it is necessary to raise fast growing valuable & well stocked plantation. All these species may be indigenous or may be exotic.

Furthermore, to meet the demand of various industry like, paper mill, veener mill, pulpwood mill etc. the composition of local forests should have to be changed and new species suitable for that locality should be introduced if the local forests do not have those species.

Each silvicultural system has some advantages and disadvantages in terms of higher yield execution of work, improvement of growing stock etc. In past, before scientific management of forests, most of our forests were irregular due to unregulated fellings. These are worked under selection aim improvement felling. But due to advancement of management these unregulated forests are managed under particular system depending upon the locality, silviculture of the sps. local demand of timber etc. In some cases, some silvicultural system may be failed, in such cases it is necessary to change that system, e.g. conversion of uniform system to Indian Irregular Shelterwood system of deodar forests in Chakrata (U.P.) and Ramnagar Division. Sometimes conversion of silvicultural system is also adopted for perfection of regeneration technique by natural and or artificial means: e.g. conversion to uniform system by clear felling followed by natural regeneration mostly by seedling coppice in Saranda Sal (Bihar), South Raipur Sal etc. where communication.are poorly developed and the market demand is low, the forests are usually worked under selective or, at best, selection cum-improvement felling. But where the development of communication and market demand is high systems based on concentrated regeneration are usually adopted.

When it is necessary to change from one silvicultural system to another silvicultural system of an forest area, only a part of the forest is taken up for the work (change) during the working plan period rather than whole area at a time. The rest of the forest area continues to be worked under the old system.

Pace or speed of conversion also plays an important role in respect of change of silvicultural system. If the conversion period is short, the conversion proceeds with a fast pace or speed, on the other hand, if it is long, the conversion is slow. Length of conversion period also depends on the following factors like extent of sacrifice of immature crops, proportion of the over mature growing stock with negative increment, the gap between the age of first converted crop and the exploitable age at the end of conversion period etc.

However, during conversion judicious decision should be taken considering all above factors for improvement of forest crops.

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Questions:

Answer the following questions:

1. What is silvicultural system? Briefly describe the method of classifying silvicultural system.
2. Compare the pattern of fellings among the uniform system, the selection system and the Indian irregular shelterwood system.
3. However clear felling is done in a forest area? What are the advantages and disadvantages of clear felling system.
4. Write short notes on the followings:
    a) The clear strip system and the alternate strip system.
    b) The group system.
    c) The coppice with standards system.
    d) Periodic Block.
    e) The choice of species in silvicultural system.
5. Define Conversion. Briefly describe the methods or technique of Conversion.

BOTANY AND FORESTRY

Module -26

Part - I, Paper - III (2nd Half)

Forest Surveying

Contents

CHAIN SURVEYING

Chain Surveying is the simplest kind of surveying. It deals with only linear measurements in the field. This is a convenient method for surveying small areas and open ground with simple details.

The principle of a chain survey is triangulation. It consists of the arrangement of framework of triangles by dividing the area to be surveyed since triangle is the only figure which is determinate in size and shape if the lenghts of the sides are known. The framework of triangle should be equilateral as neatly as possible.

Some Common Terms Used in Chain Survey

(a) **Well conditioned Triangle :** If the triangle contains no angle smaller than 30^0 and no angle greater than 120^0.

(b) **Ill conditioned Triangle :** Here angles less than 30^0 and greater than 120^0. This type of triangulation should be avoided. If, however they are unavoidable, care should be taken in chaining and plotting.

(c) **Survey stations:** A survey stations is a point where main, base of any other chain or tie line commences or terminates. The stations are of two kinds : viz. (i) main stations (b) subsidiary or tie stations: Main stations are the principle corner of the main lines which command the boundaries of the survey. Subsidieary or tie stations are the points selected on the main survey lines where it is necessary to run auxillary lines to locate the interior detail such as fences, hedges, buildings etc. when they are distast form the main lines.

Selection of stations:

(i) Main stations should be intervisible.

(ii) All triangle should be well conditioned.

(iii) Survery lines should be as few as possible.

(iv) The main principle of surveying viz working from the whole to the part and not from the part to the whole should be strictly observed.

(v) If possible, a long line should be run roughly through the centre and the whole length of the area.

(vi) Each triangle should be provided with at least one check line, "Tie lines" should be run to locate the detail.

(vii) Survery lines should be so arranged as to avoid obstacles to ranging and chaining.

(d) **Station lines :** These ar lines joining different station points. They may be main lines or subsidiary or tie lines if then lines join main station or if there join subsidiary or tie station.

(e) **Base line :** It is the longest and the most important chain line. It usually runs through the middle of the area to be surveyed. It should be laid off on as level ground as possible through the centre and the length of the area. It should be correctly measured horizontally. If convenient two base lines in the form of the letter 'X' should be laid out. Base line avoids accumulations or errors in the system of triangle built thereon.

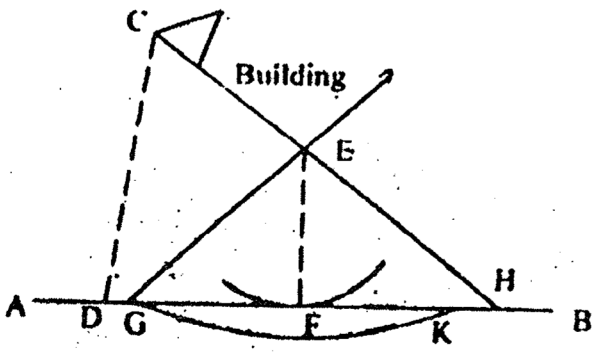
(f) **Checkline or Proofline :** It is a line joining the apex of a triangle to some fixed point on the side opposite, or a line joining some fixed points on any two sides of a triangle. A check line or proof line is required for checking the accuracy of plotting or framework.

(g) **Tie line:** It is a line joining some fixed points termed as tie stations on the main survey lines. Tie line checks the accuracy of the frame work and also enables the survey or to locate the interior details which are far away from the main chain lines.

(h) **Offsets :** These are the lateral measurements from the chain line taken to pbjects such as fences, boundaries, building, roads, nallas etc. to the right or left of the chain lines. These are required to fix the details of the survey. Offsets may be of the two types -

i) Perpendicular, Rectangular offsets

ii) Oblique of tie offsets.



CD & EF = Perpendicular offset

AB = chain line

EG & EH = oblique offset

EF = Swinging offset

(iii) **Swinging offset :** Taken by swinging the tape in an are along the chain line.

Length of offsets : Offsets should be as short as possible and usually 15 to 20 mts in length. But longer offsets upto 40-50 mt may be taken in case of boundaries, which are nearly parallel to the chain line.

No. of Offsets: The generagl rule for taking offsets are taken as many offsets as are necessary to define the outline of the object clearly and accurately. There are some guidelines provided for offsetting various types of objects.

(i) If the object is round - offsets are to the centre and its radius measured.

(ii) If the object is hexagonal or octagonal one of its sides near the chain line should be located by offsets and its length measured.

(iii) If the boundary is straight line like wall, road, canal, railway line, an offset to its each end is sufficient. But if long, a few additional offsets may be taken.

(iv) If object irregular - offsets are taken at each bend of change of direction.

(v) If object is curved foot path or road etc. offsets are taken to the beginning, middle and end of the curve and to the points in between.

(vi) When an object such as fence, hedge or a road etc. Crosses a chain line, the point of interection is noted. Offsets should be taken to the points in it on either side of the point of intersection to determine its direction

(vii) In case of locating building, the corners of buildings must be fixed very carefully and the right angle must be accurately set out. Offsets are taken to the corners of the buildings only, night as well as check lie, and the dimenstions of the building measured and recorded.

Instrument for Taking Perpendicular Offsets :

The following instruments are used for taking perpendicular offsets :

1. Cross staff: These are of the following points.

   (i) Wooden cross staff.

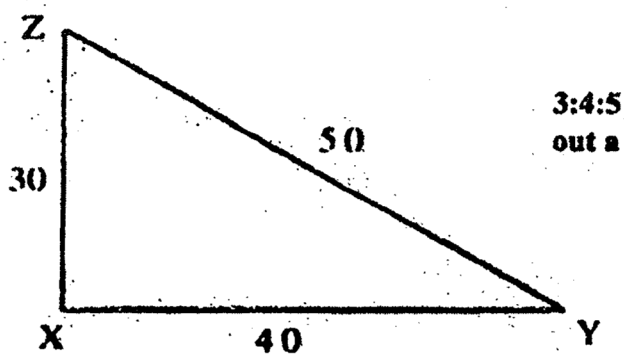
   (ii) Open brass cross staff.

   (iii) French cross staff,

2. Optical square :

3. Chain or a Tape :

Example : (a) 3:4:5 method : Let points X and Y are fixed 40 units distance apart with X as centre and radius of 30 units draw an are; with Y as centre and radius of 50 units draw another arc. Mark point of intersection Z; ZX is perpendicular to XY, because $30^{u}+40^{u}=50^{u}$. *This is known as 3:4:5 method of lying a right angle.* This can also be done by 5:12:13 method.



3:4:5 method of setting out a right angle

Execution of Chain Survey - Field Work :

Equipments : (i) A chain (usually 20 mt) and 10 arrows (ii) a 20 mt, metallic tape, (iii) ranging rods (iv) offset rod. (v) Optical square, or Cross staff (vi) a plumb bob (vii) Field book, Pencil (viii) Pegs et.

A chain survey may be executed in the following steps:

(1) **Preliminary Re-Cotinassiance :**

Before surveying, one should go over the entire area properly and thoroughly for deciding the arrangement of field work. Study carefully all the details such as boundaries, roads, fenes, culverts, gates etc. Then select stations and determine their visibiloits. Boundary lines are paced to get an idea of their length and extent of the area for deciding the scale of drawing. A neat sketch also called key plan is drawn on the first page the field book (Not to the scale). Stations are marked by capital letters and survey lines by usually consecutive numbers each placed in a circle.

(2) **Marking stations:**

After reconnessiance each station is marked on the ground. Wooden pegs may be used in cases on soft ground. Stations are udually distinguished by the letter A, B, C, D etc. In case of a grass land, the turf around the peg should be cleaned. Nails or spikes are used in case of a hard ground.

(3) **Chaining and Offsetting :**

Chanining is usually done alter preparing the frame-work and dividing the area into suitable triangles. Chaining operation starts normally from the base line and them in a regular clockwise or anti clockwise direction. All the relevant details which are located within easy reach from the chain line, such as corners of building trees, boundaries, hedges, stream banks etc. are fixed by offsetting and recorded in the field note book. This process is continued till the end of the line is reached and all other chain line are similoarly dealt with.

(4) **Field book recording:**

Reading taken in the ground are recorded in the field note book. Field note book is a special kind of note book opening length wise. The first entry in the field book on the first page will be an index to contents. On the next page a sketch plan is drawn. All the distances along the chain line are estered in the central column and offsetts written oppposite them on the right or left of the column as they may on their position. Entry in the field book should be in pencil in the field and later inked. Each chain line should short on a new page, though a survey line may extend to two or more page. Offsets should be recorded in metres and decimals. The recorder should face the direction of chain line and note down the measurements as soon as they are called out.

(5) **Plotting :**

Plotting is done on a drawing sheet after selecting a proper scale of drawing on the drawing sheet. After plotting inking an dcolouring is done. As far as possible, north of the plan should be towards the top conventional siges or symbols are used to in dicase various features should be given on the left or right hand bottom of the drawing.

Conventional Signs and Symptomps (Some examples)

Feature	Symbol
Foot path	
Briddle path	
Road	
Gate	
Bridge or Culvert	
Chiline & Sun stn.....	
Forest	
Building	

During Plotting, attentions are also given for Border Title, point, lettering, Colouring, and Offset plotting on the drawing sheet.

OBSTACLES IN CHAINING :

Various obstacles or obstructions such as woods hills, ponds, rivers, building etc. are usually met within chaining. Special methods are applied to overcome there obstacles for continued chaining to overcome there obstacles for continued chaining in a straihgt line. These are as follows.

(1) Chaining Free, Vision obstructed. Example rising ground or an intervening hill. Wooded fields with trees or brush wood.

There are two cases to be considered.

(i) Both points may be visible from intermediate points on the line.

(ii) Both points may not be visiable from any intermediate point.

Case I : In this case the difficulty may be got over by reciprocal ranging.

Case II : In such cases *Rasdom line method is* usually followed:

Let AB is a line which is to be ranged and chained. From point A run a straight line AB -rndomly, in a direction as near to that of B and station B is visible from B^{1}

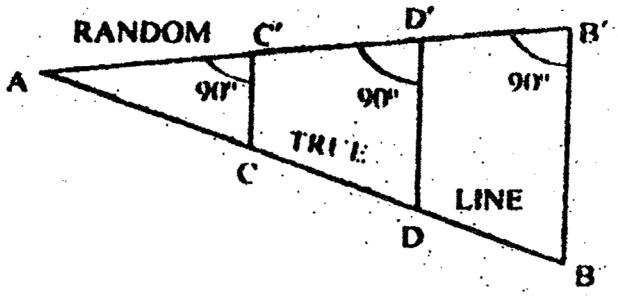
Fix station $B^{/}$ so that $BB^{/}$ is perpendicular to $AB^{/}$. Measure $BB^{/}$.

Then $(AB)^{2} = (AB^{/})^{2} + (BB^{/})^{2}$

or $AB = \sqrt{(AB')^{2} \times (BB')^{2}}$

If any other length AC_{1} is measured along AB_{1}, a point C is located on the line AB by measuring the perpendicular distance.

or $C'C = \frac{AC'}{AB'} \times B'B$. In this way a sufficient no. of points can be located. The line is then cleared and the distance measured.



Random line method

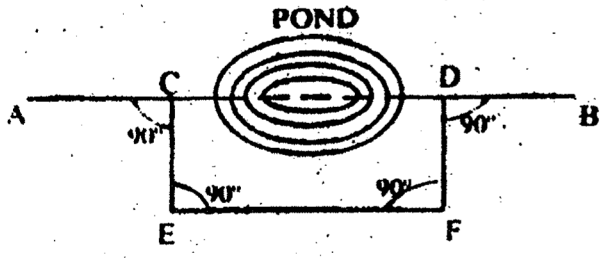
(2) **Chaining obstructed but vision free:**

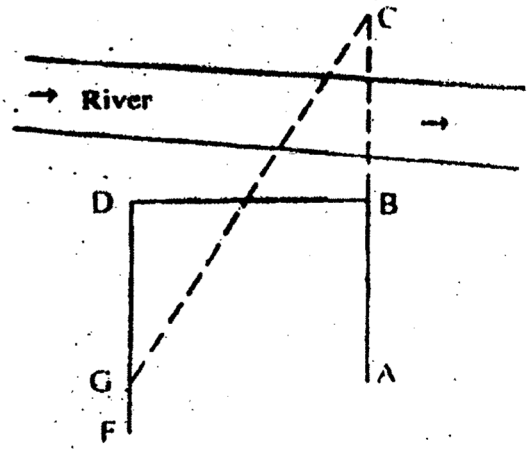
Example : river, canal, deep stream etc. Pond there are several methods. but simple one is give

Let AB is the chain line obstructed by a river. C is a point on the other side of the river ranged is line with AB. It is required to measure the gap BC and continue chain line AB across the river.

Set out a perpendicular BD at B on AB and fix its mid point F. Set out another perpendicular DF on BD at D. Fix rod at E. An assistant with another ranging rod in hand, moves along the line DF and fiues a rod at G so that points G, E and C are ranged in a line.

Tringles DE, CG and BEC being congruent BC = DG.

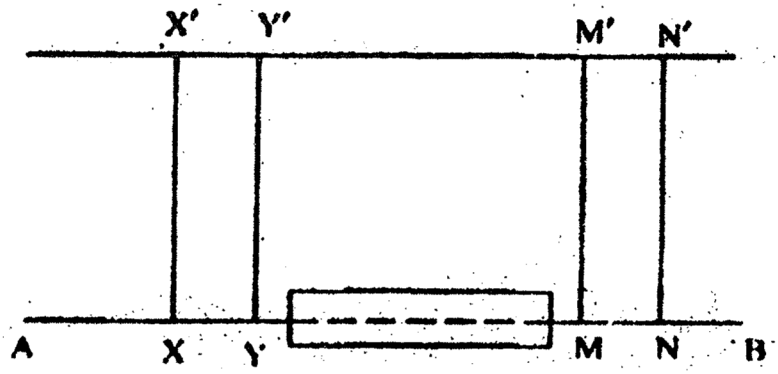




(3) Chaining and vision both obstructed:

Example " Building.

Select point X & Y on the chain line AB. At X and Y erect perpendicular XX^{1} and YY^{1} of equal length. Check the diagonals XY' & YX' which should be equal and also $X'Y'$ which should be equal to XY. Extend the line $X'Y'$ pass the obstacte and select two points M^{1} & N^{1} on it. At M' and N' set out perpendicular $M'M$ and $N'N$ equal in length ot XX'. The points M & N are obviously on the chain line AB and $YM=Y'M'$



Care should be taken in setting out the perpendiculars very accurately and to see the their lengths are exactly equal.

CHAIN AND PRISMATIC COMPASS SURVEY

Chain Sruveying is usually employed when an area is small and compact, it can be easily surveyed. But when the area to be surveyed is extensive, terrain is difficult or where it is in the form of a very long strip in such areas chain is used with a prismatic compass for the chain and compass survey. In compass survey, chainage of the survery lines and recording will be necessary as in chain survey, but the direction of the survey lines is fixed from the data in any of the following three ways.

(a) by measuring the foward and backward magnetic bearings at each corner.

(b) By measuring the interior angles at each corner.

(c) By measuring the exterior angles at each corner.

Here the alignment of the survey line is found by fixing the position of each survey station with respect to that of the previous station. This process is known as traversing. Traverse may be of the following kinds :

(i) Closed Traverse : It is said to be closed when a complete circuit is made.

(ii) Open traverse : It is said to be open when it does not form a closed polygon.

Methods of Travfersing : There are four methods of traversing.

(a) Traversing by chain angles.

(b) Traversing by chain and optical square.

(c) Traversing by chain and theodolite.

(d) Traversing by chain and prismatic compass.

Checking the accuracy of a closed Traverse :

A. Check on angular Measurements:

(i) Sum of interior angles of a traverse polygon should be (2n - 4) right angles or 180 (n-2) degrees.

(ii) Sum of measured exterior angles should be equal to (2n+4) right angles or 180(n+2) degrees.

(iii) In case of traversing by direct by direct observation of bearings, the accuracy can be checked by the comparing the F,B & B, B of each line of each line of the traverse.

B. Check on linear Measurements :

In a closed traverse, the sum of Northing should equal the sum of Southings and sum of Easting should be equal to Westing.

Closing error and adjustment of closing Error :

Closing error arises due to error in chaining and ro anguar measurements in the field-the last station measured to do not coincide with the starting station of a closed traverse. This error is adjusted by the following way.

(i) Mathematical adjustment.

(a) Bowditch's Rule.

(b) Transit Rule.

If closing error is small i.e. 1 in 100 for accurate work and upto 1 in 200 for ordinary survey-it may be eliminated by slight modification of the plotted traverse by graphical application of Bowditch's Rule. If

the error is large measurements should be remeasured.

Slope and application of Prismatic Campass Survey:

(i) For surveying in hilly and broken areas where chain survey is tedious.

(ii) Used in areas comprising of a large open tract with few isolated details and under conditions where great accuracy is not required.

(iii) Not suitable for magnetic areas.

(iv) For linear survey like Road, canal, railway track etc. Compass and chain survey is quicker.

(v) Prismatic compass is usufull for filling details in a survey.

Practical Utility:

(i) Locating one's position on a plan or map.

(ii) Locating the position of an inaccesible objects difficult to chain.

(iii) Ranging out a straight line between two points in a forest.

(iv) Laying out a forest Coupe.

(v) Determining the width of a winding stream.

(vi) Checking of forest boundaries.

Measurements of angles and Bearings:

Bearings: The bearing of a line is the horizontal angle with the line makes with some reference directioin or meridian. The reference direction employed in surveying may be (i) a true meridian (ii) a magentic meridian (iii) an arbitrary a assumed meridian.

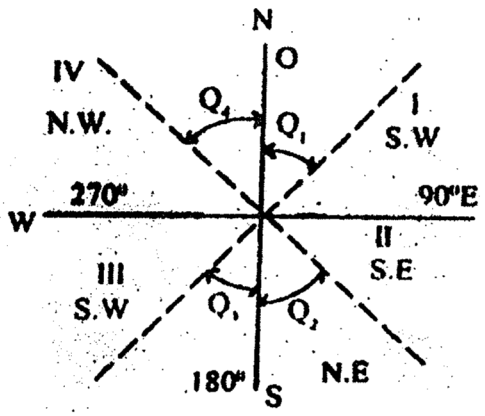
Designation of Bearing : There are two systems of notation usualiy used to express bearings :

(a) **Whole circle system (W-L-B) :** In this system the bearing of a line is always measured *clock-wise* from the north point of the reference meridian towards the line right round the circle. The angle thus measured is called the whole circle clearing. It may have any value between 0^{0} and 360^{0}.

(b) **Quadrantal system :** In this system the bearing of a line is measured clockwise or anticlockwise from the north or the south point, whichever is nearer. The angle so measured is called the Quadrantal bearing (Q.B.) or Reduced Bearing (R.B.). Bumerical value of Q.B. cannot be more than 90^{0}.

The method of obtaining R.B. from W.C.B. is tabulated below:

	W.C.B. lies between	Reduced Bearing	Quadrant
I.	0^0 and 90^0	W.C.B.	N.E.
II.	90^0 and 180^0	180-W.C.B.	S.E.
III.	180^0 and 270^0	W.C.B. - 180^0	S.W.
IV.	270^0 and 360^0	360^0 - W.C.B.	N.W.



Quardrantal Bearings

Fore and Back Bearing : The bearing of a line in the direction of the progress of survey is called the Fore or Forward bearing (F.B.) while its bearing in the opposite direction is known as the back or reverse bearing. (B.B.)

Back Bearing = Forebearing $\pm 180^0$ plus sign is used when F.B. is less than 180^0 and minus sign is used when F.B. is more than 180^0.

Calculation of Angles from bearings: Following rules may be applied to find the included (interior) angle between any two lines whose bearings are known.

I. Given the whole circle Bearings of lines :

II. When Reduced Bearings of the lines are given.

Local attraction: Magnetic needle of compass sometimes render unreliable readings due to the presence of some disturbing influence of the magnetic objects like keys, penknife, iron buttom, water chain, iron fence, lamp post etc. in the vicinity of the needle. Which is known as local attraction.

Dip of the needle : It is the inclination of the needle with the horizontal plane.

Mathematical Problems :

Example I. Convert the following W.C. Bs to R.B.

(i) $45^0 30'$ (ii) $68^0 32'$ (iii) $334^0 52'$ using the rule for R.B. we get.

Solution : (i) R.B. = (W.C.B.) N.E. = $45^0 30'$ N.E.

(ii) R.B. = (W.C.B.) N.E. = $68^0 32'$ N.E.

(iii) W.C.B. = $334^0 52'$

Q.B. = 360^0 - W.C.B. = $360^0 - 334^0\ 52' = 25^0 8'$ N.W.

Example II. Convert the following reduced bearing to W.C.B.

(i) N 30^0E (ii) N 30^0W

Solution : (i) W.C.B. = R.B. = 30^0

(ii) W.C.B. = 360^0 - R.B. = $360^0 - 30^0 = 33^0$

Example III: The following are the observed fore bearings of the lines :

AB, $38^0 14'$, BC, $142^0 18'$, CD $208^0 37'$ and DE $318^0 26'$

Find their back bearings.

We know that B.B. = FB $\pm$ 180^0

So using this rule we get the following

F.B. of AB = $38^0 14'$

$\therefore$ B.B. of AB = $38^0 14' + 180^0 = 218^0 14'$

FB of BC = $142^0 18'$

B.B. of BC = $142^0 18' + 180^0 = 322^0 18'$

FB of CD = $208^0 37'$

B.B. of CD = $208^0 37' - 180^0 = 28^0 37'$

FB of DE = $318^0 26'$

$\therefore$ B.B. of DE = $318^0 26' - 18^1 = 138^0 26'$

Example IV. (a) Following table shows the record of an unclosed campass traverse. State if there is local attraction at the stations, if so compute the correct bearings of the lines.

Line	F.B.	B.B.
AB	$89^{0}30'$	$271^{0}30$
BC	$110^{0}20'$	$290^{0}30'$
CD	$188^{0}30'$	$8^{0}15'$
DE	$91^{0}15'$	$273^{0}30'$
EF	$95^{0}15'$	$275^{0}15'$

(b) If the declination is $2^{0}30'$E, find true fore bearing of all the lines.

Solution:

(i) First find out the station which is uneffected by observing the F.B. and B.B. Where F.B. and B.B. establish the proper relation i.e. abide the rule, B.B. = F.B. $\pm 180^{0}$ that point is unaffected.

(ii). Here station E. and F are unaffected. Because

BB of EF = $275^{0}15'$

F.B. of EF = $95^{0}15'$

if we apply the rule i.e. B.B. = F.B. $\pm 180^{0}$ then we get,

$275^{0}15'=95^{0}15'+180^{0}=275^{0}15'$

So, the point E and F are unaffected. From those point we can correct the other Bearings of the line as follows.

B.B. of DE is 273^{0} is correct (Because E is unaffected). its F.B. should be $273^{0}30'-180^{0}$ = $93^{0}30'$ instead of $91^{0}15'$. hence station D is offered and correction is plus $2^{0}15'$ ($93^{0}30' - 91^{0}15'$) = $2^{0}15'$ is to be applied to all observations at D.

Now B.B. of CD should be $8^{0}15' + 2^{0}15' = 10^{0}30'$ and FB $190^{0}30'$ instead of $188^{0}30'$. So station C is affected.

A correction of $+2^{0}0$ is necessary for all bearings observed at C. So. B.B. of BC should be $292^{0}30$ ($290^{0}30 + 2^{0}0 = 292^{0}30$) and F.B. should be $112^{0}30'$ instead of $110^{0}20$.

So station B is also affected and a correction of plus $2^{0}10'$ is to be applied to all bearings observed at B. Now B.B. of AB should be $271^{0}30' + 2^{0}10' = 273^{0}40'$ and its FB $93^{0}40'$ ($89^{0}30' + 2^{0}10'$) instead of $89^{0}30'$. Hence A is also affected and a correction of plus $4^{0}10'$ is required in all bearings taken at A.

The result may be tabulated as follows :

	Observed Bearings			Corrected Bearings		
Line	FB	BB	Correction	FB	BB	Ramarks
AB	$89^{0}30$	$271^{0}30$	$+4^{0}10'$ at A $+2^{0}10'$ at B	$93^{0}40'$	$273^{0}40'$	Station A & B affected
BC	$110^{0}20'$	$290^{0}30^{0}$	$+2^{0}10'$ at B $+2^{0}0'$ at C	$112^{0}30'$	$292^{0}30'$	Station B & C affected.
CD	$188^{0}30'$	$8^{0}15'$	$+2^{0}0'$ at C $+2^{0}15'$ at D	$190^{0}30'$	$10^{0}30'$	Station C & D affected
DE	$91^{0}15'$	$273^{0}30'$	$+2^{0}15'$ at D	$93^{0}30'$	$273^{0}30'$	Station D affected.
EF	$95^{0}15'$	$275^{0}15'$	Nil	$95^{0}15'$	$275^{0}15'$	Station E & F unaffected

(b) Here declination is $2^{0}30'$E. True bearing should be $96^{0}10'$, $115^{0}0'$, $193^{0}0'$, $96^{0}0'$ and $97^{0}45'$ by adding $2^{0}3-'$ to the corrected bearings of all the lines :

PLANE - TABLE SURVEYING

Plane table surveying is a graphical method of surveying in which the field observations, measurements and plotting proceeds simultaneously in the field. This method is suited for filling in interior details of a closed traverse. It is also used for small scale mapping, topographic and engineering surveys, fie maps etc.

Plane Table and its accessories : The plane table consists of a drawing board mounted on a tripod and an alidade. A declinator (called trough campass). A spirit level, a plumbing form or U-frame and a water proof cover constitute the requisite accessories.

1. **Drawing board :** It is made of good, well seasoned wood. Sizes varies from 40cm x 30cm to 75cm x 60 cm and about 2.5cm thick. The Board is mounted on a portable tripod stand in such a manner that it can be levelled rotated about its vertical axis and also clamped in any position with a wing nut or butterfly nut.

2. **Alidade :** (Also called sight rule or sight vane) : It is a combined sight and straight edge ruler. It may be of wooden or metal ruler usually 40 to 60 cm long and about 5cm wide. it has two brass sight vanes one at each end; about 15 cms and perpendicular to the lerights or the rule. The sight vane is provided with a narrow slit running down the centre, whereas the orservation vane is open and carries a hair or fine thread. The line of sight between the vanes is parallel to the edges of teh alidade. One of the edges of teh alidade is levelled and is termed as the fiducial edge. Some alidades are filled with a tele-scopic sight.

3. **Declinator or Trough Compass :** It consist of a magnetic needle enclosed in a rectangular box. It is used for marking the magnetic meridian on paper and for orienting the table.

4. **Spirit level :** It is used for levelling the plane table.

5. **Plumbing fork or u-frame :** It is a U-shaped form made of a non-magnetic metal. It is used for centering the station point on the drawing sheet over the corresponding ground station. It is 25 to 40cm long provided with a plumb bob.

6. **Water proof Cover :** It is required to protect the sheet from rain during rainy weather conditions

PROCEDURE:

Like chain and compass survey preliminary reconnaissance of the area, selection of station, baseline etc. are important in case of plane table survey. The following steps are involved in Plane Table Surveying.

1. **Setting up of PT :** Set up at convenient height about waist height for easy execution of work. Legs of tripod stand should be firmly fixed in the ground.

2. **Centering :** The P-T should be placed in such a way over the station on the ground that the point plotted on the drawing sheet is exactly over the station it represent on the ground. This is usually done by U-Frame, or sometimes by dropping a pebble from the corresponding point below the table.

3. **Levelling the P-T :** Levelling is done with the help of a spirit level or by rolling a round pencil over the drawing board. Legs are adjusted as per requirement of the spirit level.

4. **Orientation:** The term orientation may be defined as "the operation of keeping the P-T at each of the successive stations parallel to the position which it occupied at the first stations". If not properly oriented al rays drawn at that station will be incorrect. Orientation is done by any of the following two methods.

   (a) Orientation by the magnetic needle (Dedinator)

   (b) Orientation by back sighting.

METHODS OF PLATE TABLE SURVEYING

There are four methods of plane table surveying

i) Rediation

ii) Intersection

iii) Traversing

iv) Resection.

1. Radiation Method (Methods of Angles and distance):

Radiation is a method of P-T. Survey, involving measurements along the rays. It is suitable for the survey of the small areas which can be commanded from a single station. Steps are as follows:

(i) Select an instrument station O so that all points to be located are visible from it.

(ii) Set up the table at M and after levelling is clamp the board.

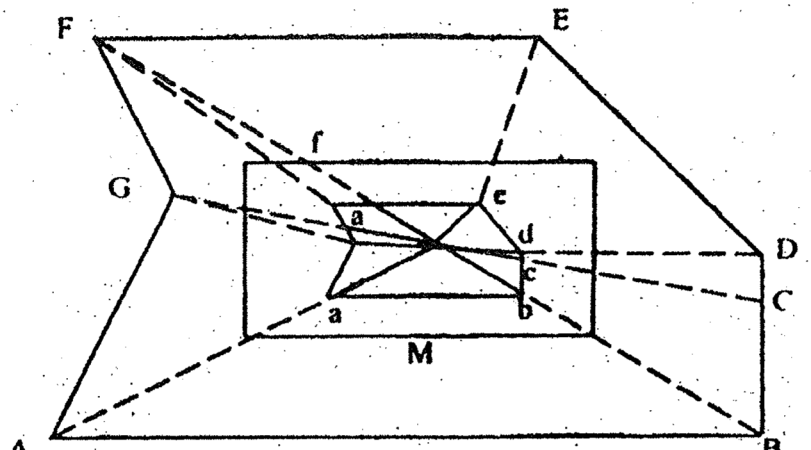
(iii) Select a point M on the sheet so that it is exactly over the station M on the ground by the use of U frame.

(iv) Mark the direction of the direction of the magnetic meridian with help of campass in the top corner of the sheet.

(v) Centering the alidade on M. sight the various points. A, B, C,D, E etc. draw rays along the fiduicial edge by pencil.

(vi) Measure the distance MA, MB, MC, MD etc. from M to the various points with the chain or tape and plot them to scale along the corresponding rays. Join the points a, b, c, d, e etc. to give the outline of the survey.

The field work can be checked by measuring the distances of AB, BC, CD etc. and compaming there with their plotted lengths ab, bc, cd, etc.



Radiation

Closing error :

If it is seen that the traverse has formed closed figure on the ground but he same does not close on the plan a closing error results. If the error is within permissible limit i.e. 1 in 500 in linear measurements on 15 minutes in every angular, the traverse may be adjusted/ closed by graphical method. If the error is in excess the field work should be repeated.

Advantages of plane Tabling :

(1) Suitable for preparing small scale mapl

(2) Most rapid method.

(3) Field book is not necessary.

(4) There is not possibility of omitting data or necessary measurements as the map is plotted in the field.

(5) Errors may be easily detected by check lines.

(6) Required comparatively less skill.

(7) Useful in magnetic areas.

(8) Contours and irregular objects may be represented accurately.

Disadvantages:

(1) It is not suitable for work in a wet climate.

(2) Not suitable for very accurate work.

(3) It is essentially a tropical instrument

(4) P.T. accessories are heavy and cumbersome to carry.

(5) The plan is liable to be damaged and disgigured in the field.

CONTOURS - CONTOURING - TOPOGRAPHICAL SURVEY

Tophographical survey may be defined as the delineation of the natural physical features of the earths surface, such as hills, valleys, ridges, rivers, lakes etc., i.e. physical relief on the earth's surface. It is important that relief is clearly and accurately represented in the map. Relief may be represented by Relief models, shading, Handers, Form lines, Spot Heights, Layer tints, Photo Relief maps or Contour lines.

1. **Contour - contourlines** : A Contourline or contours may be defined as representation of an imaginary line running along the surface of the ground at the same height above mean - see-level (M.S.L.) throughtout its length".

   Contour internal or vertical internal: The constant vertical distance between any two consecutive contour lines on a map is known as C.I. & V.I.

2. **Relief Model** : It is a representation of ground form in three dimenstions in miniature scales. Plane materials, wax or clay are used. These models are very expensive.

3. **Shading** : Here relief is represented in a plan shading is used to depict rays of light flooding teh physical features for an angle.

4. **Hauchures** : Hauchures represent relief more definitely but less legibly than shading. Hauchers comprise of rows of short. almost parallel lines whose thickness and spacing varies with relief.

