FOREST MANAGEMENT

CHAPTER 1
INTRODUCTION

DEFINITION AND SCOPE:

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

(i) "**Forest Management** is that branch of forestry whose function is the organization of a forest property of management and maintenance, by ordering in time and places the various operations necessary for the conservation, protection and improvement of the forest on the one hand, and the controlled harvesting of the forest on the other."

(ii) "**Forest Management** is the application of business methods and technical forestry principles to the operation of a forest property" (SAF)

The above definitions highlight the varied nature of the subject which is concerned with the task of "building up, putting in order and keeping in order a forest business". 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, tan bark, etc. It is based on the knowledge of a number of basic subjects / sciences, such as Siliviculture, Ecology, Geology, Pedology, Botony, Mensuration, Pathology, Economics, and Finance etc. In addition, a forester needs the practical experience gained from observations in the field, results of past treatments given to a forest and deductions there from.

Management of forests broadly involves three main tasks viz,

(i) Control of composition and structure of the growing stock,

(ii) Harvesting and marketing of forest produce, and

(iii) Administration of forest property and personnel.

It is , unlike any other commercial enterprise, complication; as forests, particularly the State-owned as most of the forests are in India (95.8%), are managed for a multiplicity of purpose – productive, protective, climatic, wildlife, recreational and bil-aesthetic, with one use dominant, viz., most often the production of wood. Though the forest land can be managed simultaneously for several uses, however, in some cases, uses are incompatible with one another; e.g., grazing is not compatible with timber production, environmental conservation and recreational use. In each case, priorities are laid down by the owner - the State or the private owner as the case may be, and the management is oriented to achieve the prescribed objectives. In the forests dedicated primarily to recreational and bio-aesthetic use, and conservation of ecology and environment, grazing, fellings, timber extraction and even hunting may have to the suspended.

Productive and protective functions of the forests cannot be bifurcated. As a matter of fact, scientifically managed forests perform both these, simultaneously; productive forests do protect and protective forests do produce – the distinction between the two is of degree rather of kind - a matter of emphasis of the primary function of the forest that the management aims at. It is, therefore, essential that forest resources are maintained in a state of maximum production, consistent with their subsidiary or even the other main functions. Forests have to be managed in such a way so as to provide maximum benefits to maximum people and for all time, ensuring that the soil produces most and deteriorates least under their treatment.

Scope of Forest Management:

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

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

A. *Control of Growing Stock, its Structure and Composition*:

i. Site adaptation

ii. Choice of species

iii. Manipulation of stands

iv. Harvesting the produce

v. Regeneration

vi. Protection.

B. *Distribution and Marketing of produce:*

i. Transportation and communication.

ii. logging Plan

iii. Marketing data

iv. Sale of produce

v. Revenue

C. *Administration of Forest Property:*

i. Forest organization

ii. Management of Personnel

iii. Monitoring and control or works

iv. Labour management and welfare

v. Financial control and economy efficiency

vi. Fulfillment of social obligations

vii. Record for present and future reference.

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

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

PRINCIPLES OF FOREST MANAGEMENT NATIONAL FOREST POLICY:

Fundamental principle of sound management of any enterprise is the fulfillment 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's 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 form the devastating action of hill torrents. Even though some safeguards were provided, demand for culturable land was proposed to be ordinarily met by clearing 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 complimentary land – use, under which each type of land would produce most and deteriorate least.

(ii) Need for checking denudation of mountainous 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 conditions 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 realization of maximum amount of revenue in perpetuity, consistent with the fulfillment 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
(b) National forests
(c) Village forests
(d) Tree- lands.

The Policy also suggested keeping a minimum of one third of the country's total land areas under forests, with 60% in the Himalayas and other hilly tracts liable to erosion and 20% in the Plains. The Policy strongly deprecated the notion widely entertained that 'forestry as such had no intrinsic right to the land but may be permitted on sufferance on residual land not required for any other purpose.

RECOMMENTATIONS OF NATIONAL COMMISSION ON AGRICULTURE (N.C.A) 1976:

The N.C.A, constituted on 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 requirements of goods, i.e., industrial wood for forest-based industries, Defence, Communications and other public purposes and small timber, fuel- wood 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) recognizes 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, tree- less river bands and waste- lands.

(iii) Need for realizing maximum productivity of the forests 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 fulfill these needs, the policy suggests that, on an average, 33% of the land areas should be dedicated to forest comprising of 60% in the hills and 20% in the plains. The fallacious notion that forests may be permitted on sufferance on residual land should be vigorously counteracted.

The policy clearly spells out the multiple purposes for which the forests will be managed, e.g.

(i) Environmental Conservation: to manage and provide for rehabilitation and improvement of forests for their protective influeneces 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 of existing and developing industries and the national requirements of timber for Defence, Communication and domestic needs.

(iii) Social: to meet social needs of the Community, consistent with other objects such as recreation, agricultural timber fuel-wood and regulated grazing for rural people.

States have been enjoined to regulate their policies on the lines of and in consonance with, the above principles.

FORESTS ON CONCURRENT LIST

Realizing the importance of forests for the well-being of the nation, the Parliament, by the 42nd Amendment to the Constitution in 1976, brought forests and wildlife on the concurrent list in 7th schedule. This has enabled the Central Govt. to play a more effective role, than a mere advisory one, in the management of forests. The President of India promulgated the Forest (Conservation) Ordinance, 1980, which put severe restrictions on de-reservation of forests, or use of forestland for non- forest purposes, without prior approval of the Central Govt.

SOME PECULIAR FEATURES OF FORESTRY ENTERPRISE

Forestry presents some distinct features as compared with agriculture or any industrial enterprise. Firstly, forestry is a long term investment and there is a long interval between the formation and harvesting of forest crops. In agriculture, sowing and harvesting of forest crops are done every year, if not several times a year. Similarly, in industry the interval between the investment of capital and the date of first production is continuous. In forest plantations, the interval between the date of formation and date of harvesting may be several decades. This long production period involves delayed returns on the invested capital, which is locked up in the form of maturing timber on the ground.

Second peculiarity is the identity of the product and the manufacturing plant, that is, the income or annual increment of the forest is not distinct from the capital or the growing stock. Trees themselves are the machinery which manufacture the raw material, wood, formed as thin annual rings round the stems and branches of trees. This circumferential growth is the result of absorption of water and nutrients (salts) from the soil, of oxygen from the air and assimilation of carbon from the atmosphere by photo-synthetic process in the leaves in the presence of sunlight. Both the capital (trees) and the yield (increment) are just trees, and there is no natural line of distinction between the trees that may be felled as yield and the trees that must be retained as growing stock to form the capital. In agriculture, the land is the capital and the crop is the interest or income. In industry, the machinery, land and buildings are the capital and the manufactured product is the yield or income. In both these enterprises, there is little danger of capital being encroached upon as both the consumable product (the dividend or interest earned) and the capital are inseparable from each other, and it is not possible to harvest the product separately from the capital, only whole trees, when exploitable, can be felled. It is therefore, imperative to correlate the quantity of growth (increment/yield) to the whole trees that may be cut, ensuring, simultaneously, that the trees left are sufficient to provide the capital (growing stock) necessary for sustained yield.

This identity in the form of capital and income, combined with the length of rotation, calls for a special approach to problems of forest management. The need for regulating the yield is thus very vital, even though it is not very easy to do so, especially in forests which are not normal.

Another peculiarity inherent in forestry is the multiple and varied uses of forests. Forests satisfy innumerable human needs varying from tangible material products to uncomputable benefits they bestow; the latter create difficulty in deciding priorities when several benefits, not all assessable in terms of money, can be provided from the same piece of forest land. The difficulty is pronounced in case of public forests wherein claims and needs of multiple beneficiaries are not easy to decide.

To the foregoing peculiarities complicating forest management, may be added another, viz., forests, generally, occupy more remote, less accessible and less fertile lands as compared to agricultural lands. This results in diffused working and resultant difficulties in supervision and protection as well.

INSTRUMENTS OF FOREST MANAGEMENT

Since forestry is a long term enterprise, it is necessary to record the plan of forest management in the form of a written document, for guidance of the forest manager incharge of the forest estate. This will not only save the management from the whims and idiosyncracies 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 to 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 realize the objects of management.

Working plans are invariably based on the principle of sustained yield. One of the objects of management is always to bring the forest to a condition as nearly normal as possible, and as early as practicable. A working plan gives full account of the physical factors of the locality, composition of the forest, describes the past history, reviews past management, furnishes statistical data and lays down silvicultural management of the various types of forest.

A working plan 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 forest.

CHAPTER II

OBJECTS OF MANAGEMENT

PURPOSE AND POLICY

"Primary object of good management is provision of the maximum benefit to the greatest number of people for all time" (Brasnett). This fundamental purpose is expressed in a similar way by Knuchel (1953) as: "The object of management under any circumstances is the most advantageous utilization possible of the soil allotted to forestry".

As already stated in the preceding Chapter, forests may be managed primarily for productive purposes, i.e. direct material benefits, or protective purposes, i.e., indirect benefits. As a matter of fact, a scientifically managed forest may fulfill both these purposes, simultaneously. However, it is expedient to determine priorities – i.e., the primary (major) and the secondary (minor) objectives of the owner. In case of extensive national forests, it may be sometimes possible to allocate separate forests, in different locations, to fulfill distinctly separate functions, e.g., wildlife reserves, national parks, recreation and natural beauty spots may be clearly demarcated, as also soil conservation areas on the hill slopes, from the production forests. Forests fulfill more than one purpose, with usually one use dominant – the primary object, which is most often timber production. They have, however, to be so managed as to afford the highest possible direct and indirect benefits in perpetuity.

Objects 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 plans (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 plane, thereby providing a broad framework for management.

General objects of management:

(i) Maintaining and, as far as possible, raising the productive capacity of 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 protection of the physical factors such as natural scenery, local flora and fauna.

(iii) Execution of silvicultural operations and regulation of fellings 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 principal objects.

(iv) Satisfaction or rights of the right holders in respect of timber, firewood, grazing, etc., in particular, and to meet the bonafide requirements of the local population in general.

(v) Subject to the above Silvicultural, 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 rent 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 characterized by a distinct vegetation type, more suited for certain purposes as compared to other. In short priorities of objects are re-arranged. Some examples are given below:

(i) Badly eroded areas and steep hill slopes may be constituted into a Protection Working Circle, where the special object will be protection, afforestation, “Soil and Water Conservation; satisfaction of only the minimum social needs of the local population, ignoring considerations for market supplies and financial returns.

(ii) In the watershed of municipal water supplies, irrigation and hydro-electric generation dams, the special objective being the maintenance 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 dominant object, timber fellings, grazing and even hunting will have to be entirely stopped. Such forests serve as ‘magnificent playgrounds for tired mankind seeking peace and spiritual strength.’

(iv) Mixed miscellaneous open forests, heavily grazed and felled in the past, with low proportion of valuable timber and industrially important species are clear felled and converted into plantations of desired species pure or simple compatible mixtures. Such areas have extensively been constituted into Plantation Working Circles and / or Industrial Timber Working Circle 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 and plywood industries.

(v) In Chir-pine forests, one of the special objects 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 / Katha and Match industries.

CHOICE OF OBJECTS:

Whereas the choice in case of private industrial enterprises, where profit alone is the main consideration, is comparatively easy, it is not so in case of State-owned properties, particularly such as forest lands which can provide a wide range of goods and services. Decisions regarding the extent of forest land to be dedicated for providing goods and services required for the local population, and the rate at which these should be provided at a profit or at cost or even free at the cost of general tax payer are quite difficult to take. Policy decisions regarding the course of action to be taken are even harder to take, as policy will change with the conditions and objects and has to be revised from time to time.

Difficulties in deciding the purpose and policy of forestry enterprise increase with the variety of its potential products and their importance to consumers local population and the community as a whole. In additions, new inventions and discoveries, trends in development of resources and progress in standards of living, add new dimensions to the pattern of demand necessitating re-arrangement of priorities and objectives.

Attitude of the owner: Forest lands may be public-owned or privately-owned; in India, however, these are almost entirely State owned and / or managed. A forester is deeply concerned with the important, though sometimes perplexing, management problem of forest lands which are, as we know, capable of providing a variety immediate interest of the private owners is limited, which is mainly financial and, therefore, naturally focused on products which will bring direct monetary returns. Unlikely public ownership, their management is *marked-oriented* responsive to market demands and fluctuations in prices. Management objectives of private owners are usually specific, often narrow as compared with those of State forests, financial considerations being invariably dominant.

It frequently so happens that private interests in forest management do not adequately safeguard public interests, which in the long run must be paramount. The public has a stake in all forest lands, irrespective of ownership and hence a measure of control provided in forest enactment by the State on private forests against their wanton destruction.

In U.S.A., where there are extensive forest estates under private ownership as well, there is a large area of common interest. Forest Management, whether public or private, is a business requiring the same skill, technical knowledge and general managerial ability. Every owner is concerned with managing his forest lands in a thoroughly business like manner to obtain maximum benefits or returns that may be, or however measured. Fundamentally a forest business is very much akin to any other, the difference being primarily in application.

Approach of the owner to the intangible and incomputable services is different from that to material goods, while deciding his objects of management. He has to assess the importance and value of each service, both to the owner and the community the extent to which the service can be provided by forestry, or by some other activity and the cost of providing each service by forestry or by some other land use. This will enable him to determine whether forestry or some other land- use is best suited to supply the services, in whole or in part and, secondly, for areas allotted to forestry what priority is to be given to various services both among themselves and relative to material forest products. He should also be able to decide the degree to which the supply of services may be segregated to particular areas or combined with supply of other services or products in the same area. However, the crux of the matter, and its greatest difficulty, is the assessment of values and costs in comparable real terms, e.g., in money. Costs of providing services can often be judged more easily by estimating the value of what the land could produce in material goods were it not used for ensuring the service than by calculating the actual costs of a administering the service.

As regards material forest products or goods, there is a large variety, ranging from major products such as timber, industrial raw material, firewood, charcoal, to minor products such as gums, resins, oils, tans, drugs, fruits, medicinal plants, fodder, to name only a few. Choice of the type of products to grow depends mainly on the owner, his objects and limitations and constraints, if any. The tow paramount considerations will, however, be:

(i) What tree species are suited to the locality and what forest products can be raised.

(ii) To what use the products thus raised can be put to the best advantage.

The first is an obvious limiting influence. Even if a valuable species can grow in a locality but only slowly, it may be financially disadvantageous to grow. The second factor is more difficult to assess as it will involve fore-casting the trend of demand. The owner, in the first instance, should decide as to which of the following three alternative meanings he gives to works *best advantage* namely:-

(i) Production of a particular kind of product for a particular consumer (industrial raw material, etc.).