5. **Form lines** : It is similar to contour lines. But there are not drawn to scale; and not in at regular intervals. It gives only quantitative and approximate information.

6. **Layer tints** : Here the elevation of different localities is shown by various shades of colour applying flat tints. Such a map is said to layered. For example, area may be divided into different elevation zones such a 0-200 mt. 200-400 mts.; 400-600 mt..... and each category gives a different colour of shade.

7. **Spot height :** This is a system of selecting a number of important points and their elevation written in figures near dots depicting their location.

8. **Photo relief :** Here relief is depicted by photographically reproducing a plaster of paris relief model of a particular area.

Topographical - Survey : Contouring over large areas is known as Topographical survey. Here considerable fiedl data such as elevation of different point, surface plan; surface relief, roads, forests etc. are needed.

Object of Topographical survey in forestry :-

i) To study the topographic features of the area.

ii) To determinate the gradients and carryout alignment of roads, extraction paths; inspection paths, contour trenches etc.

iii) Computation of earth-work for engineering etc.

iv) For layout of fine lines, irrigation channels, etc.

v) Preparation of stock maps, management maps etc. Uses of Topographic maps :

It is used for selection of suitable site., layout of roads, irrigation channels, nurseries, soil conservation works, various engineering projects, etc.

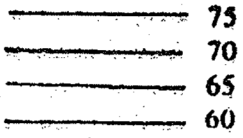
Contour Representaion of Important Relief Features

1. Triangulation point	:	It is point from where various triangles for survey work are laid out.
2. Plane surface	:	Contours - straight, parallel and quually spaced.
3. Depression or Hollow	:	Series of contours which close on themselves with lower contour in side.
4. Hill-top or a peak	:	Series of closed contours with higher value of contour inside for peak, Hill top.
5. Valleys and Spurs	:	Projection from the hill side running out of the main feature are spung. Depression in the hill side are called valley.
6. Vertical cliff	:	Here contour unite and merge to form one line.
7. Over hanging cliff	:	here contours interseck.

8. Ridge or crest : It is the line joining the points of higher elevation in their immediate neighbourhood.

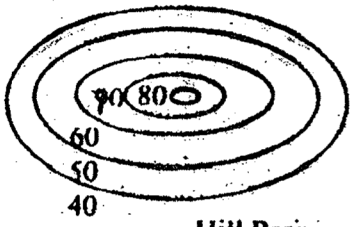
9. Saddle : A depression between two adjact hills, rounds or ridges or break or a dip in a ridge.

10. Plateau or Table land : Here separation between the two contour lines of equal heights is large.

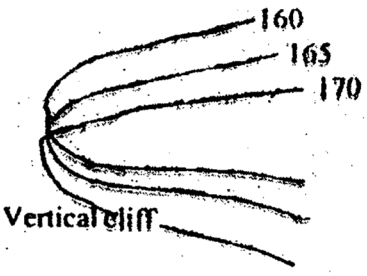


Plane surface

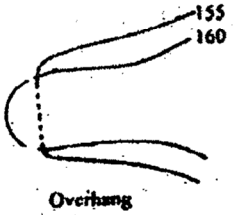
Depression



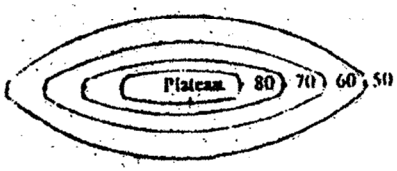
Hill Pear



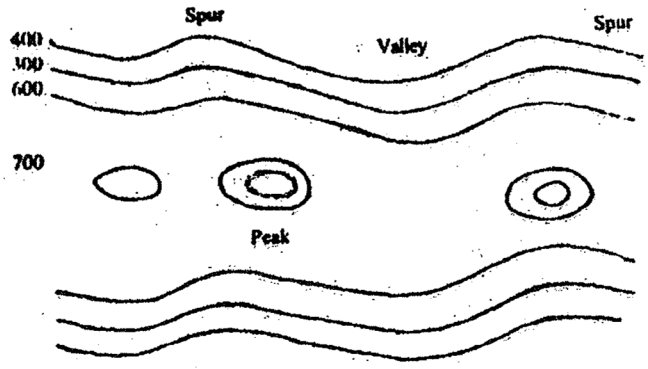
Vertical cliff



Overhang



Plateau



MAPS AND MAP READING

In forestry map reading is necessary for various purposes. An skilled an experienced map reader can get an idea from map reading reagarding the country or area by reading its terrain. undulations. ridges and valleys. hills and depression etc.

A map may be defined as

i) a reproduction of a portion of the earths surface.

ii) "a conventional delineation of the earth's surface of portion thereof on a flat sheet".

iii) "A reduced tacsimile of the features on earth's surface".

Main features of map :-

i) All objects represented on the map are in the same relative position as on ground.

ii) All angles between the lines drawn on the map are equal to the angles between the corresponding lines drawn on the ground.

iii) A map must contain certain conventional sisma or symbols. to indicate feature or object on the ground.

Map reading :

It is necessary to know the following pre-requisite for correct and through reading of a map. There are as following :

a) Scale of the map.

b) Conventional sign.

c) Orientation of the map. May be done by with compass or without compass.

d) Finding out one's position

On the map - i.e. by (i) with prismatic compass (ii) with chain or prismatic compass (iii) with plane table (iv) with Chain or Tape.

Different Types of map used in forestry :-

A. Management maps

i) Management maps - Working plan Maps 1/50000 scale.

ii) Stock maps - 1/15000 scale.

iii) Control maps - 1/15000 scale etc.

B. Administrative maps.

C. Miscellaneous.

COMPUTATION OF AREAS

One of the main objects of land surveying is to determine the area of the land surveyed. In forestry, surveyed are usually done for determinatioin of plantation area, nurseries area, felling coupes, boundary demarcation etc. purposes.

'Area' is meant the area of a tract of land as projected upon a horizontal plane.

Units used commonly in surveyed ar

i) Hectare - in rural lands.

ii) Square meter - in Urban lands.

General Method of Determining area :-

1) Computation of Areas by direct use of field notes - by surveying the area and calculation of area thereafter.

(a) By triangles - chain survey notes -

Area (Δ)= $\sqrt{s(s-a)(s-b)(s-c)}$ where a,b,c are lengths of the three sides of the triangle and s = semi perimeter of the triangle = 1/2 (a+b+c)

or Area = $^{1}/_{2}$ bh where b is the base and h is perpendicular distance.

or Area = $^{1}/_{2}$ ab sin c = $^{1}/_{2}$ bc sin A = $^{1}/_{2}$ ca sin B uniform coordinates.

(b) Area along Boundaries :

By the formula

$$\text{Area } (\Delta) = \frac{0_1 + 0_2}{2} x(x_2 - x_1)$$

Where 0_1 = the offset at chainage x_1 along the survey line

0_2 = the offset at chainage x_2 along the survey line

$\frac{O_1 + O_2}{2}$ = Mean offset.

The $x_2 - x_1$ = the distance between the offsets.

The areas of the irregular stips is calculated by this method.

2. Computation from plotted plans :-

A. By graphical Methods

B. By Mechanical Methods.

C. By Instrumental Method i.e. by planimeter.

A. **Graphical Method:**

a) Entire areas - by divisions into geometrical figures

i) By Division into Triangles.

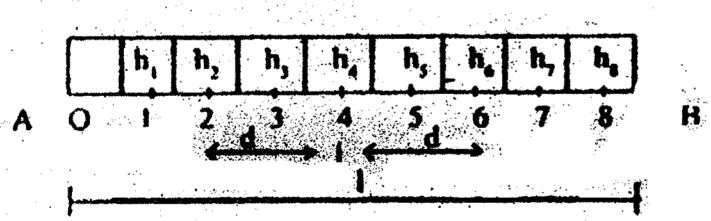
ii) By divisions into square.

iii) By divisions into strips.

b) By ordinates - Area entire or along Boundaries.

The areas enclosed between the adjacent survey lines and the curved boundaries are determined by ordinates. A base line is taken through the area and divided into a number of equal parts. The ordinates at each of the points of division are drawn and scaled. From these lengths and their common distance apart, the area may be calculated by

(i) The Mid ordinate rule



$$\text{Area } (\Delta) = \frac{h_1 + h_2 + h_3 + \ldots\ldots h_n}{n} \times l$$

or = $(h_1 + h_2 + h_3 + \ldots\ldots h_n)d$

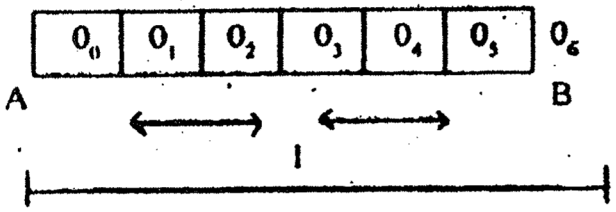
Where h_1 h_2 etc. = the ordinates at the mid points of each division.

l = the length of the base line.

n = the number of equal parts into which the base line is divided.

d = the common distance between the rodineates = l/n

(ii) the average ordinates rule



$$\text{Area } (\Delta) = \frac{(0_0 + 0_1 \times 0_2 + \ldots\ldots 0_n)l}{n+1}$$

in which $0, 0_1, 0_2$ etc. = te ordinates at each of the points of division.

l = the length of the base line.

n = the number of equal parts into which the base line is divided.

(iii) The Trapezoidal Rule : Here, in this method the area is divided into a series of traperzoids. The rule may be as follows :

"Multiply the common distance of the ordinates by the sum of half the first and last ordinates plus all the othes".

Area $(\Delta) = d\,[(0_0 + 0_n)/2 + 0_1 + 0_2 + 0_3 \ldots\ldots\ldots 0_n - I]$

(iv) Simpson's one third Rule or Parabolic Rule:

"To the sum of first and last ordinates, add twice the sum of remaining odd ordinates and four times the sum of all the even ordinates. Multiply the sum obtained by 1/3 of the common distance between ordinates and the result is the requires area".

Area $(\Delta) = (d/3)\,(0_0 + 40_1 + 20_2 + 40_3 + \ldots\ldots 20_{n-2} + 40_{n-2} + 40_{n-1} 0_n)$

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1. Forest Surveying - By Ram Prakash.
2. Suveying & Levelling - By Kanetkar & Kulkerni.
3. A Hand Book Forestry - By S.S. Negi.

Questionf for Student's Response Sheet

1. Write short notes on : (a) well conditioned triangle and ill-conditioned triangle, (b) check line, (c) Tie line (d) offset. (e) 3 : 4: 5 method. (f) obstaclesin chaining.

2. Define : (a) Whole Circle Bearings and Reduced Bearings.
(b) Dip of the needle.
(c) Geographical meridian, Magnetic meridian and Arbitrayr meridian.
(d) Local attraction.

3. (i) Following bearings were taken in running a compass traverse, Find out the stations affected by local attraction and the corrected Bearings.

Line	F.B.	B.B.
AB	$66^{\circ}15'$	$244^{\circ}0'$
BC	$129^{\circ}45'$	$313^{\circ}0'$
CD	$218^{\circ}30'$	$37^{\circ}30'$
DA	$306^{\circ}45'$	$126^{\circ}45'$

Find the corrected fore bearings and the true bearings of the lines, given that the magentic declination is $8^{\circ}40'E$.

(ii) The following bearings were observed in running a compass traverse.

Line	F.B.	B.B.
AB	344°	164°
BC	88°	$269^{\circ}30'$
CD	$173^{\circ}30'$	$350^{\circ}30'$
DA	$263^{\circ}30'$	85°

(iii) The following are the observed F.B. of the lines:

AB	=	$38^{\circ}14'$
BC	=	$142^{\circ}18'$
CD	=	$208^{\circ}37'$
DE	=	$318^{\circ}26'$

Find their back Bearing.

4. Define plane tabling. How plane table is oriented during surveying? Briefly describe the Radiation method of plane table survey. What are the practical application of plane table surveying?

5. Define : (i) Contours (ii) Hauchers (iii) C.F. & V.I. (iv) Vertical cliff (v) Simpson's one third.

BOTANY AND FORESTRY
Module -27,28
Part - I, Paper - III (2nd Half)

Contents

FOREST MENSURATION

DEFINITION

Mensuratioin is derived from the lating work 'Mensura' meaning 'Measure'. It is, therefore, concerned with the determinatiion of lengths, areas and volumes.

Forestry is a management activity involving land, and the plants and animals growing on it.

Forest mensuration is that branch of forestry which deals with the determination of dimensions (e.g. diameter, height, volume etc.) forms, volume, age and increment of single trees, stands ow whole woods, either standing.

or after felling.

OBJECT

1. Basis for Sale

Forest mensuration forms the basis of every tansaction involving sale of forest or their products. Before any sale, it is required to prepare estimates of the quantity of timber or other produce contained in various sale lots and the value which each lot is likely to fetch.

2. Basis for Management

It is desirable that forests should meet the demand of timber and other forest produce in perpetuity. For this purpose, it requires to have a knowledge of the quantity of timber standing in forests and the increment it is putting on every year or in a period of years.

3. Measurement for Research

It is necessary to find out which treatment and method of management is suitable to maximise production. It involves laying out of sample plots and comparing the results of their periodic measurements.

4. Measurement for Planning

Forest Mensuration supplies basic statistical data to plan for the future and serves as a yard stick to check the Viability of projects.

MEASUREMENT OF DIAMETER AND GIRTH

Linear Measurement is a fundamental measurement for any mensurational work. In forestry linear measurement is required in the measurement of boundary of a tract of land and various linear dimensions of a tree, such as, diameter and girth, height, crown width, length of the commercial bole, length of bole containing standard timber etc.

Place of Measurement

The place at which diameter or girth is measured varies with circumstances. In the case of logs, diameters are measured at thick and thin ends or at the middle of the logs or sometimes at all the three places. In case of standing trees the diameters or girths can be measured at several places, some within the easy reach of man standing on ground and others beyond it. The place has since been standardized in favour of breast height. *Breast height* (B.H. or b.h.) is defined as almost universally adopted standard height for measuring girth, diameters and basal area of standing trees. In India, it is taken as 1.37m (4 ft. 6 in) above ground level.

STANDING RULES GOVERNING BREAST HEIGHT MEASUREMENTS.

A. For Statistical work in sample plots:

(1) Breast height should be marked by means of a measuring stick on standing trees at 1.37 m above the ground level.

(2) The breast height point should be marked be marked by intersecting vertical and horizontal lines 12 cm long, pointed with white point. this is referred to as cross mark.

(3) On slopping ground, the diameter at breast height should be measured on the uphill side, after removing any dead leaves or meedles lodged there.

(4) In case the tree is leaving, diameter at breast height (dbh) is measured along the tree stem and not vertically, in the side of the lean for trees growing on flat ground on sloping ground.

(5) The dbh should not be measured at 1.37 m if the stem is abnormal at the level. Breast height mark should be shifted up or down as little as possible to a more normal position of the stem and then diameter measured.

(6) When the tree is forked above the breast height, it is counted as one tree, but when it is forked below breast-height, each fork should be treated as though is were a separate tree. If orking under the

breast - height poing abnormal, the foregoing rule should be applied and the tree counted as one or two depending on the place measurement.

(7) When buttress formation is the characteristic of the species and is known or is likely to extend upwords with the development of the tree the breast height should be taken at the lowest point above which the abnormal formation is not likely to extend.

(8) The height of the cross - mark above ground level should always be recorded for each tree measured.

(9) Moss, Creepers, lickens and loose bark found on the tree must be removed before measuring the diameter or girth over bark.

(10) Diameter measurement should be recorded in centimeters and to the nearest multiple of two miltimeters girth should be measured in meters and to the nearest centimeters. Diameter or girth of each tree measured is recorded separately.

B. FOR RONTINE FOREST WORKS.

Some of the above rules are either not followed or modified as follows :

Rule No. (1) : Measuring stick is not used to mark that point.

Rule No. (2) :- Not followed.

Rule No. (7) :- The diameter or girth is measured just above the buttress formation upto that year without making allowance for its future development upwards.

Rule No. (8) : Not followed.

Rule No. (10) :- Instead of recording diameter or girth separately for each trees and to the limits mentioned in that rule, the trees are grouped in diameter or girth classes.

INSTRUMENTS USED IN MEASUREMENT

The instruments used in measurement for diameter or girth at breast-height in case of standing trees and for logs of filled trees are :

(1) Wooden scale

(2) Callipers

(3) Tape

The above instruments are commonly used in Indai. However, there are several other instruments like Biltmore stick, Sector fork, penta prism etc. but they are not in use in India. However, the selection of instrument depends upon

-- Whether the tree is standing or felled.

-- if felled, the condition in which the logs are lying.

-- the digree of accuracy required.

(1) Wooden Scale

It is a flat wooden piece marked in centimeters and millimeters. It is available in two size viz. 30 cm and 60 cm. the 30 cm wooden scale is 3 cm wide while the 60 cm wooden scale is about 1.5 cm wide.

It is conviniently used in measuring diameter of stamp or end sections of logs. It is also used in stump and stem analysis.

Rules for measuring diameter

(a) The diameter is to be measured along the passing through the path. However, two diameters one along major axis and the other at right angles to it are to be taken if the stumps or logs are ecentric.

(b) To avoid incorrect measurement, the measurement may be taken from first centimetre and not from the Zero mark, because the end of scale often opts worn off.

(c) The scale should be ploaced on edge.

(d) To avoid the eror of parallax, the eye should be just above the mark, while reading measurement.

(2) Callipers

Callipers consist of a graduated rule and two arms. One arm is fixed at right angles to one end or rule so that its inner edge lies on the starting point of the graduated scale. The other arm moves along the rule parallel to the fixed arm. Each arm should be at least half the length of rule. Callipers usually do not exceed 120 cm in length. Callipers are marked in centimeters and show diameter classes painted in different colours for routine forest works, while callipers are marked in centimeters and millimeters for research or sample pbt work.

Callipers are generally made of wood. But metal callipers made of attuminium alloys are preferred, as they are not heavier than wooden callipers and also are easier to keep cllean and in adjustment.

Callipers give diameters, but they can also be graduated to give girth of a tree or log directly.

METHOD OF USE

The handles of the two arms of callipers are held in two hands. The movable arm is pushed inwards too have enough space to accomodate the tree between them without touching when the tree touches the graduated rules, the movable arm is pushed in position to ensure that there is no gap in between the arms and the tree and the diameter is read off on the rule.

PRECAUTIONS OBSERVED IN MEASURING DIAMETER

(1) The Callipers should be placed on the Tree with movable arms will opened and must not be foreced on the tree to avoid damage to the arms.

(2) The reading should be taken before the calliper is removed from the tree.

(3) If the cross section ofthe stem is more or less elliptical, it is necessary any to measure two diameters which corresspond to the major and minor areas of the ellipse. Diameter is then understood to be the average of the two measurements.

(4) In case of trees with elliptical cross-section, the two diameters must be measured in proper orientation. i.e. they must be measured along the real major and minor areas. For this purpose, the major axis should be correctly located first and measured and the second diameter measured at right angles to it.

(5) Callipers mut be placed at right angles to the axis of the tree.

(6) The two arms of the clipers must be in contact with thre tree and then movable arm should be at right angles to the scale arm.

(7) As the two arms of the callipers must be in contact with the tree, so also the scale arm must also tourch it.

ADVANTAGES OF CALLIPERS

- Diameters can be read directly in centemeters and millimeters. This making the instruments appliable for precise scientific work.
- The points of arms touching the tree are always in sight and irregularities it any, can be avoided.
- By firmly pressing the arms against the tree bole, the loose swollen bark is crushed out and irregularity from this source is avoided.
- It is adoptable for used by unskilled labour.

The errors are both positive and negative and therefore the chances are that they may neutralize to give more accurate results than the tape which give only positive erros.

DISADVANTAGES OF CALLIPERS

- Not accurate when not in adjustment.
- Callipers sufficient in size to measure large trees are very awkward to carry and handle.
- Two measurments have to be taken on every tree to get the correct diameter. In steep hilly tenain, measurement of the second diameter in correct orientation is often very difficult.
- Movable arms often sticks when the scale is wet or dirty, thus wasting a lot of time.

3. Tape

It is a band of cloth, reinforced cloth. plastic or steel about 1.5 cm wide and of varying length and is used to measure girth of trees and logs. The coth tappes are made of cloth, though they may be painted with some paint on both sides to give a better look and to protect them from moisture, the better quanlity of cloth tapes are usually reinforced inside by metal wire and are thus. called metallic tapes. Steel tapes are used for precise work and are mostly used in forests for measurements in sample or research plots. The tree measureing tapes are generally 3m or even upto 50m long. It is usually graduated on one side in centimeters and millimeters, but sometimes graduated on both side to give measurements in metric systems on one side and those in British system on the other.

PRECAUTIONS IN USING TAPE

- The taps should not be old and therefore stretched or possibly with the end broken off.
- It must be flat against the tree and not in twisted manner.
- It must lie in plane perpendicular to the axis of the tree. If the tape does not lie in a plane perpendicular to the axis of the tree, the girth and consequently the basal area is over estimated.
- After swinging the loose end of the tape round the tree, care should be taken to see that no climber or branch of nearly shrub has initiated the girth measurement. If so, they should be cut out before swinging the loose end of the tape round the tree.
- After the tape has been sung round the end of the tape in the right hand of the measurer should be brought under the starting point of the tape in the left hand to enable reading of the correct girth on diameter.
- The tape should be taken care of. It should not be trailed on the ground and should not be rolled when wet or twisted.

ADVANTAGES OF TAPE

- It is convenient to carry.
- It does not require constant adjustment.
- Only one measurement is needed.
- In case of logs lying on ground, it is not possible to measure two diameters at right angle to each other by callipers, whereas tree diameter measurement by tape is the easiest.
- the erros in case of tape are always positive and systematic and so if any adjustment is needed, it can be done easily.
- Tape negotiates the whole circumference of the tree while the callipers touch only three points on it. So a tape measures the size of the tree better than a callipers.
- Callipers give different reading for the same Tree when different men use them as measurements are not always taken in the same direction unless these directions are marked. Tapes do not suffer from this defect. Their readings are therefore more consistent.

DISADVANTAGES OF TAPE

- If the tree has rough bark, the tape exaggerates the diameter or girth measurement.
- It is somewhat slower to used particularly in areas with dense shrub growth.
- The observer does not see the full circumference of the tree and has no knowledge of the presence of knots or swellings which may affect the diameter or girth measurement.
- As the tape has to be swung round the tree, it is frequently not applied in a plane at right angles to the axis of the tree.
- Difference in tension of the tape due to elasticity affects true diameter or girth measurement.

CHOICE BETWEEN CALLIPERS AND TAPE

Tape and callipers have their own advantages and disadvantage. Callipers gives more accurate results but its measurements are more susceptible to erros than those of tape. Tapes gives more consisten results but in time consuming in ordinary forestry practice. So the choice between the two instruments will depend upon the kind and circumstances of work and the prejudices of the men using them.

DIAMETER AND GIRTH CLASSES

In sample plots and research work, the diameters and girths of all the trees are recorded separately

to the nearest multiple of two millimeters or centimeters respectively when the callipers are used to measure diameters for such works, two diameters of each tree are recorded one over the other, viz. $\frac{25.4cm}{25.8cm}$.

But in routine forest measurements it is not necessary to record the exact diameter or girth of each tree. As the ultimate object of such measurements is to estimate volume of a large number of trees approximately, it is customary to to allot them to diameter or girth classes.

With this object, callipers and diameter tapes are calibrated to read or show diameter or girth classes. The usual diameter classes used in India are 2cm 5 cm and 10cm. The 2 cm. diameter classes have an interval of 2 cm in the extremes of the classes e.g. 0.2cm, 2.4cm, 4.6 cm and so on. The 5cm diameter classes have an interval of 5cm between the extremes of their classes, e.g. 0.5 cm, 5-10 cm, 10-15 cm and so on. Similarly, 10cm diameter classes have an interval of 10cm between the extremes of their classes e.g. 0.10 cm, 10-20 cm, 20-30 cm so on. The diameter class grouping to be as depends upon the size, which the trees constituting a crop, attain at maturity. The following table shows the sizes of the trees at maturity for which various diameter classes are used :-

(i) 2cm class for trees usually attaining maturity under 30 cm d.b.h.

(ii) 5 cm class for trees usually attaining maturity at 30 cm to 50 cm d.b.h.

(iii) 10 cm Class for trees usually attaining maturity at 50 cm d.b.h. and above.

In places where grith places where grith measurements are in vogue, girth classes are used. The usual girth Classes used in India are 30cm., 15cm and 5 cm for large, medium and small sized trees.

In India, Illiterate mazdoors are very often employed to calliper or tape the trees and it is customery to colour the scale of the callipers and the tape with distinctive colours to represent the diameter or grith class colouring the diameter or grith classes facilitates the reading and spealling them out for record by illiterate mazdoors because they read or speak out the colour class and the forester records the tree in respective diameter or girth class.

MEASUREMENT OF HEIGHT

OBJECTS

Measurement of height is required to find out

- Volume, as height is one of important component of true volume
- To read volume tables, form factor tables yield tables etc.
- To find out productive capacity of site.

DEFINITIONS

(i) **Total Height**

It is the straight line distance from the tip of the leading shoot (or from the heighest point) of the crown where there is no leader) to the ground level.

(ii) **Bole Height**

It is the distance between ground level and crown point. The crown point is the position of the first crown forming living or dead branch. Bole height expresses the height or length of the clear main stem of a tree.

(iii) **Commercial bole height**

It is the height of bole that is usually fit for utilisation as timber

(iv) **Height of standard timber bole**

It is the height of the bole from the ground level upto the point where average diameter over bark is 20 cm.

(v) **Stump height**

It is the height of the top of the stump above ground. It gives the height of the tree stem which left attached to the ground after felling.

(vi) **Crown length**

It is the vertical measurement of the crown of a tree from the tip to the point half way between the lowest green branches forming green all round and the lowest green branch on the bole.

(vii) **Crown height**

It is the height of the crown as measured vertically from the ground level to the point half way between the lowest green branch and the green branches forming green crown all round.

Thus the total height is the summation of crown length and crown height.

METHODS OF MEASUREMENT OF HEIGHT

Heights of all trees are measured only in small permanent sample plots. For all other purposes, heights of a few trees are measured with instruments and for others, it is estimated by eye or by some other non-instrumental method.

Thus the methods of measurement of height may be classified into :-

(1) Ocular method.

(2) Non-instrumental methods and

(3) Instrumental methods.

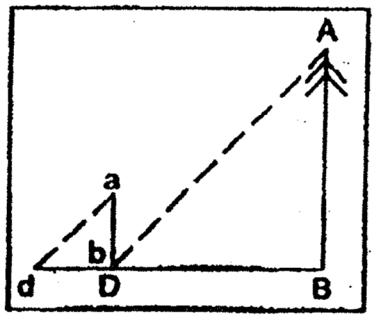
(1) Ocular method

the heights of a few trees are measured with some instrument before the start of work and that of a few trees again in the middle of work. With this standard in mind, the estimator judges the heights of trees to be measured and recorded. however, occular estimate is not very reliable and serious erros may result if the estimator has not previous exprience of work or constant practice.

(2) Non-instrumental Methods

Ocular estimate is not very reliable. Also height measurement by instruments is slow and therefore expensive. As such, several non-instrumental methods have been developed to meet the requirements of routine forest operations as follows :

Shadow Method



A pole (ab) of convinient length is fixed up right in the ground and its height above the ground is measured. The shadows of the pole and the tree are also measured. The height of the tree can then be calculated by simple proportion as follows :

$$\frac{AB}{ab} = \frac{BD}{bd}$$

$$\text{Therefore } AB = \frac{BD \times ab}{bd}$$

Where , AB is the tree.

ab is the portioin of the pole above ground level.

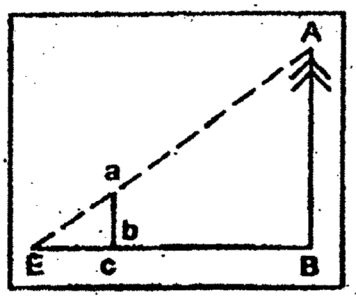
BD is the length of the shadow of the tree and

bd is the shadow of ab.

However, this method is difficult to apply in well stocked forests and applicable on clear sunny days only.

SINGLE POLE METHOD

A Pole of about 1.5m length is held vertically at an arm's length in one hand in such a manner that the portion of the pole above the hand is equal in length to the distance of the pole from the eye. Without changing the position on hand with reference to the eye, the observer moves slowly forward and backward till the line of sight to the tip of the tree passes through the tip of the pole and that to the base of the tree through the point where the pole is held by hand. This means that the portion of the pole above the hand covers the tree completely. The height of the tree is then equal to the distance of the observer's eye from the base of the tree as shown below :-



Let AB be the tree and ac a pole about 1.5 m long, held at b vertically so that distance from obse ver's eye E to be is equal to ab. Then :

$$\frac{AB}{ab} = \frac{EB}{Eb}$$

$$\text{There fore } AB = \frac{EB \times ab}{Eb}$$

Since ab = Eb, AB = EB

(3) Instrumental methods:

The instruments used in height measurement of trees are called hypsometers, altimeters, and clinometers.

Hypsometer is an instrument used for determining the height of standing trees from observation taken at some distance from the tree.

Altimeters are generally altitude measuring instruments but one instrument has been devised to determine heights of trees.

Clinometers are instruments which measure angle of slope. Any instrument which measures angles of slope, can be used for determing the heights of trees by trigonometrical methods and as such clinometers are also used for height measurement of trees.

All these instruments are based either on geometric principles of similar triangles or on trigonometrical principles based on relations between the sides of a right angled triangle.

GEOMETRIC PRINCIPLE OF SIMILAR TRIANGLES

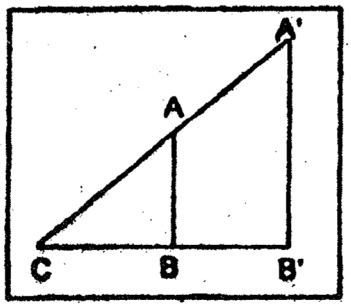
Two triangles are said to be similar, when the corresponding angles are equal and the corresponding sides are proportional. The fact that two triangles are similar should satisfy the following conditions:

(i) Each angle of triangle is equal to its corresponding angle of the other triangle.

(ii) Each side of a triangle is proportional to the corresponding side of the other triangle and

(iii) One angle of a triangle is equal to one angle of the other and the corresponding sides which the subtend the equal angles are proportional.

Once it is established that two triangles are similar then if two sides of a triangle are known and only one side of the other, the corresponding second side can be found in the following way:-



Let ABC and $A'B'C$, are two similar triangles. AB and BC are known in triangle ABC and only $B'C$ is known is triangle $A'B'C$

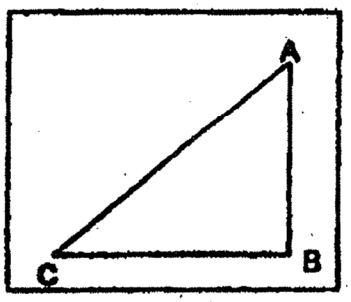
Then $A'B' = AB :: B'C : B'C$

$$\therefore A'B' \frac{AB \times B'C}{BC}$$

These principles have been made use of by some instruments in measuring the heights of trees directly. The basic assumptions is applying these principles for measuring the heights of trees are that (i) the trees is vertical and (ii) the tip and the base of the tree are simultaneously visible. When the base of the tree is not visible from a distance, the sight cases, it is better to place a staff of height equal to observers eye height against the tree and sight the top of the staff in place of the base. After finding out the height of hte tree above the top of the staff, the eye height should be added upto calculate the total height of the tree.

TRIGONOMETRIC PRINCIPLES

In a right - angled triangle, the trigonometrical ratios or functions of angles other than the right angle can be defined in terms of the sides of the triangle.



Let ABC be a right angled triangle. The trigonometrical ratios of the <ACB are defined as follows :

$$\text{Since of } < ACB = \frac{AB}{AC} \text{ i.e. } \frac{\text{Perpendicular}}{\text{Hypotenuse}}$$

$$\text{Cosince of } < ACB = \frac{BC}{AC} \text{ i.e. } \frac{\text{Base}}{\text{Hypotenuse}}$$

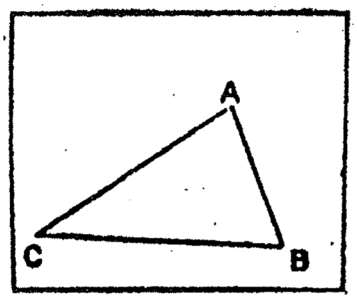
$$\text{Tangent of } < ACB = \frac{AB}{BC} \text{ i.e. } \frac{\text{Perpendicular}}{\text{Base}}$$

Let AB be a tree and C, the position of the observer, then AB can be found out from tangent ratio as

BC x tan <ACB where BC is the horizontal distance of the observer from the tree and <ACB can be measured by any angle measuring instrument. This is known as the **Tangent method.**

Again, in any triangle since of angles are proportional to the opposite side. Thus in the triangle ABC.

$$\frac{\text{Sin} < ACB}{AB} = \frac{\text{Sin} < CAB}{BC} = \frac{\text{Sin} < ACB}{AC}$$



The knowledge of this relationship can also be used in calculation of heights of trees and is known as the *Sine method.*

The trigonometrical ratios can be used for calculation of heights of trees by one of the following methods:

(i) Tangent method.

(ii) Sine method.

(i) Tangent method

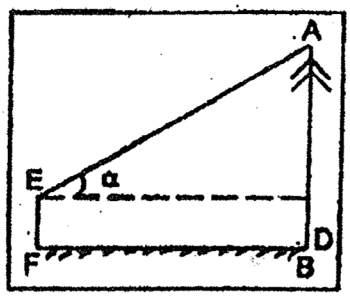
Tangent method means that the height of the tree is calculated with the help of the tangents of the angles to the top and base of the tree and the distance of the observer from the tree. As true situation of the observer with respect to the tree will differ according to the terrain the procedures of calculating heights of trees have to be modified accordingly. The following situations are generally meet with :-

(a) On level ground.

(b) On sloping ground where the top of the tree is above eye level and the base below it.

(c) On sloping ground where top and base are above (i) *the eye level and* (2) *below the eye level.*

(a) **ON LEVEL GROUND**



Let AB be the tree which is being observed by observer EF standing on the same horizontal plane as the tree. Let the angle to the top of the tree be α and ED the horizontal line of sight making a right angle on the tree at D. In the right angled triangle AED.

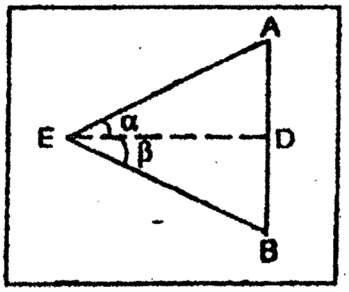
$$AD = ED \tan \alpha$$

$$\text{Thus, } AB = AD + BD = ED \tan \alpha + BD$$

$$= BF \tan \alpha + EF.$$

BF can be measured along ground and tan α can be found out from any mathematical table. EF is the eye height of the observer.