(ii) Securing most desirable financial results, irrespective of any particular type of product.

(iii) Production of the greatest quantity of products irrespective of the degree of financial gain.

Different owners may ascribe different meanings to the *most desirable financial results.* For example, a community owning a forest in a village may decide in favour of growing firewood because other forms of fuel may not be available, or be too expensive. A paper manufacturing company may, however, decide to grow only those species and sizes which are most suitable for a pulping plant, even if the profits are lower from forests, but more from its paper project, its primary activity, so that the combined profits are increased. It is obvious that the type of owner, or owning body, may substantially influence choice of objects of growing a particular product or products.

SOCIAL ROLE OF FORESTRY: SOCIAL FORESTRY

In her thought provoking message to the Centenary Celebration of Forest Education at the F.R.I. and Colleges, Dehra Dun, in Decembter, 1981, (late) Smt. Indira Gandhi, the beloved Prime Minister of India, highlighted the Social role of forestry in the following words.

“Forests have always occupied a special position in our culture folk- lore and religion. There has been emphasis on conservation and non-destruction of plant wealth. But greed and a growing population have led to progressive shrinkage of our forest cover, and to the inevitable consequences in the form of erosion, floods and drought. In a developing economy, there is bound to be conflict of interest in resource management. The challenge is to work out a balanced programme for forests, both for conservation and development. The forester has to serve the immediate needs of the villager, specially as regards fuel for the home needs. But he has also to think of the future. A well thought out programme of training for foresters is a basic pre-requisite of good national developed.

As stated earlier, forests are one of the most valuable natural resources inexhaustible and self perpetuating if properly managed unlike oil, coal and minerals providing a wide range of goods and service and serving the mankind in multifarious ways.

The National Commission on Agriculture report high- lighted the importance of the socio-economic role of forms for the rural communities and in the management of the forest resources of the country. It has defined *Social Forestry* in include *Farm Forestry, Extension Forestry, Recreation Forestry and Reforestation* in degraded forests.

Objectives of Social Forestry, taking into consideration the basic socio-economic needs of the community for betterment of their living conditions, include:-

(i) Fuelwood supply to villagers and replacement of cow-dung for cooking.

(ii) Supply of small timber

(iii) Supply of fodder.

(iv) Protection of agricultural fields against wind erosion

(v) Recreational needs of the community.

Social Forestry, a forestry programme for Community Development, (*also called Rural Forestry, Extension Forestry, Enrichment Forestry, Community Forestry, etc.),* has picked up momentum in India, as well as in many other under-developed countries of the world. It is essentially a people-oriented joint forestry management programme with the main objective of satisfying the needs and aspirations of both the people and the State.

Community forestry is the final expressions of the peoples involvement in tree plantation, conservation, development and harvesting of forests for the benefit of the local communities and the Nation.

In India, with a vast majority of population living in villages, subsisting and / or employed mainly on agriculture, forests play a significant role, particularly in rural economy, Trees meet the day to day vital requirements of rural and sub-urban communities in respect of fuel, fodder, grass, timber of small huts and agricultural implements, etc. in addition, forest products such as tan-bark, leaves, fruits and seeds supply raw material for a number of cottage industries such as tassar and silk production (by rearing tassar and silk worm / cocoons on *arjun* (*Terminalia arjuna*) and mulberry leaves, respectively), oil extraction from seeds of *Kanji (Pongamia pinnata), Neem (Azadirachta indica)(and mahua (Madhuca longiforlia Var. latifolia),* paper pulp from Saijna (*Moringa oleifera), Sesbania* spp., *Ailanthus excelsa, Acacia nilotica, Albizia,* if planted on a sizable scale in suitable areas, can sustain schemes of rearing milch cattle as well, by the landless villagers.

Since our forests are not inadequate in extent, generally poorly stocked and not uniformly distributed, the problem of meeting multifarious needs of villagers becomes all the more serious. For cooking food alone an estimated quantity of 400 million tones of cattle-dung is burnt in the form of dung-cakes which deprives the village fields of valuable nitrogenous manure, equivalent to the production of chemical fertilizers by eight Sindri Fertilizer Plants. In addition, it is estimated that about 4 million tones of fuel is required annually for cremation of the dead another important social requirement. Supply of fuelwood to divert cow-dung from village hearths to village fields, small timber of rural housing and agricultural implements, fodder for cattle or rural population living far a away from the forest areas, protection of agriculture by creation of diverse ecosystem and arresting wind and water erosion, and creation of recreational forests for the benefit of rural as well as urban population, are the basic economic and cultural needs of the community without which there can be no improvement in the standards of their living. Accordingly, the Govt. of India, on the recommendation of the National Commission of Agriculture (1976) has embarked on a large scale Social Forestry Programme, through State organizations. Very impressive results have been obtained in Social Forestry Schemes / Projects launched in various States, particularly Gujarat, Uttar Pradesh, Haryana and Maharashtra. Large scale plantations of locally useful tree species are being raised in compact areas or scattered in waste-lands, village Panchayat lands, compounds, private and public degraded lands, etc. But for such Social Forestry programmes executed with the active co-operation of the villagers, Gram Panchayats and voluntary organizations, it would be very difficult to rehabilitate rural economy, which is mainly agricultural. All that is needed in this regard is the determination and effort, and not much of an investment.

Forestry in relation to Agricultural: A reading feature of the modern industrial civilization is the recognition of the importance of forests to our national economy. Our revised National Forest Policy has taken cognizance of the indispensability of forests, for both productive and protective purposes in our planning for national prosperity. Our forests are no longer to be considered as inexhaustible reserves for extension of agriculture. The right of forests to occupy land permanently has now been recognized and forestry is no longer to be viewed as a mere *hand maiden* of agriculture, but its promoter and protector as *forester-mother*. In a balanced national economy, both forestry and agriculture play supremely important roles for sustenance of human civilization. Another fact which deserves better recognition is that forests are also essential to maintain and increase the productivity of agricultural lands I various ways, e.g., by regulating water supply, maintenance of an equable climate, provision of leaf manure and fodder, timber for agricultural implements and fuel for the hearth so as to divert cowdung to its normal (and legitimate) use as manure in the fields. Shelter-belt plantations along coastal fringes (e.g., *Casuarina* plantations on shifting sands on the Orissa, West Bengal, Andhra Pradesh, Tamil Nadu, Maharashtra and Gujarat sea-coasts) control the ravages of violent winds, immobilize coastal sands and protect agricultural crops. In the arid regions, windbreak plantings protect the agricultural fields against desiccating winds.

Fertility and productivity of agricultural land is so intimately bound up with sound forestry practices, in and around the farms, that the wanton destruction of country's forest resources is invariably reflected in diminishing agricultural returns. Forestry is, thus, not a competitive but a complementary land use to agriculture; hence the urgent need for making *Social Forestry* a people's programme.

Concept of Social Forestry envisages the practice of forestry on lands outside th conventional forest areas for achieving social objectives for the benefit or rural and urban communities. This is a new dimension added to the concept of forestry and encompasses, with in its scope: (i) *Farm Forestry,* (ii) *Extension Forestry* including *mixed forestry*, shelterbelt and linear strip plantations, (iii) *Reforestation* of degraded forests (iv) *Recreational or Aesthetic Forestry.*

A forester engaged in Social Forestry projects is a veritable social worker, promoter or rural economy and a *de-facto* rural development officer as well.

CHAPTER III

FOREST ORGANISATION

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

(i) Geographical & Climatic (or Ecological)

(ii) Functional

(iii) Legal (or Statutory)

(iv) Territorial

(v) Administrative (or Organizational) and

(vi) Management (or Silvicultural)

GEOGRAPHICAL AND CLIMATIC (ECOLOGICAL) CLASSIFICATION:

Under this, forests are divided into different forest types. Five major groups are recognized in India, viz, Tropical, Montane Sub-Tropical, Montance Temperate, Sub-apline and Alpine Scrub. These major groups have been further divided into sixteen type-groups, or simply groups or type-groups have been further differentiated into two sub-groups, describing Southern and Northern forms. Each sub- group is further divided into forest type climax, edaphic, seral, etc.

FUNCTIONAL CLASSIFICATION:

National Forest Policy of 1952 suggested a functional classification of Indian Forests into Protection Forests, National Forests, Village Forests and Tree- lands. The National Commission on Agriuclture (1976) has suggested a modified functional classification as Production Forest (sub-divided into *valuable forests, mixed quality forests and inaccessible forests),* Protection Forests and Social Forests (including *minor forests* on marginal lands).

LEGAL CLASSIFICATION:

Forests are broadly classified as Reserved, Protected, Village and Un-classes forests.

Reserved Forests are constituted under the Indian Forest Act (I.F.A), or other forest laws (e.g., M.P. Forest Act). They are the exclusive property of the Govt. and subject to complete protection. Villagers have no rights what so ever in these forests;

however, they may sometimes be granted certain concessions, such as watering their cattle, collection of dry and fallen firewood by head- loads for their bonafide domestic use, etc., in consideration of their co-operation and assistance in forest protection.

Protected Forest is a legal term for an area subject to limited degree of protection, and constituted as such under the provisions of the I.F.A. Rights of villagers are settled and recorded, and the Govt. exercises control on felling and transport of timber, and removal of forest produce in whatever form it may be.

Village Forests are State Forests assigned to a village community under the provisions of the I.F.A. or forests established and managed for supply of forest produce to a village.

Un-classed Forests are forest lands owned by Govt. but not constituted into Reserved, Protected or Village Forests. These are generally heavily burdened with rights and are excessively grazed and felled, and even burnt.

TERRITORIAL CLASSIFICATION:

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

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

Compartment: A block is divided into several compartments which are *territorial Units of a forest permanently defined for purposes of administration and record (preferably designated by Arabic mumerals 1, 2, 3, etc.).* It is the smallest permanent Working Plan unit of management, location of works and record; as such, its boundaries are carefully chosen on the ground and marked on the map. The boundaries are formed either by natural features such as ridges, valley bottoms, streams or artificial lines such a s fire lines. The size of a compartment depends on the intensity of management. Smaller the compartment, easier it is to include areas homogeneous in site factors and forest types in each. In intensively worked forests, Compartments can be quite small, whatever the Silvicultural System adopted. As far as possible a compartment should be homogeneous throughout its extent as regards soil, aspect and composition of growing stock. In protection and Selection forests, working intensity is light and compartments are usually large in size.

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

ADMINISTRATIVE (ORGANISATIONAL) CLASSIFICATION:

At the Central Government level, all Govt. owned forests in the Union Territories are under the control of the Govt. of India, and administrated on their behalf by the Inspector General of Forests, India (I.G.F), with head quarters at Delhi. He is assisted by an Additional Inspector General of Forests (Addl. I.G.F.), a number of Deputy Inspectors General (D.I.Gs.) And Assistant Inspectors General (A.I.Gs.) of Forests, incharge of various wings or special works, such as General Administration, Wild Life, Central Forestry Commission, Forest Industries, Social Forestry, etc. He is currently, *ex-officio* Special Secretary to the Govt. of India in the Ministry of Environment & Forests, and is technical advisor on forestry matters to all the State Governments as well.

The Govt. owned forests in the States are under the control of the respective State Governments. As the forests have now been included in the Concurrent List since 1976, central Government has also some say in their management and control. The Head of the State Forest Department is designated as the Chief Conservator of Forests (C.C.F.). In several major States, like Madhya Pradesh (M.P.), Uttar Pradesh (U.P.), Himachal Pradesh (H.P.), Maharashtra, Gujarat, Karnataka, Kerala, etc., there are at present more than one C.C.F. and the senior most amongst them is the administrative Head and designated as Conservator- in-Chief (as in M.P.), or Principal C.C.F. (as in U.P). The C.C.F. is assisted by Additional Chief conservators of Forest (Addl. C.C.F.) with supervisory and administrative jurisdiction over a number (usually 4 to 5) of Circles, each under a Conservator of Forest (C.F). Corresponding posts of Deputy Chief Conservator of Forests (Dy. C.F.) have since been abolished in almost all the States. With the expansion and stream- lining of forestry activities, and with a view to eliminating the middleman / contractors, State Forest Corporations have come up in most of the State. These Corporations handle not only the timber trade, but also the extraction and marketing of other forest produce as well. A Forest Corporation is generally headed by a Managing Director (M.D.) usually of the rank of a C.C.F. (as in Himachal Pradesh, Maharashtra, U.P., M.P.) and sometimes an addl. C.C.F. He is assisted by Directors and Deputy Managers and Assistant Managers for comparable positions in the administration of Corporations. The Forest Minister of the State is usually the chairman of such Corporations.

Similarly, in some States, as in U.P., H.P. and Gujarat, separate Directorates of Social Forestry have been created under the charge of a C.C.F. In West Bengal, the Director is of the rank of Addl. C.C.F.

State forests, under the Head of State Forest Departments, are divided into a number of Circles, each under a Conservator of Forests (C.F.). There is Territorial as well as Functional Circles. A circle is divided into a number of Divisions, each under the charge of a divisional (or District) Forest Officer (D.F.O.) who is generally of the grade of a Deputy Conservator of Forests (D.C.F.). There is Territorial as well as Functional Divisions, such as Siliviculture, soil Conservation, Working Plans and Logging Divisions. A D.F.O. is the kingpin of forest administration in India.

In many States, Forest Divisions are sometimes divided into two or more Sub-divisions, each under a Sub-Divisional Officer (S.D.O.), an officer of the rank of an Assistant Conservator of Forests (A.C.F.). In West Bengal, there are posts of Addl. D.F.Os. as well.

In our Indian set-up, direct recruitment to the Gazetted ranks is made only at the level of an A.C.F. All other higher posts (of D.C.F., C.F., Addl. C.C.F., I.G.F.) are filled up by promotion from this rank. Thus, the post of an A.C.F. is of great importance. A certain proportion of these posts is filled up from the non-Gazetted ranks of Forest Rangers (F. Rs.) by promotion.

Each Division or Sub-Division is divided into a number of subordinate units called *Ranges*, each under a Range Forest Officer, also designated simply as Range

Officer (R.F.O. or R.O.) of the rank of a Forest Ranger (F.R.) or, sometimes, a senior Deputy Ranger (D.R.). A range is a very important unit in the management and administration of Forests. Ranges are further split up into a number of *Sub-Ranges, Blocks or Section*, each under the charge of a Forest Guard for protection and execution of field operations. *Beat* in the smallest functional territorial Units, and is the foundation of Indian forest administration.

Summing up, hierarchy of the State Forest Department is, generally, of the following pattern.

	Administrative Units	*Officer Incharge*
1.	State Forest Department	C.C.F.
2.	Circle	C.F.
3.	Forest Division	D.F.O. (D.C.F.)
4.	Forest Sub-Division	Sub-D.C.O. / S.D.P. (A.C.F.)
5.	Range	R.F.O. / R.O. (F.R., or D.R)
6.	Sub-Range, Section or Block	Sub Range Officer; S.O. or B.O. (D.R or Forester)
7.	Beat	Beat Officer (Forest Guard)

MANAGEMENT (SILVICULTURAL) CLASSIFICATION:

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

(i) Working Circles

(ii) Felling Series

(iii) Cutting Section,

(iv) Coupes

(v) Periodic Blocks.

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

Felling Series: If is is considered undesirable for silvicultural, social or economic reasons to concentrate fellings in any one place, e.g., if it is desired to provide a sustained yield of forest produce to one or more markets, or to distribute works of all kings over one or more ranges, a W.C. may by divided into *Felling Series* (F.S.). A F.S is defined as: *a forest area forming the whole or part of a Working Circle and delimited so as: (i) to distribute felling and regeneration to suit local conditions and (ii) to maintain or create rately for each F.S. which should have an independent representation of age-classes (BCFT Modif.).* Each F.S. is a self- contained unit of management with a separate calculation of yield and a separate series of silvicultural operations. Divisions of a W.C. into several F.S. enables effective control and distribution of work in different ranges. When a W.C. is no divided it is, of course, one Felling Series.

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

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

FERIODIC BLOCKS: RELLING SERIES IN UNIFORM SYSTEM:

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

FELLING CYCLE – FELLING SERIES IN SELECTION FOREST:

In an ideal Selection Forest the entire area will be worked every year and will represent a complete and undivided Felling Series. Such annual working of the entire area of the Working Circle is neither practicable nor desirable. The usual practice is to divide the area into a number of coupes (also sometimes known as Cutting Sections) each of which is worked at an interval of a planned number of years, known as *Felling Cycles* (F.C.), which is defined as: *the time that elapses between successive main fellings on the same area (*Glossary). It may vary from about 10 to 30 years (in some cases even 5 to 40 years) depending on the intensity of working. Larger the number of coupes, longer the felling cycle, heavier the intensity of felling in each coupe and, consequently, less irregular crop, and *vice-versa.* The number of coupes will obviously be equal to the number of year n the F.C and they may be made up of one or more compartments.

In practice, rotation means very little and is practically of no consequence in a selection forest; trees which are felled at each F.C. are those which are deemed to have completed their period of maximum growth, and are interfering with potentially more valuable trees, or require removal for Silvicultural reasons.

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

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

CHAPTER IV
SUSTAINED YIELD

INTRODUCTION – DEFINITION:

The principle of *Maximum Sustained Yield* has been the backbone of forest management ever since forests were brought under scientific management. Many foresters consider sustained yield synonymous with good management. It is one of the aims of National Forest Polices of all Progressive countries of the world.

Sustained Yield is defined and / or expressed variously as:-

(i) (a) " The material that a forest can yield annually (or periodically) in perpetuity. (b) As applied to policy, method or plan of management (*Sustained Yield Management),* it implies continuous production with the aim of achieving at the earliest practical time at the highest practical level an approximate balance between net growth and harvest by annual or somewhat longer periods." (BCFT)

(ii) "The regular, continuous supply of the desired produce to the full capacity of the forest." (Osmaston)

(iii) "The yield of timber or other forest produces from a forest which is managed in such a way as to permit the removal of approximately equal volume or quantity of timber or other forest produce annually or periodically in perpetuity.

Sustained Yield may be annual or periodic, depending on whether a complete series of age-gradations (or ages mixed together) is maintained or only an incomplete series.

Periodic Yield is also considered as sustained, provided the period is short.

A sustained yield is essential where large areas, specially state owned, are concerned this ensures continuous yield and safeguards against extinction of forest property, which is a trust with the present generation we have a right of use only but not to lead to its destruction. In case of private property, it is not practicable to maintain a complete series of age-gradations; in such eases the crop is worked for *intermittent Yield,* which is defined as: *the material or cash return obtained from time to time from a forest not organized for continuous production.*

CONCEPT AND PRINCIPLE OF SUSTAINED YIELD (EVEN FLOW) MNAGEMENT:

Yield signifies the flow of forest products, measured in terms of either volume or value units, harvested from a forest at a particular time. Forestry being a long term investment, forest yields, unlike agriculture, take a long time before utilizable produce is obtained.

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* (or Sustenance) has been evolved from the basic consideration that the later generations may derive from the forest at least as much of the benefits as the present generation. It is an accepted norm in forest management and forms the core of organized forestry.

The principle of *Sustained Yield* envisages that a forest should be so exploited that the annual or periodic fellings do not exceed the annual or periodic growth, as the case may be. *Sustained Yield* is, therefore, expressed as the allowable cut which may differ little from net increment (i.e., gross increment *minus* natural loss due to fire, wind, epidemics, etc.) Depending on the growing stock and distribution of age-classes.

Much has been written about sustained yield as a major objective of forest management; it is, therefore, necessary to understand clearly the connotation of the term. Basic aim of management is to keep forest lands productive. Sustained productivity may be visualized in two respects, viz., continuity of growth and continutity of yield or harvest. The two often do not mean the same thing, hence the confusion. The tow often do not mean the same thing, hence the confusion. The forest may be, currently, immature and unmerchantable though putting on excellent growth; in such cases, production is sustained but not the harvest or cut which will be available only later on. In contrast, there may be a forest area including the entire range of age or size classes which may be managed as a unit to yield a sustained flow of harvest, as well as maintained in a state of continuous productivity. *Sustained Yield* management, as the term is most accurately and commonly employed, mans 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 and remove the 10 year old wood annually, and plant up the area again. The mature wood would represent the increment on the whole forest and the difficulty of removing the annual increment from each unit area, say one hectare, is overcome by removing accumulating production of 10 hectare on $1/10^{th}$ part of the total area.

As the forest in the above example has equal area of every age in it, an equal area will be available for felling at maturity. The establishment of such a series of age-gradations, as illustrated above, is one form of the crop necessary for *Sustained Yield Management* and for maintaining it in perpetuity. Such a forest provides a conceptual picture of a theoretical *Normal Forest,* which will be discussed in detail in a subsequent Chapter. 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 old with 500 m^3 volume per hectare but this is by no means the only arrangement, nor is it necessarily the best. In several cases, it may be considered advisable from silvicultural point of view to grow several age-gradations mixed together, forming an age-class, on a proportionately larger are instead of growing each year's crop on separate area as in areas worked under *Regular Shelterwood (Uniform) System* with natural regeneration. In such cases, sustained yield will be available if all the *Periodic Blocks* occupy equal / equiproductive areas. Similarly, sustained annual yields from irregular Selection forest will be available if all age-classes are present therein and in balanced proportion. These are the attributes of normality of a forest with different patterns of age gradation / class distribution; hence for a sustained yield management the forest must be normal, whether regular or irregular, though in the latter case management becomes rather complicated.

In the first rotation of scientific forest management, density and quality of crop are generally variable due to past management or due to mal-distribution of age-classes and, similarly, the composition of the main species in the mixture. In such cases, where forests generally comprise of old growth, it is not possible to apply sustained yield principle. Similarly, virgin forests, with a large percentage of deteriorating trees brought under management for the first time, cannot be suitably worked under sustained yield principle; instead, *accelerated-cut management* is indicated therein. Likewise, forests under afforestation schemes provide variable yield until after the end of first rotation, starting from no yield to regular sustained yield in the second rotation.

It will be appreciated that in the first rotation, sometimes even in the second rotation, due to unfavourable distribution of age-gradations, some sacrifice of younger age-classes or trees will be involved if sustained yield principle is rigidly followed. However, as long as the present treatment is expected to result in equal sustained yields in future, it is considered to satisfy *Sustained Yield* principle: "*Variable yield to-day to ensure sustained yield tomorrow.*"

On occasions, such as a national emergency, principle of sustained yield may have to be held in abeyance. Over-exploitation for sometime may become unavaoidable, which can be obviated by adopting a policy of retaining *Reserves.* For example, five trees of Deodar per hectare in Regular Working Circle of Kanagra division (H.P) are held over for full one period after the final fellings in P.B.I. as *Emergency Reserves.* If this is not feasible, the situation must be retrieved by building up the depleted growing stock, as early as possible after the emergency is over.

The *Sustained Yield* principle is applicable to production forestry, but where protection and other accessory benefits far out-weight the other benefits, then they must be given precedence over material benefits, and the silvicultural treatment modified accordingly.

CONCEPT OF INCREASING AND PROGRESSIVE YIELDS:

The concept of *Sustained Yield* has now been replaced by that of *progressive yield*, originally advocated by a German forester, Hartig. This takes into account both the gradual evolution of the economy as well as the progress in the silvicultural techniques, as a result of experience and research, which is considered as an important ingredient of scientific management. The concept of *Progressive Yield* envisages raising the productivity of soil, and of the crop, by silvicultural treatments, judicious tending, enrichment of the forest by changing the crop composition and by replacement of the original inferior forest by valuable forest species. It also stipulates avoidance of loss of increment by effective protection and tending and adoption of quick and efficient regeneration techniques. The new concept signifies a dynamic outlook in Man to build up and maximize productive enterprises through technological efficiency. It connotes a sysnthesis of ecological and economic considerations, and a long range view of forest products requirement for economic self sufficiency.

The principle of *Progressive Yield* as against the *Sustained yield* principle was discussed at the VI Indian Silvicultural Conference held in Dehra Dun in 1939 and the III World Forestry Conference held in Helsinki in 1948, an d adopted. Some foresters consider that the principle of *Progressive Yield* is embodies in the principle of *Sustained Yield*. Foresters, who advocate the principle of *Progressive Yield*, maintain that while the principle of progressive yield is a dynamic one, the one of *Sustained Yield*, aiming at the same yield in perpetuity is *static*. As Dr. J.C. Nautiyal put it; “Sustained Yield can be practiced in a stagnant economy, it has no justification in a growing or a developing economy.” No individual or Organization, leave alone a nation, would accept a static economy.

A normal industrial concern will gear itself to producing that quantity which the market demands; not only this, it will take steps to stimulate the market and promote more sales. Incase of forestry it is rather different. The forest goes on putting increment till the maximum is reached. Removing yield which is materially less than the annual increment is as bad management, and detrimental to the forest, as removing more than the annual increment. It was in view of this that subject was considered at the VI Silvicultural Conference that in the first stages of developed the aim should be not a *Sustained Yield* but an *increasing yield*. This aim will necessitate steps towards further development of the forest, communications and the market. The principle was unanimously adopted.

The principle of *progressive yield* goes a step further than that of increasing yield, included i n the latest definition of *Sustained Yield.* While the idea of increasing yield primarily covers the case of forests in the earlier stages of development, that of *Progressive Yield* is intended to cover the entire forest management. In a developing country like India, the demand of wood is progressively increasing and, with the economic development and higher standards of living, the demand is expected to rise at a much faster rate. We should, therefore, think in terms of expanding yields instead of sustaining the yield of our forests.

Protagonists of *Progressive Yield Principle* consider that the development of a forest is a continuing process; a natural progress of any forest towards higher and higher production as a result of scientific research and experience. As the research and experience are not static but dynamic and, if applied to the management of a forest, must result ingreater and greater yields, the aim of good management must be *Progressive yield* and not merely *Sustained yield.* Those who consider that the principle of *Sustained Yield* embodies the idea of *Progressive Yield* maintain that the correct term should be the *Maximum Sustained Yield* in perpetuity, which term would include the principle of *Progressive Yield*. As already stated, the principle aims to cover the effect of experience and research in silvicultural techniques which even the principle of *Sustained Yield* does not convey the dynamic idea that the yield must go on progressing or progressively increasing, which would be the natural result of application of knowledge from experience and research. It is, therefore, considered that *Sustained yield principle* was all right so long as research was not an important factor research is given an important place in any forest policy, the dynamic principle of *Progressive Yield* should be the aim of all scientific managements. '*Sustained Yield Principle* is as out-dated as the cross-cut saw which has now been replaced by machines.' 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.

ARGUMENTS FOR AND AGAINST SUSTAINED YIELD PRICIPLE:

In case of State Forests, some of the advantages are:

(i) It facilitates budgeting and regulation of taxation; ensures a steady income to the State. However, volume yield does not necessarily mean sustained revenue as well, due to fluctuation in price.

(ii) Local labour is always fully employed; by constant employment it is possible to establish permanent skilled labour force.

(iii) Staff employed is fully and permanently engaged. It affords scope for systematic work and equal employment continuously. Organization of current and future works is facilitated by sustained yield. The staff is not periodically over-or under-worked; use of mechanical equipment and other *infra-structure* is steady.

(iv) Contractors 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.

(v) Wood-using industries have an assured continuous supply of raw material, and the local people sustained supplies of wood for their domestic and agricultural needs.

(vi) Markets can be developed and their confidence gained with sustained supplies.

Some of the arguments *against the principle of Sustained Yield* may be summarized as followed.

(i) Sustained yield management treats timber production as only a biological function rather that a response to economic demand.

(ii) It ignores the costs involved in producing a fixed quality, i.e., production is carried on irrespective of price fluctuations resulting in inefficient resource management. Under this principle, the supply functions of timber would be completely in – elastic, i.e., unresponsive to price changes; price fluctuations would be more severe.

(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) It ignores the inter-relationship between forestry and other sections of national economy.

(v) Such a rigid (inflexible) policy is not suitable for a dynamic or growing economy.

(vi) A price-responsive supply will cause less severe fluctuation in price, and whatever changes in price do occur, will automatically regulate the demand.

(vii) In practice, sustained yield, has merely been an ideal; wide fluctuations is yield are quite common.

(viii) The application of Sustained / Progressive Yield is beset with the serious difficulty of fore-seeing the future trend of timber and forest product requirement.

(ix) There are two economic objections also to the principle of sustained yield. Firstly, regulated annual yield prevent an increase of felling and sales during 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 cutting the crop either before or after the financially more advantageous time. For example, stock of slow growing mature and over-mature trees may be held over longer by reduced fellings until immature stands grow to maturity, though financially it would be better to realize the mature stand quickly by heavy fellings and endure a gap in yield until the younger crops reach maturity. But the heavy felling now, and the proportionately larger regeneration following, will perpetuate maldistirbution of ages and sizes of trees in the forest and yields will again fluctuate.