(b) **On sloping ground whole the top of the tree is above the eye level and the base below it.**



Let AB be the tree, α be the angle to the top and β be the angle to the base of the, tree. Let ED be the horizontal rene from observer's eye E making a right angle on the tree at D.

$$AB = AD + DB$$

$$= ED \tan \alpha + ED \tan \beta$$

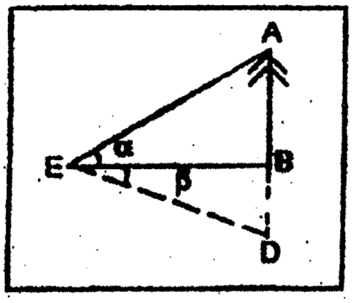
$$= ED (\tan \alpha + \tan \beta)$$

But if the horizontal line drown from the eye cuts the tree high, making measurement of ED difficult it will have to be changed in terms of EB. In the right angle triangle BDE, ED = EB cos β. Thus, AB=EB (cosβ) tanα+tanβ. In this formula, EB can be measured and cos and tan of angles can be found out from any mathematical table.

Actually, E is the observer's eye and not a point on the ground and so the measurement should be made from observir's eye to the base of the tree. But as this can not be done correctly, the measurement can be made from the feet of the observer to the base of the tree. Error involved in measuring the distance along the ground instead of from the eye to the base of tree is small.

(c) On sloping ground -

(1) Where top and base of the tree are above the eyelevel



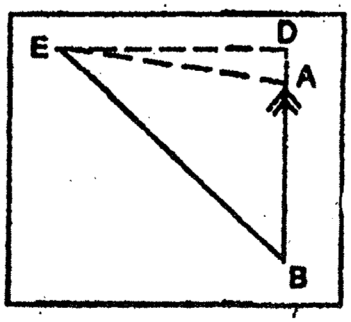
AB = AD - BD

= ED tanα - ED tanβ

= ED (tanα + tanβ)

= EB cosβ (tanα - tanβ)

(2) base and top of the tree are below the eyelevel



$AB = BD - AD$

$= ED \tan\beta - ED \tan\alpha$

$= ED (\tan\beta - \tan\alpha)$

$= EB \cos\beta (\tan\beta - \tan\alpha)$

SINE METHOD

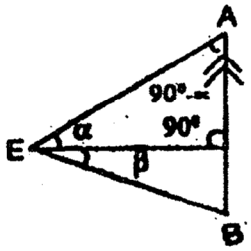
According to the sine law, in the triangle AEB.

$$\frac{\text{Sin} < AEB}{AB} = \frac{\text{Sin} < EAB}{EB}$$

$$\text{or } AB = \frac{EB \text{ Sin } AEB}{\text{Sin } EAB}$$

$$= \frac{EB \text{ Sin}(\alpha+\beta)}{\text{Sin}(90^0 - \alpha)}$$

$$= \frac{EB \text{ Sin}(\alpha+\beta)}{\text{Cos } \alpha}$$



In the above equation, EB can be measured and since and cosines of the angles can be found from any mathematical tables.

HEIGHT MEASURING INSTRUMENTS

Instruments devised on the first principle

i.e. on properties of similar triangles are

(i) Christen's Hypsometer

(ii) Smythies' Hyposometer

(iii) Improvised Callipers.

The instruments based on similar triangles are generally getting out of use as other quick, better and more reliable instruments based on trigonometrical principles are now available in the market. The chief advantage of these instruments is that they can be made in the forest if no other instrument is available.

Instruments based on the second principle

i.e. on trigonometrical principle are

(i) Brandi's hypsometer

(ii) Abney's level.

(iii) Topographical Abney's level.

(iv) Haga Altimeter

(v) Relaskop.

(vi) Tele Relaskop.

(vii) Barr and strand dendrometer.

However most of the instruments are expensive and their use is therefore, limited, The Abney's level is most commonly used in India and tehrefore, it is being described below in detail.

ABNEY'S LEVEL

This instrument is most commonly used not only for measurement of height of trees but also for contour serveyers in forest and alignment of roads.

It consists of a hollow tube with an eye piece fitted at one end and a shortsighting tube fitted at the other. The eye piece consists of two or three tellescopic hollow tubes with a pin hole at the end. The sighting tube is a small detachable tube fitted with a horizontal wire across the centre at the inner end, and a mirror behind the horizontal wire but covering only half of the tube so fitted that it makes angle of 45^0 to tangitudinal axis of the main tube. The length of the tube is such that the mirror is immediately below the bublle of a small spirit level which can be seen in the mirror through a rectangular slot in the main tube when the spirit level is in horizontal position.

The Spirit level is fitted to the main tube in such a way that it can be rotated by one screw or a wheel and a screw when a wheel and a screw are fitted, wheel is for quicker movement and the screw is extreme for final adjustments. An index arm is also attaced to the Sprit level and as the spirit level is rotated, the index arm moves on a graduated semicircular axis. The arc is graduated to read whole degrees. As the Abney's level is required to read angles of elevation and depression, the graduation in degrees upto 90^0 are on either

side of the zero mark which is in the middle of the are vernier and magnifying glass are also fitted on the index arm. The vernier scale is used for reading fraction of degrees. Each division of the vernier scale represents $10'$ (minutes). The number of the division coinciding with any division on the main scale on semi circular arc gives the reading in units of 10 minutes. For example, if the reading is more than 35^{0} (degrees) and if the 4th division of coincides with any division of the mainscale the angle of inclination will be $35^{0}\ 40'$. The magnifying glass helps in easy reading of the vernier.

While using the instrument, the observer stands away from the tree at a place from where the top of the tree and the base are visible. Then the top of the tree is sighted through the pinhole of the eyepiece after pulling it out. This makes the instrument inclined and the pubble is not seen in the mirror. Therefore, while sighting the top, the screw is rotated to bring the spirit level in horizontal position. As the spirit level approaches horizontal position, the bubble appears on the edge of the mirror. The Spirit level is continued to be moved slowly to the position where the bubble image is bisected by the line of horizontal wire on the mirror and in the other half the tree top is seen touching the horizontal wire. At this position, the index arm reads the angle of ellevation to the topof the tree on the circular arc. Similarly the angle of depression to the base can also be read and the height of the tree determined by any of the formula mentioned earlier.

ADVANTAGES OF ABNEY'S LEVEL

(i) Accurate angles or elevation of depression with the vernier with a count of 10 minutes can be found out.

(ii) Readings can be taken after sighting the tree without disturbing the index arm.

(iii) It being small and light can be used even in hills wiithout difficulty.

DISADVANTAGES OF THE ABNEY'S LEVEL

(i) Shaking of the hand makes the sighting of the top or bottom of the tree a little difficult and time consuming, as there is no provision of a stand. However, this draw back can be removed by a forked branch as stand.

(ii) It is quite tiresome to adjust the spirit level by marking the head of the screq while simultaneously looking to the top or bottom of the tree.

SOURCES OF ERROR IN HEIGHT MEASUREMENT

(1) **Instrumental error**

Instrumental errors are those errors arising as a result of some deficiency in instrument apart from its incorrectness because it is presumed that the accuracy of the instrument will be cheked and only

accurate instrument will be used. It is difficult to assess tree magnitude of such errors, as they vary with the instruments, the user and the weather conditions.

(2) **Personal error**

It depends on the steadiness of the observer, the shaking of hands of the observer can give very inaccurate result even with a accurate instrument like the Abney's level.

(3) **Errors due to measurement**

Correct measurement of distance is difficult in the forst full of shrubs and under growing as it is not often possible to keep the tape straight through bushes and weeds. The distance and the calculated height will be incorrect if the tape is not kept in level while finding out the horizontal distance by stepping. Similar error can take place in measuring the angles of elevation and depression. Unless the angles are measured correctly, the resultant height will also be in correct.

(4) **Errors due to observation**

In a forest, it is generally difficult to see the base of a tree from a distance and if the tree base is not observed, the height will be incorrect. If the base can not be observed due to bushes, a staff shopuld be placed, the tree and its top sighted later, the height of the staff should be added to the calculated height of the tree. In the case of broad leaved trees, it is often difficult to see the top of the tree and a side branch may be mistaken for the tip. This will result in the same type or error as would be committed by assuming a tree leaning towards the observer to be vertical. This type of error can be avoided by standing as far away from the tree as practicable.

(5) **Errors due to learn of trees**

All height measurements assume that the tree is vertical. But forest trees are seldom vertical. Thus, by assuming a leaning trees as vertical, serious error is introduced in the calculation of the height. In order to avoid errors due to leans, the following measures are suggested:-

(i) Measurement should be taken from such a position that the lean is to the side rather than towards or away from the observer.

(ii) Tube measurement of the horizontal distance from the point of observation to the point vertically below the tip of the tree. Though the method may give very accurate result by keeping the angle as 45^0, it does not seem to be practical in view of the difficulty involved in locating tree point vertically below the tip.

(iii) To measure the height of the tree from two opposite sides, once with the tree leaning towards

the observer and the other with the tree leaning away. The average of the two will give the height with minimum error.

MEASUREMENT OF HEIGHT OF LEANING TREES

In view of the serious errors involved in assuming a leaning tree to be vertical, it is necessary to know the method of calculation of height of leaning tree.

Some typical situations are explained below in diagrams along with the evaluation:-

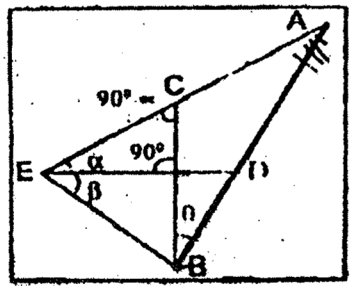
Case 1 (a)

The observer standing at a place whose eye level lies between the top and bottom of the tree i.e. the horizontal line drawn from the eye of the observer cuts the tree. The observer stands in the same plane as the lean which is away from the observer.

Let AB be a tree leaning away from the observer, E the observer's eye and ED the horizontal line drawn from eye cutting the tree at D. Let α and β be the angles ot the top and base of the tree from E. Let BC be a verical line drawn from the foot of the Tree B meeting AE, the line of sight to the tip of the tree at C. Angle CBA denotes the lean of the Tree. Let θ be the angle of this lean.

On evaluation, the height of the lean tree i.e. AB is :-

$$AB = \frac{EB \sin(\alpha+\beta)}{\cos(\alpha+\theta)}$$

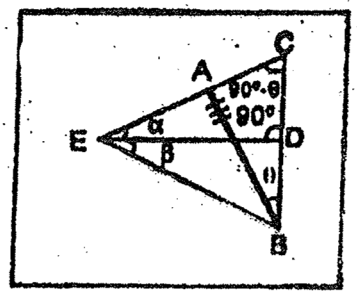


Case 1 (b)

The following is a case similar to case (a) with the difference that the lean is towards the observer.

Let AB be a tree toward the observer. Let and be the angle to the top and base of the tree from the observer's eye E. Let<CBA be , and this denotes the lean of the tree on a evaluation, theweight of the lean tree i.e. AB is

$$AB = \frac{EB \sin(\alpha+\beta)}{\cos(\alpha-\theta)}$$



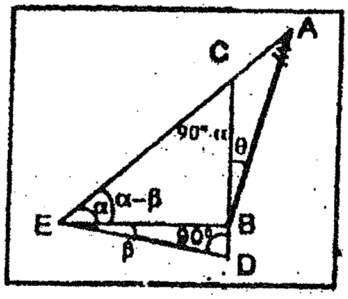
Case - II (a)

The following is the case in which the horizontal line drawn from the observer's eye cuts below the tre i.e. the tree is above the observer and the lean away from him.

Let AB be a tree bearing away from the observer. Let β and α be the angles to the top and base of the tree from the observer's eye E. Let BC be a vertical line drawn from the foot of the tree B meeting AE at C and the horizontal line from eye at D. Let <CBA, which denotes the lean of the tree, be θ.

On evaluation the height of the lean tree i.e. AB is

$$AB = \frac{EB \sin(\alpha-\beta)}{\cos(\alpha+\theta)}$$



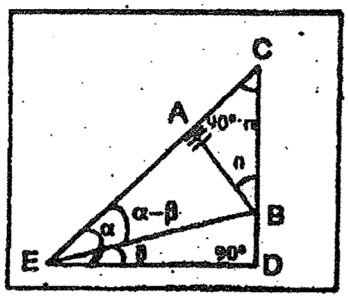
Case II (b)

This is similar to case II (a) except that the lean is towards the observer.

Let AB be the tree leaning towards the tree from observer's eye E. Let BC be a vertical line drawn from the foot of the tree B meeting EA produced at C and the horizontal line from observer's eye at D, Let <CBA, which denotes the lean of the tree, be θ.

On evaluation the height of the lean tree i.e. AB is

$$AB = \frac{EB \sin(\alpha - \beta)}{\cos(\alpha - \theta)}$$



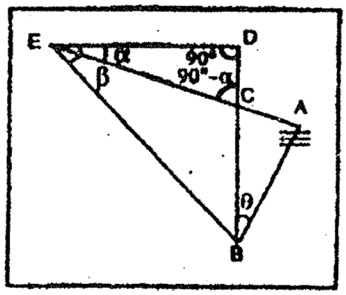
Case III (a)

The following is the case in which the horizontal line from the observer's eye cuts above the tree i.e. the tree is below the observer and lean away from him.

Let AB be a tree leaning away from the observer. Let α and β be the angles to the tip and base of the tree from the observer's eye E. Let BC be a vertical line drawn from the foot of the tree β AE at C and the horizontal line drawn from observer's eye at D. Let <CBA which denotes the lean of the tree be θ .

On evaluation, the height of the lean tree AB is

$$AB = \frac{EB \sin(\alpha - \beta)}{\cos(\alpha - \theta)}$$



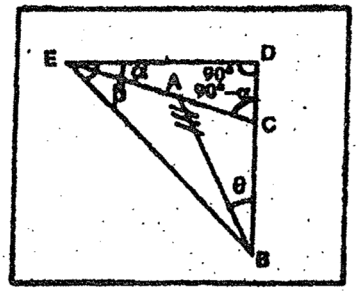
Case III (b)

The case is similar to the case III (a) except that the lean is towards the observer.

Let AB be the tree leaning towards the observer. Let α and β be the angles to the tip and base of the tree from the observer's eye E. Let BD be a vertical line drawn from the foot of the tree B meeting EA. Produced at C and the horizontal line drawn from eye at D. Let <ABC which denotes the leans of the tree, be θ.

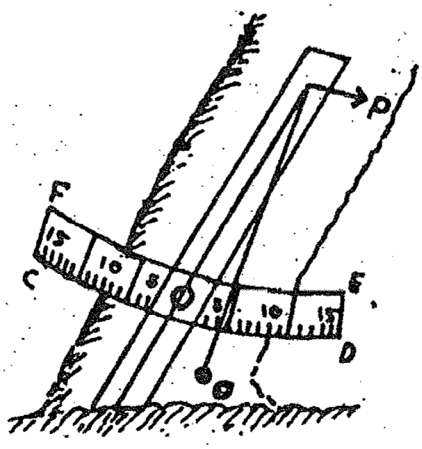
On evaluation, the height of the lean tree AB is

$$AB = \frac{EB \sin(\alpha - \beta)}{\cos(\alpha + \theta)}$$



MEASUREMENT OF THE LEAN OF TREES (KRISHNA SWAMY)

AB is a smooth radius rectangular in section about 1.5 to 1 8m in length. A centre line is drawn on the board face. Near one end at P, a hole is bored right through. Through this hole a linen string with a bob θ is suspended, when measurements have to be taken. About 45cm from B a cross piece CDEF is fixed flush to the batten. In this crosspicce, EF is arc of a circle with PF = PE as the radious. Similarly CD is the arc of a circle with PC = PD as radius. The point where centre of the of batten AD passes through this cross batten, is marked zero. On either side of this zero mark graduations are made 1,2,3,45 & c. This simple instrument is placed against the tree to be measured in such a way that AB is parallel to the asces of the lean of the tree. The reading on the cross scale. Over which the sticking of the bob passes represent the angles ofthe lean of the tree.



TREE STEM FORM

The stems of trees are not truly cylindrical and hence calculation of volume of trees or logs requires knowledge of diameter from whichcross sectional area can be calculated, height or length in case of logs and stem form.

Form is defined as the rate of taper of a log or stem where as

Taper is the decrease in diameter of a stem of a tree or of a log. Form base upwards. The taper varies with species with species, age, site and crop density and even in the different parts of the same tree.

METHODS OF SYUDYING FORM

The form of a tree can be studied in one of the following ways :-

(A) By comparison of standard form ratios

(B) By classification of form on the basis of form ratios and

(C) By compilation of taper tables.

(A) By Comparison of standard form ratios:

Two form ratios are in Vogue :-

(1) Form Factor and

(2) Form Quotient

(1) Form Factor

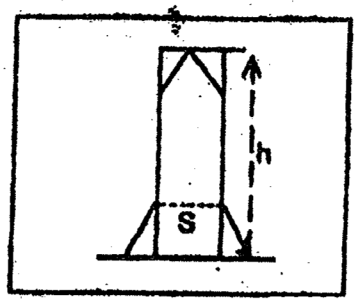
It is defined as the ratio of the volume of a tree or its points to the volume of cylinder having the same length and cross section as the tree.

Depending on the height of measurement of basal area, the following classess of form factors will arise.

(i) Artificial form factor

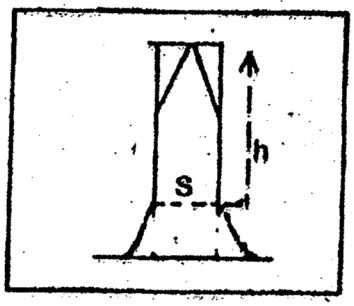
It is also known as Breast-height form factor. Here the basal area is measured at breast height and the volume refers to the whole tree both above and below the point of measurement.

The artificial form factor is not a reliable guide of the form. The point of diameter measurement is fined and as this bears no fixed relation to the height of the tree which is that of the whole tree and not of the portion above the breast hight, the trees of same form but different heights, will have different form factors.



(ii) Absolute form factor

Here, basal area is measured at any convient height and the volume refers only to that part of tree above the point of measurement. Thus, it is tree ratio between the volume of the tree above the point of diameter or basal area measurement with the cylinder which has the same basal area and whose height is equal to the height of the tree above that point.



(iii) Normal (or true) from factor

Here, basal area is measured at a constant proportion of tree total height of the tree e.g. 1_{10th}, $1/_{20th}$ etc. of the total height and the volume refers to the whole tree above ground level.

However, Absolute form factor and Normal Form factor are no longer used. Form factor in India implies **Artificial form factor** with basal area calculated at 1.37 m. above ground level.

Thus the equation of the Form Factor (F) will be

$$F = \frac{V}{Sh}$$

Where F is the Form Factor.

V is the Volume in cubic units

S is the tree basal area at breast height in area units.

h is the height of the tree in linear units.

USE OF FORM FACTORS

(i) **To Estimate Volume of standing trees.**

Form factors are compiled into tabular form giving average, form factor of trees of different dimensions by diameter and height classes. These tables are used to estimate the volume of standing tree by measuring their diameter and height.

(ii) **To Study Laws of growth**

Form factor along with form point and form quotient give an insight into the laws of growth, particularly the stem form, of trees.

Kind of the form factor

Based on the volume represented -

(i) Tree form factor.

(ii) Stem timber forms factor.l

(iii) Stem small wood form factor.

FORM HEIGHT

It is defined as the product of from factor and total height of tree.

Thus, as Form factor $F = \frac{V}{Sh}$

From height $Fh = \frac{V}{S}$

Where Fh is form height

V is the volume of tree

S is the basal area.

Volume is calculated from underbark measurement and the basal area is calculated from d.b.h.(o.b.). Form height is used to determine how far is it reasonable to assume that volume is proportional to the basal area. If form height remains constant with increasing diameter, then it is clear that the assumption is justified.

FORM QUOTIENT

Taper depends on form quotient (F.Q.) and it is defined as the ratio between the middiameter and the d.b.h. Thus,

$$F.Q. = \frac{\text{mid-diameter}}{\text{d.b.h.}}$$

Normal form quotient is defined as the ratio of mid-diameter or mid girth or a tree to its diameter or girth at breast height.

Absolute Form quotient is defined as the ratio of diameter or girth of a stem at one half its height above the breast height to the diameter or girth at breast height.

Normal form quotient is now out of vogue, and unless otherwise stated, form qutient now, means absolute form quotient.

(B) CLASSIFICATION OF FORM ON THE BASIS OF FORM RATIIO

For is classed in two ways on the basis of form ratios :-

(i) Form Class

(ii) Form print ratio

(i) Form Class

It is defined as one of the intervals in which the range of form quotient of trees is divided for classification and use. It also applies to the class of trees which fall into such an interval.

Trees may be grouped into form classes expressed by form quotient intervals such as 0.50to 0.55, 0.55 to 0.60 and so on.

(ii) Form point ratio

It is defined as the point in the crown at which the wind pressure is estimated to be centred. Therefore, form point ratir (or height) is defined as the relationship usually expressed as a percentage, of the height of the form point above the tree.

It is claimed that form point ratio bears a consistent relation to the form quotient and form class of a tree can be determined if the form point ratio is known.

(c) By compilation of taper tables

The method of studying form of trees is by compilation of taper tables, which show the actual form by diameters at fixed points from the base to the tip of a tree. They are used for the following purpose :-

(i) Volume of the average tree for each diameter and height class can be found readily without direct measurement. They only measurement that will be needed is the b.d.h. (o.b.) and the height of the standing tree.

(ii) Volume tables can thus be prepared from taper tables in desired units.

TAPER TABLES

The following kinds of taper tables are available:-

(i) **Ordinary taper table of diameter taper table**

These tables give the taper directly for diameter at breast height with out reference to the tree forms. Thus they enable computation on volumes without reference to the tree form.

(ii) **Form class taper table**

These tables give for different form classes the diameter at fixed points on the stem expresses as percentage of d.b.h. (o.b.).

General formula or equations for tree form

To determine diameter quotient (i.e. the ratio of the diameter of a stem at any given height to its breast height diameter) for each form class.

(i) **Hejer's formula** $$\frac{d}{d.b.h.} = 'C' \log \frac{C+1}{C}$$

Where is the diameter at any point on the stem, 'C' and C are constants for each form class L is the distance from the top of the tree to the point at which d is measured.

(ii) **Behre's formula** . $$\frac{d}{d.b.h.} = \frac{L}{a + bl}$$

Where a and b are constants for each form class much that a+b=1 and d and I have the same meaning as given for Hojer's formula.

Thus formula have been used for preparation of taper tables in Western countries.

MEASUREMENT OF VOLUME OF TREES

OBJECT

To calculate or estimate quantity of wood contained in trees and consequently in crops for various purposes such as sale, reaserch, predicting future yields, estimating increment to assess return on capital etc.

TREE VOLUME

The volume of a tree may be calculated after the tree has been filled or when it is standing.

(1) **volume of felled trees**

Volume of felled trees consist of volume of stem wood, branch wood and root wood, where it may be valuable and its digging is permitted.

Conversion to logs

The tree tapers irregularly and it is usual to cut the felled Trees into logs. The length of the logs depend upon the rate of taper and market requirements. As the diameter at the either end of the log determines the sown volume that can be taken out of it, the greater the rate of taper, the lesser is the length of the log. But in certain cases higher rate for a longer timber is so profitable that longer lengths of logs are cut inspite of decrease in the converted volume. The length of the logs also depend on the mode of Transport. Carts can transport much longer logs than the Trucks can do. For truck transport the longer of the logs are not longer than 4.5m. or so. But when logs are made for calculating volume of felled trees for research work, all logs including the first are of uniformly 3m. in length except the top end evg. which may be upto 4.5m. But if the end section is more than 1.5m in height, it is left as a separate log.

Volume of logs

The following formulas are adopted in measuring the volume of logs :-

(1) Smalians formula.

(2) Huber's formula.

(3) Prismoidal or Newton's formula.

(4) Quarter girth formula also known as Hoppus's rule.

1. **Smalian's formula**

$$V = \frac{S_1 + S_2}{2} \times I$$

Where S_1 is the sectional area at the thick end in square units.

S_2 is the Sectional area at the thick end in square units.

I is the length of the log in linear units.

It is easier to measure the diameter of end crops sections of logs with a wooden scale. The Smalian's formula is easier to apply as compared to Huber's or Newton's formula. However, the Smalian's formula over estimates the volume.

2. Huber's formula

Volume V = Sm x I

Where Sm is the sectional area at the middle in square units, I is the length of the log in linear units.

It requires the measurement of mid crossectional area of a log. It is thus impossible to use it when the logs are stacked without incurring extra expenditure in separating them. It, however, underestimates the volume of logs. Still, Huber's formula is more accurate than the Smalian's formula.

3. Prismoidal or Newton's formula

$$\text{Volume } V = \frac{S_1 + 4\,Sm + S_2}{6} \times I$$

Where S_1 is the sectional area at the thick end in square units.

S_2 is the sectional area at the thin end in square units.

Sm is the sectional area at the middle in square units.

I is the length of the log in linear units.

Newton's formula is most accurate out of the all formula. But it is a cumbersome formula to use as it necessitates the measurement of diameter and calculation of areas of three crossections. This formula is difficult to apply particularly when the logs are stacked and the middiameter can not be measured.

4. Quartergirth formula or Hopper's rule

$$\text{Volume } V = \left(\frac{g}{4}\right)^2 \times I$$

Where g is the girth of the log at the middle

I is the length of the log.

Though not accurate, the formula is used by traders, public and the government in view of its simplicity.

FORMULATION OF QUARTERGIRTH FORMULA

We know that the full circular voluem

Volume $V = \pi r^2 I$ Where r = radius and I = length

= Basalarea x lenght

We also know that the circumstances i.e.

girth, $g = 2\pi r$ Where r = radius.

$$\text{Hence, } r = \frac{g}{2\pi}$$

Thus volume $V = \pi r^2 I$

$$= \pi\left(\frac{g}{2\pi}\right)^2 I \left[\because r = \frac{g}{2\pi}\right]$$

$$= \pi \frac{g^2}{4\pi^2} \times I$$

$$= \frac{g^2}{\pi} \times I$$

π is actually equal to 3.1416, but it has been roughly taken be equal to 4.

$$\text{Therefore Volume } V = \frac{g^2}{4x4} xI$$

$$= \left(\frac{g}{4}\right)^2 xI$$

An approximate has been made in the value of π from 3.14 and hence. the volume derived by this formula is lesser than the true volume.

The following comparison of the formula by quartergrith method and the full circular method shows that teh former gives only 78.5% of the true volumes.

$$\text{Full circular volume } V_1 = \frac{g^2}{4\pi} xI$$

Quarter girth volume $V = \left(\frac{g}{4}\right)^2 xl = \frac{g^2}{16} xl$.

Thus, $\frac{v}{v_1} = \frac{4\pi}{16} = 0.785$ or 78.5%

The underlying idea was to find out a method which would give approximately correct volume of squared timber contained in a log after rough squaring, when a log is measured in the forest, the girth is taken under bark but before conversion into scantlings, it has to be squared. Full circular measurement can not then represent the marktable volume of log and quartergirth measurement was devised to make some allowance for bark and also for loss in squaring. Thus the shortage of 21.5% in volume was supposed to cover this loss.

To distinguish quarter girth volume from the true cicular volume, quarter girth volumes are generally specified as quarter girth or hoppes volume i.e. 25.5 cum q.g. or simply 25.5 cum hoppes.

Stem Volume

(i) Commercial Volume

It is the volume of stem measured down to a thin end diameter upto which converstion is usually done. This volume includes volume of the stump.

(ii) Standard stemtimber

It is the volume of stemwood timber in round from ground level down to 20 cm diameter are bark, volume being taken exclusive of a bark.

(iii) Standard stem smallwood

It is the volume of stemwood in round between 20 cm diameter are bark and 5 cm diameter over bark, volume being taken. Inclusive of bark.

TIMBER CALCULATORS

The measurement of volume of timber is facilitated by the use of specially prepared table. These are called timber calculators or timber measurement tables. They generally give volume in metric system, of round timber calculated by quarter girth formula for length from 1 to 25 m and girths up to 90 cm and of sawn timber for lengths form 1 to 25 m and cross section 1 x $1cm^2$ to 25x $25cm^2$. They also give surface area sawn for various lengths and breadths of plants.

(ii) Volume of standing trees

The following are some of the methods used for estimation of volume of trees without felling them:-

(i) Ocular estimate

Experienced persons can make facility accurate estimate of volume of standing tree marked in felling lots by careful inspection on the banks of records of past fellings. But this method is too subjective for reliable results. Different workers produce different results for the same tree and even the same worker may estimate differently under teh influence of fatigue, hunger etc.

(ii) Partly ocular and partly by measurement

The uncertainty of purely ocular estimate can be overcome by measuring the diameter and height of the tree and then estimating the volume keeping the tree taper in view. In the method, the estimator estimates the diameters of subsequent logs after the based log and from them the volume till whole length is covered. This method also requires lot of experience and practive without which estimates may not be correct.

(iii) Direct measurements

The unreliability of the ocular estimates is completely removed if the diameters of tree at different heights are measured by a man climbing the tree with the help of a ladder to some height and there after by his own effort. This method then becomes similar to the method of calculating volume of trees after they have been filled. This method is however very time consuming and tiring and cannot be used when large number of trees all involved.

(iv) Indirect measurement

With the development of optical dendrometers, it is no longer necessary to climb trees for measurement of volume. These instruments are special Rilaskop, Tele Rilaskop, wheeler pentaprism calliper and Barr and strond dendrometer, with the help of these instrument the volume of the standing trees can be estimated accurately.

(v) Use of volume tables

Volume tables is defined as a table showing for a given species the average contents of trees, logs or sawn timber for one or more given dimensions. The given dimensiions may be (i) d.b.h. alone, (ii) d.b.h. and height or (iii) d.b.h., height and some measure of form or taper.

The main object of these tables is to estimate the volume of an average standing tree of known dimension and thus to estimate the volume of a given crop or of marked. Trees in given crop. These tables are based on the actual measurement of sufficiently large number of trees and have been prepared on the assumption that the trees of the same species with the same dimensions will have the same volume. However, the volume table does not give exact volume of an individual Tree because the volumes of the individual tree may be different from the average based on several individuals. Thus, the volume table approach can truly applied to a group of trees e.g., Coupe. but not to individual trees.

Variables

The volume of a tree depnds mainly upon three variables:

(i) diameter

(ii) height

(iii) form

The selection of variable or variables depends on the extends of their intended application. Simplicity speed with which they have to be applied and derived accuracy. Volume table applicable to a larger area should be based on at least two variables of height and diameters, volume table based on three variables are more accurate, but they need more measurements for applying their in the field. It volume table is to be made on a single variable, then surely d.b.h. should be tat variable as it involves minimum error and moreover, it is the dimension which can be easily measured.

CLASSIFICATION OF VOLUME TABLES

Volume tables can be classified in the following ways :-

(1) Classification on the basis of number of variables

The volumes tables can be further subdivided according to the number of independent variables:-

(i) Volume tables based on one variables i.e. diameter along

Hence, the Trees are classified by d.b.h (o.b.). These tables show average volume of Trees by diameter classes. Since height variation in the same diameter may be frequent in different localities, such volumes tables cannot be used for extensive areas. They can be used only locally and these are called **local volumes tables.** They are easy and quick to use as they require the measurement of only d.b.h.(o.b.).

(ii) Volume tables based on two variables i.e. diameter and height.

These volume tables give volumes of trees by diameter classes as well as by height classes pertaining to the total height of the Trees. Sometimes, instead of giving height classes for the total height, these give volumes for different height classes of the merchantable boles. The volume tables applicable to longer areas.

(iii) Volume tables based on three variables

These tables are based on diameter, height and form quotient and called the form class volume tables. These are more accurate. But such tables have not been prepared in India.

(II) Classification on the basis of scope of application

(i) General Volume table

These volume tables are based on the average volume of Trees growing over a large geographical area. thus being applicable to a wider range of distribution of the species. They tables show volumes of Trees by diameter classes and in each diameter class be height classes. These tables are based on measurement ot Trees growing in wider range of distribution of the species and as they require measurement of diameters and heights for their application these tables house a limited direct application. Several kinds of general volume tables are meet with depending on the kind of volume they show eg.

Standard volume table.

Commercial volume table.

Sawn outtern table.

Assortment table etc.

(ii) Regional volume table

These are compiled from measurement of tree growing a region and therefore have a limited application when compared to general volume table.

(iii) Local volume table

These volume tables are compiled from the measurement of trees growing in restricted locality. These are generally based on one independent variable viz. d.b.h. (o.b.). These are, therefore, applicable to such restricted localities as a coupe or a compartment. Because in such small areas the assumption that the Trees of the same diameter will have the same height, will hold good.

The local volume tables are used for

(i) estimating the volume of standing trees before felling with the object of regulating yield in accordance with working plan prescriptions, or (ii) for making confidential estimate of the volume of a coupe.

Then tables are either prepared directly from field data or derived from general volume table.

(III) Classification on the basis of the kind of out turn

(i) Standard volume table

Then volume tables give separately the estimated out turn in the form of standard timber, i.e. from ground level to the limit of the portion of Tree stem or branch where diameter is 20 cm measured overbark and smallwood i.e. volume between the diameter limits of 20 cm and 5 cm both measured overbark.

(ii) Commercial volume tables

These are volume tables in which the contents of round timber are given as volume measured down to their end diameter to which converstion is done, the stump volume being omitted. As the diameter level to which conversion is done may vary with time and place the scope of applicability of these tables is limited to areas having the same closeness of conversion and to certain periods of time when standard conversion is the same. And market requirements decide the minimum limit of exploitation, violent fluctuations in market render the table unfit for use. The chief use of this tables is to serve as a basis for preparation of local and usually temporary tables for individual coupes.

(iii) Sawn outtern tables

These are volume tables in which contents of sawn timber are given as volume measured down to a thin end diameter to which conversion is done, the stump volume being omitted. Thus there are similar to commercial volume tables except for the fact that these give volume of sawn timber instead volume in roound.

(iv) Assortment tables

These are volume tables which give volume in round down to various stated thin end diameters. For example it will be possible to find out volume of a true of given linear dimensions when the converstion was done upto 25cm 20 cm or 15cm diameter limit. Thus the standard volume table and commercial volume table are special cases assortment table.

(v) **Sawn outturn assortment aables**

These tables are similar to assortment tables except that they give sawn outturn in the number of standardized pieces in stead volume in round.

Methods of preparation of volume tables

The volume tables are prepared by the following methods:-

(i) Graphical method

(ii) Regression equations method or the method of test square's fit.