Summing up, the forests should be managed so as to give maximum sustained vegetative production, whether the material output or yield of the forest is sustained or not. Sustained or not. Sustained production must always be the aim; to achieve this, the soil must be kept in healthy and fertile condition as far as possible, preferably improved.

CHAPTER V

ROTATION OR PRODUCTION PERIOD

INTRODUCTION – DEFINITION:

Agricultural crops are sown; they ripen and are harvested once or twice a year. As a rule, all plants ripen at the same time and are also harvest at the same time; their period of maturity is easily determined. However, it is not so in case of forest crops. The main forest product, timber, takes a long time to mature for harvest; neither does it ripen the way agricultural crops do. Though trees are utilizable / saleable even at a younger age, there is a steep size / price gradient and the price per unit volume rises sharply with the size of trees. Ripeness of the trees can be estimated from the age beyond which quality of timber starts falling off; this age varies, not only from species to species but also from tree to tree. Trees should be harvested after they have reached utilizable size, and before their timber quality starts deteriorating. The maturity of timber depends on natural conditions of growth on the one hand and economic conditions on the other. In some cases, however, other considerations, such as protective, recreational and scenic value may also come into the picture.

Unlike agriculture, trees have variable standards of ripeness or maturity as they satisfy different demands at different times and different sizes. What standard of ripeness we may then apply to trees size, age, vigour of growth or a combination of these? Such considerations complicate decisions on forest policy, finance and planning. Object of management will be an important consideration in this respect.

The period which a forest crop takes between its formation and final felling is known as *Rotation or Production Period.* This term is also defined in various other ways by different authors; some of these definitions are given below:-

(i) “The planned number of year between the formation or regeneration of a crop and its final felling. In the case of a selection forest, the average age at which a tree is considered mature for felling.”

(ii) “The number of years fixed by the *Working Plan* between the formation or regeneration and the final felling of a crop.”

(iii) “Rotation age is the age of trees or crops at which when they are felled, objects of management for the time being are best served.”

(iv) “Rotation or Production Period is the interval of time between the formation of a young crop by seeding, planting or other means and its final harvesting.”

(v) “Rotation is the period which elapses between the formation of a wood and the time when it is finally cut over.”

CONCEPT OF ROTATION IN REGUALR AND IRREGULAR CROPS:

The term *Rotation*, strictly speaking, is correctly applicable to regular crops only. In *Clear-felling* System and plantations, rotation is a definite period of interval between the year of formation and final felling. In these, and regular forests in general, entire crops of trees of a sizeable area are felled at a time or during a comparatively short period (regeneration period in Regular Shelterwood System) when ready for felling. There is, more or less, a clear production period which can be planned in advance to give timber which satisfies the object of management. In the latter case, rotation is fixed for the whole working circle a unit, as the average length of time between the establishment of crops and their harvesting. Though this system facilitates better planning and organization of work, it does not take into consideration that:

(i) Rate of growth will vary with site variation, even for the same species.

(ii) It involves sacrifice of immature trees / crops, as some will not have reached exploitable size.

(iii) Accidents, such as fire, disease, and wind-throw may happen, necessitation gelling earlier than planned.

(iv) If profit is the main object of management, some difficulties may arise, as the degree of profit is affected by rotation, rate of growth, size / price gradients of timber and the cost of growing it. To obtain desired profits, stands will have to be finally at various times depending on their rate of growth.

From the fore- going, it is evident that whatever the object of management size of timber or profit *rotation* is associated with *final felling age or removal age* and, even with a planned *rotation, the removal age* may vary with rate of growth. On better sites rotation will be shorter; damage / mortality due to accidents may necessitate earlier removal of some parts thereby increasing the tendency to break up uniformity of original crops into smaller segments, until they start approaching the structure of uneven aged forest.

In uneven aged (irregular) selection forests, trees are selected individually on their merit for felling, depending on:

(i) Qualities of size, vigour and suitability for markets.

(ii) Adjustment of proportion of different sizes.

(iii) Silvicultural principles; e.g., removal of inferior stems in favour of better ones.

Such a system clearly has greater flexibility, and enables forester to adopt fellings to suit different rates of growth caused by variation in site or species. Moreover, forest is a perpetual entity and never suffers complete clearance of trees on any part of the area, except periodical thinning. Therefore:-

(i) Size being the criterion for felling, age is known, and

(ii) There being no final harvesting, there is no rotation as defined above. However, one could say that its rotation period is equal to that of the average age

of the exploitable size trees removed the exploitable age, at which they attain the size required to fulfill the objects of management.

Therefore, in selection / irregular forests, concept of *Rotation* assumes, by and large, only an academic importance for accounting purposes. In these forests, there is no definite cor-relation between age and diameter; the latter depending on site and available light conditions and even individual characters also. The trees of all ages are mixed together and the crop as a whole, on any unit area, does not reach the age of final felling at a time. Consequently, the term *Rotation or Production Period,* is not correctly applicable to the age at which individual trees reach the age of maturity and are remove. Maturity in selection forests is related to size, and exploitable size is fixed for removal of individual trees. Correct term expressive of maturity in selection forests is, as started above, exploitable age, or size. Size should therefore, be used as a standard of exploitability, and not age.

Adherence to a fixed rotation in such cases is more in conformity with requirements of an out-of date king of Adherence to a fixed *Rotation* in such cases is more in conformity with requirements of an out-of date king of *Yield Regulation* that with timber production.

TYPES OF ROTATION:

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

Various types of rotation recognized in forestry are:-

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

2. **Silvicultural Rotation:**

It is the rotation *through which a species retains satisfactory vigour of growth and reproduction on a given site.*

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

Silvicultural Rotation may be useful in forests managed primarily for aesthetic and recreational purposes, where large old trees with accompanying regeneration provide scenic beauty.

Some foresters do not distinguish between *Physical and Silvicultural Rotations.*

3. Technical Rotation:

It is the *rotation under which a species yields the maximum material of a specified size or suitability* for economic conversion or for special use. It aims at producing the maximum material of specific dimension / quality for specific purposes, such as railway sleepers, saw- logs, mine-props, transmission poles, match-wood, paper-wood, etc. Since one and the same tree any yield different assortments of material, and the trees in a crop may attain given size at different times, the technical exploitable age offers no reliable fixed point for fixing the rotation. It does, however, allow for fixation of limits within which a tree or stand is adopted for the production of assortments in greater number or better quality.

Technical rotation is adopted, particularly, by industrial firms which own forests / plantations for the purpose of supplying raw material for their plants (e.g., NEPA and West-Coast Paper Mills, WIMCO match factory).

4. Rotation of Maximum Volume Production:

It is the rotation *that yields the maximum annual quantity of material*; *i.e., the ge at which the Mean Annual Increment (M.A.I) culminates*. The M.A.I referred to is that of the stand and not that of individual trees.

The quantity (usually the volume of wood above a minimum thickness) referred to naturally includes material from all thinnings, as well as the final volume felled at the end of *rotation.*

The length of this rotation will coincide with the year when the average rate of growth, or volume increment per unit area, reaches the maximum, i.e., the age indicated by the point of intersection of C.A.I. (Current Annual Increment) and the M.A.I. curves (dealt with in greater detail in Chapter VII-INCREMENT).

This rotation yields largest volume per unit area, per annum, and is an important rotation which is adopted frequently as such, or in combination with some other rotation (e.g., Technical Rotation).

If rotation is r, final yield Yr and volume of thinning at various age V_a, V_b, V_c etc. then the age at which:-

$$M.A.I. = \frac{Yr + \sum V}{r}$$

is the maximum, is the *Rotation Of Maximum Volume Production.*

The following table shows the age of culmination of C.A.I. and M.A.I. for stem timber volumes for *Sal* and *teak* of different site qualities:-

Species	**Quality**	**Age of max. C.A.I. (years)**	**Age of max. M.A.I. (years)**	**Crop dia. at max. M.A.I. (cm)**
Sal	I	75	128	57.40
(High Forest)	II	80	133	53.09
	III	85	142	45.98
	IV	90	148	37.50
Teak (Plantation)	I	42	70	68.58
	II	45	78	62.99
	III	48	Over 80	60.45
	IV	68	Over 80	-

These figures indicate that M.A.I. culminates later in the lower qualities and earlier in the higher qualities, and generally the crop diameter at the culmination point is lower in poorer qualities and higher in the better qualities.

This rotation is particularly suitable for adoption where the total quantity of woody material is important and not the size and specification, e.g. firewood, raw material for paper pulp fibreboard and industries based on disintegration processes of wood.

More often than not the objective in forestry is quality or value production, and Rotation for higher value production is usually longer than for highest volume production. In turn, maximum volume rotation is usually longer than Financial Rotation. Common practice in forestry is to adopt a combination of *Rotation of Maximum Volume Production and Financial Rotation.*

5. Rotation of Highest Income / Revenue (or Forest Rental):

It is the rotation which yields the highest average annual gross or net revenue irrespective of the capital value of the forest. It is calculated without interest and irrespective of the times when the items of income or expenditure occur. This rotation is important from the 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:-

$$\text{Mean annual net revenue per unit area} = \frac{Yr + \sum Tr - C - \sum e}{R}$$

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, R = Rotation (years).

The rotation, at which the net revenue as calculated above is maximum, is the Rotation of highest Revenue / Income (Rental). Calculation of this rotation is similar to that of the highest volume production. Thus the mean annual net volume production (i.e., M.A.I.) is

also $= \dfrac{Yr + \sum Tr}{R}$ where Yr and $\sum Tr$ are the values of final and thinning yields as used in the net income formula. To use the net income formula, it is, therefore necessary to multiply the volume yields expected by the net prices anticipated from timber; in other words to use a *Money Yield Table* instead of *Volume Yield Table* and, in addition, subtract cost of formation and maintenance.

The two rotations will be about the same unless there is an appreciable increase in price for larger-sized timber which is, in fact, usual. If the size / price gradient is marked, then the rotation of highest net income will be comparatively longer. Again, if there is a special size of timber which fetches a particularly high price, the rotation which provides that price may be the *rotation of highest income*, and possibly coincide with *Technical Rotation.*

6. Financial (or Economic) Rotation:

It is *rotation which yields the highest net return on the invested capital.* It differs from the *Rotation of Highest Net Income* in that all items of revenue and expenditure are calculated with compound interest at an assumed rate, usually the rate at which the Govt. it 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* (S_e) calculated with a given rate of interest is the maximum.

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 (for detailed account refer to books on *FOREST VALUATION*). The two prominent methods, however, may be summarized as:-

(a) Based on the *Soil Expectation Value* (S_e) 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 rotations *Faustmann's Formula.*

(b) Based on the financial yield, i.e., the rate of interest or *Mean Annual 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.

The two last named *rotations* are concerned with money return from the forest and there has been considerable controversy as to which would be the correct rotation to adopt for Indian State forests. In cases when money has to be borrowed at compound interest for making new plantations the first *rotation* should be, as gives the maximum interest on the capital. Once, however, the original capital has been paid off, the rotation of highest net income may be adopted. For ordinary forests of Indian, the most paying rotation would probably be the rotation of highest sustained net income.

SOIL EXPECTATION VALUE (S_e):

"If a piece of land is expected to provide a continual net income of X rupees yearly, then that land can be valued at a sum, which at an acceptable rate of interest gives the same yearly income of Rs. X; that value is known as *Soil Expectation Value* (S_e).

Expressed by formula, $S_e = \dfrac{X}{0.0p}$; where p – rate of interest, percent

$$\left(\text{Because } X = S_e \times \frac{P}{100} \text{ or } Se = \frac{X}{0.0p} \right)$$

But if the land produces income periodically, instead of yearly, such as coppice forest the present discounted value of that return = Y_r / ($1.0p^r$ – 1) where Y_r is the net periodic income every r^{th} year for every. 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 *Faustmann's Formula,* is as:-

$$Se = \frac{Y_r + T_a\, 1.0p^{r-a} + \ldots T_q\, 1.0p^{r-q} - C.1.0p^{r}}{1.0p^{r} - 1} - E$$

Where Y_r is the net value of final felling made in the year r at the end of rotation; T_a …. T_q are the net value of the several thinnings 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 of interest and E = e / 0.0p, where e = the sum of all annual expenses. The formula depends on the assumption that each item of income or cost recurs at definite and constant intervals for ever, and is the same constant figure at each recurrence. Each item of the formula thus becomes the sum of an infinite series of discounted costs. Thus, the same final net yield, Yr, is received at the end of r, 2r, 3r years etc., for ever and the sum of the infinite series of discounted values of Yr / 1.0pr – 1.

LENGTH OF ROTATION

The choice of the type of rotation will depend on the object of management, but the length of rotation of whatever, type, will depend on the interaction of several physical and economic factors given below. While commonly expressed as an average age, the rotation is in practice the age range within which the major crop will be harvested a new crop started.

(i) **Rate of Growth:** This will vary with species, site fertility (soil, climate, topography, etc.) and intensity of thinnings, etc.

(ii) **Silvicultural Characteristics of the Species:** For example, natural span of life, age of fertile seed production, age at which rate of growth culminates, age at which the quality of its timber is most desirable or begins to fall, etc.

(iii) **Response of the Soil:** That is, deterioration or exhaustion of soil due to exposure (short coppice rotation) biotic influence etc.

(iv) **Economic Considerations:** Depending on a combination of factors of cost, prices of different sizes, time required to reach those sizes, etc. a factor tending to lengthen the rotation is the increase in value of large-size timber – though not economically sound to grow large-size timber over a long rotation.

(v) **Soil Conditions:** Socio-economic and employment policy of the State. Climate and topography may necessitate long, protective rotation or the adoption of uneven aged forestry, whatever the economics may be.

Some of the above factors may affect the management policy. The inevitable combination of factors may require different rotations in different parts of a forest and thereby complicate management.

Summing up, the following points may be kept in view while fixing the rotation period:-

(i) The size of timber to be produced is first determined with reference to market and national requirements. A tentative rotation is fixed with reference to *Yield Tables* for the prevailing site quality and thinnings practice. The *Stand Table* should also be consulted to find out the percentage of trees above or below the average diameter at the rotation age.