(iii) Alignment chart method.

Information incorporated in volume tables

The volume tables primarily show the volumes of Trees by diameter classes and height classes if two variables are used. The volume tables also furnish the following informations in a descriptive form as introduction:-

(i) Name of the species (both common and scientific) and its distribution.

(ii) Basic data. i.e. the locality from which the data were collected and the number of trees measured for compilation of table together with any other work done to collect in formation such as increment forings, stem or stump analysis etc.

(iii) The method of compilation and computation i.e. the method of measuring sample Trees whether accroding to standard procedure or ley some other method upto certain diameter limits, whether the method of computation was according to standard procedure or some other methods the check applied etc.

(iv) Mathematical equations, if fitted, to the basis data.

(v) Applicability.

The volume tables then give a number of Tables e.g.

(i) Table of basic averages.

(ii) Table of individual and aggregate checks.

(iii) Table for underbark volume.

(iv) Table for bark thickness and/or bark percentage.

(v) Other tables such as diameter growth table, commercial volume table (if the main volume table is for standard timber) and conversion factors etc.

Determination of volume of crops

The volume of crops over small areas is either estimated with the help of volume tables or with the help of studies made in small plots representing the crop. When volume tables is to be used, the crop in the small area is enumerated and classified by diameter classes. If the local volume table is available, then the number of trees in each diameter class is multiplied by the volume corresponding to the diameter class given in the table and the sum of the volumes of all diameters classes is the volume of the crop in the area.

BIOMASS MEASUREMENT

While volume is the most important measurement from the point of view of forest Management, weight which is also referred to as biomass to being increasingly used now in place of volume.

Weight or biomass measurements is preferred for

(i) Species while Sandal and rosewood as they are very valuable woods and

(ii) Firewood, pulpwood etc. where volume measurement was not practicable.

Biomass is an alternative primary unit of measurement for forest practices and investigations that is already being used to some extent in place of volume. Thes use of biomass permits measurement of all the vegetation in the forest which is becoming of increasing importance as forestry and the general public become more concerned with multipurpose use of the forests.

Factors affecting weight

It is comparatively easy and straight forward task to measure physically the gross weight of a quantity of felled wood but an estimate of the dry weight of the standing tree itself is not so simple. The overall weight of a quantity of wood is affected by the following follows.

1. Density
2. Moisture content.
3. Basic and foreign material.

1. Density

Density of any substance is its mass per unit volume. More often, relative density or specific gravity which is the ratio of density of the substance to density of water is used. In case of wood both weight as well

as volume shrink due in driage. For comparision between various woods ovendry weight and green volume are used for determining density as a standard term. Where are dry weight is mentioned a percentage moisture content of 12 is understood.

In most species there is a tendency for the specific gravity to decrease from base to top of stem. This variation is however, small compared to difference between trees of the same species.

2. Moisture content

The moisture content of wood varies by locality, species, season of felling and the length of time following the outting of the Tree. It also varies with age and physical condition of the Tree. It is this variability in the moisture contest of wood and the difficulty of its measurement that constitutes a major problem with the used of weight as a measure of wood quantity. Moisture occurs as free water in intercellular spaces and as absorbed water in cell wall material. The moisture content when free water has been evaporated leaving only absorbed water is called the fibre saturation point. The moisture content of wood is expressed as a percentage of ovendry weight, ovendry weight is obtained by drying at $103\pm2^{0}C$ until no further moisture loss occurs and a stable weight has been reached. The woody tissues of a tree following cutting lose moisture gradually and its moisture content reaches 12 percent in air drying. The rate of loss of moisture and the percentage of moisture content of wood, wever, varies with surrounding air temperature and humidity.

Moisture content in green condition has been notices to be as high as 151.2 percent in case of Gmelina arborea, specific gravity based on dry weight and green volume for some species are recorded below:

1.	Acacia catechu	0.670
2.	Bombax Cliba	0.329
3.	Dalbergia firoo	0.692
4.	Eucalyptus hybrid	0.577
5.	Shorea robusts	0.745
6.	Tectona grandis	0.554

3. Bark and foreign material

Bark has a lower density than wood. It should therefore be removed before wighting depending on the species it may make up between 1 and 19 percent of the weight of green pulpwood.

Studies in India

Very few biomass studies have been carried out in India as biomass studies require measurement of roots, stems and branches completely. Even in case of sandal wood whose roots are dug out, systematic studies have not been made. The weight tables sine prepared are :-

(i) Pulpwood table for twisted chair.

(ii) Weight tables for heartwood of khainbind Katha.

(iii) Weight tables for Anygesisons latifolia, poplar and Eucalyptus hybrid.

AGE OF TREES

Object

The determination of the age of the indivdual trees is a very important factor to be studied after the etermination of volume or biomass because it indicates the time required to produce that volume or biomass. Since ages of individual Trees form the basis of determination of age of woods, its study assumes added importance because in absence of knowledge of age, it is neither possible to know at which rate the wood capital is growing, nor is it possible to compare financial results of foresting with comparable land uses like agriculture, horticulture etc.

Methods of determination of Age

Except for the trees which produces annual rings and whose age can be determined by counting rings if the trees are filled, the age of the trees has to be estimated by certain ways which vary with situations i.e. whether the Tree is standing or filled.

Determination of Age of Single Trees when standing

The age of the individual trees when standing can be estimated by the following methods:-

(1) From existing records

In the Case of trees raised by sowing or planting, the record of the year of much operations is very useful in finding the age of Trees as the differences between the year of determining the age and the year of sowing and planting is the age of the tree. In case of trees raised by natural regeneration, under systems of concentrated regeneration, the difference in the year of seeding felling and the year of estimating the age gives the age of trees. The method, however, is not very accurate as the record of artificial and natural regeneration pertains to crops and not individual trees. In a plantation, all Trees are not of the same age as some are raised in beating up operations. Similarly in natural

regeneration areas, the year of seeding felling cannot give the age of Trees correctly because regeneration come gradually over a period of years which may be upto 40 years.

(2) From General appearance

The age of staniding Trees can also by formed be ocular estimates taking the following into account:

(a) Size and relative taper of the Tree

Young trees have very tapering boles while older. Trees have ulatively less has tapering boles.

(b) The size and shape of the crown

In certain species, the size and shape of the crown changes with advancing age. If knowledge of such development exist, the age of trees can be estimated by looking at the age of trees can be estimated by looking at the crown. For example, chir (Pinus rouburgh ii) has a conical crown in early ages and becomes rounded as Tree grows older.

(c) The colour and condition of bark

The colour and condition of the bark changes with age. The older trees have generally smooth and light Coloured bark while the younger Trees have rough, fairly cracked and darker coloured bark as in the case of Sal (Shorea robusia).

This methods, however, requires great practice and experience before age can beestimate without reasonable limits of accuracy. These conditions, however, change due to locality factors.

(3) By the number of annual rings or whorls of branches

In species which have clear marks of annual shoots, age of tree can be ascertained by counting these shoots from top downwards and adding a proportionate number of years for that part in whch their are not visible. Some other species form only one whorl of branches every year. Counting the whorl or stubs. There of and making an increase of proportionate number of years for portion in which such whorls are not usable, gives an approximate idea of the age of the tree Sinual (Bombase cliba) shows annual whorls in early ages.

(4) By means of Pressler's increment forest

Age of trees with annual rings can also be determined by means of Pressler's increment forest. The instrument helps to contract a narrow cylinder of wood from a Tree and the sance is examined for counting of rings or measuring diameter for deterimination of increment.

This method his however, applicable only to species which show distinct annual rings. Borings are made 30 cm above ground in case of smaller trees and at breast height in case of bigger trees. The smaller trees can be bored upto the pith for ring corent for determining age. As the pith is not always in the centre, more than one bogis is sometimes necessary. The age corresponding to the height at which boring is done, has to be added to ring count to get the age of the Trees.

In case of bigger trees which cannot be fored upto pith in the absence of power, driven angers used in some countries, borings can be resticted is 5 or 10 rings and the diameter 5 or 10 years ago is obtained by deducting twice the width of 5 or 10 rings from the present diameter. In that case, the age of tree may be found by any of the two methods described below :-

(5) By taking three periodic measurements

The age of trees without rings can be found out by three periodic measurement. Suppose d_1 was the initial diameter of the tree and d_2 and d_3 diameters at subsequent periodic measurements. Let p_1 be growth per unit diameter per year during first two periodic measurements and p_2 the growth per unit diameter per year during the period between the second and third periodic measurements. The age of the tree then can be found out by the following formula:-

$$\text{Age} = \frac{1}{P_1 S} \text{ where S is a constant equal to}$$

$$\frac{\log P_1 - \log P_2}{\log d_2 - \log d_1}$$

Example

The diameter of a sal tree in 1970 was 30 cm in 1975 it was 33 cm and in 1980 it was 36 cm. find the age of thtree in 1970.

$$p_1 = \frac{3}{30 \times 5} = 0.02$$

$$p_2 = \frac{3}{33 \times 5} = 0.018 \text{(approx)}$$

$$S = \frac{\log 0.0_2 - \log 0.018}{\log 33 - \log 30}$$

$$= \frac{\bar{2}.3010 - \bar{2}.2553}{1.5185 - 1.4771}$$

$$\frac{457}{414} = 1.1$$

Therefore age in 1970

$$= \frac{1}{0.02 \times 1.1} = \frac{1}{0.022} = \frac{1000}{22} = 45 \text{ years (approx.)}$$

(6) By reading age from diameter age curve prepared from measurements of tree in an area

Didmeter of trees in the area are recorded diameter found out. the same trees are measured at an interval 5 to 10 years and the average diameter of each diameter class is found. The difference between the two averages gives the periodic diameter increment which is plotted against d.b.h. and a smooth curve drawn. The increment curve is this transformed into diameter age curve by the following step:-

(i) The lowest diameter on the increment curve is taken and its inrement is read off directly from the curve. This is added to the original diameter to obtain final diameter at the end of the period. Increment against this diameter is reas off again and added similarly. The process is repeated for the whole range of values available from the Curve.

(ii) The diameter values so obtained are plotted against a succession of equidistant points spaces at intervals corresponding to the number of years in the period and diameter growth curve drawn through the plotted points.

(iii) The time axis of the curve is corrected to read age by shifting the zero point to the left by the necessary number of units corresponding to the estimate time required to reach lowest diameter plotted. In the time required to reach the lowest point cannot be estimated or is not known, the curve may be produced backwards on the basis of experience of similar curves and the age corrected from where the curve cuts the x-axis. The age of the tree can than be read from this curve with reference to the diameter.

(7) Mathematical relationships

The age of Tree can also be determined if an equation showing relationship between age and diameter or girth has been prepared for the species. This method is however not reliable as diameter growth is affected by several other factors apart from age.

Determination of Age of felled trees

The age of a filled tree can be determind if the stumpsshow annual rings. The only thing that has to be done is to count the rings on stumps and add the estimated period the tree would have taken to grow to stump height.

This method is, however, based with following difficulties:-

(i) **Incidence of false rings**- There are often false rings. Hence care should be taken so that false rings are not counted.

(ii) **Closed formed rings**- Centain trees may have rings very close and hence care should be taken not to miss any ring.

(iii) **Absence of growth rings in certain years** - In certain years when the Tree is subjected to aheavy defoliator attack, ring formation may not take place.

Still this is best and quickest method of determining age of a tree.

MEASUREMENT OF CROPS

Forest crops consist of trees, but methods of measurement of individual trees, do not apply to cheer measurement due to certain characteristics described below:-

(i) **Gradual diminution of number**

Most of the forest crops start with a very large number of plants and as they grow, there is a competition between the individuals constituting them and the number of trees goes on reducing by the death and decay of some individuals with the removal of smaller trees by death, the average age of the diameters and heights of the remaining trees increase. Similarly, if the old mature trees dia there is a reduction in average diameter and height. Thus, in a forest crop, the average diameter, height etc. change not only by the increments of the individual trees constituting it but also by the gradual diminution of number of trees.

(ii) **Stand structure**

The measurement of crop is further complicated by its constitution or stand structure. All crops are neither even-aged nor pure crops of one spices. Some are regular, others are irregular, some are pure. Others mixed. Even in regular crops, the distribution and representation of age and/or size classes may vary from place to place. As the growth of trees depends not only on their growth

potential but also on the size and form of the nighbouring trees, the growth is regular and irregular forests is different. Therefore, the methods of measurement of different dimensions of crop may have to be varied with the type of forest in order to get a clear idea of its growth.

(iii) Object of measurement

In case of individual trees, the object of measurement is to find out its growth in terms of its diameter, height, colume etc. But in case of crops the object is to find out the number of trees, crop diameter, crop height, distribution of trees by varicus sizes, volumes etc.

Determination of Diameter of Crop

As the main object of determination of diameter of a crop is to find out its volume and as volume is dependent on basal area, the crop diameter is based on the mean basel area and not the mean of diameter alone.

(i) Crop diameter

It is a diameter corresponding to the mean basal area of a uniform, generally pure crop.

(ii) Mean diameter

It is a diameter corresponding to the mean basal area of a group of trees or a stand; sometimes used for the arithmetic mean of summated diameters.

Thus, mean diameter is a general term while crop diameter is a specialized term applied to only even-aged pure crops. However, both are obtained by finding out the mean basal area. The mean basal area is obtained by the following formula:-

$$\text{Mean basal area} = \frac{n_1 s_1 + n_2 s_2 + n_3 s_3 + \ldots\ldots}{n_1 + n_2 + n_3 \ldots\ldots}$$

Where $n_1\ n_2\ n_3$ are the number of trees in each diameter class and

$s_1\ s_2\ s_3$ are the basal areas of mean trees of different diameter classes.

Crop diameter is the diameter of the trees corresponding to mean basal area.

Mean diameter could also the calculated as an arithmetic average of the diameter of tree i.e.

$$\text{Mean diameter } D = \frac{n_1 d_1 + n_2 d_2 + n_3 d_3 + \ldots\ldots}{n_1 + n_2 + n_3 \ldots\ldots}$$

Where $n_1 n_2 n_3$ are the number of trees in each diameter class and

$d_1 d_2 d_3$ are the average doameter of these diameter classes.

But this average diameter would not be crop diameter. The mean diameter obtained through the mean basal area is always smaller than that obtained by the direct average of diameters.

(iii) **Top diameter**

It is the diameter corresponding to the mean basal area of the biggest trees in a uniforms generally pure crop, taking into consideration 250 biggest diameters per ha. It is used for determining top height of a crop, which in turn, is used for assessing the site quality. In this case two diameters of each tree are measured at breast height at right angles in each other. Each diameter is then considered separately.

Determination of height of crop

(i) **Crop height**

It is the average height if a regular crop as determined by Lorey's formula :-

$$\text{Crop height} = \frac{n_1h_1 + n_2h_2 + n_3h_3 + \ldots\ldots}{n_1 + n_2 + n_3 \ldots\ldots}$$

Where $s_1 s_2 s_3$ are the total basal areas of each of the diameter class.

$h_1 h_2 h_3$ are the average doameter of these diameter classes.

(ii) **Mean height**

It is the height corresponding to the mean diameter or a group of trees or the crop diameter of a stand. Thus for determining the mean height a height diameter curve has to the drawn from the data collected on a sufficiently large number of trees classified into diameter classes. The height and diameters of individual trees are plotted and smooth curve is drawn. Then the mean crop diameter is calculated by the formula given earlier. Against this mean diameter height is read from the curve this height is known as the mean height.

(iii) **Top height**

It is defined as the height corresponding to mean diameter (calculated from basal area) of 250 biggest diameters per hectare as read from height diameter curve.

Thus while the crop or mean height relates to all the trees of the crop, the top height relates to only

250 biggest diameters (or about 125 trees) of the crop.

Detrmination of Age of crop

Depending on the variation of age of trees constituting a crop, forest crops are classified into evenaged and unevenaged crops.

Evenaged crop

The age of an evenaged crop is described by the term crop age which is defined as the age of a regular crop correcponding to its crop diameter. When the difference in ages of trees is very small as is the case of plantations crop or the crops raised under uniform system of forest management, crop age is the age corresponding to the age of the tree of mean diameter.

If the different in age in trees is appreciable they should be grouped in even aged group. They the total basal area of each group is found and also the age of the group :

$$\text{Crop age} = \frac{s_1a_1 + s_2a_2 + s_3a_3 + \ldots\ldots}{s_1 + s_2 + s_3 \ldots\ldots}$$

Where $s_1 s_2 s_3$ are the basal areas of the evenaged group.

$a_1 a_2 a_3$ are the ages of the evenaged groups.

Uneven age Crop

Meanage of unevenaged crop is defined as the average age of dominant trees in a crop according to the Indian Forest and forest products Terminology Part I, whereas schlich defined mean age of an uneven aged crop as that period which an evenaged wood requires to produce the same volume as the uneven-aged wood

A few fromula commonly used are :-

(i) Mean annual increment i.e. m.a.i. is equal to volume divided by age. Therefore age is equal to volume divided by m.a.i.

$$\text{Hence, Mean age} = \frac{V_1 + V_2 + V_3 + \ldots\ldots}{\frac{V_1}{a_1} + \frac{V_2}{a_2} + \frac{V_3}{a_3} \ldots\ldots}$$ smaller and Heyer's formula

Where $v_1 v_2 v_3$ are the some of volumes of evenaged groups.

$a_1 a_2 a_3$ are the ages of the groups.

As the ages of standing trees are difficult to as certain, age classes may be substituted by diameter classes. This formula gives most accurate results as its correctly correlates volume with age.

(ii) As volume depends to a large extent on basal area, the ages may be correlated with it and thus the means age can be determined.

$$\text{Mean Age} = \frac{s_1a_1 + s_2a_2 + s_3a_3 + \ldots\ldots}{\text{'S'}}$$

Where $s_1\ s_2\ s_3$ are the some of volumes of evenaged groups.

$a_1\ a_2\ a_3$ are the ages of the groups.

'S' is the total basal area of the whole forest.

This formula is simple and easy to apply and it works will if form heights of the diameter classes are equal.

(iii) A less dependable method is to substitute the number of trees for the basal area in each age or diameter class. Then

$$\text{Mean age} = = \frac{n_1a_1 + n_2a_2 + n_3a_3 + \ldots\ldots}{n_1 + n_2 + n_3 + \ldots\ldots}$$

Where $s_1\ s_2\ s_3$ are the number of trees.

$a_1\ a_2\ a_3$ are the average ages of evenaged groups.

This formula stresses the effect of numbers and disregards the size of trees within the age or diameter class.

(iv) If the evenaged groups occupy distinct areas the area occupied by each age class may be used to determine mean age. Thus

$$\text{Mean age} = = \frac{m_1a_1 + m_2a_2 + m_3a_3 + \ldots\ldots}{m_1 + m_2 + m_3 + \ldots\ldots}$$

Where $m_1\ m_2\ m_3$ are the areas occupied by different age classes.

$a_1\ a_2\ a_3$ are the average ages of these classes.

(v) The easiest method, though not very occurate, is to take the mean age as equal to the average of sample trees representing different age classes. Then

$$\text{Mean age} = = \frac{n_1a_1 + n_2a_2 + n_3a_3 + \ldots\ldots}{n_1 + n_2 + n_3 + \ldots\ldots}$$

Where $a_1 a_2 a_3$ are the sample trees representing the different ages classes.

n is the total number of trees.

Top Age

It is defined as the age corresponding to the top diameter of a regular crops. It is read from age diameter curve against the top diameter calculated from basal area of 250 biggest diameter per ha.

Determination of volume of crops

Determination of volume of crops by direct measurement extending over the whole area is neither practicable nor economic. Therefore, the volume of crops over small area is either estimated with the help of volume tables or with the help of studies made in small plots representing the crop. When volume table is to be used, the crop in the small area is enumerated and classified by diameter clases. If the local volume table is available, then the number of trees in each diameter class in multiplied by the volume corresponding to the diameter class given in the table and the sum of the volume of all diameter classes is the volume of the crop in that area. If local volume table is not available then the diameters and the heights of a few trees are measured to prepared local volume table from general volume tables. As measurement of large areas is time consuming and entensive, study of growth of crops is carried out by laying small plots. Such plots are called sample plots.

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2. Forest mensuration by *A.N. Chaturbedi & L.S. Khanna.*
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Questions:

1. What do you understand by Breast height measurement. Narrate the rules of Governing breast height measurement.

2. (i) What are the objects of measurement of height?

   (ii) What are the methods of measurement of height?

   (iii) Describe the sources of error in height measurement.

3. What is form factor? What are the classes of form factor? What for form factors are used?

4. What do you under stand by volume of felled trees? What are the formula adopted in meaning volume? log? How the quarter girth formula is arrived and what is its utility?

5. What is volume table? How they are classified?

6. Describe how the age of trees are determined. What are the methods for determination the age of simple trees when standing?

Botany

Part- I, Paper III (2nd half)

Module- 29,30

Contents

BOTANY AND FORESTRY

CHAPTER - I

Module No.-29, 30

Part - I, Paper - III (2nd half)

Forest Management

[Points : Introduction - Definition and Scope of Forest Management - Principles of Forest Management - National Forest Policy - Forest on Concurent list - Instruments of Forest Management - Objects of Management.]

Forst Management is one of the important forestry subjects prescribed in the curriculor of forestry education and training, for India Forest service and State Forest service probationers, as well as the Forest Ranger trainees at the Forest Colleges. It also forms a component of forestry, now being offered as one of the elective subjects, at various Universities in India. It is not only the forestry students but also the practising foresters as well who need to have clear ideas of the basic principles and their applicatiion in planned management of forests.

Definition and Scope :

Forest Management is defined in the Glossary of Technical and economic principal of forestry. The term is variously defined by different authors embodying in essence, the same essential ingredients. Some of these are -

(i) "**Forest Management** is that branch of forestry whose function is the organisation of a forest property for management and maintenance, by ordering in time and place the various operations necessary for the conservation; protection and improvement of the forest on the one hand, and the controlled hervesting 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'.

Forest Management by implication, is not a basic Subject in itself; it is the practical application of science, technology and economics to a forest estate for the achievement of certain objectives - mainly production of wood - timber and industrial raw material, and other forest products such as resin, gum, tanbark etc. It is based on the knowledge of a basic subjects/sciences, such as Silviculture, Ecology, Geology, Pedology, Botany, Mensuration, Pathology, Economics, Finance etc. In addition, it needs the practical experience of observations in the field, results of past treatments given to a forest and deductions thereform.

Management of forests braodly 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 objective of the owner. There decisions involves. in turn. a plan of action. Planning is the responsibility of the state Forest Policies. Detailed plants are prepard by the Forest Managers of 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 entensive : 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.

Distribution and Marketing of Produce :

(i) Transportations and communication.

(ii) Logging plan.

(iii) Marketing data.

(iv) Sale of produce.

(v) Revenue.

C. **Administration of Forest Property :**

(i) Forest Organisation.

(ii) Management of Personnel.

(iii) Monitoring and control of works.

(iv) Labour management and welfare.

(v) Financial control and economy efficiency.

(vi) Fulfilment of social obligations.

(vii) Record for present and future reference.

Principles of Forest Management - National Forest Policy :

Fundamental principle of sound management of any enterprise is the fulfilment of the owner's objectives to the maximum extent possible. In case of the state Forests. the objects are embodied in the National Forest Policy and the concerned state Forest Policy.

Forest Policy of 1894:

India'a first Forest Policy was enunciated in 1894, which laid down public benefit as the sole objective of management of public forests. The Policy suggested the maintenance of forests in hilly areas for preservation of climatic and physical conditions and for protection of cultivated land below in the plains from the devastating action of hill horrents. Even though some safeguards were provided. demand for culturable land was proposed to be ordinarily met by cleaning forest areas, thus giving preference to agriculture over forestry.

National Forest Policy 1952:

After attaining independence in 1947, it was felt that the revolutionary changes, which had taken place during the interval in the physical, economic and political fields called for reorientation of the old policy. Indian Republic formulated its first **National Forest Policy** in 1952. It retained the fundamental concepts underlying the old policy but considered the following paramount needs of the country in its formulation':

(i) Need for evolving a system of balanced and complimentry land use. under which each type of land would produce most and deteriorate least.

(ii) Need for checking denudation of mountanous regions, erosion along treeless banks of rivers and vast stretches of undulating waste-lands, invasion of sea-sands along coastal tracts and shifting sand dunes.

(iii) Need for establishing tree - lands wherever possible for the amelioration of physical and climatic condtions promoting the well-being of the people

(iv) Need for progressively increasing supplies of grazing, small-wood for agricultural implements, and particularly of firewood to release cattle-dung for manuring agricultural fields.

(v) Need for sustained supply of timber and other forest produce required for Defence. communications and Industry.

(vi) Need for realisation of maximum amount of revenue in perpetuity, consistent with the fulfilment of the needs enumerated above.

The Policy advocated a functional classification of India's Forests, apart from legal classification. to focus attention on the specific object of management in each case. into :

(a) Protection forests (ii) National forests (c) Village forests (d) Tree-lands.

The Policy also suggested to keep a minimum of one third of the country's total land area under forests, with 60% in the Himalayas and other hilly tracts laible to erosion and 20% in the plains. The Policy strongly deprecated the notice widely entertained that 'forestry' as such had not intrinsic right to the land but may be permitted on sufferance on residual land nor required for any other purpose.

Recommendation of National Commission of Agriculture (N.C.A.) 1976 :

The N.C.A. constituted in 1970, suggested the need for a revised Forest Policy, in their report of 1976.

The N.C.A. concluded that National Forest Policy should rest on two important points, viz.:

(i) Meeting the requirement of goods, i.e, industrial wood for forest based industries. Defence, communications and other public purposes and small t mber, fuelwood and fodder for rural community.

(ii) Satisfaction of the present and future demands for protective and recreational functions of the forests.

To meet these requirements, N.C.A. Suggested a revised Forest Policy. Revised National Forest Policy draft) recognises the following vital needs of Forest Management:

(i) for providing maximum goods and services for the public well-being and economic progress of the country.

(ii) Need for checking denudation and erosion in the mountainous region treeless river banks and waste lands.

(iii) Need for realising maximum productivity of the frorests to meet increasing requirement of industrial raw material, timber and other forest produce.

(iv) Providing small timber, firewood and grazing for rural population; however, indiscriminate and harmful grazing to be strictly controlled.

To fulfil these needs, the policy suggests that, on an average 33% of the land area should be dedicated to forest - comprising of 60% in the hills and 20% in the plains.

The policy clearly spells out the multiple purposes for which the forest will be managed, e.g. :

(i) **Environmental conservation:**

To manage and to provide for rehabilitation and improvement of forests for their protective influences-specially soil and water conservation. Forests purify the air we breathe temper climate, cushion the rain and storms, protect the soil from the ravages of floods and erosion and help in regulating stream flow.

(ii) **Production** : To meet the demands to existing and developing undustries and the national requirements of timber for Defence, comunication and domestic needs.

(iii) **Social:** To meet social needs to the community, consistant with other objects such as recreation, agriculture timber, fuelwood and regulated grazing for rural people.

States have been enjoined to regulate their policies on the lines of, and in consonance with, the above principle

Forest of Concurrent List:

Realising the importance of forest for the well-being of the nation, the Parliament. by the 42nd Amendment to the constitution in 1976, brought forests and wild life on the concurrent list in seventh schedule. This has enabled the central Govt. to play a more effective role, than a were advisory one in the management of forests. The president of India, promulgated the **Forest (conservation) Ordinance, 1930** which put severe restreictions on de-reservation of forests, or use of forest land for non-forest purpose without prior approval of the central Govt.

Instruments of Forest management :

Since forestry is a long term enterprise, it is necessary to record the plan of forest manangement in the form of a written document, for guidance of the forest manager in charge of the forest estate. This will not only save the management from the whims and idio-syncracies of individuals. provide summary of the results of past working and guidelines for future, but also serve as an instrument for execution of operations decided upon the achieve the desired objectives. A Working Plan of a forest is such an instrument which discusses and prescribes the management of a forest so as to realise the objects of management.

'Working plan' is a written scheme of management aiming at continuity of policy. controlling the treatment of a forest. A working plan is not is not only a plan of operations for the management of the forest but also a document of reference on all matters connected with the forests.

Objects of Management:

Primary object of good management is provision of the maximum benefit to the greatest number of people for all time(Brasnelt). This fundamental purpose is expressed in a similar way by knuchel as, "The

object of management under any circumstances is the most advantageous utilization possible of the soil alloted to forestry."

Object of management broadly express the basic purpose of the forestry enterprise rather than the production of a specific product. In the state-owned forests the management plant (Forest working Plans), irrespective of the location and forest type, invariably stipulate the following (or more or less so) general objects of management as applicable to the entire forest estate under the specific plan, thereby providing a broad frame work for management.

(i) Maintaining and, as far as possible, raising the productive capacity to the soil and of the forest stands consistent with the maximum site potential.

(ii) Promoting the protective effect of the forest, against soil erosion, avalanches, floods and protect on of the physical factors, such as natural scenery, local flora and fauna.

(iii) Execution of Silviculture operations and regulation of felling in such a way so as to bring the forest to a condition of as near normality as possible; in simple words, attainment of a normal forest is one of the principle objects.

(iv) Satisfaction of rights of the right holders in respect of timber, firewood, grazing etc, in particular and to meet the bonafide requirement of the local population of general.

(v) Subject to the above Silviculture, conservational and social considerations, providing the maximum possible volume of valuable timber for constructional and industrial purposes, and other forest produce for meeting the market demands and securing the highest possible financial results.

Special Objects of Management:

Whereas the general objects of management provide the framework for the entire forest estate under a management plan, special objects may be laid down for different regions/ Locations, with different site factors and forest types, more suited for specific purposes. Accordingly our Working Plans invariably specify general objects for the entire Working Plan area and in Addition, special objects of management of each working circle, which is characterised by a district vegetation type, more suited for certain purpose as compared to others. In short, priorities of objects are re-arranged. Some examples are given below

(i) Badly eroded area and steep hill slopes may be constituted into a Protection Working Circle, whereas the special object will be protection, afforestation, soil and water conservation, satisfaction of only the minimum social needs of the local population, ignoring consideration for market supplies and financial returns.

(ii) In the watershed of municipal water supplies, irigation and hydro-electric generation dams the

special obj- ive being the maintanance of an undisturbed protective vegetative cover. all other forms of use must be subordinated to it.

(iii) In forest areas of natural scenic beauty wood lands near urban habitation. recreation often being the dominate object. timber felling, garzing and even hunting will have to be entirely stopped. Such forests serve as "magnificient playgrounds for tired mankind seeking peace and spiritual strenght"

(iv) Mixed miscellaneous open forests, heavily grazed and felled in the past. with low proportion of valuable timber and indus trially important species are celarfelled and converted into plantation of desired species - pure or simple compatible mixture. Such area have extensively been constituted into plantation working circle and/ or Industrial Timber working circles in plains and terai areas of U.P. and West Bengal, Bihar, Orissa, with a view to meeting increasing demand for industrial raw material for pulp, match an dplywood industries.

In chir-pine forests, one of the special object is invariably the production of resin for resin and turpentine industries.

In dry and moist mixed deciduous forests, containing quantities of khair and semal, one of the special objects will be to ensure their reproduction and increase their proportion to feed cutch/ketha and Match industries.

CHAPTER - II

Sustained Yield

Introduction - Definition :

The principle of **Maximum Sustain of Yield has been the back bone 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 definied variously as :

(i) 'The material that a forest can yield annually (or periodically) in perpetuily.' (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 produce from a forest which is managed in such a way as to permit the removal of a approximately equal volume or quantity of timeber or other forest produce annually or periodically in perpetuity".

Periodic Yield is also considered as **sustained**, provided the period is short.

Principle of Sustained Yield Management :

Yield signifies the flow of forest products, measured in terms of either voluem or value units, harvested from a forest at a particular time. The yield from the forest includes all the forest products, the tangible and the intangible, including protective, amenity, timber and non-timber products. The principle of sustained Yield ensures stability and continuous supply of raw material to the industries and to meet the social and domestic needs of the people.

Concept of Sustained Yield has been avolved from the basic consideration that the later generations may desire 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 organised forestry.

The principle Sustained Yield envisage, that a forest should be so expolited that the annual or periodic felling 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 growing stock and distribution of age classes.

Sustained Yield management as the term is the term is most accurately and commonly employed, means continuity of harvest indefinitely, without impairment of the productivity of the soil.

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 (say 10 years, for illustration) and remove the 10 years old wood annually, and plant up the area again. This nature wood represent the increment on the whole forest and the difficulty of removing the annual increment.

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. The establishment of such a series of age gradatio is, as illustrated above, is one form of crop necessary for **Sustained Yield Management** and for maintaining it in perpetuity. Such a forest provides a conceptual picture of a theoretical Normal Forest. The ideal of a normal forest is a logical corollary to the principle of **Sustained Yield** in perpetuity.

Arrangement of crop as described above is a simple form of management which would enable us to remove the old crop, 10 years with 500m^3 volume per hectare (as in **clear-felling and coppice system**).

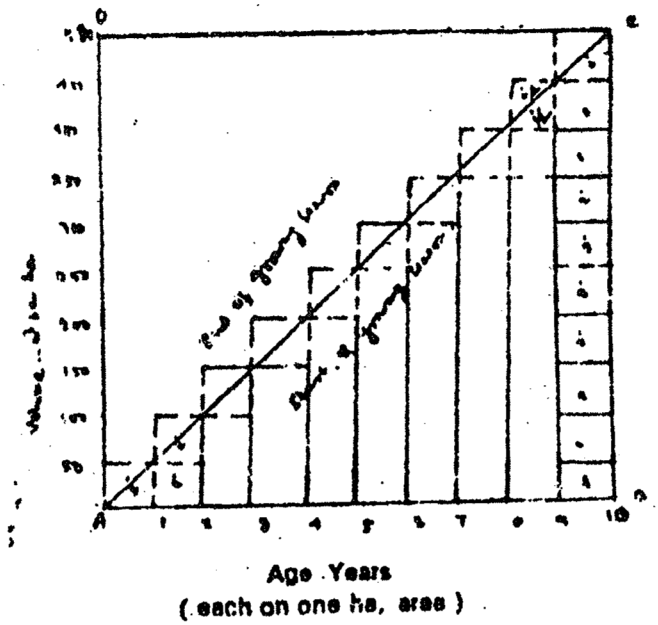


Fig 1 : Theoritical Normal Growing stock in a series of R (10) equal Age graduations (one hectare each) from each unit area, say one hectare, is overcome by removing accumulated production of 10 hectare on 1/ 10 th part of the total area, as illustrated in Fig. 1. Such a series of trees or crops of all ages, from seedling to maturity, so as to enable the removal of the oldest is knows as a **Complete series, of age-gradation.**

Argument for an against Sustained Yield Principle :

In case of State Forests, of the **advantages are** -

(i) It facilitates budgeting and regulation of taxation, ensures a steady income of the state. However. sustained volume yield does not necessarily mean sustained revenue as well, due to fluctuations in price;

(ii) Local labour is always fully employed; by constant employment it is possible to establish permanent skilled labour force.