(ii) Shorter rotations are financially attractive for private owners, but in State-owned forests longer rotations are generally suggested for following reasons:-

   a. Forest are meant to fulfill large national interests, especially those of Defence, communications and wood-based industries which demand larger assortments. These must have priority in production from public owned forests. With rapid industrialization and potentialities of cheap electric power from river valley projects, the general tendency is the steadily increasing demand for quality timber, which must be met even though less profitable than the production of smaller assortments giving higher rate of interest on the forest capital.

b. Silvicultural, biological and protective principles definitely favour the choice of longer rotations with increased volume of growing stock.

c. Forests with large growing stock have an insurance value in times of emergency, financial crises or unforeseen abnormal demands.

Thus, fixation of rotation is a compromise between several considerations and cannot be just computed mathematically. In case of State forests, it would be desirable to follow the following procedure in determining the length of rotation:-

(i) Determine the size of timber to be produced (specify object of management) with regard to market and national demand.

(ii) Consult the yield table for the prevailing site quality and thinning practice in vogue, to determine the age corresponding to the desired size.

(iii) Examine the age of maximum volume production and silvicultural of species to arrive at a tentative rotation.

(iv) Prepare *Money Yield Table* to see the rotation of Maximum net income.

(v) Then strike a compromise.

ROTATION OF SOME IMPORTANT INDIAN SPECIES

The following tables gives rotations currently adopted for management of some important species.

Species	**Locality Division / State**	**Rotation / Conversion Period (years)**	**Remarks**
Teak	Gorakhpur (U.P)	60	Teak Taungya W.C.
	Haldwani (U.P)	50	Under-planting; Teak introduction Working circle.
	Darjeeling (W.B.)	80	Teak Conversion W.C
	North Betul (M.P.	100	Conversion to Uniform System : Teak Conversion W.C.

	Hoshangabad (M.P) (Bori)	120	Bori Species Teak W.C. Conversion to Uniform and selection-cum-improvement.
	Hoshangabad (M.P) (Bori)	80	General Teak W.C. Conversion to uniform.
	Allapalli (maharastra)	120 (Plains F.S.)	Teak conversion W.C.; Modified Uniform System with P.Bs.
		100 (Elchil F.S.)	Teak conversion W.C.; Modified Uniform System with P.Bs.
	Nilambur (Kerala)	60 (Teak F.S.)	Clear felling and planting
Sal	South Raipur (M.P.)	180	Sal High Forest W.C. Conversion to Uniform.
	South Raipur (M.P.)	40	C.W.R; Coppice rotation.
	Gorakhpur (U.P.)	75&90	Sal Taungya W.C.
	East Dehra (U.P.)	120	Uniform
	Haldwani (U.P.)	150	Irregular Shelterwood W.C. ; Floating P.B.
Blue Gum *Eucalyptus Globules*	Nilgiris South (T.N.)	10	Simple Coppice.
Eucalyptus Hybrid (E. Tereticornis)	U.P., Punjab, Haryana	8 to 12	Simple coppice.
Wattle (Acacia mearnsii Syn. *A.mollissima)*	Nilgiris South (T.N.)	10	Clear felling with natural regeneration, supplemented by artificial regeneration.
Deodar	Kulu (H.P.)	150	Punjab (Modified) Shelterwood System.
	Chakrata (U.P.)	160	Uniform system.
Chir	Kangra (H.P.)	120	Punjab (modified) Shelterwood system.
	Chakrata (U.P.)	100	Uniform with Floation P.B.
Fir	Kulu (H.P.)	90	Modified clear felling (over 40 cm dia.) and planting; selection on slopes.

CHOICE OF THE TYPE / KIND OF ROTATION

For considering the choice of most suitable rotations under different social, silvicultural and economic conditions, the above mentioned types may be sub-divided into three main groups which satisfy three different broad objectives, viz., :-

(i) Rotations controlling the supply of certain services i.e., the *Silvicultural and Physical Rotation.*

(ii) Rotations controlling the output of material forest products in form or quantity i.e., the *Technical and maximum volume rotations.*

(iii) Rotations controlling the financial returns, i.e., the *Rotations of maximum Gross or net Income and the Financial Rotation.*

Choice of rotation, as already pointed out, is one of the most important decisions in forest management. Different arguments have been advanced in favour of one or the other type. Two controversial views expressed in forestry literature are :-

(i) Forest means capital and, as such, it should yield the maximum revenue or interest, i.e., it should satisfy economic and financial aspects of investment.

(ii) The second view is that more important than the financial aspects is the general usefulness of products specially incase of state-owned forests.

Before making a choice of a suitable rotation, the forester has to carefully consider the following:-

(i) Objects of management.

(ii) Silvicultural requirements of the species.

(iii) Productivity of the site.

(iv) The market demands and / or national requirements.

(v) Socio economic policy of the State (labour conditions, employments, etc.)

(vi) Financial and economic aspects.

Where the objects are commercial, the rotation adopted is a compromise between *Silvicultural and Technical Rotation,* tempered by some economic considerations and financial test. The mistake is often made of working timber forests on the rotation of maximum volume productions, as it is readily ascertained by the point of intersection of C.A.I. and M.A.I. curves. In actual practice, as has already been started, there is invariably a price increment for larger sizes of timber and, in order to find the most paying rotation, it is necessary to collect data for the average net value per m^3 of timber obtained from trees of various sizes and applying these net values to the *Yield Tables* figures, a *Money Yield Table* can be prepared. Care should be taken to use appropriate data for the yield from thinnings which have a lower mean diameter than the main crop. The total money yield for each age divided by the age gives the mean annual net value increment per unit area. These values when plotted against each age give a curve, the culmination point of which is the *rotation of maximum net income.*

Experience in Europe has shown that economic and financial considerations should not dictate the choice of Rotation as it often endangers the productivity of the soil, which is the basic capital of the forest.

ROTATION AND CONVERSION PERIOD

The term conversion is defined as : "a change from on e silvicultural system or one (set of) species to another," and *conversion period* as ; "The period during which a change from one Silvicultural system to another is effected."

Rotation and conversion period as defined above are basically the two entirely different terms. *Conversion Period* is indicated where a change in silvicultural system is contemplated, or where a forest is brought under scientific management for the first time, and no rotation can be calculated or applied straight away for various reasons.

While it is necessary to fix a Rotation in case of regular forests, it is not so with *conversion period*; the latter is fixed where it is considered necessary to minimize sacrifice. For the purpose of management and yield control it takes the place of rotation, usually in the first rotation. *Conversion period* is usually less than *Rotation*; may be sometimes even more than rotation, but when equal, it is not distinguished.

Conversion Period is usually kept less than *Rotation* when it is desirable to remove the mature crop earlier that the rotation period due to:-

(a) Crop not likely to survive the full rotation period.

(b) Crop has suffered from some injury.

(c) Crop is very openly or irregularly stocked.

(d) Crop is putting on small increment.

(e) Advance growth is already present on the ground and, therefore, time required for replacement of mature crop by new one can be shortened.

The shortening of the conversion period, or the extent to which it can be shortened would be limited by:-

(i) Size of the material produced and its marketability, as compared to the size produced in the contemplated rotation.

(ii) The extent of sacrifice involved.

The greater the difference between the conversion period and *rotation* greater is the sacrifice and more difficult it is to bring the forest on to the contemplated *Rotation* at the end of *Conversion Period*.

CHAPTER VI

THE NORMAL FOREST

GNEREAL REMARKS 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 purposes of sustained yield management. On a given site and for a given object of management, it is forest which has an ideal growing stock, an ideal distribution of age-classes of the component crop and is putting on an ideal increment. From such a forest, annual or periodic yields equal to the increment can be realized indefinitely, without endangering future yields and without detriment to the site. In forestry, concept of *Normal Forest* envisages an ideal state of perfection, serving the purpose of good scientific management.

Normal series of age-gradations, normal growing stock and normal increment form the 'Trinity of Norms' in forestry, as Osmaston calls it. The word *normal* does not mean *usual, common, or regular* as one ordinarily understands it; it means an *ideal condition* in the context of forestry.

Normal forest is, thus, a conception of forest management based on the principle of *Sustained Yield.* It was evolved in early 19th century by German Foresters. The term is variously described or defined as:-

(i) "A forest which, for a given site and given objects of management, is ideally constituted as regards growing stock, age class distribution and increment, and from which the annual or periodic removal of produce equal to the increment can be continued indefinitely without endangering future yields. A forest which by reason of its normalcy in these respects serves as a standard of comparison for sustained yield management."

(ii) "A forest which, corresponds in every way to the objects of management is called a *Normal Forest.* It serves as an ideal to be aimed at, though it may never be altogether reached or, if established, not permanently maintained. Normal state of a forest, under given set of conditions, depends chiefly on the presence in it of:-

a. A normal increment.

b. A normal distribution of age-classes, and

c. A normal growing stock."

(iii) "That forest which has reached and maintains a practically attainable degree of perfection in all its parts for the full satisfaction of the purpose of management".

(iv) "A forest which has (a) a normal series of age-gradations or age-classes, (b) a normal increment, and consequently, (c) a normal growing stock, it termed a *normal forest.* It follows that there is nothing absolute in the term. A forest normal under one method of treatment or rotation, would be abnormal under any other treatment or rotation."

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

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

BASIC FACTORS (ATTRIBUTES / CHARCTERISTICS) OF NORMALITY:

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

(i) A normal series of age-gradations or age-classes.

(ii) A normal increment.

(iii) A normal growing stock.

By *normal series of age-gradations or classes* is meant the presence in the forest, in appropriate quantity, trees of all ages from one year old to rotation age. When the trees of each age occur on separate areas, they constitute a series of age- gradations. When trees falling within certain ago limits occur mixed together on the same area, they form an age-class. In very irregular forests there may neither be age-gradations nor age-classes; in such cases is the sign of normality the proper distribution of trees of all ages.

Normal Increment is the best or maximum increment attainable by a given species and for a given rotation, per unit area on a given site. An abnormal increment may be caused by faulty formation, faulty treatment injurious external influences and also unequal distribution of age-classes.

Normal Growing Stock is the volume 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. It must, however, be remembered that a *normal forest* represent an ideal condition rarely, if ever, attained in practice; while the Yield Tables are the averages of actual *Sample Plots,* which were varying degrees short of the normal.

It will be seen that the conditions determining the normality of a forest are, in fact, only two, viz., normal age-classes and normal increment; normal growing stock follows as a matter of course, if these two conditions are satisfied. On the other hand, the presence of a normal growing stock does not necessarily imply a normal forest. A natural sal forest of low density may consist entirely of mature and over-mature trees and may carry a volume of timber equal to, or even greater than that indicated in the Yield Table but such a forest is definitely abnormal because of the absence of younger age-classes, and cannot produce sustained yield.

The easiest way to visualize the conception of a *Normal Forest* is to consider is as a series of even-aged plantations of equal area, each of one age- gradation, worked under Clear-felling or coppice system. A plantation of one hectare was planted every year for ten years. These are, therefore ten age-gradations of equal size, constituting a *normal series of age-gradations,* of which one is assumed to be ripe for harvesting every year. 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 is now ten year old and due for felling.

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.*

It is not at all necessary that each gradation / class may be distinctly separated into separate crops, as in forests worked under Clear- felling and Uniform Systems; they may as well be thoroughly mixed up on the ground as in the case of irregular all-aged

Selection forests, without altering the basic concept. It is the balanced proportion of all age and size classes that is essential, rather than their actual distribution on the ground.

NEED FOR AN IDEAL STANDARD:

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

NORMALITY CONCEPT NOT ABSOULTE: RELATED TO TREATMENT AND ROTATION:

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

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

KINDS OF ABNORMALITY:

Forest may be abnormal usually in the following ways:-

(i) They may be *over-stocked*. A forest past the age of maturity, or having excessive distribution of older age-classes, will have more volume per unit area that the normal.

(ii) They may be *under stocked*. This condition may be caused due to preponderance of younger age-classes, poor density or extension in rotation. In such cases conservative treatment, i.e., felling less than the permissible amount in order to build up a proper reserve of growing stock is indicated. The accumulation of growing stock to remedy a deficit is often secured by adopting a rotation longer than that necessary, or by cutting less then the possibility.

(iii) They may have *normal growing stock volume but abnormal distribution of age-classes or age-gradations*; i.e., they may be disproportionate, some of them may be even missing. This is the worst form of abnormality because the entire forest may be practically of one age-class. The conversion of such a forest to normality is a very difficult problem, and involves either an interruption in sustained yield or sacrifice of material by decay or unsoundness.

(iv) The increment may be sub-normal. This condition may be caused by defective density, fire disease, etc., or it may be due to preponderance of over-mature trees.

(v) *Normal increment volume in an abnormal forest*: Annual increment of a forest may be the correct volume for normal increment, but unless it is laid on to trees of the right size-class in the right proportion it is not a normal increment.

EFFECT OF SILVICULTURAL SYSTEM ON NORMALITY:

Silvicultural systems can be broadly classified into two main groups:

(i) Even-aged system - e.g., Clear felling, Coppice and Uniform.

(ii) Uneven-aged system – e.g., True or Single Tree selection and group selection.

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

In very intensive even-aged forestry, in order to take full advantage of differences in site individual stands of one age may also be small, perhaps 0.2 or even 0.1 hectare. The forest then approaches and begins to merge into an uneven-aged one.

The basic difference between the two groups is whether separate ages and areas can be distinguished, and delineated on the ground and on the map or not. In even aged forestry they can be distinguished so that management can be based on area and age. If they cannot be distinguished, as in true selection forests, then management must be based on individual trees and their size and not on age and area.

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

(i) The Normal Even-aged Forest and

(ii) The Normal Uneven-aged Forest.

NORMALITY IN REGULAR / EVEN-AGED FORESTS:

The clear- felling system in which all age-gradations from one year to rotation age (R years) are present, each occupying equi-extensive / equi-productive areas, in which the rotation age coupe is felled and regenerated every year, offers the simplest example of a conventional *Normal Forest,* capable of giving annual sustained yield. If *A* hectares is the area of the F.S., the normal annual coupe would be A/R hectares the area occupied by each age gradation. In addition, each gradation must be fully and ideally stocked and putting on normal increment.

Thus, there is ‘trinity of norms’ in the Normal Forest in respect of distribution of age- gradations / classes, growing stock and increment. It is, however, not at all necessary, though desirable, that each age-gradation be in one compact area; it may be scattered among other age-gradations throughout the forest, provided their total area is correct. A fifteen year old gradation may be found in several stands in several places and may be occurring next to twenty, thirty or other aged stand.