(iii) Persons employed on felling conversion and transport have an assured and steady permanent employment. It results in regular demand and a fair competition among the purchasers.

(iv) Wood-using industries have an assured continuous supply of row materiai and the local people

sustained supplies of wood for their domestic and agricultural needs.

(v) markets can be developed and their confidence gained with sustained supplies.

Some of the arguments against the **principle of Sustained Yield** may be summarised as follows -

(i) Sustained Yield management treats timber production as only a biological function rather than a response to economic demand.

(ii) It ignores the cost involved in producing a fixed quantity, i.e. production is carried on irrespective of price fluctuations resulting in inefficient resource management.

(iii) Fixed supply is not only economically inefficient but also ignores the possibility of changes taking place in the use of forest products, due to change in technology and Social values.

(iv) Such a rigid (inflexible) policy is not suitable for a dynamic or growing economy.

(v) In practice, Sustained Yield has merely been an ideal, wide fluctuations are quite commones.

(vi) The application of Sustained Yield is be set with the serious difficulty of fore-seesing the future trends of timber and forest product requirement.

(vii) There are two economic objections also to the principle of Sustained Yield. Firstly, regulated annual Yields pervgent an increase of felling and sales during the time of high prices, or a reduction for low prices. There is no modification of fellings to suit demand; consequently, not only does the owner suffer but high prices tend to rise still higher and low prices to fall still more.

Secondly, for **Sustained Yield Management** the forest must conform to an ideal of a normal forest. To mould the forest into a normal one, it will involve the sacrifice of crop either before or after the financially more advantageous time.

Concept of Progressive Yield:

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, a 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 maximise productive enterprises through technological efficiency.

The principle of **Progressive Yield** as against the Sustained Yield was discussed at the VI Indian Silvicultural conference held in Dehradun in 1939 and the III world Forestry conference held in Helsinki in 1948 and adopted. some foresters consider that the principle of **Progressive Yield** is embodied in the principle of **Sustained Yield** Foresters, who advocate the principle of Progressive Yield, mention that while the principle of **Progressive Yield is a dynamic** one the one of Sustained Yield aiming at the Same Yield in perpetuity is State.

The new principle expresses the dynamic character of a wise forest administration, which must take into account both the increasing requirement of wood in a progressive country and the gradual improvement in the productive capacity of a forest under improved silvicultural techniques.

CHAPTER - III

ROTATION OF PRODUCTION PERIDO

Introduction - Defi. ition :

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 harvested at the same times their period of maturity is easily determined. However it is not so in case of forest crops. The main forest production, 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 steap size/ prize gradient and the price per unit volume rises sharply with the size of trees. Trees should be harvested after they have reached utilizable size, and before their timber quality starts deterorating. 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 consideration such as protective, recreational and scenic values may also come into the picture. Object of management is the main consideration in this respect.

The period which a forest crop takes between its formati and final felling is knows as **Rotation or Production Period.** This term is also defined in various other ways by different authrs; some of these definitions are given below:-

(i) "The planned number of years 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 forlling" (Glossary).

(ii) "The number of years fixed by the Working Plan between the formations or regeneration and the final felling of a crop" (Brasnet)

(iii) 'Rotation age is the age of trees or crops at which when they are felled, object of management for the time being are best Served". (Kunchel).

(iv) 'Rotation or Production Period is the interval of time between the formation of a yound crop by seeding planting or other means and its final harvesting" (Osmaston).

(v) "Rotation is the time interval between successive crop regeneration" (B.R. Johnston et al).

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 in regular forests in general, entire crops of trees of a sizeable area are felled data time (as in clear - felling) 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 **unevenaged (irregular) Selection forests,** trees are selected individually on their of felling, depending on:-

(i) Qualities of size, vigour and suitability for markets.

(ii) Adjustment of proportion of different sizes.

(iii) silvicultureal principle, 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.

So, in this case, one could say that its rotation period is equal to that of the average age of the exploitable size removed - the **exploitable age,** at which they attain the size required to fulfil the objects of management.

Therefore, in selection irregular forests, concepts of Rotation assumes by and large, only an academic importance for accounting purposes. Here, 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. Correct term expressive of maturity in selection forests is as stated above, exploitable (or utilizable)

age or size.

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 recognised in forestry are ;-

1. Physical Rotation.
2. Silvicultural Rotation.
3. Technical Rotation.
4. Rotation of Maximum Volume Production.
5. Rotation of Highest Income.
6. Financial Rotation.

1. Physical Rotation :

It is the rotation which coincides with the natural lease of life of a species or a given site.

The natural life span (longevity) of trees varies greatly with species and the site factors. This rotation is applicable only in the case of protection and amenity forests, park lands, and in some cases 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 reproductions 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.

3. **Technical Rotation :**

It is the rotation under which a species yields the maximum meterial 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.

Technical Rotation is adopted, particularly, by industrial firms which own forests/ plantations for the purpose of supplying raw materials for their plants (e.g west coast Paper Mills, WIMCO match factory etc.)

4. **Rotation of Maximum Volume Production:**

It is the rotation that yields the maximum annual quantity of material, e.g. the age at which the Mean Annual Increment (M.A.I.) culminates. The M.A.I. referred to is that of the stand (as from the Yield Table) 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. curres.

This rotation yields largest volume per unit area, per annum and is important rotation which is adopted frequently as such, or in combination with some other rotation (e.g. Technical Rotation).

If rotation is or final yield Yr. and volumes of thinning at various ages Va, Vb, Vc, etc. then the age at which:

$$\text{M.A.I.} = \frac{Yr + \Sigma v}{r}$$ is the maximum, is the **Rotation of Maximum Volume Production.**

This rotation is particularly suitable for adoption where the total quantity of wood material is important and not the size and specification e.g. firewood, raw material for paper pulp, fibre board and particle board industries based on disintegration processes of wood.

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 over all 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.

The average net annual revenue or rental obtained from a stand of trees is expressed by the formula:-

$$\text{Mean annual net revenue per unit area} = Yr - \frac{\Sigma Tr}{R} - C - \Sigma e$$

Where Yr = Value of final felling (final yield) per unit area.

Tr = Value of all thinnings during rotation period R, per unit area.

C = Cost of formation of stand, per unit area.

e = Annual cost of administration / maintenance, per unit area.

R = Rotation (years).

The rotation at which the net revenue as calculated above is maximum, is the **Rotation of Highest Revenue / Income (Rental).**

6. Financial (or Economic) Rotation :

It is the rotation which yields the highest net return on the invested capital.

It differes 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 (Brasnett).

There are several methods of determining the Financial Rotation, but as there are no agreed criteria for assessment of profit, they do not give the same result. The two prominent methods, however may be summarised as :-

(a) Based on Soil Expection Value (se) of the land. i.e. value based on the net income which it is expected to Yield and calculated at selected rate of interest at different rotation - Faustmann's Formula.

(b) Based on the tinancial Yield. i.e. the rate of interest or Mean Annaul Forest Percent (M.A.F.%) which the forest enterprise Yields on investment. M.A.F% is merely a financial equivalent of M.A.I. and used the same way as M.A.I. is used to determine rotation of maximum volume production.

Soil Expectation Value (se) :

"If a piece of land is expected to provide a continual net income of X rupees yearly, then 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), which is expressed by the formula -

$$Se = \frac{X}{0.0\,p}$$, where

P = rate of interest, percent $\left(\text{because } X = Se \times \frac{P}{100} \text{ or } Se. = \frac{X}{100}\right)$

But if the land produces income periodically, instead of yearly, such as coppice forest, the present discounted value of that return = $Yr/(1.0p^{r-1})$, where Yr is the net periodice income every 4th year for ever. Consequently a formula can be derived to calculate the expectation value of land by discounting to the present all fore-casted future net incomes, whether collected yearly or at regular intervals and subtracting from the sum the discounted fore-casted future expenses calculated in the same way. Such a formula, known as **Faustman's Formula**, is as :

$$Se = \frac{Yr + Ta.1.0p^{r-a} + \ldots Tq1.0p^{r-q} - C.1.0p^{r}}{1.0p^{r} - 1} - E$$

Where Yr is net value of final felling made in the year r at the end of rotation.

Ta ... Tq are the net values of the several thinning made in the years r - a ..., r-q;

C is the cost of raising the plantation at the beginning of the rotation.

p is the selected rate or interest and

E = e/0.0P, where e= the sum of all annual expenses.

Choice of the Type / kind of Rotation

For considering the choice of most suitable rotations under different social silvicultural and economic conditions. the different types of rotation 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 Rotations.**

(ii) Rotations controlling the out of materials forest products in form or quantity - i.e. the **Technical and** Maximum Volume Rotation.

(iii) Rotations controlling the financial returns, i.e. the **Rotation of Maximum Gross or net Income and the Financial Rotation.**

However, before making a choice of a suitable rotation, a forester has to carefully consider the followings -

(i) Objects of management.

(ii) The Market demands and / or national requirements.

(iii) Rate of growth of the species.

(iv) Silvicultural characteristics of the species.

(v) Productivity of the site.

(vi) Financial and economic aspects.

(vii) Socio-economic policy of the state (Labour conditions employment etc.)

(ix) Natural factors like climate, and diseares etc.

Where the objects are commercial, the rotation adopted is a compromise between Silvicultural and **Technical Rotation,** tempered by some economic considerations and financial test.

Procedure to Determine the Rotation:

1. Determine the size of timber to be produced with respect to market demand.
2. Determine the age of the crop corresponding to the size of the timber (from Yield Table corresponding to different site quality).
3. Examine the age of Maximum volume production.
4. Examine the Silvicultural age (upto what age, the crop become healthy).

5. Determine the rotation of Maximum Net Income by consulting Money Yield Table.

6. Determine Mean Annual Forest Percent to work out Financial Yield.

7. Strike a balance (become you have got a no. of years. corresponding to different rotation) and give weightage to the first preference and determine the rotational age.

CHAPTER - IV

THE NORMAL FOREST

[Points : Introduction, Defination, Basic factors (Attributes/ Characteristics) of Normality, Need for an ideal standar, De Liocourt's Law, Conclusion]

Introducion - Definition :

A **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 purpose of Sustained Yield **Management**. On a given site, and for a given object of management, it is a 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 realised indefinitely, without endangering future yield and without detriment to the site. In forestry, concept of **Normal Forest** enrisages an ideal site of perfection sarving the purpose of good scientificd 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 content of forestry.

Normal Forest is thus. a conception of forest management based on th principle of **Sustained Yield.** It was evolved in early 19th century by German Foresters. The term is variously described or defined as-

(1) "A forest which has (a) a normal series of age gradations or age classes, (b) a normal increment, and cons quently, (c) a normal growing stock, is termed 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". (Darcy).

(2) "A normal forest is an ideally constituted forest with such volume of trees of various ages so distributed and growing in such a way that they produce equal annual volumes of produce which can be removed continuously without detriment to future production." (Brasnett).

Basic Factors (Attributes / Characteristics) of Normality :

The above definitions stipulate the presence of three main attributes of an ideal forest managed for sustained yield in perpetuity (called **Normal Forest**) :-

(i) A normal series of age gradations or age classes.

(ii) A normal increment.

(iii) A normal groowing 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 seperate areas, they constitute a series of **age - gradations.** When trees falling within certain age 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 the sign of normality is the proper distribution of all ages.

Normal Increment in the best or maximum increment attainable by a given and for a given rotation, per unit area on o glven site. An abnormal increment may be caused by faulty formation, foulty treatment injurious external incluences and aly unequal distribution of age classes.

Normal Growing Stock is thevolume of stands in a forest with normal age classes and a normal increment. In practice, this is taken to be the volume indicated in Yield Tables for each age-class.

The easiest way to visualise the conception of a Normal Forest (a fully-regulated forest) is to consider it as a series of even - aged plantations of equal area, each of one age gradation, worked under clear - felling or coppice system as illustrated in Fig. 1. A plantation of one hectare was planted every year for ten years (rotation age). There are, therefore, ten age gradations to equal size. constituting a **normal series** of age gradations, of which one is assumed to be ripe for harvesting every year (the annual Coupe). At the end of tenth year, the plantation planted first of all is cut and regenerated by **coppice** natural seeding, sowing or **planting.** At the end of next year, this regenerated coupe becomes one year old age-gradation; the series is **complete again** and the oldest plantation (coupe) is now ten years old and due for felling. This arrangement is shown in Fig. 1, where the age gradation areas are shown along the base-line AB, with the theoritical volumes standing on each, assuming hypothetically (though not correctly) that each hectare of plantation lays or an equal volume of wood in each year of its life.

In the diagram, ten-years old plantation has grown $500m^3$ volume of wood so that M.A.I. at that age $= 500/10 = 500m^3$, and this is shown as the volume on the one year old hectare as I. The volume on the two year old hectare is shown as zi and so on, upto the volume of rotation (r) year old hectare as r x i (or 1 to i) in which r, the rotation, is shown as 10 years in the diagram. This r x i, which is the volume standing on the

oldest age gradation at the end of r years (in this case, Fig. 1 50x10 = 500m^3), is also the sum of M.A. is of all the r (10) age gradations and may be called 1 to represent the increment of the whole series. Therefoe, by felling the rotation age hectare each year, the normal increment of this normal series for that rotation i.e. 500m^3 is being felled. Taking a general case. If a hectare is the area of the Felling series, r the rotation annual felling coupe in such e forest would be A r he (rotation - age coupe); cleanings and thinnings, if any, are provided in other age-gradations. Each operations will be done on A r ua area.

An area operated on such a basis, with all age-classes represented and with uniform conditions of increment and stocking is a **fully regulated forest or a Normal Forest.**

Need for an Ideal Standard :

As state already, a normal forest is an ideal model after which we aim to mould our forest. Attainign 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 can not be maintained in that condition for long. This is however, not to suggest that the ideal condition of wormality should not be the aim under the apprehension of its likely failure at some stages. Such an attitude would not only be defeatist but will also leave 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.

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 refeired 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 compositions.** This seried is represented by the geometrical progression:

$$a, aq^{-1}, aq^{-2}, aq^{-3} \ldots aq^{-(n-1)}$$

Where a = number of stems in the lowest dia class.

q = co-efficient of reduction in the number of stems : the quotient.

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.

k = relative stand density which is dependent on site conditions.

e = 2.71828. the base of Napierian Logarithms.

By plotting the logs numbers of stems agienst their middia meter valves on an ordinary grapn paper, if the resulting points are in a straight line, it would indicate a balanced crop. The abnormality in number any diaclass can be readily detercted, and silvicultural treatment can be given to obtain ideal distribution in coure of time. For example, if there is preporderance of smaller trees mid-sized or large-sized trees, the positions can be rectified by thinnings, heavy thinnings or regeneration felling respectively.

Conclusion :

Concepts of an ideal forest - a **Normal Forest** - and that of Sustained Yield Management, the aims of good management, from the basis of sccientific management of forests all over the world. "Trinitp of norms" viz. the normal distribution of age-gradations/classes, normal volume of the growing stock and normal increment determine the normality or otherwise, of a given forest-whether regular or irregular; in the former case it can be easily assessed but not so in the latter case. In a Selection Forest, the test of normality is the presence of various age/size classes in balanced proportion. This calls for enumeration data and the stand Taldes applicable to the site and component species.

CHAPTER - V

THE GROWING STOCK

General Concept - Definition :

Growing stock (GS) in a forest is the forest capital; the other basic factor of this capital being the forest soil. It is however, ultimately, the G.S. which gives the return (yield), which is the aim of every enterprise. It represents the investment of the owner from which he receives the income. Ordinarily, any increase or decrease in the capital (G.S.), is immediately reflected in the income (increment/yield). Just as in a business enterprise, the investment may be over - capitalised, normally-capitalised or under-capitalised, in forestry enterprise also the G.S. (capital) may be over - stocked, normally stocked or under sotcked. An overmature and or very densely stocked crop may have an excess G.S. to the extent that it is over-crowded, and not only increment is retarded but even the excess G.S. may also gradually be lost by decay.

Growing Stock (G.S.) is defined as : "The sum (by numbers or volume) of all the trees trees growing

in the forest, or a specified past of it". (Glossary).

Normal Growing Stock (N.G.S.) is defined as : "The total volume of trees in a fully stocked forest with normal distribution of age-classes for a given rotation". (Glossary).

Determination of Actual Growing Stock :

Measurement of volume of single trees and crops forms a part of the subject of Forest Measuration. These may be determined by any of the following methods and with the help of Volume Tables.

(i) By Total or **Complete Enumeration:**

Seldom practicable over large forest asecs; practised only in very valuable forests limited extent.

(ii) By Partial or Sample Enumeration:

Statiscally acceptable methods are adopted for the purpose. This gives results which are reasonably accurate for the purpose.

(iii) **By Sample Plot Measurement :**

In selected representative areas of the crop.

For preparation of inventories of large forest areas, of late. **Aerial Photography** is being increasingly used. There methods have been exclusively adopted by the Directorate of Forest Resources of India for estimation of G.S. in Various regions of the country.

Determination of Normal Growing Stock :

Normal Growing stock (N.G.S.) of forests worked under various representative Silvicultural systems may be determines as follows:

(A) N.G.S. in Clear Felling System :

(a) Based on Final M.A.I.

The simplest example may be taken of a firewood Eucalyptus plantation of ten hectares, one hectare of which has been planted annualy for ten years - the proposed rotation period, as has been illustrated in Fig. 1.

As per that example, it each years growth in each plantation is represented by i, the volume of each are gradation starting from one year old, will be i, 2i, 3i, ... 9i and 10i as illustrated in the diagram. The volume of 10 year old gradation on one hectare area has grown $500m^3$, so the final M.A.I. at this rotation age = $500/10=60m^3$, and this is shown as the volume or one-year old hectare as i.

The volume rxi standing on the oldest age-gradation at the end of r years (in this case, 10 x 50 = 500m^3) is also the sum of the M.A.I.s of all the r(10) age-gradations, and may be termed as I to represent the increment of the whole series.

Then Total G.S. or r age-gradations one to r year old, is the sum of the series.

i, 2i, 3i ..... (r-I), i, ri, in arithmetical progression, at the end of the growing season and before the oldest r year old, plantation is felled.

$$\text{The sum is} = \frac{(i+ri)}{2} xr = \frac{ri}{2} + \frac{r}{2}(r \times i)$$

Substituting I for ri, it is

$\frac{I\,r}{2} + \frac{I}{2}$ So, this is the formula for calculating N.G.S. before havesting, i.e. atthe end of growing season.

Similarly, with the removal of oldest plantaion (Volume = rxi=I), the increment I of the whole series is removed and the volume at the beginning of the next growing season will be

$$\frac{I}{2} + \frac{Ir}{2} - I$$

$\frac{I+Ir-2I}{2} = \frac{Ir-I}{2} = \frac{Ir}{2} - \frac{I}{2}$ This formula is used for calculating the N.G.S. after harvesting and at the beginning of the growing season.

Now, the volume of the N.G.S. in the middle of the growing season is the average of two values ie.

$$\frac{\frac{Ir}{2} + \frac{I}{2} + \frac{Ir}{2} - \frac{I}{2}}{2} = \frac{\frac{2Ir}{2}}{2} = \frac{Ir}{2}$$

For all practical purposes, the mid season formula is generally used.

Applying the above formulas to the particular case of Eucalyptus plantation, worked on 10 years rotation on 10ha area, one ha, under each gradation, the volume of 10-year gradation being 500m^3, the N.G.S. will be :

(a) $I \times \frac{r}{2} = 500 \times \frac{10}{2} = 2500m^3$ at the middle of growing Season.

(b) $\left(1 \times \frac{r}{2}\right) + \frac{I}{2} = 2500 + \frac{500}{2} = 2750 m^3$ at the end of the growing season.

(c) $\left(I \times \frac{r}{2}\right) - \frac{I}{2} = 2500 - \frac{500}{2} = 2250 m^3$ at the beginning of the growing season.

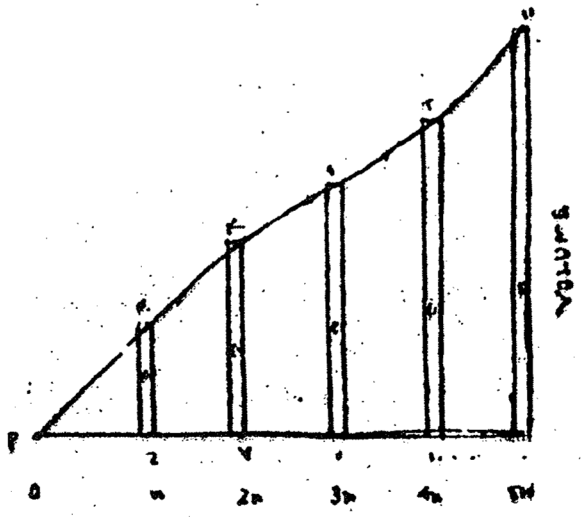
This N.G.S. at the mid season, i.e. $2500 m^3$, is standing or r ha area; so the average N.G.S. per ha in this case is = $\frac{2500}{10} = 250 m^3$

If in the diagram (Fig : 1), we substitute age class of 10 years for age-gradations, it will represent a normal series of age-calsses, of, say, for teak crop, 1-10, 11-20, 21-30, ... 91-100 old for a 100 year rotation.

The sum of age - gradations/ classes in a forest is then the G.S. of the forest; the sum of the normal such series is the N.G.S.

(b) Calculation of N.G.S. from Yield Table :

If a Yield Table gives data for intervals of one year that is. it gives the volume of each age-gradation. the G.S. volume can be readily calculated by adding up the volumes of successive years. But the Yield Tables usually give data for intervals of five or ten years. In such cases. the volume of N.G.S. can be acurately determined by plotting the Yield table data on a graph paper, drawing a smooth cure and computing the area below the curve either by a planimeter, area - square or by counting the squares.



AGE (Years)

Assume a Yield Table showing only 5 entries at intervals of n years (as in the above cases) : the volumes in the years n, 2n. 3n. 4n and 5n being A, B. C, D and E as shown by rectanges in Fig. 2. The volumes are plotted against age and a smooth curve PORSTU drawn through the plotted points. Total volume of mid season or Summer N.G.S. for the rotation r=5n or r hectares, will be the area below the curve i.e. area PQRSTUVWXYZP.

PQZ + trapeziums (QZYR + RYXR + SXWP+TWVU)

[Note : Segments PQ, QR, RS, ST and TU of the curve may be assumed to be straight line]

$$\text{N.G.S.} = \frac{1}{2}x^{n\times A} + \frac{A+B}{2}x^{n} + \frac{B+C}{2}x^{n} + \frac{C+D}{2}x^{n} + \frac{D+E}{2}x^{n}.$$

$$= \frac{An}{2} + \frac{An}{2} + \frac{Bn}{2} + \frac{Bn}{2} + \frac{Cn}{2} + \frac{Cn}{2} + \frac{Dn}{2} + \frac{Dn}{2} + \frac{En}{2}$$

$$= \frac{n}{2}(2A + 2B + 2C + 2D + E)$$

$$= n\left(A + B + C + D + \frac{E}{2}\right)$$

For the sake of convenience only five values have been taken in the above example; if the rotation is r years, n the yield table interval and Vn, V2n, V3n, ...Vr-n and Vr the volume at ages n, 2n, 3nn ..... r-n and r years, then the general formula can be written as -

$$\text{N.G.S.} = n\left(V_n + V_{2n} + V_{3n} + V_{r-n} + \frac{Vr}{2}\right) \text{ over r units of area (acres hectares)}$$

N.G.S. at the end of growing season (Autumn N.G.S) and at the beginning of growing season (spring N.G.S. with Similarly be :

$$n\left(A+B+C+D+\frac{E}{2}\right)+\frac{E}{2} \text{ and } n\left(A+B+C+D+\frac{E}{2}\right)-\frac{E}{2} \text{ respectively.}$$

Example :

Calculate the average N.G.S. per hectare in a teak plantation of site Quality - II, worked on a rotation of 40 years to which the following Yield Table figures apply.

Age (Years)	Final (stem timber m^3)	Age (Years)	Final (stem timber; m^3)
5	-	25	51.43
10	0.70	30	73.82
15	8.40	35	94.81
25	27.99	40	114.75

Solution :

(i) By M.A.I. formula N.G.S. on 40 ha = $1 \times \frac{r}{2} = 114.75 \times \frac{40}{2}$

or average N.G.S. per ha = $114.75 \times \frac{40}{3} \times \frac{1}{40} = 57.38 m^3$

(ii) By Y.T. formula, N.G.S. on 40 ha = $n\left(A + B + C + D + \frac{E}{2}\right)$

$$= \left(0 + 0.70 + 8.40 + 27.99 + 51.43 + 73.82 + 94.81 + \frac{114.75}{2}\right) = 5 \times 314.53 m^3$$

$$\text{or average N.G.S. per ha} = \frac{5 \times 314.53}{40} = 39.31 m^3$$

It is seen in this case the N.G.S. calculated by M.A.I. is greater than that calculated from Yield Tables for 40 yr. rotation. Here, the difference is because, if we put the Yield Table data in graph, we will not get direct straight line. However Yield Table method is reliable method than M.A.I. method.

Comparison of Real and Theoretical N.G.S. - Flury's Constant:

As the G.S. obtained from the Yield Table (reas N.G.S.) is more accurate than that obtained from the M.A.I. formula (theoretical N.G.S.), the former is ordinarily the method employed for its determination. since the Yield Tables are not always available, it has led many foresters to find some modification to the more convenient M.A.I. formula, which would allow for varying conditions under different systems of management. Amongst them, FLURY (Swiss Forest Service) is the more prominent. He suggested that in the mid-season formula G.S. = $^1/2$ x I/r a variable constant 'C' (different for each rotation) should be substituted for '1/2' to obtain more correct result; and the formual would read, G.S. = l x r x c, where in, 'C' is known as **Flury's Constant.**

Flury actually calculated values of "C' at various ages to substitute for "a/2" in the formula, for various species. various rotations and varying sets of growing conditions.

From experiment it has been seen that the value of "C" will be less than "1 '2" for short rotations and more than "1/2" for long rotations.

Determination of Flury's Constant 'C'

We shall take up the numerical Example (discussed in previous pages) in whcih N.G.S. real and theoretical, was determined by Yield Table and M.A.I., formula methods. Since the Yield Table method is the more accurate method, we shall equate M.A.I. formula results with variable "C" to the Yield Table method results and find the value of variable "C".

Example :

From example given in previous page, the real/ correct N.G.S. by Yield Table Method - 39,31m^3/ ha By M.A.I. formula this is = 1 x rx c over r/ha.

or l x c per ha, where 1 - 114.75m^3

$$\frac{1xrxc}{r} = 39.31 m^3 / ha$$

. or $114.75 \times C = 39.31$

$$C = \frac{39.31}{114.75} = 0.34$$

Relation Between G.S and Yield:

A complete picture of the N.G.S. at the end of the first rotation is given in Gig. 1. The 10 years old crop will be felled at the beginning of the next rotation and will be immediately regenerated by planting or coppice. Similarly, every plantation will reach maturity and in its turn, felled to give annual Yield. Thus the G.S. removed during a rotation period of r years will be :

I (annual coupe / Yield) x r (rotation) 1 x r as represented by rectangle ABCD, which is twice the tringle ABC, the N.G.S. tringle. Thus, during a rotation the Yield is twice the existing G.S. the other half coming from the increment put on by the G.S. during the interval (rotations); in other words. during a rotation, half the Yield is provided by existing G.S and the other half the increment occuring during the rotation is used in this way, the other half goes to form the G.S. of the next rotation.

In this way although the volume equal to the increment inly is felled during the rotation (ixr) and

this is what it should be, it is composed of the G.S. received from the previous rotation and this loan is repaid to the next rotation.

CHAPTER - VI

YIELD REGULATION - METHODS AND APPLICATIONS

[Points : Principles - Objects - Definitions, Basis of Yield regulation, Yield regulation in regular forests - Yield regulation in clear felling system - Annual coupe by gross area. Annual coupe by reduced area, Yield regulation in Regular shelterwood system - Yield based or Area allotment by periods. Hafnag's variation or modification, Yield based on volume of growing stock - Von Mentel's formula, Yield regulation in Irregular forests - brandis Diameter class method or the Indian Method - Smythies sate guarding formula].

Principles - Objects - Denition :

The management of forests for production and supply of wood, requires continuous (or periodic) cutting of individual trees or crops of trees. The chief object of Forest Management, may, therefore, be stated as the regulation of this production and supply, i.e. the Yield. Before it can be regulated. it has to be determined or calculated.

Yield Regulation, therefore, involves two seperate functions, viz. :

i) Calculation/ determination of what the amount of Yield should be.

ii) the construction of a cutting (felling) plan which determines the identity of the stands to be cut.

Broadly, Yield regulation is the estimation of what the French call, possibility, i.e. the productive capacity of an area, deciding as to how much of this could be removed how much re-invested in the wood capital of the area, or how much ofthe excess (from normal) wood capital could be removed in addition and how much and from what portion of the growing stock of felling should be made.

In a normal forest the entire annual increment could be removed each year, and the same capital would always be left undisturbed, of the growing stock is not normal, but consists of young trees only, obviously the wood capital is too small and the increment must be left un-cut to built it up. If the bulk of the growing stock is old there will be excess of wood capital and the rate of increment will be low. The capital will have to be reduced by cutting more than the increment to made room for young trees. In the production forest, the object of management is usually to obtain a fairly stready Yield, while aiming to bring it to a condition so as to give maximum sustained Yield from the wood capital invested in the soil.

Yield Regulation:

"A term generally applied to the determination of the Yield and the prescribed means of realising it". It means the fining in advance usually for a short period - the Working Plan period - the amount of timber or other produce which may be removed from the forest, annually or periodically.

The objects of regulation Yield, in short, are -

(i) to cut each crop or tree at maturity.

(ii) to obtain maximum Yield of the desired produce.

(iii) to cut, approximately, the same quantity of material annually or periodically.

and (iv) to limit the area to be felled to that which can be regenerated.

The achievement of the above objects is quite easy in the second and subsequent rotations by which times the forests are, more or less, converted/ regulated, in the first rotation of scientific forest management the first and second objective are difficult to achieve and some compromise has to be made. The aims and objects should, however, remain the same.

In the first rotation difficulty aries due to -

(i) In virgin forests, crops are generally over mature and decrepit, necessitating early removal; regeneration conditions therein are also not favourable.

(ii) The crops are usually irregular both in density and composition.

(iii) Growth and composition data are not available for quite a few decades. In case of even aged systems the Yield is regulated by area in the first rotation, so as to build up equal age gradation/ classes for sustained Yield in subsequent rotations rather equlaising Yield in the cument rotation.

Basis of Yield Regulation:

In general, there is no recognised correlation between a method of **Yield Regulation** and a **Silvicultural** system. Several methods of regulation liave been applied to crops ans Systems other than those for which there were originally evolved. It would be more appropriate to classify them according to their underlying basic principles.

The Yield can broadly, be prescribed in three ways. viz by area, by volume or by area and volume combined. In case of Yield by area the entire area, irrespective of the growing stock forms the basis of calculation. In case of Yield by volume, the volume of growing stock (either whole or past thereof), the increment or both volume of growing stock and its increments, may form the basis. There are a new of methods of Yield calculation which can be classified as follows -

Basis	Method
A. Area only	A_1 - Annual coupe by gross area A_2 - Annual coupe by reduced area.
B. Volume only (Growing Stock volume)	B_1 - von Mantel's Formula B_2 - Howard's modification B_3 - Simmon's modification B_4 - Smythies modification B_5 - Burmor modification.
C. Area and Volume	C_1 - Permanent P.B. method; allotment by - (i) equalising area (ii) equalising volume; hartig's method. (iii) equalising area and volume. C_2 - Revocaple P.B. method. C_3 - Single P.B. method. C_4 - Floating P.B. method. C_5 - JUDEICH'S Stand Selection (Management, Method).
D. Increment	D_1 - Increment Method D_2 - Swiss Method. D_3 - Biolley's "Cheek Method".
E. Volume and increment of whole Growing stock	E_1 - Formula Methods (composition of actual and normal G.S.) (i) Austrian (iii) Heyer's (iii) Karl's (iv) Hundeshagen's (v) Breymann's E_2 - Hufnagl's Method.
(Dia classes)	E_3 - (i) French Method of 1883 (ii) 1894 Modification or Melard's Method (Regeneration Area Method)

(iii) Symthes Modification

(iv) Chafurvedi's Modification.

E_4 - Hufnagl's Diameter class Method.

E_5 - Brandis diameter class Method.
(or or the Indian Method).

(No. of trees)

E - Volume Unit Method.

F_7^6 - Symthies' Safe-guarding Formula
(Or U.P. Safe - gurarding formula)

Of the above methods, B_2, B_3, B_4, E_5 and E_7 are purely of Indian origin; these were evolved to deal with special situations and problems of forest management in India.

YIELD REGULATION IN REGULAR FOREST

1. Yield Regulation in clear-felling system :

(a) Annual Coupes by Gross Area (A_1)

This is the oldest and simplest form of regulating Yield from a forest. It wal first applied in France in 14th century, when the need for some control on felling was realised. It was initially applied to coppice crops worked on short rotations, upto twenty years. Subsequently, with the introduction of coppice-with standards system. the same method of area control continued to be applied, wherein a certain number of Standards was reserved for two. three or four coppice roations. This method is applicable to coppice forests and also to high forests worked on a system of clear-felling and artificial regeneration as in Nilambur (Kerala). Bori and Betul (M.P.) teak plantations.

In India. this method is widely adopted in plantations particularly those coppiced for fuel. It is also adopted in coppice-with-standards and coppice-with-Reserves systems. It regulates the Final Yield i.e. felling in areas to be finally felled at rotation age and regenerated, it does not take into account Intermediate Yield from cleaning and thinning in the younger crops.

In its simplest form the area of the forest or the Felling Series (Say, A ha) is divided into a number of annual coupes equal to the number of years in the rotation (Say, r), and one coupe telled every years A/r ha in year.

This method of **Yield regulation** will ensure equal sustained Yield in the second and subsequent rotations (if there are no unforeseen accidents). though it may not in the first. Annual coupes so formed, and equal in the area on the ground, are known as equiextensive coupes. A typical example of this case is illustrated in **fig. 1.**

(b) Annual Coupes by Reduced Area (A_2)

Since the density and site quality may very from coupe to coupe, reduction factors should be applied for equalising annual yields and area alloted to each coupe wade equi-productive, rather than equi-extensive. Reduction for density is seldom made, as this variation may be only a temporary feature and full stocking may be expected after regeneration operations and this factor will not affect future Yields. However Yield variation due to site quality may be a permanent feature of the locality, and is taken into account by determining and applying suitable **reduction factors** before formation of equi-productive coupes.

Advantages of Yields Regulation by Area:

(i) It is easy to apply.

(ii) Leads to absolute regularity of age gradations.

Disadvantages:

(i) It is very rigid, every change of rotation will necessitate redivision of the coupes.

(ii) Prescribes fellings without consideration of the crop condition.

Limitations :

(i) In unmanaged forests, it is not possible to lay out equi-productive coupes.

(ii) In mined natural forests, regulation by area is only a creade method, it was givenup in Europe in early 19th century in favour of regulation by area and volume.

II Yield Regulation in Regular Shelterwood Systems:

(a) Yield based on Area Allotment by Periods :

This is similar to regulation by fixed area, but is less rigid. It differs in that the felling areas are not permanently fixed on the ground in order of felling, but instead compartments and / or compartments are alloted to various of rotation. Rotation is divided into a number of convenient perids (depending on regeneration period/ 10 to 30 years); areas allotted to various periods (P) are known as P.Bs. All P.Bs. are of equal or equi-productive areas. The method is also known as **Periodic Block Method.** Final Yield is obtained from the mature regeneration block (P.B.I.) and this may be regulated by :

(i) Area (gross or reduced) or (ii) Volume or (iii) Area and Volume.

Allotment to P.B.S. may be permanent [fixed P.B.S.], revolable. single or floating [floating P.B.S.].

However, have only the method of regulation by Area is being discussed.

Permanent Allotment Method (C_1)

Regulation by Area :

In its simplest form the method of area allotment by periods consists in permanent allocation of areas in all P.B.S. In other words, actual forest or the felling series is made, by adjustments and compromises, to fit into a pre-conceived pattern. This arrangement is possible in forests where regeneration presents no difficulty and accidents do not up set the time schedule.

Area of each P.B. of the felling series [or the forest, as the case may be] is $\frac{A}{R} xP =$, where P is the regeneration period. A the area of the F.S. and R the rotation. This may be gross area, where crop and growth conditions are uniform in regular forests, or reduced for quality. Areas may also be reduced for age, as suggested by Hufnagl.

In this method instead of annual coupes we have periodic coupes and annual Yield is fixed by volume.

Hufnagl's Variation or Modification :

For sustention of annual Yield during the rotation, Hufnagl suggested a modification that the area (of the annual coupe in clear felling system, or P.B. in shelterwood system), should be multiplied by :

Average age + $\frac{1}{2}$ i.e Area of the annual coupe or P.B. = Normal Yield are of P.B. =

$$\frac{\text{Average age of the crop}}{\frac{1}{2}\ \text{Rotation}}$$

The actual average age is determined by multiplying the area of each age class in the series by average age of that age-class, summing up the products and by divioling the sum by the total area of the Felling series. If there is an excess of older age-classes, the actual average age of the series would be higher than the normal average (or half rotation) age and consequently, the coupe (or P.B.) would be larger than the normal: conversely if there was an excess of younger age classes, the claculated area of the coupe (or P.B.) would be smaller than the normal).

Example:

Area of the F.S. = 1000 ha; Rotation = 80 years; Period = 20 years;

Normal area of each P.B. $\frac{1000 \times 20}{80} = 25$ ha.

Distribution of age - classes is as follows :

Age class (Years)	Area of the class (ha)	Av. age of the class x area	Actual average age of the series (years)
1-20	200	10x200 = 2000	
21-40	150	20 x150 = 4500	
41-60	350	50 x350 =17500	$\frac{45000}{1000} = 45$
61-80	300	70x300 = 21000	
	1000	45000	

So, the modified area (in respect of age) of each P.B. would be equivalent to 25) x $\frac{45}{\frac{1}{2} \times 80}$ = 281 ha instead of the normal 250 ha. This is due to the excess of te older age-classes over the normal distributiion. This extra 31 ha should be taken from adjacent area and to be worked out for period of 20 yrs.

(b) Yield Based on Volume of Growing stock (G.S) :

Methods of Yield Regulation based on volume of G.S. is generally referred so as Formula Methods. Formula methods are widely used due to their convenience and is some cases, to the impossibility of applying a more suitable and accurate method. Their use is justified provided the Yield so calculated is not prescribed blindly, but is modified as necessary to suit the actual conditions in the forest, and the Working Plan is frequently revised and the Yield is re-calculated on the basis of measurements of the G.S.

Von Mantel's Formula (B) :

It has already been shown in chapter - V (The Growing Stock) that the volume of the normal G.S, is equal to the m.a.i. of the F.S. multiplied by half the rotation, i.e.

N.G.S. = I x $\frac{r}{2}$, where I represents the volume of the oldest age gradation (and also the total

annual increment of the F.S.) and is the normal annual Yield. I is. there fore equal to $\frac{N.G.S.}{r/2} = \frac{2N.G.S.}{r}$

Von Mantel's simple formula derived from the above relation is :

$$\text{Annual Yield} = \frac{\text{Actual Volume of G.S}}{\frac{1}{2}\text{ rotation}} = \frac{2G.S}{r}$$

This in Von Mantel's Formula, sometimes known as the formual of glorious simplicity.

According to Von Mantels, the annual yield from any forest must bear the some proportion to the actual growing stock as normal increment bears to the normal growing stock.

$$\frac{\text{Actaul yield}}{\text{Actual G.S.}} = \frac{\text{Normal yield}}{\text{Normal G.S.}} \text{ or } \frac{Ya}{Va} = \frac{Yn}{Vn}$$

Von Mantels formula may written as :

$I \times r = 2\ G.S.$

$$\text{or } Ir = G.S + \left(I \times \frac{r}{2}\right)$$

Normal yield and N.G.S. are found from Yield Table.

Example :

Actual G.S. is $5000m^3$ at age of 40 yrs of teak forest. Yield table for teak is given below for same locality. Find out the actual yield obtained.

Yield Table

Age (yr.)	Final yield (m^3)	Age (yr)	Final yield (m^3)
10	0	30	304
15	104	35	400
20	174	35	400
25	268		

Answer :

Actual G.S. (Va) = $500m^3$

Normal Yield (Yr) = $444m^3$

N.G.S. (Vr) $= n\left(A + B + C + \frac{D}{2}\right)$ i.e.

$= 5\ (0+104 + 174 + -268 + 04 + 400 + \frac{444}{2}\ )$

$= 7360\ m^3$

$\therefore$ Actual Yield (Ya) $= \frac{\text{Normal yield (Ya)}}{\text{Normal G.S.(Va)}} \times \text{Actual G.S. (Va)}$

$= \frac{444}{7360} \times 5000$

$= 3016m^3/ha.$

Advantages :

1) It is easy to apply; requires determination of G.S. and rotation only.

2) It regulates the yield according to acutal G.S. over-stocked forests will be heavily felled and understocked forests eightly felled.

3) It is useful as a preliminary step in Yield regulation, specially in irregular forests.

4) It give conservative Yield and helps in enrichment of the G.S.

Disadvantages:

1) It does not take in to consideration the difference beter the actual and the normal G.S., nor of the composition of G.S. which may vary from forest to forest.

2) It involves complete enumeration of the G.S., which is not always practicable.

3) It neglects the age-class distribution and rate of growth of the crop.

4) It gives only the final yield and is usuful where natural forests are being brouhgt under regulation, where thinning constitute on important part of the yield, the formula gives very low figures.

5) The assumption that all age-gradations put on equal increment throughout is wrong - this is why Flury introduced a constant 'C' in place of " $\frac{1}{2}$ "in 'r'.

Yield Regulation in Ir - Regular Forests

Yield based on G.S. and Increment :

(1) Brandis' Diameter class Method or the Indian Method (F_s)

This is a method of Yield Regulation by volume, based on Tree as a unit. Yield in Brandis' method is based on the number of trees in various dia girth classes, and time taken to pass from one to the next, with or without consideration of volume.

this is some what rough and ready method was devised by Brandis in the middle of 19th century, to meet the need for enploitation of large areas of tropical forests. It must, therefore be assessed against the background that practically nothing was known about these forests then.

The main principle of this method is that the number of tree of exploitable size to be cut/ year should not exceed the number of trees which passes from just lower girth size to the exploitable girth class.

As for example; suppose in an area.

Girth Class	No. of tree
$0 - 1\frac{1}{2}'$	10,000
$1\frac{1}{2}' - 3'$	800
$3' - 4\frac{1}{2}'$	500
$4\frac{1}{2}' - 6'$	400
$6'$ and above	300

(Exploitable girth class)

In this example, suppose 100 trees has come from ($4\frac{1}{2}' - 6'$) girth class to ($6'$ above) girth class, so the trees to be cut will be less than 100 trees.

Methodology adopted :

The following are the steps adopted by Brandis;

1) First, he fix a girth limit (in previous example $6'$ & above), below which no trees will be felled i.e. exploitable size he fixed. first.

2) Then he carried out enumeration to determine the no of trees in each girth class.

3) Then he carried out **stump analysis** to determine the age for various girth size and with the help of this. he determined the **Transition period** (i.e. the no. of years required to pass from 1st girth class to the next higher girth classes).

Determination of the transition period:

Suppose in previous example,

In $1\frac{1}{2}'$ -3 girth class, age at $1\frac{1}{2}'$ girth class = 20 yrs. (the stump having 20 annual rings).

and $3'$- $4\frac{1}{2}'$ girth class, age at $3'$ girth class = 50 yr. (the stump having 50 annual rings).

50 - 20 =30 yrs. is required to come from ($1\frac{1}{2}'$ - $3'$) girth class to ($3'$- $4\frac{1}{2}'$) girth class.

Transition period will be 30 years.

(4) By adding the transition periods and allowing some years extra (establishment period) the rotation corresponding to the exploitable girth was worked out.

(5) Then the no. of trees isdetermined which is coming from one girth class to next higher girth class.

(6) Survival co-efficient i.e. the percentage of trees of each class Surviving to the exploitable class was estimated on the basis of extensive observation of the G.S.

(7) A felling cycle (f.c) was fixed, which was a Sub-multiple of rotation (r) and was not less than the period of transition form class - II (next below the exploitable class I) to Class - I.

The annual Yield was then fixed by the no. of trees as -

Yield = Average no. of trees reaching exploitable size annually plus of fraction of surplus no. of trees of over the exploitable girth/ size, if any.

Example :

Suppose, the area of a Forest patch is 3360 ha, haring the trees of exploitable girth class 2.5 mt and above. Rotation addopted was 160 years and felling cyde - 32 years - a submultiple of rotation, and the enumeration data is as follows :

Class	Girth class	Age of entry in class [yrs.]	Survixal%	No. of trees enumerated
I	2.5mt & Above	156	95%	31525
II	2.0mt - 2.5mt	130	85%	18114
III.	1.5mt - 2.0 mt	93	70%	42768
IV.	1.0mt-1.5mt	60	50%	101737
V.	0.5 mt- 1.0 mt	31	25%	150910

Calculate the yield.

Solution :

Class	Girth class (mt)	No. of trees enumerate	Surviral%	Age of entry in class	Transition period	Actual No. of trees going to exploitable size
I.	2.5m & above	31523	95%	156 yrs.		29947
					26 yrs.	
II.	2.0 m - 2.5m	18114	85%	130 yrs.		15397
					27 yrs.	
III.	1.5m - 2m	42768	70%	93 yrs.		29938
					33 yrs.	
IV.	1.0m - 1.5m	101737	50%	60 yrs.		50869
					29 yrs.	
V.	0.5m-1.0m	150910	25%	31 yrs.	125 yrs.	37728

Now the yield may be calculated on the basis of -

1) Average recruitment rate form the upper classes to class - I during the first felling- cyde period only.

2) Average recruitment rate for the whole period during which the smallest enumetrated tree (class -V) will reach class 1 (125 yrs. in the above example).

Calculation in each cash will be as follows :

(1) In this case, yield is based on the recruitment into class I in the first felling cycle only. This is a more realistic approach than the second case, as in the case, in the first felling cyde, actually trees of class - II and possibly,

some of class - III only will more into class - I. Thus in, a, f. e, or 32 yrs. during the first 26 yrs. all the 15,397 class-II trees would reach class - I; the exploitable size. During each of the next six years, the average No. of class - III trees which have been reaching class - II each yrs. will also pass into class - I. Therefore, the number of class-III trees passing into class-I in the first 32 yrs. f.c.

$$= \frac{29938 \times (32 - 26)}{37}$$

= 4355 trees (as an average class - III trees takes 37 years to reach class - I0,

Therefore, total recruitment to class - I in 32 yrs. (i.e. the yield) = 15397+4855 = 20252 trees.

Annual yield = $\frac{20252}{323}$ = 633 trees.

∴ Now, for already existing trees in class - I, they should also be removed, otherwise , those will be damaged. But all the trees should not be removed at a time, because, some trees should be removed be there to maintain capital.

So for determining the No. of trees of class - I to be removed, we will have to determine the optimum growing stock. Then excess trees will be removed.

So, optimum growing stock will be = $\frac{1}{2} \times I \times r$

= $\frac{1}{2} \times 633 \times 32$

= 10128 No. of trees.

So. Excess No. of trees = 29947 - 10128

in Exploitable girth class = 19819 trees.

∴ No of trees to be cut/yr = $\frac{19819}{32}$ =620 no.

∴ Totoal annual yield will be = 633 + 620 = 1253 No. trees.

(2) According to the 2nd method, the calculation of yield will be as follows :

Total number of potentially explotable trees in class - II to class - V is

= 15397 +29938+50869+37728 = 133932

Total period of transition from class V to Class I = 125 yrs. So, average No. of trees passing from the lower enumerated classes inti class - I annually is therefore = 133932 ÷ 125 = 1071,

Working stock of class I trees required to be kept as reserve = annual recruitment x $\frac{1}{2}$ f.c

$$= 1071 \times \frac{1}{2} \times 32 = 17136 \text{ trees.}$$

∴ Surplus of class I stock = 29947 - 17136 = 12,811 trees.

So, the annual yield of these surplus I class tree = $\frac{12811}{32}$ = 400 trees.

There, total annual yield will be = = 1071 + 400 = 7471 trees.

So, according to first method, No. of trees to be removed /yr = 1253 No.

and according to second method No. of trees to be removed/yr = 1471 No;

So, for determining the No. of trees to be removed annually, we will have to calculate both the way and which will be less, should be removed. So, in this case 1253 No. trees should be removed annually.

However, in order to preserved mature trees for regeneration, and in view of price increment on trees of 3m and 3.5m girth, the actual yield may be reduced to 1000 trees in the working plan.

So, summing up, the data required for the application of brandis' method, is as follows (based on enumeration Yield Tables and stump Analysis).

(i) Number of class I, II, III etc, trees.

(ii) Transtition period (years required to pass through various classes).

(iii) Percentage of trees in each class, likely to survive till in class - I, and the net number of harvestable trees in each class.

(iv) Annual recruitment to class - I.

(v) Working stock (= Annual Increment x $\frac{1}{2}$ felling cyde)

(vi) Surplus of class - I trees, i.e. existing No. of class - I trees minus the working stock.

(vii) Period during which the surplus of class - I stock is to be liquidated.

Merits of Brandis method:

1. With minimum data like G.S. and stump analysis, the Yield can be determined.

2. Data collection is not so difficult i.e. Field work easy.

3. Yield is expressed in terms of trees here.

4. With the help of this, selection cum Improvement felling can be carried out.

5. According to one's requirement one can mark the trees,

6. It can be applied in the selection system and where predominant species have attained ezplaitable girth.

7. Broad girth and dia-classes can be applied here.

8. Yield can be expressed in volume with the help of volume table easily.

Demerits of Brandis' Method:

1. The survival percentage has considered Orbitrarily. No scientific basis for that. Therefore calculation may not be accurate.

2. In case of species without annual ring, it can not be applied easily.

3. In case of mixed species where two or three species, have attained exploitable size, the procedure cannot be applied easily.

4. It does not speak anything regarding natural regeneration.

5. If felling cyde changes, it creates complexity.

(2) Smythies' Safe - guarding formula (E_7):

This is also known as U:P. Safe-guarding formula. It was evolved by Smythies in the thirtees, mainly for the sal forests of U.P. which were worked under selection system and where the chief object of management was the production of trees of large size.

Smythies' Safe - guarding Formula is based on the following assumptions:

(i) That exploitable (selection) trees already exists and are being recruited everywhere (and not in any particular compartments only) and that felling pass regularly though the forests in consecutive annual coupes in a felling cycle of 10, 15, 20, 25 or 30 years.

(ii) the basic object of management is to ensure, as far as possible. sustained or increasing Yield of exploitable trees above the exploitation limit at every felling cycle.

(iii) The middle-aged younger dia, classes are well represented, and the present rate of recruitment into the two highest dia. Classes (I & II) will not decrease for quite a few decades.

(iv) Sustained Yield of selection tree is adequately safeguarded if, in any area, the number that may be felled is limit to the number that will pass up from below by the time fellings come round again.

Procedure :

1. Fix the exploitable dia or girth.
2. Fix the felling cycle.
3. Fix the diameter classes - there are indicated by symbols, I, II, III, IV etc. - class I standing for trees above the exploitable dia, and others usccessively below it to the youngest.
4. Carriesout enumerations in various dia. classes (I & II) necessarily. Though the other classes do not enter in to Yield calculation, but still class III and IV also, are enumerated to verify the assumption that the middle and younger age-classes are also well represented, to ensure sustained Yield in subsequent felling cycles also. The youngest dia. class, usually below 20 cm. dia is not enumerated.
5. Determine the transition period for class II trees by stump analysis (for tree having annual rings) or by Linear Increment plots (for trees not having annual rings).
6. Determine mortality percentage, i.e. determine the percentage of class II trees that do not pass into class I
7. Then determine the number of II classes trees which pass into class I during the felling cycle "f" - let this number be "x" per hectare.

   This number "x" is determined from the formula.

$$"x" = \frac{f}{t}(II - Z\%\ II)$$

   f = felling cycle.

   t = time taken by a II class tree to pass into I class.

   z = percentage of II class trees that do not pass into I class in t years; due to mortality of removal in thinnings etc.

8. After calculating 'x' the area of the felling series is subdivided into 'f' annual coupes, made as equiproductive as enumerations and working plan officer's knowledge of forest permits. The W.P.O. may prescribile the annual yield of I class trees by any of he two alternative methods viz:

1. Fix the volume Yield of "x" trees per hectare area of the coupe, per annum i.e. x $\frac{\text{Total area of F.S.}}{\text{f.c.}}$

This is similar to Brandis' Method. without providing for removal of surplus threes> the exploitable dia. If the data are correct. no reduction of I class trees at the end of the felling cycle. However, this alternative has all the disadvantages of a volume Yield - viz, Cumulative error due to inaccurate data.

The second alternative (and a better one) is to Prescribe an area yield, by dividing the forest into "f"" annual coupes and limiting the removal of I class trees to a percentage "p" of their number per ha (N') in the coupe of the year at the time of making. The number "N" is ascestained by the marking officer at the time of marking the year's coupe and can also be expressed in terms of "I" the number of I class trees per ha at the beginning of the f.c and "x".

The number of I class trees per ha at the end of the f.c. = I+x.

Therefore, the average number of trees, i.e. "N" during the f.c. $I + \frac{x}{2}$

The percentage of I class trees to be removed in any year's coupe than becomes (taking average value of "N", which is Strictly true of the "f/2" year's coupe only; it will be an over-estimate for the earlier coupes and an under estimate of subsequent coupes) :

$$\text{Yield} = \left(\frac{x}{I + x/2} x100 \right)$$

In order to allow for the influence of various factors, which may affect the realisation of the full calculated yield, (e.g. silvicultural non-availability), allowance for low density of I class trees requiring to be increased need for sustaining average yield and revenue etc. and also to round off the percentage an arbitrary allowance of ± A is given and formula becomes:

$$\text{Yield} = \left(\frac{x}{I + x/2} x100 \pm A \right) \%N$$

Of the two formula involved in this method, the principle underlying the equation :

$x = \frac{I}{t}$ (II-2% II), gives the measure of recruitment of selection trees from the next lower class, and forms the basis of the Safe- guarding Formula. The actual yield is prescribed as a percentage of the exploitable trees found in the course of the years, as given above.

Example :

Suppose the area of forest = 3360 ha.

Felling cycle = 10 yrs.

Exploitable girth = 2.5m and above.

No. of class I trees = 29947

No. of class I trees = 15397

Mortality % = 10%

Years taken to pass from class I to class I = 25 yrs.

Allowance = + 10%

Calculate the yield.

Solution :

Here, f = 10 yrs t = 25 yrs., z = 10%

A = + 10%, I = 29947

So, No. of class II trees going to class I during felling cycle (x)

$$\frac{f}{t} \times (II - z\%\ II)$$

$$= \frac{10}{25} \times \left(15397 - \frac{10 \times 15397}{100}\right)$$

$$= \frac{10}{25} (15397 - 15397)$$

$$= \frac{10}{25} \times 13657.3$$

$$\therefore \text{Per ha } (x) = \frac{1}{2.5} \times \frac{13857.3}{3360} = 1.6 \text{ trees / ha.}$$

$$\therefore \text{ Yield } (Y) = \frac{x}{1 + x/2} \times 100 \pm A$$

$$= \left(\frac{1.6}{\frac{29947}{3360} + \frac{1.6}{2}} \times 100 + 10 \right)\%$$

$$= \left(\frac{1.6}{8.7 + 0.8} \times 100 + 10 \right)\%$$

$$= 27\%$$

So, 27% of the number of I class trees present at the time of marking. So, 7% of total yield to be harvested.

Limitation and disadvantages of the method :

(1) Formula can be used to calculated Yield, for those species for which I, II & III class trees have been enumerated, and for which values of "t" and "f" are known. However, as in Brandis method, value of "t" and "f" cannot be accurately determined.

(2) It holds good only if "I" is within certain reasonable limits and nt in general. thus if I=0, Yield will be 200% of 'N' which is absurd. Similarly if value of "I" is comparatively very high, that of yield percent (of "n") will be very turall. In that case these trees will be deteriorating, and it should be permissible to remove a larger percentage of these. If "I"=x/3. Yield will be 100% of "N" again an inpracticable situation. It is therefore, clear that it is not possible to apply the above formula values "I" is greater than x/2.

(3) Since the removal of class I trees depened on the Silvicultural availability, and the extent to which regeneration is present, Yield. is bound to vary.

(4) The formula bears no relation to the increment of the forests as a whole, it takes only I and II class trees into calculation.

(5) It requires as much data from enumeration and more statistical data for estimating "t" and 'f' - than volume formula and is therefore, liable to go wrong.

(6) This formula is merely a modification of Brandis' Methods, whereis Yield regulation is based only on the stocking of class II trees and liquidation of the surplus G.S. is not provided for.

However, Smythies' formula is now very widely used is selection forests of India.

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QUESTIONS FOR THE STUDENTS' RESPONSE SHEET

1. Define Forest management. Briefly discuss the Principles and objects of Forest Management.
2. What is Sustained Yield. What are the pre-requisites for sustained Yield Management. Discuss briefly with example. Discuss the advantages and disadvantages of sustained Yield Principle.
3. What is rotation? Discuss the different types of rotation with example. What do you mean by Soil Expection Value. Discuss Faustmann's Formula. For making a choice of a suitable rotation, what are the points to be considered. Discuss the procedure to determine the rotation.
4. Define Normal Forest. discuss briefly the basic factors or characteristics of normality. Discuss normality with on example. What is De Liecourt's Law. Discuss briefly.
5. What is Growing Stock. Discuss the determination of Normal Growing Stock in clear felling system based on Final M.A.I. What is Flury's constant. Now, this can be determined. When Flury's constant is used.

Calculated the average W.G.S. per hectare in a Deodar plantation of site quality II worked on a rotation of 100 years, to which the following Yield Table Figures apply. Use both the method.

Crop age (years)	Final Yield (m^3/ha	Crop age (years)	Final Yield (m^3/ha)
10	-	60	480.50
20	9.80	70	574.47
30	74.17	80	656.34
40	210.62	90	734.01
50	347.06	100	806.77

(Answer : By M.A.I. formula = 403.39m^3 From yield table figure = 350.04m^3)

From the above sum, Calculate the value of "c" [Flury's constant]

(Ans : C = 0.43)

6. What are the objectives of regulating yield. What are the different method of yield calculation. Discuss the methods of yield regulation in clear felling system through annual coupe by Reduced Area. What is Hufnagl's variation or modiciation. Discuss in brief.

7. What is Von Mantel's formula? Discuss in brief with advantage and disadvantage of the method?

8. Discuss Brandis' Diameter class method for yield regulation is Irregular forests. What are the merits and demerits of Brandis method.

Calculate the Yield for Sal forests of Bastar by Brandis Formula. Area under Sal Forest = 32,426 areas, Felling cyle = 40 years and Exploitable dia is 20 inches x above, and the enumeration data is as follows;

Class	Dia (inches)	No of trees	Yrs. in class (Transition period)	Survival % to class I
I	20 x X	54,946	-	95
II	16-20	1,38,621	50	64
III	12-16	2,88,714	38	37
IV	8-12	5,57,301	32	20

(Ans. 2571 trees)

9. Enumeration data and information collected from stump analysis is tabulated below :

Class	Dia-range (cm)	No of trees enumerate	Age on entry in class (yr.)	Survival coefficient (%)
I	x 50	15,000	88	90
II	40 - 50	12,250	74	80
III	30-40	27,000	56	60
IV	20-30	60,000	32	40
V	10-20	80,000	16	25

Rotation is fixed at 100 years and the felling cycle at 20 years. Calculate the Yield.

(Ans: 1055 trees)

10. What is symthies Safe-guarding Formula. What are different limitations and disadvantage of this method. How it differs from Brandis Method.

Suppose, Sal selection working circle of a Forest Division is being worked under selection system and the yield is regulated by smythies Safe-guarding Formula where the following data has obtained. Calculated the Yield.

Felling cyle = 10 yrs., Exploitable dia = 50 cm.

No. of I class trees = 18.3 per ha,

No. of II class trees = 22.5 per ha.

Mortality % = 45%

time taken for an average II class tree to reach I class = 30 years. (And ; 20%)

Chapter VI

Yield Table and Stand Table

Yield Table : "It is a tabular statement which summarizes on an acrea or other unit area basis all the essential data relating to development of a fully stocked and regularly thinned even aged crop at periodic intervals covering the greater part of its useful life".

Yield table is not applicable to uneven aged forest. The three main factors involved in the study of yield are volume, area and height. In case of uneven aged crops, tables have been compiled for uneven aged forests but there are difficult to apply and their utility is restricted to the determination of CAI and MAI.

An average yield table contains the following informations.

— Number of trees.

— mean diameter of the trees.

— basal area of the crop.

— mean and top height

— Volume at different stages; and of the different stages of yield

— CAI and Mai

— form factors.

Kinds of Yield Tables : It is of the following kinds.

1. Local yield table : It gives information about a local area.
2. General yield table : It deals with the species as a whole for a particular region or country.
3. Multiple Yield table : These are yield tables in which data are given for different grades of thinning.
4. Single yield table : It is an yield table in which parameters have been given only for one grade of thinning which is usually a grade.
5. Volume yield table : Area those which deal with only volume.

6. **Money yield table** : It is an yield table constructed from volume yield table in which out turn is expressed in terms of money instead of volume.

Preparation of Yield Table : Several steps are required to prepare a yield table.

However A new method suggested by senior author is given below. His method consists of the following steps:

1. Linear regression equations are fitted between timber volume as well as for total wood volume against the product of based area and Crop height.
2. Linear regressions are also fitted between
   a) Crop height and top height
   b) Crop diameter and Crop height.

Uses of yield Table:

1. **Used to determine site quality :** Various quality classes are specifically dealt with in the yield tarco. Usually different information such so age, diameter, volume, top height, form factor etc. is given for different quality classes.
2. **Used to determine yield or growing stock :** Present and future volume of a stand of any age can be determine by the yield table. But it necessary to know the age, quality and density of the Stand or crop.
3. Used to prepare stock-map by site qualities : For the same species rate of growth is different in different site qualities. So it is necessary to make stock map by site qualities so that different treatments may be prescribed for each quality class. For this purpose, the area may be traversed by an observer who will note the top height at various points. Based on this top height, the quality classes may be determined from the yield table.
4. Used to determine increment of stand : Using the following method increment may be calculated from yield table.

$$\frac{Va}{Vb} = \frac{Va+n}{Va+n} \qquad I = Va\,\frac{(Va+n)}{Va} - 1$$

Where I is the increment, Va is the volume as per the yield table; Va is the actual volume of the wood; Va+h is the Volume as per yield table n year later.

5. **Used to determine isolation of Crop** : The rotation showing the maximum volume production for Crops at a given site quality is the age at which the mean annual increment (MAI) culminates. First the quality of the site is determined and rest from the yield table of this quality ..., the age at which the MAI culminates is obtained. This age will give the desired rotation.

6. **Used to determine the intensity of Silvicultural thinning** : Yield table give an idea of the intensity of thinning to be carried out yield taste give an idea of the ideal number of steps at a particular age under a given site quality and also the ideal number of stems corresponding to a given crop diameter. Thinning may then be carried out according to be ideal number of stems.

Stand Table : Stand table is a table showing the distribution of stand by diameter classes for each of the series of Crop diameters. It is appeared at the end of the yield taste of the species and yield able is not complete with out it. Stand Table is very useful for forest management and stand false can be used in various ways like

a) to determine the financial value of crops and

b) for preparation of money yield table.

c) Number of trees per hectare and crop diameter,

d) Crop height of subsidiary Crop and Crop height of main Crop.

e) Limiting curves are drawn for site quality from these curves top height is obtained corresponding to each decode for each site quality.

f) For each decode values of Crop height and Crop diameter are obtained by the regression of Crop height/top height and Crop diameter/Crop height. The number of trees is obtained from the regression of number/Crop diameter From the values of number and Crop diameter, basal area per hectare is obtained by the formula $BA = \frac{\pi D^2}{4} N$. The Product of basal area and Crop height is used to get timber volume from the regressions obtained earlier.

YIELD TABLE, SHOREA ROBUSTA, QUALITY, IC GRADE THINNING, STEM TIMBER ONLY

Main Crop		Thinning	Final	Accumulated	Total	m.a.i.	c.a.i.
Age	Standing Volume cu.ft.		Yield	yield of thinnings	yield		
10	0	0	0	0	0	0	
15	0	0	0	0	0	0	
20	20	0	20	0	20	1	
25	180	0	180	0	180	7	
30	430	20	450	20	480	15	
35	760	50	810	70	830	24	
40	1160	90	1250	160	1320	33	
45	1590	150	1740	310	1900	42	
50	2020	210	2230	520	2540	57	
55	2400	280	2680	800	3200	58	
60	2760	340	3100	1140	3900	65	
65	3060	400	3460	1540	4600	71	
70	3320	440	3760	1980	5300	76	
75	3560	470	4030	2450	6010	80	
80	3780	490	4270	2940	6720	84	
85	3970	510	4480	3450	7421	87	
90	4150	510	4660	3960	8110	90	
95	4340	500	4840	4460	8800	93	
100	4530	490	5020	4950	9480	95	
105	470	480	5180	5430	10130	96	
110	4860	450	5310	5880	10740	98	
115	5030	430	5460	6310	11340	99	
120	5200	400	5600	6710	11910	99	
125	5350	360	5710	7070	12420	99	
130	5510	330	5840	7400	12910	99	
135	5670	300	5970	7700	13370	99	
140	5820	260	6080	7960	13780	98	
145	5980	230	6210	8190	14170	98	
150	6140	200	6340	8390	14530	97	

CHAPTER - VII

CAL and MAL

During eacn growing search, a tree grows by elongation of the top shoot, side branches, roots and also by adding a new layer of wood and bark, all over. This increase is termed as increment. In terms of mensuration, increment may be defined as the increase in girth, diameter, basal area, height, volume, quality, price or value of trees or crops during a given period.

Classification of increment:

Increment may be classified into the following

i) Curreent **Annual Increment (CAI)** : Increment put on by a tree or Crop in a single or current year. In practice, it is a periodic annual increment, where increments over a period are divided by the period and increment so obtained are taken as CAI. Volume of a tree or a crop at any age is the sum of CAI for each year upto that age.

ii) **Mean Annual Increment (MAI)** : The mean of all CAI i.e. total increment upto any specific age divided by that age. If the mean annual increment is calculated from portion of the total age, it is called periodic mean annual increment. If it is calculated at the rotation age, it is called the final mean annual increment.

iii) **Periodic Increment (PI)** : It is the average annual increment for any short period when there is regular yield from thinning, the final MAI is equal to the final crop plus the yields from thinnings divided by the rotation.

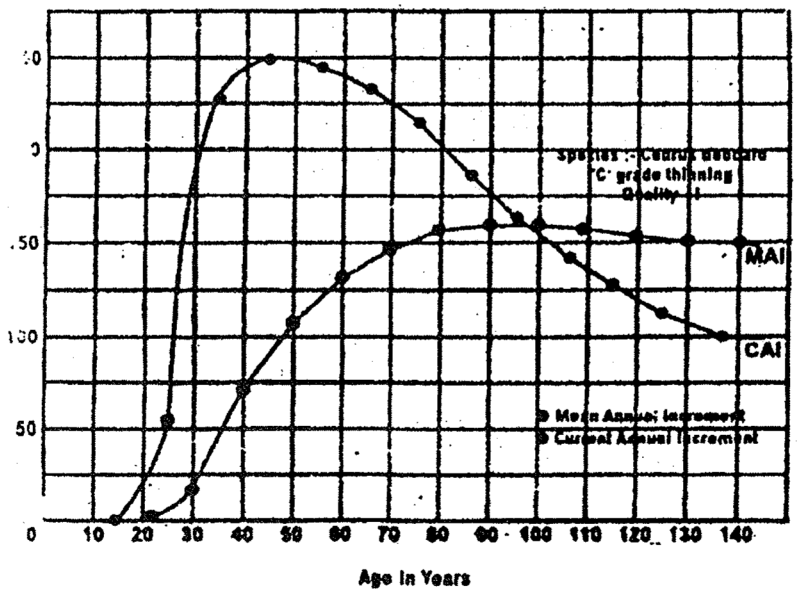
The current annual increment is smaller in the seedling stage, becomes progressive greater and after attaining a maximum, drops till mortality occurs. As to MAI is merely the mean of all the current annual increment to date, so there is a definite relationship between the CAI and MAI at all ages.