Except when the rotations are very short, as in Coppice System and / or plantations of some fast growing species, it is seldom practical to distinguish between age differences of only one year. This is definitely so where regeneration is mainly natural. In such cases five, ten or even more age- gradations may be grouped together to form an age-class. A forest worked on a hundred year rotation might then have for example ten age-classes each having crops 1 – 10, 10 – 20 …… 80 – 90, 90 – 100 and occupying one tenth of the equi-productive area of the F.S., as already explained in an earlier paragraph. The oldest age-class will be felled and regenerated in ten years, preferable but not necessarily in equal yearly quantities. A degree of flexibility is thus introduces which is consistent with the definition that a normal forest has that perfection which is practically attainable.

This conception may be extended to the division of forest area into periodic blocks. In the above example we might allot them to five P.Bs., each containing two ten-years. Each P.B. would be felled and regenerated, in turn during twenty years regeneration period in as regular a manner as possible.

This kind of organization is not only simple but provided some flexibility which is both useful to meet market fluctuation and essential to vary fellings designed for natural regeneration.

It will be readily appreciated that shorter the regeneration period, narrower will be the age-class range and more even-aged the stand; conversely, longer the regeneration period, wider will be the age class range and less even aged the stand therefore, whereas the short rotation plantations of *Eucalyptus*, worked under annual coupes and with one year age class are absolutely even aged the Chir converted crops, worked under Uniform System on 120 year rotation with 30 year regeneration period and 30 year age classes are only more or less even aged.

In each case of the forest worked under clear felling coppice, coppice-with-standards or Uniform Systems, the stands are even-aged and the test of normality is the presence of all age- gradation / classes, occupying equi-extensive / productive areas, fully stocked and putting on normal increment. Strictly speaking, occupation of equal areas by each class is not essential, but the proportion of different ages should be correct; in other words, in theory each of the age-gradations must occupy in series areas of equal productiveness. Such a proportion between various age-gradations is known as normal proportion. These may occupy compact, self-contained areas or be scattered.

NORMALITY IN IRREGULAR / UNEVENAGED FORESTS:

In an entirely uneven-aged forest worked under selection system, trees of all ages are found mixed together on every unit of area, even as small as half an hectare. Younger and smaller trees occur in groups partly under older and larger trees and partly in gaps or openings of the upper canopy. The oldest and the largest trees are scattered everywhere singly or in pairs. In such circumstances neither the age of trees can be known nor the areas occupied by each class.

Fellings, therefore, cannot be distinguished by either area or age; nor can thinnings be separated from final fellings and yields. Consequently, definite areas cannot be set aside ever year either for final felling or intermediate yields. All fellings are, in fact, a continuous process of thinning a perpetual forest by selection of individual trees for felling every year but for practical considerations, the fellings are confined to one section each year in turn, i.e., the F.S. is divided into a number of sections, equal to the number of years in the felling cycle, and gone over during the felling cycle, which may be 5, 10 or 15 years.

Larger, mature trees are felled when they reach *exploitable size* or their increment falls below the acceptable level. Other trees are removed on principles of thinnings to give proper growing space to the better stems. All fellings are so made as to maintain or, if necessary, increase the irregularity of the stand and maintain or acquire the ideal proportion of large, medium and small trees.

Age and rotation are meaningless concepts in selection forests; the only scheme in the arrangement of growing stock is the proper intermingling of different sized trees in their ideal proportion so that a regular sequence of maturing trees is obtained, on the general assumption that, on an average, size indicated the age.

Therefore, normality of an uneven aged selection forest can be ascertained by the number of trees in each *size class*; it must have a normal series of *size gradations* instead of *age-gradations* of the normal even-aged forest. In addition, it must have the normal volume and normal increment, as well as the amount of irregularity per unit area that is deemed to be most satisfactory.

Although it is obvious that a normal uneven aged forest contains larger number of smaller trees than bigger ones per hectare, it is not possible to devise a simple model such as the triangle of normality for even aged forests to represent the numbers or volumes of trees in the various size-classes. We do not have Yield Tables either for irregular forests, to show what the normal numbers of trees should be in each size class.

About irregular selection forests, some people even think that there can be no normal selection forest; this of course is incorrect. It is true that it is easy to visualize a normal forest of pure even aged, densely stocked stand, each age occupying separate areas arranged in a sequence. We have also yield Tables applicable to even-aged regular crops for reference, but none for selection forests. However, it is not only possible but even necessary to have some conception of a normal selection forest for an ideal to aim at.

The uncertainty of what the constitution of a normal uneven-aged forest should be, led some foresters on the continent and elsewhere, like, M. Biolley, consider the ideal redundant and are of the opinion that the forest should be brought on to maximum production by frequent checks. This is possible by keeping exact comparable records, frequently and periodically complied of the standing growing stock, its distribution in each size-class and of similar for what is felled; the progress of increment and yields can thus be watched. With that knowledge and long experience of working such forests, the growing stock can be moulded to that which is most productive of valuable increment.

Bulk of our Indian forests is irregular; they are thoroughly irregular in density and diameter distribution, etc., and such deviations take place over relatively small areas. As the ultimate aim is to bring them to a normally productive state, the fellings, thinnings and regeneration operations have to be regulated that all undesirable irregularity is smoothened out and the forest is brought to correspond to a properly balanced irregular forest. This cannot be done till we know what a normal irregular forest should be; very little work has been done in India in this regard.

DE LIOCOURT'S LAW:

A very important fact was discovered by F. De. Liocourt that in a fully stocked selection forest, the number of stems falls off from one diameter class to the next in geometrical progression, which means that the percentage reduction in the stem number from one diameter class to the next is constant. This is referred to as *De Liocourt's Law*. If the quotient of the series is known and the number of stems in any class is given, the whole series can be worked out and this should give the *proportionate distribution* in an Ideal Selection forest or its *balanced composition*. This series is represented by the geometrical progression:

$$a, aq^{-1}, aq^{-2}, aq^{-3} \ldots\ldots\ldots\ldots\ldots. aq^{-(n-1)}$$

where a = number of stems in the lowest dia class.

q = Co-efficient of reduction in the number of stems; the quotient.

By itself, it is a very important discovery, but it does not readily lead us to the ideal selection forest. Firstly, it is not known what the ideal number in known class should be and, secondly, what the quotient should be. Later researches found that the normal stem number distribution for different site qualities varies. It was still in geometrical progression but the quotient was different for different qualities. For example, this quotient q for silver fir Q.I is reported as 1.30, 1.35 for Q.II, and 1.40 for Q.III and 1.50 for Q.IV.

In India, it was only in 1952 that some studies were made in this regard, in the plots laid out in 1939. Some of the conclusions reported by S.K. Seth and G.S. Mathauda at the Ninth Silvicultural Conference at the F.R.I., Dehra Dun, in 1956 are:

(1) The number of stems in successive diameter classes of true selection forest of tropical wet ever-green, southern moist deciduous or hill sal type follows De liocourt's law, which was hitherto known to hold well for temperate forest.

(2) A set of 'empirical yield Tables' for selection *Sal* forest in one locality, and 'empirical stand Tables' for *true* selection sal forest for various qualities have been prepared. It is felt that there is urgent need for a study of the rate of growth and the composition in a selection forest and for the preparation of stand tables for different types of forest.

The problem of a normal forest, for the irregular and / or mixed forest, continues to be a complex one: management of Indian irregular forest would remain unscientific till the problems of composition and growth solved.

Meyer (1933) simplified De Liocourt's law in the form of an exponential function: *y* = Ke-ax

Where y = number of stems in the dia, interval; x = diameter at breast height.

A = percentage reduction in number of stems for each dia.

K = relative stand density which is dependant on site conditions.

e = 2.71828, the base of Napierian logarithms.

By plotting the log, mumbers of stems against their mid-diameter values on an ordinary graph paper, if the resulting points are in a straight line, it would indicate a balanced crop. The abnormality in number in any dia-class can be readily detected and silvicultural treatment can be given to obtain ideal distribution in course of time. For example, if there is preponderance of smaller trees, mid-sized or larger-sized tree, the position can be rectified by thinnings, heavy thinnings or regeneration fellings, respectively.

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

Theoretical selection forest is supposed to have all diameter classes intermingled in balanced proportion. Uneven-aged crops are continuous in nature and have no point of termination; when mature trees are removed a new crop of the next order is started. Growth data of unevernaged forests cannot be presented in the form of yield tables. Age of the crop is usually difficult to determine. Mathauda studied the distribution of number of stems in different dia. classes in uneven-aged sal forests in Ram Nagar forest division (U.P.).

Application of De Liocourt's law to enumeration results of spruce and silver fir forests of Mandi and Nachan forests of Himachal Pradesh yields the ideal stocking of fir forests as given in the following table (source: article "Ideal stocking and normal growing stock of selection forests of fir and spruce", by R.V.Singh, Indian Forester, January, 1975).

Dia. Class (cm)	No. of trees per ha	Standing Vol. m^3/ha	% of total growing stock
20-30	108.7	30.78	8.7
30-40	65.0	55.20	15.6
40-50	39.5	67.17	19.0
50-60	22.7	65.49	18.5
60-70	12.3	52.47	14.8
70-80	7.4	44.08	12.5
80-90	4.4	34.00	9.6
Over 90	0.5	4.61	1.3
Total	260.5	353.80	100.0

Summing up: Concepts of an ideal forests – a normal forest – and that of standard yield management, the aims of good management, form the basis of scientific management of forests all over the world. Trinity 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 tables applicable to the site and component species.

CHAPTER VII
INCREMENT

GENERAL REMARKS – TERMS - DEFINITIONS

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

In forest management, the term increment refers usually to only volume increment, and that too of crops rather than of individual trees.

Increment of both individual trees and crops is influenced by species, site quality, silvicultural treatment (tending operation) and also the nature of the crop – whether even-aged or uneven-aged. Increment of a forest is its most vital character as it is intimately connected not only with the health and species of the trees, and the fertility of the sites they occupy, but also with the volume and age of the crops. A virgin forest, or any forest undisturbed for a long time, has no net increment; in fact its increment may even be slightly negative for a period (adverse climatic conditions, etc.) followed by an equivalent positive increment. Individual trees may be growing fast or slow but others decay and die. The volume of forest vegetation has reached a climax, more than that the site cannot sustain; and the forest has attained a static equilibrium. But if this virgin or long undisturbed forest is worked/felled, it will try to regain the climax volume and then have a positive net increment.

The increase in growth that takes place in a particular year is called the current annual increment (C.A.I.) for that year. It may be expressed, figuratively, as $(V_{n+1} – V_n)$ where V_{n+1} is the volume of wood produced in (n+1) years and V_n is the volume in *n* years. Since it is not feasible to record measurements every year to determine increment accurately for a single year, these are usually taken at intervals (of 5 or 10 years period, as in yield tables) and the periodic increment is divided by the period and the increment so obtained is taken as the C.A.I. (as in yield tables); though, strictly speaking, it should be termed as periodic annual increment (P.A.I.). If the period is short, P.A.I. and C.A.I. will be very close to each other. Yield tables also give data for, generally, five or ten year intervals, and the figures under C.A.I. column are the average P.A.I. and shown in intermediate positions between two successive ages.

The volume of a tree is built up of successive CAIs, which of course, vary considerably from year to year. The CAI is, so to stay, a chapter in the history of the tree. The mean or average of all CAIs is known as mean annual increment (MAI), an average annual rate of growth upto any given age; it is derived by dividing total increment upto any specified age by that age. When the MAI is for the entire rotation period, it is known as final mean annual increment. The expression giving percentage relationship between increment and the volume producing it, is known as increment per cent.

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

i) Increment: The increase in girth, diameter, basal area, height, volume, quality, price of individual trees or crops during a given period.

ii) Current annual increment (CAI): Strictly the increment in a specific year. Usually taken as the periodic annual increment over a short preceding period.

iii) Periodic annual increment (PAI): The average annual increment for any short period; sometimes referred to as periodic mean annual increment.

iv) Mean annual increment (MAI): The total increment upto a given age divided by that age.

v) Final mean annual increment: The MAI at rotation age.

vi) Increment per cent: The average annual growth in volume (or basal area) over a specified period expressed as percentage of the volume (or basal area) either at the beginning or, more usually, half way through the period.

Current and mean annual increments (CAI and MAI)

CAI is small in early stages (seedlings and saplings), increase slowly at first, then more rapidly to the maximum, after which it begins to decline, and finally ceases with its mortality. This is true both of individual trees and crops. The sum of the CAIs laid on for the entire period gives the total volume, which when divided by the age gives the

MAI – the average of the past production. It is an arithmetically derived value and coincides with actually only twice in the life of a crop; once at the end of the first year and once later, when it culminates and equals the CAI. The current annual increment tends to increase constantly upto a maximum. During this period the volume laid each year to the total volume of the stand is greater than the average of MAI upto that year. The rising CAI raises the MAI also; but the curve of the latter cannot show as steep a rise as that of the CAI, since the effect of the increasing growth each year is spread over all the previous years. When the CAI curve reaches its culmination and begins to decline, the successive average increments, i.e., the MAI figures for each year still continue to rise inspite of this fact, since the amount of growth added to the stand during the year, although less than formerly is still greater than the average or mean. When the CAI for the year finally falls to an amount equal to the average or mean for the entire period, the curve of MAI has reached its highest point, i.e., has culminated. During the following years, the CAI is less than the mean, hence the MAI curve begins to drop but only to the extent that it is pulled down by the effect of this lesser CAI for single years, spread over the age. Hence, as before, the MAI curve shows a fall, more gradual than the CAI curve. Unless the stand is felled, the losses in the stand will finally exceed the growth, and the CAI will then become negative. But until the entire stand is destroyed, the curve of the MAI will still be positive.

Conclusions from the above description, tabulated data and trends of the MAI and CAI curves may be summed up as:

i) To begin with the MAI keeps below the CAI

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

iii) The CAI attains the maximum before the MAI

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

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

INCREMENT PER CENT

The term has already been defined; it is an expression of the relation between the increment and volume.

Current increment per cent: is the relation of the increment during a given year to the volume at the beginning of the year.

Periodic increment per cent: is the relation of the increment during a given period to a basic volume which may be taken as the mean or average volume for the period, or the volume at the beginning of the period.

Mean annual increment per cent: is the per cent ratio which the MAI for a given age bears to the total volume at that age.

The main purpose for which the increment per cent is utilized is to test the maturity or ripeness of individual trees or crops, which is a very useful information for fixing the rotation or the yield. Those trees or crops, which show the lowest increment per cent on their present volume compared with other trees or crops, should be selected for felling. The object of such selection is to remove from the forest the greatest possible volume of wood capital, while at the same time reducing the increment of the crop by the smallest possible amount. If this is done, the effect is to transform the forest capital from a condition in which the ratio of increment to volume is low, to one in which the ratio is materially increased for the forest as a whole.