TABLE No. 1
YIELD TABLE FOR CEDRUS DEODARA,
C GRADE THINNING

	Total Stem Timber and small wood Volume (cu.ft.)							
Crop age years	Main Crop	Thinning	Final Yield	Accumulated yield of thinning		Total yield	m.a.i.	c.a.i.
10	0	0	0	0	0	0		
20	710	20	730	20	730	37	73	
30	3210	120	3330	140	3350	112	262	
40	5190	450	5640	590	5780	145	243	
50	6940	850	7790	1440	8380	168	260	
60	8650	950	9600	2390	11040	184	266	
70	10280	920	11200	3310	13590	194	255	
80	11750	820	12570	4130	15880	199	229	
90	13100	700	13800	4830	17930	199	205	
100	14370	590	14960	5420	19790	198	186	
110	15470	490	15960	5910	21380	194	159	

Fig.1

Figure showing both the CAI and MAI curves brings out the relationship



These curve show that:

i) While CAI is greater than MAI. the MAI is raising.

ii) To bring with MAI keeps below CAI.

iii) CAI attains its maximum before MAI.

iv) CAI is falling when MAI is still raising.

v) When CAI equals MAI, MAI is stationary or has attained its maximum when CAI and MAI curves meet.

If a Crop is felled at the age at which MAI is maximum, maximum volume/Ha is obtained.

Increment Percentage : Increment percentage is average annual growth in volume (or basal area) over a specific period of time, expressed as a percentage of the volume (or basal area) either at the beginning or usually halfway through the period.

Increment percent may be determined by a) Pressler's Formula, b) Compound interest formula :

a) Pressler's formula :

$$P = \frac{V-v}{V+v} \times \frac{200}{n}$$, Where P = increment

V = Volume of Crop sow

n = volume of Crops in n years ageo.

Quality Increment : The increment in value per unit volume of a tree Crop.

Price Increment : The increment in price, independently of quality increment, resulting from the fluctuations in the market on account of charges in money value in general and demand and supply position in particular.

Quality Increment Percent $P = \frac{K-k}{K+k} \times \frac{200}{n}$

Where K the value of unit volume rising to value K during n years.

Price increment percent $P = \frac{P^2-p^1}{P^2+p^1} \times \frac{200}{n}$

P^1 is the price of unit volume of wood n years back and P^2 is present price.

M.Sc. in Botany (New Syllabus)

Part-I

Module No. – 25

MODULE ON NONWOOD FOREST PRODUCE (NWFP)

The total surface area of the earth is approximately 510 million km^2, of which nearly 71 percent i.e., 361 million km^2 is ocean and the remaining 29 percent i.e. 149 million km^2 is land. Land support all forms of plants and animal lives.

India is blessed with almost all kinds or climate. Therefore, a large variety of vegetation forms are found in the country. Out of about two lakh known species of plants in the world, about 20,000 occur in India, which indicates the richness of flora in the country.

Out of the total geographical area of 328.8 million hectare in India, approximately 61.42 million hectare land is classified as forests.

Forest products are classified broadly in two main groups: (i) wood produce and (ii) non-wood produce. The wood produce includes timber and firewood and non-wood produce are commonly referred to as minor forest produce (MFP). Minor forest products, specially include grass, fruit, leaves, bark, bamboos & canes, tans and dyes, gum, resins, drugs, spices, edible products, animal and mineral products found in the forest and collect there form. In view of the great economic importance of minor forest products, it is rather a misnomer to call them 'minor' and in fact, it has been recommended that these may be termed as Economic Forest Produce other than wood.

The collection and marketing of MFPs are for the most part in the hands of petty contractors who obtain a lease permit from the forest department to collect these from the forest areas, through the agencies of villages living in the fringe of the forest.

The non-wood Forest Produce (NWFP) or MFPs of commercial importance may be classified in to following classes:

1. Fibre and Flosses.
2. Grasses, Bamboos & Canes
3. Distillation and extraction products, including grass oils,
4. Oil seeds
5. Tan and dyes
6. Gum, resins and oleoresins

7. Animal, mineral and miscellaneous products
8. Drugs, spices and poison
9. Edible products

1. FIBRE AND FLOSSES

Man used fibre of plant origin since time immemorial for various purposes such as ropes, cordages, fabrics, etc. Among the earliest of such fibres was flax; cotton, the greatest of modern textile came later. The chemical composition of all vegetable fibres mainly shows the presence of cellulose, hemicelluloses, lignin and pectin. Natural fibres are susceptible to microbial decomposition.

Fibres generally occur as sclerenchyma cells and serve to impart rigidity to the plant. They are found in various parts of plant such as stems, leaves, roots, fruits and even seeds.

Fibres can be classified by origin and structure into:

(a) Hard fibres (leaf or structural fibres)

(b) Soft fibres from fast or stem

(c) Surface fibres borne on the surface of stems, leaves, seeds etc.

Fibre from stems

Fibres are obtained from the vast tissue of many woody species, some of which yield long strong fibres, which are suitable for twisting in to ropes, whereas others yield silky fibres, which are fine enough for textile purposes.

The method of extracting fibres from one another is called 'retting'. Retting is done by soaking the fibres in water to soften the tissues, the fibres afterwards being beaten and scraped clean. There are certain fibres, which are used without any retting, and there are others, which are rendered useless if immersed in water.

The majority of plants yielding useful fibres belong to the families Sterculiaceae, Tiliaceae, Leguminosae, Asclepiadaceae, Urticaceae, Ulmaceae and Moraceae.

Some examples are given below:

Name of plants	Family	Nature of Fibres	Uses
Sterculia villosa	Sterculiaceae	Coarse strong, whitish pink fibre	Making elephant harness, drag ropes & for tying rafts.
S. urens	- do -	Coarse	For making ropes.

Name of plants	Family	Nature of Fibres	Uses
S. foetida	- do -	Coarse	For making ropes
Helecteres isora	- do -	Soft, silky, greyish brown fibre	Sacking, tying, sewing & cattle harness.
Grewia tiliaefolia	Tiliaceae	Coarse, strong, yellow fibre	Rope making & domestic purposes
G. oppositifolia	- do -	Coarse strong yellow fibre	
Bauhinia vahlii	Leguminosae	Strong fibre	Tying & other works
Butea monosperma	Leguminosae	- do -	Making ropes
Calotropis procera	Asclepiadaceae	Fine, white, silky & strong	Making fishing net & lines, bow strings, twines, etc.
C. gigantea	- do -	- do -	- do -
Trema orientalis	Ulmaceae	Strong, light brown	Making ropes, twine & coarse cloth
Ficus religiosa	Moraceae	Short, strong fibre	For making ropes
Ficus bengalensis	- do -	Short, strong fibre	- do -
Fibres from leaves			
Musa paradisiaca	Musaceae	Strong, brown colour (manila hemp)	For making ropes, twines & cable.
M. textiles	- do -		
Agave sp.	Agavaceae	Strong, coarse & flexible	For making ropes & cordages
Pandanus odoratissimus	Pandanaceae	Strong fibre	For making cordages, fishing net, sacking

On the basis of general uses, fibres can be classified in to following six categories.

i) **Textile fibre**

ii) Brush and mat fibre

iii) Plaiting and weaving fibres

iv) Filling fibres

v) Natural fibres

vi) Fibre for paper and pump.

FLOSSES:

There are several forest trees and plants, which produce silky flosses in their fruits. Some of them are as follows:

i) *Ceiba pentandra* (Kapok) which is commonly known as silk cotton, used for spinning & weaving.

ii) *Bomax ceiba* (simul) – which is known as Indian Kapok, used for stuffing mattress and pillows, quilts & cushions etc.

iii) *Calotropis gigantea* (Akanda) produce silky, soft, glossy fibres used for stuffing mattresses and pillows.

Other many floss producing plants having local importance's are *Holarrhena antidysenterica* (Kurchi), *Wrightia tomentosa* etc.

COIR: The well-known coir fibre used extensively all over the world for mats, brushes, ropes and other purposes is obtained from thick husk of coconut (*Cocas nucifera*) palm. Coir fibre is very stiff, buoyant & classic so very useful for ship's ropes.

2. GRASSES, BAMBOOS AND CANES

The utilisation of grasses is one of the most important works connected with the management of forests in the country. They are meeting the grazing needs of large number of cattle population in the country. Grasses are used for various purposes other than grazing. These are as follows:

(a) *Eulaliopsis binata* (bhabar/babui grass), is used to make paper, rope and rough mat.

(b) *Saccharum munja* (Munj) is used as thatching of roof, cordages ropes, etc. The parts of the stem used to make chair, stool, tables, basket and screws.

(c) *Saccharum sponianeum* (Ekra) is used to make ekra mud wall, which are built up with mud plastered over this grass.

(d) *Vetiveria zizanioides* (khus-khus) is used make khus-khus of commerce from its aromatic and long fibrous root. Besides khus-khus tatti it is also uses as to produce ornamental fan and buskets. Young leaves are used for thatching & fodder.

(e) Grasses used for thatching purposes are *Imperata cylindrica, Heterapogon contortus*, etc.

(f) Grasses are used to make rope is *Eulaliopsis binata, Saccharum munja, S. spontaneum, Themeda arundinacea* etc.

(g) Some other important grasses are *Typha elephantina* (elephant grass) used to make basket, mat and rope. *Phragmitis karka* (Dhadha) is used make chair and basket. *Cyperus tegetum* is used for mat making.

Fodder grasses: Some important fodder grasses found in the forests are given below:

Andropogon spp. *Cenchrus ciliaris, Apluda mutica, Chrysopogon aciculatus, Cynodon dactylon, Cenchrus ciliaris, Eragrostis* spp., *Heteropogon contortus, Panicum* sp., *Paspalum* spp., *Themeda* sp., *Arundinella* sp., *Imperata cylindrica, Phragmitis karka, Saccharum* spp., *Themeda* spp., *Pennisetum* spp. *Cymbopogon* spp., *Dichanthium* sp. etc.

BAMBOOS

Bamboos are tall, perennial, arborescent grasses, belonging to the Bambusae, a tribe of Gramineae. There are about 30 genera and 550 species of bamboos in the world. Asia accounts for more than 300 species of bamboos. Out of these, about 130 species occur in India, of them 100 species are indigenous (Gour, 1987). The most important genera found in India are *Arundinaria, Bambusa, Dinochloa, Gigantochloa, Dendrocalamus, Oxytenanthera, Melocanna, Ochlandra, Pseudoxytenanthera, Phyllostachys,* etc.

Bamboos are characterised by woody stems, commonly called culms, which arise from the rhizome. There is a great variation in length of culms and number of culms produced annually. The growth of bamboo is very fast. Bamboos are widely distributed throughout the countries like Assam, Meghalaya, Arunachal Pradesh, Manipur, Tripura, Mizoram, Nagaland, West Bengal, Orissa, Andhra Pradesh, Madhya Pradesh, Maharastra, Andaman and Nicobar Islands, western ghats etc.

Some important species of bamboo are given below:

Dendrocalamus strictus – It is most universally used of all the bamboos.

Dendrocalamus hamiltonii, D. longispathus, Melocana bambusoides, Arundinaria falcata, Bambusa balcooa, B. bambos, B. pallida, B. nutans, B. striata, B. tulda, B. polymorpha, Dendrocalamus giganteus (tallest bamboo), *Oxytenanthera albociliata, Melocana buccifera, Oxytenanthera nigrociliata, Ochlandra travancoria, Arundinaria spathiflora, Ochlandra rheedi, Dendrocalamus membranaceous* etc.

Uses: The strength of calms, their straightness, lightness, combined with hardness, their hollowness, the facility with which they can be split and range in size in which available their abundance, case of propagation and exploitation, make bamboos a usable commodity for variety of purposes. Some of the important uses of bamboos are given below:

a) Structural uses: Construction of houses & huts, rafters, ridges, post, trusses, purling, roof coverings, walls, floorings, doors and windows, scaffoldings etc.

b) **Traditional and handicraft items**: agricultural implements, anchors, arrows, baskets, buds, binds, boats, bottles, bows, bridges, brooms, brushes, buildings, caps, cart-yokes, caulking material, chair, chicks, coffin, combs, containers, cooking utensils, cordages, dust-pans, fans, fences, fish traps, fishing nets & rods, flag poles, floats for timber, flutes, flower pots, food baskets, fuel, furniture, hats, handicrafts, hedges. Stabilizer, hookah-pipes, kites, ladder, lamps, lanterns, masts, match sticks, mats, milk-vessels, musical instruments, ornaments, pens, rafters, sails, scoops, shoes, sport goods, sticks, toys, traps, trays, umbrella-handless, walking sticks etc.

c) **Paper and pulp**: most of the bamboo species yield high quality pulp suitable for making good quality of paper.

d) Medicinal uses like blood purification, emmenagogue, leucoderma, bronchitis, gonorrhoea & fever etc.

e) **Edible**: shoots of several bamboo species are used in curries and pickles, seeds are also eaten.

f) **Fodder**: leaves of bamboos are good fodder for cattle.

Canes: Canes (Rattans) are referred to as plants belonging to genus *Calamus* consisting of about 390 species. The genus belongs to the family Palmae and distributed in virgin forests of tropical and subtropical regions. The genus consists of about 30 species occurring in India chiefly in Himalayas, Assam, Kerala, Karnataka, Tamilnadu & Andaman. The stems in the climbing species are long, attain up to 100 m, usually cylindrical & uniform thickness, solid, straw-yellow, strong, tough & elastic, hard in outer surface but spongy in inner surface. The cane reaches maturity at about 5 years.

Some importance species of canes, which have variety of uses, are given below:

Calamus erectus, C. flagellum, C. floribundus, C. gracilis, C. guruba, C. latifolius, C. leptospadix, C. poseudo tenuis, C. rotang, C. tenuis, C. viminalis, C. acanthospathus, C. andamanicus, C. travancoricus, C. rheedi etc.

Uses: canes are used for variety of purposes on account of their strength, elasticity & length. Some common uses are making furniture like chair, table, sofa sets etc. polo wicket, umbrella handles, walking sticks, baskets, show-case materials, manufacture of sports goods, wicker works, containers etc. Fruits of *C. rotang* are edible & seeds of *C. erectus* are substitute for betel nut (areca nut). Roots and leaves are used as medicinal purposes to cure ulcer, dysentery, biliousness and febrifuge and tonic.

3. DISTILLATION AND EXTRACTION PRODUCTS INCLUDING GRASS OILS

Essential oils are volatile oils, odoriferous liquids, occurring naturally by various parts of plant species of more than 60 families of plant kingdom. The common oil yielding species from families are Labiatae, Rutaceae, Umbelliferae, Geraninaceae, Compositae, Lauraceae, Gramineae and Leguminosae. These oils evaporate when they come in contact with air and this property distinguishes them from fatty acids. Plants produce essential oil as a bye-product of carbohydrates and fat metabolism. They occur in special cells, glands or ducts either in a specific or several parts of the plant.

The main characteristics of these oils are as follows:

a) They are made up of a number of organic substances occur in liquid forms.

b) They have pleasant taste and strong aromatic smell and amount of oil in a plant varies with species, locality and climatic condition.

Extraction: Many processes may be adopted for recovery of essential oils from plants – the process followed depends on the following:

a) Quality of essential oil available in the plants

b) Species concerned and

c) Stability of the compound.

The main methods that may be adopted for the recovery of essential oils from plants as follows:

I) Distillation : (a) water, (b) steam, (c) water and steam distillation

II) Expression

III) Extraction by solvents: (a) by non-volatile solvents, (b) by volatile solvents

Uses:

I) In the preparation of soaps, cosmetics and other preparation mainly due to their pleasant odour and high volatility.

II) In the preparation of perfumes, particularly high quality ones. This is mainly due to their pleasant odour.

III) For adding flavour or essence to candy, ice cream, cordials, liquors and non-alcoholic beverages.

IV) In the preparation of medicines and drugs.

V) For making confectionery and aerated water.

VI) In the manufacture of toothpaste and scented tobacco.

VII) For making agarbatis and incense sticks.

VIII) As solvent of paints and varnish industry.

Important Essential Oils:

A) Grass Oil

(a) Citronella oil – a number of species and varieties of *Cymbopogon* sp. commercially cultivated and produced Citronella oil. Oil is extracted through process of distillation. Percentage of oil extracted 0.5% to 1.25% volume by volume.

Uses of citranella oil:

For making low cost perfumes, soaps, floor waxes, insecticides, mosquito repellent, chemicals and other household products.

(b) **Ginger grass oil** – The grass *Cymbopogon martini* yields ginger grass oil and process of extraction is through distillation.

Uses of ginger grass oil:

It has pleasant scent, and used for making scents and cheaper varieties of soap and number of chemicals.

(c) **Lemon grass oil** – *Cymbopogan flexuous* yields the lemon grass oil and extraction is done through steam distillation process.

Uses: It is used to manufacture of perfumes, soaps, cosmetics, flavours, mosquito repellants, balms for relief of pain, etc.

(d) **Palma Rosa oil:** Rosha grass or *Cymbopogon martini* var. *motea* yields the *palmrosa* oil obtained through destructive distillation process.

Uses: It is used for manufacturing of perfumes, cosmetics, soaps, mosquito repellents, medicines and drugs etc.

(e) **Vetiver (Khus) oil:** It is obtained from the root of densely tufted grass *Vetiveria zizanioides* and oil is extracted through steam distillation process.

Uses: It is used to manufacture of perfumes, cosmetics, soaps, adding flavour to beverages, etc.

B. Wood oils:

(a) **Agaroil:** The oil is obtained from the resinous portion of wood of *Aquillaria agallocha* through process of soaking and then distillation. The main uses of agar oil are to manufacture of perfumes, incense or agarbattis, etc.

(b) **Deodar oil:** The oil is obtained through steam distillation of wood of *Cedrus deodara*, a majestic tree found in western Himalaya usually above elevation of 1800 m. The main uses of oils are manufacture of furniture polish, paints, perfumes, soaps, cosmetics & medicines etc.

(c) **Pine oil:** The heartwood of chirpine and blue pine (*Pinus* sp.) yields pine oil through the destructive or steam distillation. The main uses of this oil are for making soaps, paints, cosmetics, drugs, pesticides, insecticides etc.

(d) **Sandal wood oil:** The oil is obtained from the heartwood of *Santalum album* through the process of steam distillation. The main uses of oil are to manufacture of soaps, perfumes etc.

(C) Leaf oil:

(a) **Camphor oil:** It is obtained from leaves of *Cinnamomum camphora* by steam distillation of leaves, the main uses of said oil is treating cough and cold, manufacture of perfumes, insecticides, liniments etc.

(b) **Cinnamon leaf and bark oil:** The oil is obtained from leaves & bark of *Cinnamomum zeylanicum*. The main uses are pharmaceuticals, confectionery etc.

(c) *Citriodora* **oil:** The oil is extracted from leaves of *Eucalyptus citriodora*, which is used to manufacture soaps, cosmetics, perfumes etc.

(d) **Eucalyptus oil:** The leaves of *Eucalyptus globulus* produced this oil and main uses are to produce low quality perfumes, pharmaceuticals, soaps, toothpaste and other toilet preparations, mosquito repellents, germicides etc.

(e) **Mint oil:** The oil is obtained from the different species of *Mentha* sp. Viz. *M. piperita* (Pepper mint), *M. arvensis* etc. The main uses of oil are to make toothpaste, mouth freshness, pharmaceuticals etc.

(f) **Pine needle oil:** The oil is extracted from the young twigs and needles of *Abies pindrow, Picea smithiana, Pinus roxburghii & P. wallichiana.* It is used in the manufacture of perfumes, soaps, room freshener's deodorants & disinfectants.

(g) **Wintergreen oil:** The leaves of *Gaultheria fragrantissima*, an aromatic shrub produced this oil & used to make candy, chewing gum, perfumes, toothpaste etc.

(D) Root Oil:

(a) **Kuth oil:** It is obtained from the roots of *Sausseria lappa* with the use of manufacturing drugs and perfumes etc.

(b) **Indian Valerian oil:** The dried rhizome of *Valeriana wallichi* produce this oil and used to make drugs, perfumes, scents & adding flavour of tobacco & other products.

(E) Flower Oils:

(a) Keora oils : *Pandanus tectoris* produced keora oil from its flower and used to make perfumes, cosmetics, scents & other toilet items.

Essential oils of minor value:

A number of essential oils of minor or lesser importance may also be extracted from plants. Some of them are given below.

(a) *Abelmoschus moschatus*: The oil is used to make cosmetics, hair oils, perfumes, insect repellent etc.

(b) *Acacia farnesiana* : The flowers yield the 'cassie' perfume of commerce.

(c) *Boswellia serrata* (salai): The green oleoresin yields an essential oil, which serves as a substitute of pine turpentine.

(d) *Citrus limonia*: The oil used in blending with other essences to give 'Verbena' perfume.

(e) *Jasminum grandiflorum*: The flower of these plant produce jasmine perfume by solvent extraction.

(f) *Michelia champaca* (Champ) : Champ oil is obtained from flowers of said species used to make an 'attar'.

(g) *Mimusops elengi* (bulletwood): The flowers on steam distillation yield an essential oil, which is used to make perfumes.

(h) *Acorus calamus*: Calamus oil or calamus perfume is the trade name of essential oil obtained from it.

(i) *Juniperus macropoda*: The oil is obtained from wood on steam distillation having medicinal value.

4. OIL SEEDS

There are very large numbers of forest plants, which bear seeds yielding oil of varying commercial importance. Forest oil seeds, however, due to scattered nature of trees cannot complete with oil seeds produced as field crops. The oil is chiefly used for cooking, lighting and adulteration of more expensive oils.

There are two main methods of extracting oil from seeds are (a) Expressions and (b) Extraction. In the first one clean seeds are pressed between chilled iron rollers and as a result of which oil is forced out by pressure between the rollers. In the second method oil is obtained from seeds on extraction with volatile solvents which yield a higher yield of oil but the resultant cake is unfit for consumption by cattle because of traces of solvents remain behind and are difficult to remove.

Some important oil yielding plants in the forests are given below:

(i) *Actinodaphne hookeri*: The fat obtained from this plant is used for making detergents & soaps.

(ii) *Azadirachta indica* (Neem): The seeds of this plant contain oil up to 45% and used in medicine, as an illuminant, manufacture of soap etc.

(iii) *Calophylum inophylum*: The tree is found in the coastal regions and locally in the hilly tracts of peninsular India. The oil is used for burning & soap making purposes.

(iv) *Madhuca indica*: The trade name of the oil obtained from its kernels is mahua butter which is used to make soaps, cooking oil, candles, hairoil, tonic, drugs, used for burning/lighting and cake is used as manure.

(v) *Garcinia indica*: The tree yields a valuable edible fat known as "kokam butter".

(vi) *Mallotus philippensis* (Kamela): The oil obtained from seed is used as a substitute for tung oil in making quick drying paints and varnishes, hair fixers and ointments.

(vii) *Hydnocarpus kurzii*: Chalmugra oil is obtained from the seeds of said species and used to cure leprosy and skin diseases.

(viii) *Melia azadarach* (Persian lilac/ghora neem): The oil obtained from oil is suitable for making soaps & hair oils.

(ix) *Mesua ferrea* (mesua): The oil is used for burning, lubricating, soap making and applying on sores.

(x) *Mimusops elengi* : The fatty oil obtained from seeds is used for edible and lighting purposes.

(xi) *Pongamia pinnata* (Karanj): The seeds yields an oil, which is used in medicines, soap making & leather tanning.

(xii) *Schleichera oleosa* (Kusum): The kusum oil of commerce is obtained from the seed of these plants and used for cooking, lighting and soap making.

(xiii) *Shorea robusta* (sal): The seeds produce the well-known sal butter, used for cooking, lighting & for adulterating ghees. It is used in confectionery & soap making industry.

(xiv) *Vateria indica* (Vellapine): The seeds yield a solid oil known as 'piney tallow' and used for lighting, as a suitable substitute of ghee & for medicinal purposes.

Waxes:

The epidermis of the leaves and fruits of many plant species have a waxy covering, mainly for preventing excessive loss of moisture though the process of transpiration. Commercial exploitation of this wax is un-economical through waxes may be obtained from *Sapium sebiferum, Copernicia cerifera* & *Rhus succedana*. The main uses of plant waxes are for making candles, soaps, dressing cloth etc.

5. TANS AND DYES:

The term tannin was introduced by Seguin in the year 1976 to indicate various plant extracts, which have the capacity to convert hides and skins in to leather. Approximately 90% of the vegetable tanning materials are used for tanning leather. Tannins, and dyes are secretion product found in the plant tissues in small or large quantities. These are simple chemical compounds of carbon, hydrogen and oxygen along with some nitrogen. The vegetable dyes have given way largely to synthetic dyes. Tannins cause a number of changes on animal skins and hides by their action make them very strong & flexible, resistant to decomposition & improve their qualities.

Tannins may be obtained from different parts of plants like wood, bark, leaves & fruit of trees and shrubs.

Types of Tan: Tanning material can be classified into (i) Bank tans, (ii) Fruit tan & (iii) leaf tans.

(i) **Bark tans:** Tans may be obtained from the bark of many forest trees & shrubs. The tan liquors are extracted from the bark or other raw material by the application of steam and mixed with other extract to give any required colour & quality of leather. Some important examples of bark tans are given below:

(a) *Acacia mollisima* (Wattle): It is an exotic tree and cultivated in South India. It is the most important among vegetable tan-staff. It has good penetrating qualities and give good biscuit colours to leather.

(b) *Acacia nilotica* (babul): The bark is cheap and abundant. The main properties and uses of the tannin obtained from tree are – the tannin contents of bark ranges from 10-20% and it is suited for treating heavier leather.

(c) *Cassia auriculata* (Avaram): It is consider superior to babul bark and contain 23% tannin materials.

(d) *Cassia fistula* (Konnai): The tannin content is 10-12%. It produces smooth grained leather and tannin obtained from twig produced better colour than that from the trunk.

(e) *Shorea robusta* (sal): The bark contains 3-9% tannin and furnishes a very tough and reddish colour to the leather.

(f) *Terminalia arjuna* (Arjun): The tannin content is bark is 20-24%. The colour of leather produced is light brown.

(g) *Ceriops roxburghiana*: The tannin content in the bark is 20-37% and in the leaves 9-15%. Reddish colour is imparted to the leather, though a lighter shade is obtained when this tannin is used in a combination with other tannins.

(h) *Rhizophora mucronata*: The tannin content of bark is more than 40%. It produces attractive leather free from cracks.

(ii) Leaf tans:

The use of leaf tans for tanning is very limited, only being used locally. They donot contain much qualities of tannin enough to use in commercial purposes. Species from which leaf tannins may be obtained for local use are given below:

(a) *Anogeissus latifolia*: The tannins are obtained from dried mature leaves of the tree. It is used to treat different types of skin and hides and it can penetrate very quickly giving light colour to the leather.

(b) *Carissa spinarum* (Karaunda): The leaves of this plant is collected throughout the year and tannin content is 9-11%. It is suitable for mixing with other tan material.

(c) Other well known but not very important leaf tans are *Emblica officinalis, Lausonia inermis, Garuga pinnata, Prosopis spicigera, Terminalia* sp. etc.

DYES:

Dyes are material or matter used for dyeing; especially, the colouring material in solution. Dyeing is the process of impregnating with colour; especially the fixing of colour in solution in textile and absorbent substances. Dyes are substances used for colouring, which includes paints, varnishes, leather, ink, paper, wood, medicines, foods, etc. These are chiefly used in textile industries. Since the introduction of aniline dyes, the value of vegetable dyes has considerably reduced.

Types of dyes: Dyes can be divided in (i) wood dyes (ii) bark dyes, (iii) flower & fruit dyes, (iv) leaf dyes & (v) root dyes.

(i) **Wood dyes**: Important dyes obtained from the woods of different species is given below:

(a) *Artocarpus* sp.: A bright yellow dye is obtained from the wood of *Artocarpus heterophyllus* and *Artocarpus lakoocha*. The main use of this dye is for imparting colour is silk.

(b) *Acacia catechu*: The dye obtained from wood is commercially known as cutch. It is used for dyeing wood, silk, fishing nets and sailcloth & leather.

(c) *Pterocarpus santalinus* (Red sandel): The dye obtained from wood is called santaline and colour of dye is bright red, used for imparting colour to leather, cotton, & wool.

(d) *Caesalpinea sappan*: This is a small tree that yield a red dye whose commercial name is 'brazilin'. It is used to dyeing the cotton, silk and wool fabrics.

(ii) **Bark dyes**: Some important plants, which produce dyes from their bark, is given below:

(a) *Acacia* sp.: The bark of *Acacia nilotica, A. leucophloea, A. concinna, A. farnesiana* yield a black dye, which imports colour to some foodstuffs and fabrics.

(b) *Alnus* species: A dye is obtained from its bark which is primarily used for depending the colour of a red brown dye obtained from the root of *Rubia cordifolia*.

(c) *Casuarina equisetifolia*: A red dye is obtained from its bark and used to colouring fabrics, fishing net and sailcloth.

(d) *Terminalia* spp.: Different species like *T. tomentosa, T. bellerica* and *T. arjuna*, yield red dye from their barks, which is mainly used for colouring fabrics, fishing nets and cordage.

(e) *Manilkara littorialis*: The bark yields a red dye.

(iii) **Flower and Fruit dyes**:

Though a large number of forest trees producing the dyes best only few of these are of real importance, the rest being of local importance.

(a) *Bixa orellana*: The scarlet colour arils around its seed yield a bright yellow dye whose trade name is 'annatoo'. The main colouring agent of this dye is bixin, which is used for colouring wool, silk and calico. It is also used for importing colour to butter & other foods.

(b) *Butea monosperma* (Palas): The flowers yield a bright yellow colour, extensively used for colouring saris and other fabrics.

(c) *Crocus sativus*: The stigma and style of blue flowers yield a powerful yellow dye, which is used for importing colour to cloth, medicines, confectionery & other foodstuffs.

(d) *Mallotus philippensis* (Kamela): The fruit of these plants yield a red dye having trade name is 'Kamela'. It is used for colouring silk and other fabrics, also imparting colour to soaps, cosmetics, edible oils, ice creams & cold drinks.

(e) *Nyctanthus arbortristis* (Seuli): The floral tubes of this species yield an orange dye whose main function is for imparting colour to fabrics and medicines.

(f) *Toona ciliata* (Toon): Its flower yield a red dye, which is used to colour the cotton and woolen fabrics.

(g) *Wrightia tinctoria*: An indigo like blue colouring substance is obtained from the seeds.

(iv) Leaf dyes:

Some plants which produce dye from their leaves are given below:

(a) *Indigofera tinctoria*: The trade name of the dye obtained from its leaves is indigo. Indigo has high degree of permanency and strength & used for dyeing fabrics. Due to introduction of synthetic dyes, this vegetable dyestuff has lost its importance.

(b) *Lawsonia inermis* (Henna dye): The brown dye obtained from the leaves of this shrub, used for dying fabrics, hair and finger nails.

(v) Root dyes:

Root dye of commercial importance have been described below:

(a) *Berberis aristata*: A yellow dye is obtained from the roots of this species, which is mainly used for imparting colour to leather and fabrics.

(b) *Morinda tinctoria*: A red dye obtained from the root of this plant, which is commercially known as 'morindone'. This dye is used for colouring wool, cotton, towels turbans & handkerchiefs.

(c) *Rubia cordifolia* (Manjito): The red dye is obtained from the roots of this species and main uses are to colouring fabrics and leather.

(d) *Punica granatum*: Dyes of yellow and red shade are obtained from the roots of this species.

(e) *Datisca cannabina*: The root of this plant have been used throughout Himalaya as a yellow dyestuff for wool & cotton.

6. GUMS, RESINS, OLEORESINS AND GUM RESINS

The uses of gums and resins obtained from trees and in some cases shrubs has been known to the human race since times immemorial. These are exuded by the stem and sometimes by the roots and other parts of plants as a natural process or as a response to disease or injury to the bark or wood.

Gums: Gums comprise of polysaccharides or their derivatives, with the formation of true gums being due to disintegration of internal plant tissues. This takes place primarily through the process of gummosis brought about by the decomposition of cellulose. The main characteristics of gum are (a) they dissolve in cold water, (b) insoluble in alcohol or other organic solvents and (c) on exposure to air, gums dry up in to a translucent, amorphous tear shaped bodies or flakes.

General uses of gum:

Gums having the least colour and highest adhesive power & viscosity are commercially most valuable. The general uses as follows:

(i) The finer varieties are use in clarification of liquors, finishing of silk & preparation of watercolours.

(ii) The medium grades are used in confectionery, phasmaceuticals, printing inks, sizing & finishing of textile fabrics & also in dyeing

(iii) The inferior grades are used as adhesives, in calico printing, sizing of paper and also in the paint industry.

Major gum yielding species of India:

The major gum yielding species of India is being described below:

(i) *Acacia catechu* (Khair): This tree yields a dark gum of good quality and is regarded as a better substitute for true gum arabic than babul gum.

(ii) *Acacia nilotica*: It is the main source of commercial Indian gum arabic or babul gum. The gum is used in calico printing, dyeing, manufacture of paper and preparation of sweetmeats.

(iii) *Acacia senegal*: The true gum arabic of commerce comes from this species. The gum is usually mixed with other gums of *Acacia* sp. and used in medicine as demulcent, in textile, mucilage paste, polish and confectionery.

(iv) *A. modesta*: This tree yields a fair quality of gum, which is highly valued in indigenous medicine & also in calico printing.

(v) *Anogeissus latifolia*: The commercial name of the gum obtained from this tree is "ghatti" gum. The main uses of this gum are in calico printing, sizing of paper, manufacture of drugs & pharmaceuticals etc.

(vi) *Cochlospermum religiosum*: The commercial name of the gum obtained from the tree is 'katira' or 'hog' gum and used as a substitute of gum tragacanth, in calico printing & leather dressing, manufacture of drugs etc.

(vii) *Lannea grandis*: The trade name of the gum obtained from this tree is 'Jhingam' gum. It is used as mucilages for making ink and confectionery. The tree is regularly tapped for a period of five years and then given a rest till the wounds are healed up.

(viii) *Pterocarpus marsupium* (Piasal/bijasal): The trade name of the gum obtained from this tree is 'kino' gum. Tapping is done by making blaze on the trunk. The main uses of the gum are in stomach ailments like dysentery and diarrhoea and other several medicinal purposes.

(ix) *Sterculia urens*: Gum karaya or katira gum is the trade name of the gum obtained from this tree and used in textile, cosmetics, food & other industries.

(x) *Bauhinia retusa*: The commercial name of the gum obtained from this tree is 'semla' gum & used for eating, sizing cloth & paper, & for water proofing terraced roofs.

(xi) *Moringqa oleifera* (Moringa gum): The gum is locally used in medicine.

(xii) *Butea monosperma*: The trade name of the gum produced from this plant is 'Bengal kino'. It resembles true gum kino and is used for similar purposes.

(xiii) *Miscellaneous gums*: Other gum yielding tree of minor importances are *Albizia chinensis, A. procera, A. lebbeck, Mangifera indica, Terminalia bellerica, Anacardium occidentale, Bauhinia variegata, B. purpurea, Pithecolobium dulce, Feronia limonia, Azadirachta indica, Terminalia alata, Chloroxylon swietenia, Elaeodendron glaucum* etc.

Resins:

Many plants secrete resins from special cavities or passages, with the resins oozing out from the bark and hardening on exposure. Resin tapping is done on a commercial basis by making wounds on the trunk of the trees. The main properties of resin are:

(a) They are insoluble in water but soluble in alcohol and turpentine.