On individual trees the increment can be found by stem-analysis, by means of Pressler's increment borer, by repeated direct measurements or is taken from the yield tables. The increment per cent of average sample trees is often assumed to be that of the crop (though not strictly correct).

RATE OF GROWTH – FAST GROWING AND SLOW GROWING SPECIES

The terms fast and slow growing species are relative terms, quite commonly used in Indian Forestry. Fast growing species offer several advantages, such as:

i) The trees become merchantable at an early age

ii) Wood production per unit area per annum is more – hence better economic return

iii) There is less chance of loss due to fire and decay, as the crop becomes exploitable at an early age

i) They may be of poor mechanical qualities, and not useful as structural timbers.

ii) They are likely to produce more defective timber

According to present concept, a fast grown species is one which yields a minimum of $10 m^3$/ha/annum. In case of younger plantations, the height increment must not be less than 60 cm per annum. A species may be fast growing at one stage of its development and turn into a slow growing one at the other. A fast growing species may not behave as such in all climatic and edaphic conditions; its growth may be faster in one locality while slower in another. Selection of species must be done carefully to utilize the maximum has been widely planted under different hybrid (*E. tereticornis*) has been widely planted under different site conditions. It has shown fast growth in some localities, while not so in others.

Many indigenous and exotic species have been found to be fast growing in many areas, which are being adopted for large scale plantations, because of their faster rates of growth and quicker returns.

Some other indigenous fast growing species are *Bischoffia javanica, Terminalia tomentosa, Kydia calycina, Holoptelia integrifolia, Ailanthus excelca, Artocarpus fraxinifolius, Erythrina indica, Sesbania, Anthocephalus cadamba*.

Tropical pines have been lately introduced in the country and they have shown varying results. The species which have shown fast growth are *Pinus caribaea, P. patula, P. radiata* and *P. eeliottia*.

POSITION OF GROWING STOCK AND INCREMENT IN INDIA

India has about 35 m ha of land under forest comprising about 22.7% of the total geographical area. Growing stock position is far from satisfactory because of the biotic interference in the past.

The position of MAI in Indian Forests is also not satisfactory. Indiscriminate fellings, over-grazing, frequent fires and poor site conditions are responsible for low increment over most parts of the Indian forests.

INCREMENT IN TREES AND CROPS: SOME DISTINCTIVE FEATURES

The Mai of single trees varies greatly with age and increases continually to maturity; while that of a crop occupying a given area varies much less and increases upto a certain point when it diminishes.

Conclusions based on increment studies of individual trees cannot safely be applied to crops. It might at first sight appear that the study of the diameter increment of an even-aged stand is merely a study of the same problem for each species of trees composing it. This is not so. An even-aged stand in its seedling stage normally has a lakh or more of seedlings to a hectare. As these increase in size, they compete with each other for light and moisture with increasing vigour, until the weaker individuals die through suppression by their thriftier neighbours. This struggle continues throughout the life of the crop, with the result that the number of trees greatly decreases, until at maturity only a very small fraction, often less than one per cent of the original, remains. Each of these trees produces many times the quantity of material that the young seedlings/ saplings do, but their number is very small. In case of individual trees, each tree starts as a young seedling producing very little, and ends as a big tree producing a great deal more – hence a constant increase in the production of individual trees.

It is evident that the chances of survival are best for the largest and thriftiest trees, and it is highly probable that the trees that die will be from among the smallest in the crop. Every time that a smaller tree dies, the average size of the living trees becomes larger. The average diameter increment increases, not only through the increasing size of the trees that live, but also through the elimination of smaller trees that die. Through the major part of its life, the average size of the crop will, therefore, increase more rapidly than that of the trees composing it.

If a stand is not absolutely even-aged, a similar complexity is introduced in the matter of average age of the crop. With the death of the younger trees, handicapped in their struggle for existence, as well as the passage of time, the average age of the crops increases more than the number of years that elapse; a stand may grow 11 years older in a single decade – it is possible, howsoever paradoxical it may seem.

The productivity of the site is used up in the growth of a constantly changing number of individuals, some free and fast growing and others more or less suppressed and slower growing. In the case of individual trees, the increment data relate to the trees themselves as producing units. Whereas in case of crops the trees constituting the crops are steadily dwindling in number and the only constant producing unit is site itself – soil productivity, leaf canopy, light, etc.

For these reasons, it is very difficult to study the growth of even-aged crops by studying that of single trees, or even of a single group of trees. The basic data for a study of crop growth should be a series of measurements on crops of various ages on the same unit area (which is the only constant factor of growth). The tabulated results thereof are called Yield Tables.

QUALITY AND PRICE INCREMENT

Quality increment: is defined as "the increment in the value per unit volume of a tree or a crop, independent of any increase in the price of forest produce resulting from any change in money value in general, or the supply and demand position in particular."

As a tree or crop grows with age, there is increase in the value per unit volume, as larger sizes always fetch higher prices (size / price gradient) due to higher utilization percent and, secondly, there is a reduction in the cost of production of unit volume of timber (proportion of stem wood to branch wood increases). The increase in the value per unit volume in case of firewood is limited upto medium sizes (the case of firewood may be left out of consideration). Quality increment per cent can be determined and expressed in the same way as volume increment per cent. By using Pressler's method the expression will be

$$p = \frac{K - k}{K + k} \times \frac{200}{n}$$

Where p is the increment per cent, k the value of unit volume rising to value K during the course of n years.

Price increment may be defined as "the increment in price, independently of quality increment, resulting from fluctuations in the market on account of changes in money value in general, and the demand and supply position in particular. We know from experience that over long periods there is always a tendency for the prices of general commodities, as well as timber and firewood, to rise. This is particularly true of countries like India with developing economics. This is due to the fact that side by side with the general rise in prices, *per capita* consumption of wood has also been increasing. Increment per cent for price may also be determined in the same way as the increment per cent for volume or quality. Supposing P_1 was the price of a unit volume of wood *n* years ago, and the present price is P_2; the increment per cent *p* by Pressler's method

$$\frac{P_2 - P_1}{P_2 + P_1} \times \frac{200}{n}$$

Effect of thinning on volume increment

The rise and fall of the CAI, on which the mathematical relationship between the CAI and the MAI depends, is a regular one. This is correct provided the growing conditions remain constant and the measurements are taken on the same trees. Seasonal variations of rainfall, temperature, etc., do not upset the regularity because the interval between the measurements is quite long, say 5 to 10 years. However, thinnings which are usually carried out do introduce a complication, and if these are heavy or irregular, curves may rise or fall with every thinning. A heavy thinning in a previously neglected crop may, however, result in checking the downward trend of the CAI curve, and even cause a second rise. Regular thinnings of a fixed grade, as are carried out in sample plots which are the basis of preparation of yield tables, do not disturb the smooth rise and fall of the curves.

Thinnings, whether natural or artificial, which take place in a crop, introduce a complication which does not arise when the increment of single trees is being considered. As stated already, the mathematical relationships between the CAI and the MAI depend on all measurements being taken on the same growing body, and this is a condition which cannot be obtained in the case of a crop the composition of which is being constantly altered by the removal of part of it in thinnings. This being so, we cannot expect to find in practice that the relationship between the CAI and MAI is exactly as stated above; and to draw conclusions from the relationship we must take precautions to ensure that, as far as possible, we should be measuring the same crop. In practice it is not so easy, though not impossible, as some of the trees from the lower, previously unmeasured, class come into the measurement class. But what must be ensured, and it is within practicable limits, is that the calculations are based on total yield, i.e., volume of the existing crop plus the volume removed in thinnings. If this is not done, neither the rise and fall will be regular, nor will it be correct to establish any relationship between the CAI and MAI. But information regarding the yield from thinnings throughout the life of a crop is not always available. In such case, either both measurements should be taken before thinning, or both after thinning, for purpose of comparison of the MAI with the CAI.

Studies on the effect of the kind of thinning on the increment reveal that in case of the individual trees the increment is markedly stimulated by repeated liberation of the crown, it is doubtful, however, if this increment improvement is obtained when the whole crop is opened out.

Experiments with various grades of thinning have consistently shown that the amount of increment of the even-aged stands cannot be greatly affected by the nature of periodic thinnings; the total volume yield being practically unaffected by thinning treatment, as exemplified by multiple yield tables for deodar. On the other hand, the value production is substantially increased by the fact that the possible increment of a stand is concentrated on the best trees. The value of a tree increases with its size because:

a) It has a larger volume and b) The value per m^3 is

higher The total increase in value is expressed by

$$1.0\ t = 1.0\ v \times 1.0\ p$$

When, t = annual increment per cent in value of the tree v

= annual increment per cent in volume of the tree

p = annual increment per cent in price per m^3

Determination of the increment

It is relatively easy to determine the CAI on individual trees by stem analysis on felled trees, by Pressler’s increment borer on standing trees, by repeated direct measurements or from the yield tables.

The increment production of crops, however, is much more difficult to determine. The simplest method consists in estimation, in which the forester goes either by experience in other forests or on yield tables. This method is, however, not appropriate for accurate assessment. The sample tree method gives better results if correctly applied. As the increment from tree to tree may be very different, definite conclusions cannot be drawn from increment studies on individual trees. The most accurate method consists in calculating the periodic mean increment from the difference between two measurements. This is suitable for calculating the increment not only on the whole stand but also by size classes.

The increment of stands does not behave regularly, as might appear from the smoothed curves of the yield tables. It may fluctuate considerably from year to year as a result of tending operations in the crop and other factors, such as weather.

Increment estimation by yield tables

For fully stocked, pure, even-aged crops of important species, yield tables are available as satisfactory means of estimation of the crop increment. Yield tables provide information about the behaviour of the volume increment as a function of age of the crop, as well as about the increment of other parameters of growth viz., diameter, basal area and height.

a) Increment from MAI

Increment of the felling series, or the yield, can be determined from the final MAI. In a normal forest, the annual yield, or increment of the series will be = MAI (at rotation age) x area of the FS. If the forest is under-stocked or over-stocked, the yield must be reduced or increase, accordingly, by an amount equal to the difference between the actual and the normal growing stock; divided by the equalization period (Heyer's formula: to be described later).

Increment from CAI

The increment can also be estimated from the CAI figures in the yield tables by

i) Area method: From the data of area under each age class, its average site quality and density, and increment per unit area, increment of each age (or diameter) class, and the total increment of the series can be determined.

ii) Per tree method: Suppose from the enumeration of the growing stock, d_1, d_2, d_3, d_4, etc. are the dia classes n_1, n_2, n_3, n_4, etc., the number of trees in the dia classes v_1, v_2, v_3, v_4, etc., the volume per tree in the dia. classes and c_1, c_2, c_3, c_4, etc., the CAI per tree in the dia classes. Then the total increment =

$$n_1v_1c_1 + n_2v_2c_2 + n_3 v_3c_3 + n_4v_4c_4$$

Note: i) The volume per tree is obtained from the yield table by dividing the standing volume corresponding to the crop diameter by the number of trees per hectare.

ii) The CAI in each dia class is obtained from graph; the CAI per tree being equal to CAI per hectare divided by the number of trees

iii) By increment per cent method: The increment per cent may be obtained from the yield table by Pressler's formula

$$p = \frac{V - v}{V + v} \times \frac{200}{n}$$

(with usual connotations: described already)

It can also be calculated with a fair degree of accuracy on standing trees by Pressler's increment borer, with the help of Schneider's formula 400/nD (described already). The increment per cent method can be used both for regular and irregular crops by determining the growth per cent in selected sample trees representing all the dia classes and site qualities. This method is very useful in the absence of precise growth data, such as the preparation of first working plan, and for extensive areas.

For practical application of this growth per cent method: total standing volume in each dia class is known (from enumeration data), with the calculation of increment per cent of each dia class (from above method) we can calculate increment in each dia class (or the yield) on its present volume, and sum of increments (yields) of all the dia classes gives the total increment of the forest area (FS) on the yield. From this, the average increment per cent of the entire FS can also be worked out as:

$$\frac{\text{Total increment of all dia. classes}}{\text{Total standing volume of all dia. classes}} \times 100$$

The CAI and increment per cent are affected by the degree of stocking. In under-stocked crops the increment is more, and in over-stocked crops less than the figures recorded in the yield table or obtained by the use of increment borer. The increment determined by the above method is, therefore, on the lower side for under-stocked forests and higher for over-stocked crops.

Increment determination in irregular crops: When enumeration of growing stock is done above a certain diameter, usually over 20 cm in Indian forest management, MAI can be calculated by the following method:

Let n_1, n_2, n_3, etc. be the number of trees in different dia. classes; p, q, r, etc., be the true ages of the dia classes; and x, the age corresponding to dia over which enumeration are done (20 cm in the above case). Then mean age of the crop by Andre's formula is:

$$A = \frac{n_1(p - x) + n_2(q - x) + n_3(r - x)}{n_1 + n_2 + n_3}$$

and the MAI would be G_a /A, where G_a is the actual volume of the growing stock.

Increment determination by successive enumerations: The yield table methods described above will give accurate increment figures only when the crop conditions correspond to those envisaged in the yield tables viz., they are pure, even-aged and normally stocked and thinned to ordinary 'C' grade, on which basis the yield tables are prepared.

Such conditions are rarely found in natural forests of India, which are heterogenous in character with varying degrees of irregularity; stocking also varies considerably. Based on these fundamental premises, increment determination methods (forestry practice in general) are drifting farther and farther from yield tables. A lead was given by Biolley's methods du controle, which is based on successive inventories for determination of increment / yield.

If V_1 = Initial volume of growing stock

V_2 = Final volume of growing stock

N = Material removed during the period (thinnings, etc.)

P = Recruitment, i.e., the growing stock which has passed the minimum enumeration limit (usually 20 cm dia)

n = Period between successive enumerations (short; usually 5 to 10 years)

Then the MAI during the period is

$$\frac{(V_2 – V_1) + N – P}{n}$$

CHAPTER VIII

DISTRIBUTION OF AGE-GRADATIONS AND AGE-CLASSES

GENERAL REMARKS – DEFINITIONS

For sustained yield management, a forest should be so managed that trees or crops are harvested at maturity (rotation age) and replaced by new trees or crops, naturally and / or artificially, so that year after year, or period after period (for annual or periodic yields), there are mature trees, or a mature crop available to give the calculated sustained yield. This stipulates the establishment of a normal series of age- gradations or age-classes, distribution of which will vary according to the Silvicultural System adopted and the resultant type of forest, whether regular or irregular, depending on whether the age-gradations / classes occupy separate areas or all ages are mixed together and represented on each unit of area. An *age-gradation* is : "an age-class with one year as the interval"; and an *age-class* is: "one of the intervals into which the range of age of trees growing in a forest is divided for classification or use: also the trees falling into such an interval". By *age-class distribution* is meant: "the local occurrence, or proportionate representation, of different age-classes in a forest".