(b) Resins are brittle, amorphous, transparent & have tusture.

(c) When ignited, resins burn with a smoky flame.

Uses: The main uses of resins are :

(a) In the manufacture of paints & varnishes & turpentine oil

(b) For caulking boats, mainly due to their water proofing qualities.

Classification: Resins may be classified into following broad classes:

(i) Hard resins: These are solid, more or less transparent & have tittle or no essential oil. They form the most important sources of varnishes & hence are commercially very important. Different commercial hard resins are Copal, Dammar, Ambar, Lacquer, Shellac, Mastic etc.

(ii) Oleoresins: These are liquid with a distinct aroma & contain considerable quantities of essential oils. Different commercial oleoresins are turpentine, balsams, etc.

(iii) Gum resins: Gum resins have both characteristics of gum and resins & contain essential oil of minor quantities. Different commercial gum resins are Gamboge and Myrrh.

Major Resin yielding species of India:

Major gum yielding species of India have been described below: Resins, oleoresins gum resins are obtained from the following species.

(i) ***Bosswellia serrata*:** The trade name of the gum obtained from the tree is "Salai" gum or Indian olibanum or guggal. The resins, which oozes from the punctured resin ducts is collected & used as incense & pharmaceutical purposes.

(ii) ***Cannarium strictum* (Black dammar):** The resin flows every year from November to April. The resins are used in the manufacture of paints, bottling work, for plasters and caulking boats.

(iii) ***Dipterocarpus turbinatus* (Gurjan oil):** It is used in lithographic inks, anti-corrosive coating for iron, medicinal purposes, preservation of timber & chaulking boats.

(iv) ***Hopea odorata*:** It is a source of 'rock dammer' which is used in the manufacture of paints and varnishes, caulking boats, as a medicine for wounds & painting pictures.

(v) ***Kingiodendron pinnatum*:** It yields a dark reddish brown oleoresin, which is used as a varnish for word and for medicinal purposes.

Boswellia serrata, Diptecocarpus turbinatus & Kingiodendron pinnatum produce oleo resins.

Gum resins produced from the following trees

(vi) ***Garcinia morella* (gamboge):** It is a source of gum resin, 'gamboge' and used in varnishes, lacquor & metal work. It has also a medicinal use as a cathartic.

(vii) *Commiphora mukul*: The resin produced from this tree has an aromatic taste and odour. It is used as incense, a fixative in perfumery, and in medicine.

Some Resin yielding plants are as follows:

(viii) ***Pinus roxburghii*** **(Chirpine);** It is the only species that regularly tapped.

(ix) ***Pinus wallichiana*** **(Kail):** This species produces resin less freely, but the quality of resin is superior.

(x) ***P. kesiya*** **(khasipine):** It produces good quality of resins, but due to its limited distribution at only Meghalaya, make tapping uneconomical.

(xi) ***Pinus gerardiana*** **(Chilgoza pine):** As the plant occurring in very remote, in –accessible areas at high attitude so commercial tapping is not feasible.

The main uses of pine resin are for the manufacture of turpentine & rosin, in paints, varnishes & sizing of papers etc.

(xii) ***Shorea robusta*** **(Sal):** The resin exudates by this plant is called 'ral' or 'lal dhuna'. It is opaque, brittle, pale yellow & aromatic. It is used as an incense, a disinfectant, fumigant, for paints & varnishes.

(xiii) ***Vateria indica*** **(Vellapine):** The resin obtained from this tree is known as 'dammar', piney resin, Indian copal or dhupa. It is used as varnish, as an ointment for sores, an incense & for caulking boats.

Classification of Indian gums & resins at a glance.

Category	Typical product	Sources
True gums	Gum arabic, gum tragacanth	*Acacia nitolica A. catechu, A. modesta, A. senegal, Anogeissus latifolia, Bauhinia retusa, Cochlospermum religiosum Lannea coromandelica Pterocarpus marsupium, Sterculia urens, S. villosa.*
Hard resins or true resins	Copal, dammar, Amber, Lacquer, Shellac, Mastic	*Cannarium strictum Hoppea adorata, Shorea robusta Vateria indica*
Oleoresins	Turpentine, Balsams of Tolu, other oleoresins, Copaiba Elemi	*Pinus roxburghii, Pinus wallichiana Pinus kesiya, Boswellia serrata Dipterocarpus turbinatus, Kingiodendron pinnatum, Garcinia morella*
Gum resins	Gamboges, Assafoetida Myrrh Olebanum	*Commiphora mukul*

7. ANIMAL, MINERAL AND MISCELLANEOUS PRODUCTS

Animal always played an important role in the life of human beings. The important animal products from forests are as follows:

i. Hides and skins.

ii. Horns and ivory.

iii. Edible birds nests.

iv. Honey and wax.

v. Fur & feathers.

vi. Silk.

vii. Bat's guano.

viii. Bee's dammar.

ix. Fishes.

x. Lac. etc.

(i) **Hides & skins:** Hides refers to the outer covering of large animals like cows, buffalos, horses, camels etc. while the term skin is used to denote the outer covering of smaller animals such as sheep, goats, deers, etc. Hides and skins of different animals are used for to make leather which is used to produce apron, buffing, clothing, roller, purses, ladies handbag, hat bands, gloves, musical instruments, footwear, slippers, bellows, suitcases & other articles.

Skin of snakes, lizard, crocodile & other animals of India is exported to different countries in tanned or raw state.

(ii) **Horns and ivory:** A wide variety of articles are carved from horns in different parts of the country such as buttons, combs, umbrella handles, scoops & shoe horns. Horns of sambar, spotted deer are largely marked and are used for making knife handle. buttons etc. It is believed that rhinoceros horn have medicinal value. Other things produced from horns are, cigarette cases, penholders, jewellery cases, tobacco pipes, ashtrays, spoons, decorative articles etc.

Ivory is chiefly confined to the task of dead elephants in the forests as well as captive elephants. It posses greater elasticity than bones & used to make decorative articles, bracelets, chair, combs, beads, buttons and other various materials.

(iii) **Edible bird nests:** *Collaclia inexpectata* is a bird found in the Indo-Australian region. These birds make its nest from its own saliva which is edible. Two species of *Collaclia* viz. *C. francica* and *C. innominata* are found in Indian Ocean, in the rocks of Andaman & Nicobar Islands.

(iv) **Honey and wax:** Honey is sweet viscid fluid obtained from the comb of honey bees, it is the nectar collected by the bees from flower stored in the cells of honey comb. It is a high source of Vit. B_1, B_2, Vit. C & extensively used in many preparation in Indian medicine. Two honey bee viz. *Apis dorsata & A. indica* mainly produce honey in the forests. The honey is either collected departmentally, by contractors or by issuing permit to local people.

Bee wax is a non crystalline solid, with honey, like aroma, tasteless, brittle & soft to touch. It is used in making foundation for artificial hives, furniture, floor polishes, electrical insulators, for grafting, candle, sealing wax, cosmetics, ointments, plusters & surgical dressings.

(v) **Fur & feathers:** Fur is the term used for dressed coat of certain mammals used as trimming or linning for garments. The important fur bearing animals includes bears cats, fishes, foxes, seals, tigers, muskrats, rabbits and squirrels. The fur is used for making gloves, ladies coat, caps, purse & other fancy articles.

The many light fringed structures that grow from a birds skin & cover its body are called feather. Feathers of peacock & other birds are used for making decorative items.

(vi) **Silk:** India is the fourth largest producer of raw silk in the world. The silkworms are of two types like mulberry feeding and wild. The best known are those which are reared on mulberry (*Morus indica & M. alba*). Other silk worms that are essentially forest insects are found wild on *Bombax ceiba Syzigium cumini, Terminalia alata & Ficus* species. Cocoons are collected in forest & placed on trees in plantations, which looked after, and the crop is obtained. Silk is valued for the lustrous, durable fabrics & the garments & articles, which can be prepared with it.

(vii) **Bat's guano:** It is found in caves in the forest areas, which consists of the accumulated excrement of birds or bats. It is a valuable source of artificial manure, being rich in phosphate & nitrates.

(viii) **Bee's dammer:** The dammer bee (*Melipona sp*) secretes a peculiar waxy resinous substance termed as dammar. The bee builds a nest of small combs in hollow walls or tree trunks. The honey excreted is sour and is used for medicinal purposes, caulking boats etc.

(ix) **Fishes:** Forests includes several kinds of water bodies having varying shape, size, width and depth. These water bodies harbours various types of fishes, which are used by local population as food. Pisciculture is also done in some of the water bodies.

(x) **Lac:** Lac is a resinous, protective, secretion of tiny lac insect (*Laccifer lacca*), which is a parasite on a number of wild and cultivated plants. Major host plants are *Butea monosperma, Schleichera oleosa, Ziziphus mauritiana, Ougeinia oojenensis, Acacia catechu, Ficus spp* & others. It finds use in glazing paper, nail polishes, dental plates, bangles, jewellery fillings, grinding wheels, confectionery etc.

Mineral products: Among the mineral products found in the forests may be mentioned building stones, road metal, limestones, gravel, slates & other similar products. The Forest departments regulate

the collection and sale of these products & considerable revenue is realised. The leases / permit for collection of minerals are usually on fixed lump-sum payment.

Miscellaneous products:

There are number of useful products are yielded from plants which are as follows:

i. Cutch and katha.
ii. Latex.
iii. Insecticides.
iv. Chemicals.
v. Nuts.
vi. Bead seeds.
vii. Leaves (Bidi, leaves for basket, umbrella, plates & cup making & thatching leaves)
viii. Shola pith.

(i) **Katha & Cutch:** Katha is obtained from heartwood of khair (*Acacia catechu*). On boiling with water, the heartwood of the tree yields catechu. The two common varieties of catechu marketed in India are the pale catechu and the dark catechu commonly called as katha & Cutch respectively.

Katha is extensively used in pan preparations and medicines. It is also considered as astringent, cooling & digestive, useful in relaxed condition of throat and gums; cough, diarrhoea etc. Cutch is used for dying cotton & silk fabrics, calico printing, etc.

(ii) **Latex:** Latex of several species are used but rubber plant yields the most useful latex & it is cultivated in the forest for rubber production. The rubber obtained from rubber tree (*Hevea brasiliensis*) is largely used for making tyres & tubes, footwear, wire & cable insulations, washer and gaskets, waterbags, ice bags, surgeon gloves, toys, erasers, telephones, combs, rubber bands etc.

(iii) **Insecticides:** The term insecticides includes substances designated for the destruction of insects & other related pests. Extract obtained from different parts of plants may be of leaves; flowers, fruits, roots & stem show pesticidal properties against different insects. Some common trees which have such properties are *Azadirachta indica, Annona reguamore, Melia azaderach, Adina cordifolia, Hopea parviflora, Acorus calamus, Dalbergia stipulacea, Deeris* indica etc.

(iv) **Chemicals:** Various parts of the plant such as leaves, roots, barks, etc. are rich in chemicals and some of these are used for large scale production of these chemicals. Few examples of such are bark of *Machilus macarantha* (kawla) produced Agarbati, oxalic acid produced from bark of *Terminalia tomentosa*, arsolic acid extracted from leaves of *Eucalyptus hybrid* etc.

(v) **Nuts:**

) **Soap nuts:** A number of plants yields products that contain as 'saponins' – a glucosides yielding a soap tooth is water & therefore can be used as substitute of soap. The soap nuts are obtained from *Sapindus mukorossi*, *S. trifoliatus* (ritha), *Acacia coccinia* (a climbing plant yield shigakai pod which are very good for washing hair, silks & wooden goods). Soap nuts are widely used for washing clothes before dyeing, for washing hair, foam stabilizer in soap less shampoos.

(b) **Marking nuts:** The pericarp of the fruit of *Semecarpus anacardium* (Velai) contain corrosive juice which is used as a marking ink, with lime as a mordant, it is indelible. The fruit is mainly used for marking clothes.

(vi) **Bead trees:** There are many kinds of seeds which are used as beads for making necklaces. Some of these are mentioned below:

(a) ***Abrus precatorius*:** Goldsmiths use the seeds for weighing. Seeds are used as beads for necklace & other commercial purposes.

(b) ***Adenanthera pavoniana*:** The hard shining, scarlet seeds which are used as beads.

(c) ***Coix lachryma-jobi*:** This a small erect grass of whose fruits are used as beads.

(d) ***Putranjiva roxburghii*:** The stones of the fruits have the widespread belief of warding off evil spirits & protecting the life of children. These are string into amulets & are worn around the neck.

(e) ***Corypha umbraculifera*:** A tall palm found in West Coast yield seeds which are hard & white. These are used for Bead buttons & other ornamental articles.

(f) ***Elaeocarpus ganitrus* (Rudraksha):** The drupe of the tree has encloses a hard longitudinally grooved tubercle stone. The stones are cleaned, polished & stained and are used for ornamental ware, these are used as beads for rosaries & bracelets. They are much prized by Brahmins and sanyasis.

(viii) **Sholapith:** *Aeschynomene aspera* is a small-stout herb with spongy floating stem, commonly met in water logged places. The stem consists of a mass of very light soft pith which is extensively used in making sola hats, toys, artificial flower, models, swimming jackets, life belts, etc. These can be used as a substitute for bottle corks.

(ix) **Leaves:** Leaves of various forest species have been employed for different purposes since ancient time. Leaves are widely used as food, medicine, fodder etc. but other than these, leaves of some trees & shrubs are put to a variety of uses. On the basis of uses, the leaves can be classified as follows:

i) **Bidi leaves.**

ii) Leaves for making plates & cups.

iii) Thatching leaves.

iv) Leaves for basket making.

v) Leaves for umbrella making.

a) **Bidileaves:** The leaves obtained from *Diospyros melanoxylon* are commercially called as bidi leaves. Tendu leaves for bidis from Madhya Pradesh, Maharashtra, Andhra Pradesh, Orissa and UP constitute major cottage industry in the country & several lacs peoples are engaged for plucking, tending, bidi rolling etc. Forest department also earned considerable amount of revenue each year. Some other leaves like *Bauhinia racemosa, Artocarpus integrifolia, Musa paradisiaca, Holorrhena antidysenterica* are also used in some parts of the country.

b) **Leaves for making cups and plates:** Leaves of *Madhuca indica, Butea monosperma, B. superba, Bauhinia* spp., *Ficus benghalensis, Shorea robusta,* etc. are used for making plates and cups.

c) Thatching leaves: Leaves of large number of plant species are used for thatching huts in rural areas particularly in tribal villages. Some of these leaves are *Tectona grandis, Shorea robusta, Bauhinia vahlii, Phoenix* spp, *Cocos nucifera, Butea monosperma, Butea superba, Madhuca indica, Nipa fruticans, Livistona parkinsonia, Borassus flabellifer,* etc.

(iv) **Leaves for making baskets:** The leaves of spices which are generally used for making plates and cups are generally used for making baskets also.

(v) **Leaves for making umbrella:** The leaves generally used for making umbrella are from *Tectona grandis, Madhuca indica, Licuala peltata, Shorea robusta, Dillenia pentagyna* etc.

FODDER TREES, SHRUBS AND CLIMBERS

India holds the largest livestock population in the world. The green leaf fodder obtained from trees, shrubs, herbs or climbers is of great values in India to feed livestock population.

Some fodder yielding plant having known nutritive value is given below:

Acacia catechu, A. leucophloea, A. nilotica, Adina cordifolia, Aegle marmelos, Ailanthus excelsa, Albizzia lebbeck, A. procera, Anogeissus latifolia, Artocarpus heterophyllus, Bauhinia malabarica, B. purpurea, B. variegata, Bombax ceiba Bridelia retusa, Careya arborea, Butea monosperma, Buchanania lanzen, Celtis australis, Cordia dichotoma, Dalbergia sissoo, Diospyros melanoxylon, Emblica officinalis, Ficus bengalensis, F. cunia, F. glomerata, F. hispida, F. roxburghii, Garuga pinnata, Falcourtia indica, Gardenia spp, *Kydia calycina, Holoptelea integrifolia, Lagerstroemea parviflora, Leucaena leucophloea, Madhuca* sp, *Lannea coromandelica, Mallotus philippensis, Mangifera* indica, *Morus alba, Moringa oleifera, Pongamia pinnata, Quercus* spp, *Schleichera aleosa, Shorea robusta, Syzygium cumini, Tamarindus indica, Terminalia bellerica, T. chebula, T. arjuna, Toona ciliata, Ziziphus* spp. etc.

Some important fodder yielding shrubs & climbers are as follows:

Bauhinia vahlii, Berberis asiatica, Butea superba, Combretum rouburghii, Ficus tinctoria, Phoenix acaulis, Sesbania cannabina, Woodfordia fruticosa, etc.

Some important fodder yielding herbs are as follows:

Atylosia spp, *Cassia tora, Crotalaria bilata, Desmodium gangeticum, Lathyrus aphaca, Medicago* spp, *Melilotus alba, Mimosa pudica, Stylosanthes* spp, *Tephrosia purpurea, Vicia sativa* etc.

8. DRUGS, SPECIES AND POISON

A very large variety of drugs, spices and edible products are obtained from forest trees & plants. The following of these are important from economic point of view.

DRUGS: Drugs from plants depends for their therapeutic effect upon a extractives of plants. People used plants as medicine since time immemorial. Charak and Shushrut were the pioneers in the field of medicine in India. Medicine comes from root, stem, bark, leaves, seeds, flowers, stem i.e. almost all parts of plants. Some important drugs obtained from plants & their medicinal values are given below in tabular form.

Scientific name	Parts used	Therapeutic uses
Abrus precatorius	Root, leaf, seed	Cures body pain, skin disease
Abuliton indicum	Root, bark, leaf	Cures dysentery, hepatitis, diabetes
Saussuria lappa	Root	Cures asthma, cough, dyspepsia, skin diseases etc.
Aconitum sp.	Root	Acts as astringent, stomachic & cures diarrhoea, dyspepsia, cough etc.
Acorus calamus	Root	Cures dyspepsia, colic etc.
Valeriana wallichii	Root	Used as stimulant, antispasmotic etc.
Berberis aristata	Root	Cures opthalmia, piles etc.
Dioscorea deltoidea	Root	Cures rheumatic pain & allergy.
Rauvolfia serpentina	Root	Cures snake bite, insomnia, insanity, blindness etc.
Alstonia scholaris	Root, bark	Cures leprosy, skin diseases, malaria, diarrhoea, asthma.
Alternenthera sessilis	Young shoot	Used as febrifuge, cures night blindness

Scientific name	Parts used	Therapeutic uses
Andrographis paniculata	Leaf, whole plant	Cures dysentery, worm infection, used as liver tonic.
Azadirachta indica	Leaf, flower, seed	Used as antibacterial, antiviral, cures skin diseases.
Bacopa monnieri	Whole plants	Used as digestive, dimetic, cures asthma, skin diseases.
Bauhinia purpurea	Root, bark	Root is curminative; bark used in diarrhoea, worm infections.
Holarrhena antidysenterica	Bark	It is astringent, antidysenterica, stomachic etc.
Cinchona officinalis	Bark	Used to cure malaria.
Soyamida febrifuga	Bark	Used to cure fever.
Artemisia sp.	Flower, fruits	Cures dyspepsia, intestinal worm, used as vermifuge & tonic.
Strychnos nux-vomica	Flower, fruits	Cures nerval disorders & paralysis.
Aegle marmelos	Fruit	Cures dysentery, diarrhoea, constipation etc.
Plantago ovata	Fruit	Used in chronic dystentery, diarrhoea, constipation etc.
Ephedra gerardiana	Leaf	Cures asthma & hay fever.
Vitex peduncularis	Leaf	Cures black water fever.
Hyoscyamus niger	Leaf	Relief spasm in urinary tract.
Connabis sativa	Leaf, flower	Used as narcotics.
Atropa belladona	Leaf	Used as narcotic, sedative etc.
Swertia chirata	Leaf, stem	Used as a tonic, febrifuge, laxative & anthelmintic.
Cassia fistula	Leaf, bark, seeds	Used in fungal infections, urinary troubles.
Curculigo orchioides	Rhizome	Used as appetizer; cures disease of blood and leucoderma

Scientific name	Parts used	Therapeutic uses
Costus speciosus	Root, leaf	Used in liver disorders.
Centella asiatisa	Leaf	Used in jaundice, dysentery.
Euphorbia hirta	Latex, whole plant	Used in dysentery, cough, Asthma, worm infections.
Helicteres isora	Bark, fruit	Used in diarrhoea, dyspepsia, gastric troubles.
Mimusops elengi	Bark, flower, fruit, seed	Used as tonic, anthelmintic.
Ocimum sanctum	Leaf	Used in treatment of common cold, asthma, bronchitis, fever
Justicia adhatoda	Leaf	Used in cough & cold.
Datura fastuosa	Leaf, seed	Used for relieving pain & fever.
Phyllanthus emblica	Bark & fruit	Cures piles, anaemia, inflammation
Piper longum	Root, leaf, fruit	Used as anthelmintic, aphrodisiac, digestive; cures insomnia, headache.
Solanum nigrum	Whole plant	Used in liver & skin diseases, dysentery, piles.
Streblus asper	Bark, leaf	Used as antiseptic, antiinflammatory; cures sinusitis, bronchitis.
Terminalia arjuna	Leaf, bark, seed	Used as cardio tonic, antidysenterica, cures cirrhosis of liver.
Tinospora cordifolia	Stem, leaf	Used as astringent, analgesic, stomachic
Vitex negundo	Leaf	Used as tonic, antiseptic, anthelmintic, tranquillizer.
Abroma angusta	Bark, Root	Used as emmenagogue, in uterine tonic, neuralgic dysmenorrhoea
Aristolochia indica	Root	Used in indigestion, fever, blood pressure.
Catharanthus roseus	Root	Used in dysentery, cholera, stomach ailments
Digitalis purpurea	Leaf	Used in heart disease.

Scientific name	Parts used	Therapeutic uses
Hemidesmus indicus	Root	Used in fever, skin diseases, rheumatic pain, urinary ailments.
Pterocarpus marsupium	Stem, bark	Used in chronic diarrhoea, toothaches. fever, urinary discharges, diabetes.
Syzigium cumini	Bark, seeds	Astringent; cures sore throat, bronchitis, asthma, ulcer, chronic dysentery, diabetes.
Terminalia bellerica	Fruit, leaves	Used to cures piles, leprosy, dropsy, diarrhoea, dysentery.
T. chebula	Fruit	It is laxative; cures ulcers & wound.

Spices: Spices are generally aromatic, vegetable products, used in cooling to add aroma or pungency to food & flavour dishes. They have strong odour & sweet bitter taste. They are marketed generally in dried form. Some of the species of spices found in the forests are as follows:

i) ***Abelmoschus moschatus* (Musk dana):** It is utilized as flavouring agent of food, tonic, stimulant & curminative.

ii) ***Alpinia galanga* (Galangal):** Besides spice value it is used in rheumatic pain, catarrhal affections etc.

iii) ***Cinnamomum zeylanicum* (Dalchini):** Barks are used as spices.

iv) ***C. tamala* (Tejpata):** Leaves are used as flavouring agent, spices or condiment.

v) ***Curcuma aromatica:*** Root is used as an ingredient in curries & colouring the foodstuffs.

vi) ***Piper nigrum* (Golmorich):** Fruit is used as species.

vii) ***Piper longum* (Pepper):** Fruit is used as spice & called as long pepper.

viii) ***Syzigium aromaticum* (clove),** Flower bud are stimulant, carminative and are used in various forms of gastric irritation & dyspepsia other than spice value.

ix) *Elettaria cardamomum* **(Cardamom/Chhota elaichi):** Fruit is used for flavouring foods & eating with pan for its pleasant aroma. It is also used as carminative, stomachic & stimulant.

x) ***Amomum subulatum* (Baro elaichi):** Dried fruit are used for flavouring foods, curries, sweet meats etc. It is not as good as *Elettaria* sp but used as substitute for it.

xi) ***Murraya koenigii* (Curry patta):** Leaves are extensively used as flavouring in curries & chutneys. It is also used to cure dysentery, diarrhoea, bruishes & skin eruptions.

9. EDIBLE PRODUCTS

India is richly endowed with about 20000 species of flowering plants. About 20% of the total plants found in the forests are having direct utility to mankind. All the food plants of present days like cereals, pulses, fruits, nuts, vegetables etc which are widely cultivated are the result of the process of continued selection over the ages by man from his wild ancestors. About 600 species in Indian forests are enumerated to have food value for human beings. A large variety of seeds, leaves, fruits, flowers, nuts etc. are used by the people. Most of the tribal people particularly those living inside the forests & the primitive tribes in India still draw a substantial quantity of food material from the forest areas. On the basis of edible parts, plants found in forests are classified as follows

i) Plants yielding edible fruits.

ii) Plant yielding edible stems & tubers.

iii) Plants yielding edible leaves.

iv) Plants yielding edible seeds.

v) Plants yielding edible flowers.

vi) Plants yielding edible underground root & rhizomes.

Some important edible products found in the forests are given below:

A. Plants yielding edible fruits.

Sl. No.	Scientific name	Family	Edible parts & uses
1.	*Aegle marmelos* (T)	Rutaceae	Fruit used as food
2.	*Anacardium occidentale*	Anacardiaceae	Hypocarp is edible
3.	*Annona squamosa* (T)	Annonaceae	White pulp is edible
4.	*A. reticulata* (T)	Annonaceae	White pulp is edible
5.	*Artocarpus heterophyllus* (T)	Moraceae	Unripe & ripe fruit is edible
6.	*Averhoea carambola* (T)	Averhoaceae	Fruit is used to make chutney
7.	*Carissa carandus* (S)	Apocynaceae	Pickle & eaten fresh
8.	*Dillenia indica* (T)	Dilleniaceae	Sepals used to make jelly, chutney
9.	*Diospyros melanoxylon* (T)	Ebenaceae	Ripe fruits are eaten
10	*Feronia elephantum* (T)	Rutaceae	Pulp is eaten
11.	*Ficus hispida* (T)	Moraceae	Eaten or cooked

Sl. No.	Scientific name	Family	Edible parts & uses
12.	*Madhuca indica* (T)	Sapotaceae	Fruits are eaten fresh or dried
13.	*Mangifera indica* (T)	Anacardiaceous	Fruits both green & ripe are eaten
14.	*Manilkara hexandra* (T)	Sapotaceae	Fruits are eaten fresh or dried
15.	*Mimusops elengi* (T)	Sapotaceae	Ripe fruits
16.	*Morinda citrifolia* (T)	Rubiaceae	Fruits are eaten raw
17.	*Moringa oleifera* (T)	Moringaceae	Tender pods are used as vegetables
18.	*Morus alba* (T)	Moraceae	Ripe fruits are eaten fresh or juiced
19.	*Murraya paniculata* (S)	Rutaceae	Ripe dried fruits are edible
20.	*Oroxylon indicum* (T)	Bignoniaceae	Fruits are eaten as vegetables.
21.	*Phoenix acaulis* (P)	Arecaceae	Pulp of fruits are eaten
22.	*Premna latifolia* (T)	Verbenaceae	Fruits are eaten
23.	*Spondias pinnata* (T)	Anacardiaceae	Ripe fruits are eaten, pickled or used in curries.
24.	*Syzigium cumini* (T)	Myrtaceae	Fruits are eaten fresh.
25.	*S. gambos* (T)	Myrtaceae	Fruits are eaten fresh
26.	*Tamarindus indica* (T)	Caesalpineaceae	Pulp of ripe fruits are used in sauces, curries, etc.
27.	*Wrightia arborea* (T)	Apocynaceae	Fruits are edible
28.	*Ziziphus* sp.	Rhamnaceae	Fresh pulp of fruits are edible & used to make pickles.
II.	**Edible Stem and tubers**		
29.	*Alocasia* (H)	Araceae	Used in curries after cooking
30.	*Alternanthera sessilis* (H)		Young shoots are used as vegetables
31.	*Bambusa* spp (B)	Bambusaceae	Tender shoots are used as vegetables, pickles, curry, chutney etc.

Sl. No.	Scientific name	Family	Edible parts & uses
32.	*Hydrocotyle asiatica* (H)	Umbelliferae	Young shoots are used as vegetables
33.	*Cycas pectinata* (T)	Cycadaceae	Do
34.	*Enhydra fluctuans* (H)	Asteraceae	Do
35.	*Equisetum arvense* (H)	Equisetaceae	Stem base
36.	*Ipomoea aquatica* (H)	Convolvulaceae	Young shoots are used as vegetables
37.	*Nyctanthus arbortristis* (T)	Nyctanthaceae	Do
38.	*Oroxylon indicum* (T)	Bignoniaceae	Do
39.	*Physalis minima* (H)	Solanaceae	Do
40.	*Portulacca oleracea* (H)	Portulaccaceae	Do
41.	*Premna latifolia* (T)	Verbenaceae	Do
III.	**Edible leaves**		
42.	*Abrus precatorius* (T)	Fabaceae	Eaten raw or vegetables.
43.	*Alocasia* sp (H)	Araceae	Petiole & leaves are used in curries.
44.	*Alternanthera sessilis* (H)	Amaranthaceae	Vegtable & soup
45.	*Amaranthus spinosus* (H)	Amaranthaceae	Vegetable
46.	*Areca catechu (T)*	Arecaceae	Salad & vegetable
47.	*Bacopa monnieri* (H)	Scrophulariaceae	Leaves & stalks are eaten
48.	*Bauhinia puruorea* (T)	Caesalpineaceae	Vegetables
49.	*Caryota urens* (Palm)	Arecaceae	Do
50.	*Celosia argentea* (H)	Amaranthaceae	Vegetable & medicine
51.	*Costus speciosus* (H)	Zingiberaceae	Vegetable
52.	*Cleome viscosa* (H)	Capparidaceae	Do
53.	*Gnetum gnemon* (T)	Gnetaceae	Eaten as vegetable
54.	*Hydrolea zeylanica* (H)	Hydrophyllaceae	Vegetables

Sl. No.	Scientific name	Family	Edible parts & uses
55.	*Ipomoea aquatica* (H)	Convolvulaceae	Do
56.	*Leucus aspera* (H)	Lamiaceae	Do
57.	*Morinda citrifolia* (T)	Rubiaceae	Do
58.	*Moringa oleifera* (T)	Moringaceae	Vegetable
59.	*Nelumbo nucifera* (Plant)	Nymphaeaceae	Used as vegetables
60.	*Nymphaea alba* (Plant)	Do	Used in salad
61.	*Nypa fruticans* (Palm)	Arecaceae	Eaten raw or cooked
62.	*Oxalis corniculata* (H)	Oxalidaceae	Eaten raw or salad
63.	*Plantago major* (H)	Plantaginaceae	Boiled & used as vegetables
64.	*Premna latifolia* (T)	Verbenaceae	Cooked as vegetables
65.	*Wrightia arborea* (T)	Apocynaceae	Used as vegetables
66.	*Rhizophora mucronata* (T)	Rhizophoraceae	Vegetable
IV.	**Edible seeds**		
67.	*Abrus precatorius* (T)	Fabaceae	Boiled seeds are edible
68.	*Anacardium occidentale* (T)	Anacardiaceae	Used as sweet meat & confectionery
69.	*Artocarpus heterophyllus* (T)	Moraceae	Both green & ripe fruits are eaten
70.	*Bambusa* spp (B)	Bambusaceae	Used as substitute of rice
71.	*Bauhinia purpurea* (T)	Caesalpineaceae	Eaten raw or roasted
72.	*Castanopsis* sp (T)	Fagaceae	Nuts are edible
73.	*Buchanania lanzen* (T)	Anacardiaceae	Used to prepare sweetmeats, puddings, etc.
74.	*Ephedra gerardiana* (S)	Ephedraceae	Edible
75.	*Equisetum arvense* (H)	Equisetaceae	Eaten cooked
76.	*Holarrhena antidysenterica*	Apocynaceae	Used as vegetable
77.	*Mangifera indica* (T)	Anacardiaceae	Used after roasting or boiling
78.	*Manilkara hexandra* (T)	Sapotaceae	Do

Sl. No.	Scientific name	Family	Edible parts & uses
79.	*Nelumbo nucifeta* (H)	Nymphaeaceae	Eaten raw or roasted
80.	*Pinus gerardiana* (T)	Pinaceae	Eaten raw or roasted
81.	*Pterigota alata* (T)	Sterculiaceae	Edible
82.	*Schleichera oleosa* (T)	Sapindaceae	Eaten raw or roasted
83.	*Sterculia urens* (T)	Sterculiaceae	Eaten like cereal after roasting.
84.	*Tamarindus indica* (T)	Caesalpineaceae	Kernels are boiled or fried before eating.
85.	*Terminalia catappa* (T)	Combretaceae	Eaten raw or roasted
86.	*Trapa bispinosa* (H)	Trapaceae	Eaten raw
87.	*Ziziphus mauritiana* (T)	Rhamnaceae	Edible
V.	**Plants yielding edible flowers**		
88.	*Bauhinia variegata* (T)	Caesalpineaceae	Buds are eaten as vegetables, made in curries etc.
89.	*Bombax ceiba* (T)	Bombacaceae	Calyx is used as vegetable
90.	*Callicarpa arborea* (T)	Verbenaceae	Vegetables
91.	*Dillenia indica* (T)	Dilleniaceae	Buds are eaten raw or vegetables
92.	*Madhuca indica* T)	Sapotaceae	Corolla is eaten raw or cooked, stamens cooked with rice, flowers used to prepare vinegar.
93.	*Moringa oleifera* T)	Moringaceae	Used as vegetable
94.	*Ougeinia oojenensis* (T)	Fabaceae	Used as vegetable after boiling
95.	*Spondias pinnata* (T)	Anacardiaceae	Used in curry
96.	*Woodfordia fruticosa* (S)	Lythraceae	Eaten cooked
VI.	**Plants yielding edible underground parts**		
97.	*Alocasia* sp (H)	Araceae	Tuber
98.	*Asparagus racemosus* (H)	Liliaceae	Tuber
99.	*Colocasia esculenta* (H)	Araceae	Tuber

"Learner's Feed-back"

After going through the Modules / Units please answer the following questionnaire.
Cut the portion and send the same to the Directorate.

To
The Director
Directorate of Distance Education,
Vidyasagar University
Midnapore - 721 102

1. The modules are : (give ✓ in appropriate box)
   ☐ easily understandable; ☐ very hard; ☐ partially understandable.

2. Write the number of the Modules/Units which are very difficult to understand :
   .....
   .....
   .....

3. Write the number of Modules / Units which according to you should be re-written :
   .....
   .....
   .....

4. Which portion / page is not understandable to you? (mention the page no. and portion)
   .....
   .....
   .....
   .....

5. Write a short comment about the study material as a learner.
   .....
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.....
(Full Signature of the Learner)

Date : .....

Enrolment No. .....

Phone / Mobile No. .....

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