NORMAL AGE-GRADATIONS CLASSES

A forest is known to have a normal series of age-gradations. If it has in it a complete series of age-gradations, from seedlings to the mature trees (one year to rotation age) in proper proportion. Similarly a forest is known to have a normal age-class distribution if it has in it a complete series of age-classes and in such proportions which will permit equal volumes from annual or periodic fellings, under the given rotation and Silvicultural System.

As already stated, the presence of normal age- gradations or age-classes, i.e., a complete series of age-gradations / classes, is a *sine-quo-non* for obtaining Sustained Yields from a forest. A very simple picture of a complete series of age-gradations may be had from the following example:

Suppose a person wants to provide for felling of one teak tree, 40 years old, every year in perpetuity. To be able to do this he must have an assortment of teak trees, one 40 years old, one 39 year old, and so on down to one tree one-year old. For every tree felled at 40 years age, he should plant a new one to replace it. Such an assortment of trees, one year old to maturity, can be said to have a complete series of age- gradations. Some would be true, if instead of an annual yield of one tree, he wants to have a yield of one hectare, he would have to provide a complete series of age- gradations, one to forty years of age, each occupying one hectare area. If there was a break in the series, e.g. if age-gradations 27 and 19 were missing, there would be no trees to fell 13 years and 21 years hence, and the yield would be interrupt.

If instead of one tree 30 years old, one of 29 and one of 28 years, there were three trees 29 years old, then 10 years hence there would be a slight fall in yield (the different being that due to the difference in a 30 years old tree and one 29 years ole): in the 11^{th} year from now the yield would be normal and in the 12^{th} year there would be a slight rise in the yield. This second type of abnormality is less serious than the first, in which there was a break in yield.

Similar considerations apply to crops as well as to single trees, but the analogy cannot be stretched too far, as there is a fundamental difference between the behaviour of individual trees and crops. In the former case the tree itself is the unit of growth, whereas in the latter the unit is the area. If all we wanted from a forest was a final yield of say 100 trees per hectare, we could, perhaps, have planted just about as many, certainly not much more numerous than the final number. There might be some casualties, but with careful protection right from the beginning we could probably ensure that 100 seedlings planted per hectare ultimately grew into almost the same number of mature trees. This, however, would not be forestry. During the greater part of the life of such a crop, the soil would be more or less exposed and subject to deterioration in this method, there would neither be natural struggle for existence not the natural selection of the best individuals. Moreover, the trees having grown in comparative isolation during the greater part of their lives, would be branchy and malformed. But this is not all ; there would be no intermediate yields from thinnings at all in this method. This intermediate yield from thinnings might account for anything from 25 to 50 percent of the total volume production. Therefore, this method of starting with the same number of plants as are required in the final crop is, apart from objections from silvicultural point of view, also financially unsound. It is not enough that is easy enough from and forest, however, abnormal. It is necessary that the Sustained Yield should be the maximum possible on a given site with a given species and for a given purpose. This means that right from the formation of the stand, there must be the fullest possible utilization of the site; the index of which is the presence of a complete canopy. Obviously, it takes a much larger number of trees to form a complete canopy in the earlier stages of crop formation, than it does in the latter and final stages. The following figures from plantation teak yield tables for various qualities illustrate the point.

NUMBER OF TREES PER HECTARE

Age (years)	**Q.I**	**Q.II**	**Q.III**	**Q.IV**
5	1331	1530	2174	-
10	632	857	1166	1610
15	378	531	736	1124
20	252	373	551	857
25	185	282	425	687
30	151	225	352	603
40	114	165	274	484
50	94	136	230	400
60	86	121	200	346
70	81	109	173	311
80	77	99	156	277

The above table clearly shows that the number of trees that a normally stocked one hectare area carries is very variable, depending on age, site quality, and also the treatment, i.e., intensity of thinnings. Assessment of normality of a forest by comparing the number of trees per hectare on the ground with the yield table figures is, therefore, a very unreliable method. The final test of normality of any age-gradation or age class is the volume of the gradation or class. A some what simpler method is to compare the total basal area of the age-class with the Yield Table figure.

Where the several age gradation occupy separate ground, the normality of distribution of age-gradations can be readily ascertained by finding the actual area occupied by each gradation, provided the density of stocking is normal throughout the forest. Where the density is not uniformly normal, but is variable, a correction factor called a reducing factor can be applied so as to convert all the areas to a standard density. The figure by which each class must be multiplied to reduce it to the standard is known as the Reducing Factor, and the area so obtained as the Reduced Areas.

Examples of forest where the age-gradations are clearly separated on the ground are the forests worked under simple coppice and clear-felling systems, specially artificial plantations. In such cases, the test of normality is simply that the several age- gradations occupy equi-extensive or equi-productive areas. In even aged forests such as those worked under Shelterwood systems, where age-classes are produced, each age-class occupying separate area, the area test may be applied but not as accurately as in case where the forest is composed of age- gradations.

In an irregular forest, age-gradations are intermingled all over the area, and it is not possible to determine the area occupied by each. Whether the forest is regular or irregular, in theory the normal forest has a complete series of age- gradations, irrespective of the manner in which these may be distributed. In irregular forests normality cannot be tested by area; it has to be tested by volume or basal area. This can be done only by enumeration, hence the difficulty of telling whether a selection forest is a normal one or not.

NORMAL AGE-GRADATION CLASSES IN REGULAR FORESTS

The unit of yield regulation in both regular and irregular forests is a Felling Series (F.S). A felling Series is an area, forming the whole or part of a working circle, containing or aiming at a normal series of age-gradations or age-classes. A working circle may be composed of a number of F.S.; when it consists of only one F.S., the two terms are synonymous and only the former term is used.

(a) ***Felling Series in Simple Coppice and Clear-felling System***

Under simple coppice and clear- felling systems, the F.S. will consist of a number of annual coupes, equal to the number of years in the rotation, differing in age by one year. The area of each will be total area of the F.S. divided by the number of years in the rotation, i.e. A/r. This provides for all the regulation of the yield required in these systems; regulation is by area only and the annual yield is represented by an annual coupe. The coupes differing in age by one year, need not necessarily adjoin each other in practice; they may be distributed in any manner subject to silvicultural considerations and convenience. There may be a planned separation into cutting sections. The figures show diagrammatically twenty annual coupes arranged first in one and then in four cutting sections, thereby providing for a 4-year interval between the fellings in two adjacent coupes. It may be noted that there are 20/4-5 age- gradations or annual coupes in each cutting section. These principles are applicable to clear felling in high forest with artificial regeneration and to simple coppice and, in a slightly modified form, to certain special cases of very quick natural regeneration under a Shelterwood. The applicability of the method of annual coupes depends on the certainty of regenerating the coupe, artificially or naturally in one year.

(b) Felling Series in Regular Shelterwood System

In a F.S. worked under regular Shelterwood systems of natural regeneration, age-classes take the place of age-gradations and periodic blocks (P.Bs) take the place of annual coupes. Each P.B. is regarded as approximately even-aged. The fewer the number of age- gradations included in each age-class in a P.B., the more nearly it is even-aged. The distribution of age-gradations within a P.B. will depend on the method of regeneration and the ease and regularity with which regeneration appears; it does not affect the scheme of management. The yield is regulated by periods and prescribed, as nearly as possible, by volume only.

NORMAL AGE-GRADATIONS / CLASSES IN IRREGULAR FORESTS

a) Felling series in selection forests: In normal irregular forests, worked under selection system, the age-gradations, though indistinguishable by area, are assumed to be present in normal quantity in any F.S. Regeneration is taking place all over the forest all the time. In the example given, a felling cycle of 10 years provides a period of rest to the crop. With an annual yield fixed at 2% of the growing stock, with a 10-year felling cycle, 20% of the growing stock will be removed; similarly with 20-year felling cycle 40% and with 30- year felling cycle (sometimes provided in remote areas) 60% of the growing stock is removed, and the felling will be heavier than a heavy seeding felling and the future crops are bound to be more and more even-aged. As a rule, the better the quality and higher the increment, the shorter should be the cycle.

b) Felling series in coppice with standards system: The silvicultural system requires the F.S. to be divided into annual coupes, equal to the number of years in the coppice rotation. As far as the coppice is concerned, there will be complete series of age-gradations, each occupying separate area, as in clear-felling system; the yield is also similarly regulated by area (annual coupe).

However, the retention of some standards out of the old crop at the time of felling, coupe after coupe, complicates the arrangement. The rotation of the standards is always a multiple of the rotation of the coppice. Where the rotation of the standards is only twice the rotation of the coppice, standards range from r+1 years to 2r years in age; in case the standards are retained for 3 or 4 times the rotation of the coppice, their ages will range from 2r + 1 years to 3r years, 3r+1 to 4r years, as the case may be (see table below).

3r+1,	3r+2,	3r+3	…….	4r	Standards rotation	4r years
2r+1,	2r+2,	2r+3	…….	3r	Standards rotation	3r years
r+1,	r+2,	r+3	…….	2r	Standards rotation	2r years
1,	2,	3	…….	r	Coppice rotation	r years

The above table shows the coppice and standards differing in ages by r, 2r and 3r years, and all occupying the same annual coupe. If viewed vertically, the arrangements is the same as would be in a selection forest worked under a felling cycle.

CHAPTER IX
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 (in case of Indian forests, generally the state) from which he receives the income. Ordinarily, any increase or decrease in the capital (GS), is immediately reflected in the income (increment/yield). Just as in a business enterprise, the investment may be over-capitalized, normally-capitalized or under-capitalized, in forestry enterprise also the G.S. (capital) may be over-stocked, normally- stocked or under-stocked. An over-mature and/or very densely stocked crop may have an excess GS to the extent that it is over-crowded, and not only the increment is retarded but even the excess GS may also gradually be lost by decay.

Besides the volume of the GS as such, its composition as regards age-classes is also important, so that it may continue to provide mature trees for regular sustained fellings (annual yields). Therefore, regularization of the GS, as also its composition, are very important factors in the practice of forestry. Both these variables can be accurately determined by regular and frequent inventories or enumerations by age-gradations/ classes. These inventories indicate the trend of the progress of the G.S. (forest capital) and increment (interest) thereon.

Growing stock (GS) is defined as “The sum (by numbers or volume) of all the trees growing in the forest, or a specified part of it” (glossary).

Normal growing stock (NGS) 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 volumes of single trees and crops forms a part of the subject of forest mensuration. 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 areas; practiced only in very valuable forests of limited extent.

ii) By partial or sample enumeration: Statistically 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. These methods have been exclusively adopted by the Directorate of Forest Resources of India for estimation of GS in various regions of the country.

The importance of determination of the actual GS and its composition by age-gradations/classes cannot be over-emphasized. However, it will not in itself indicate whether the GS volume is at its optimum and putting on optimum increment. Even frequent enumerations will only indicate the direction in which the GS is moving, but we will not know how far behind we are from the optimum, or whether the age-class distribution is shaping towards an ideal (normal), capable of giving mature crops in equal quantities, un- interruptedly (sustained yields).

DETERMINATION OF NORMAL GROWING STOCK

Normal growing stock (NGS) of forests worked under various representative silvicultural systems may be determined as follows:

A) NGS IN CLEAR FELLING SYSTEM

a) Based on final MAI: The simplest example may be taken of a firewood Eucalyptus plantation of ten hectares, one hectare of which has been planted annually for ten years – the proposed rotation period. There are, therefore, ten age-gradations of equal/equiproductive areas, consisting of a normal series of age-gradations, of which one 10 year old is felled and allowed to coppice to form future crop supplemented with planting, if an when necessary). So, at the end of next year, this regenerated area becomes one- year old age-gradation and the series is complete again, and the oldest plantation now 10 year old is harvested and regenerated. Age- gradation areas are shown along the baseline AB, with the theoretical volumes standing on each, which are represented by a number of equal rectangles, each equivalent to one year's growth, assuming that each hectare of plantation puts on equal volume of wood every year of its life. Thus, if each year's growth in each plantation is represented by *i*, the volume of each age-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 500 m^3, so the final MAI at this rotation age 500/10 = 50m^3, and this is shown as the volume on one-year old hectare as *i*.

The volume r x i standing on the oldest age-gradation at the end of *r* years (in this case, 10x50 = 500 m^3) is also the sum of the MAIs of all the r (10) age-gradations, and may be termed as I to represent the increment of the whole series. Therefore, by felling the rotation-age ha each year, the normal increment for the rotation of this normal series is being harvested.

Careful study and interpretation of this diagram brings out that the volume of the oldest or rotation (r) age-gradation is equal to

i) r x i = I (or)

ii) Final Mai of anyone age-gradation *i* multiplied by rotation *r* (or)

iii) The sum of CAIs, *i*, of all the *r* age- gradations

iv) The total MAI of the series

The annual yield of the normal forest is the volume of the oldest or rotation (r) age- gradation; it is equal to the increment of the forest and may be based on any of the above four items.

Total GS on *r* age gradations, one to *r* year old, is the sum of the series i, 2i, 3i … (r-1)i, ri, in arithmetical progression, at the end of the growing season and before the oldest, r-year old, plantation is felled. This sum is = $(i+ri)\frac{r}{2} = \frac{ri}{2} + \frac{r}{2}(r \times i)$. Sub-Stituting I for *r i*, it is = $\left(I \times \frac{r}{2}\right) + \frac{I}{2}$. Similarly, with the removal of oldest plantation (volume = r x I = I), the increment I of the whole series is removed and the volume at the beginning of the next growing season will be $\left(I \times \frac{r}{2}\right) - \frac{I}{2}$.

Therefore, the volume of N.G.S. in the middle of the growing season is the average of the two values = $I \times \frac{r}{2}$. Where in r id taken as 10 years. Assuming that half the increment is laid by the middle of the growing season, the total volume of the G.S. will be represented by the area of triangle ABC = $I \times \frac{r}{2}$; where as at the end of the growing season, it will be = Triangle ABC + r small triangles above the triangle

ABC $\left[\text{i r ir r I each} = \text{---} = I \times \text{---} + \text{----} = I \times \text{---} + \text{---} \;.\; 22222 \right]$

Similarly, at the beginning of the growing season, after the old plantation (I) is felled but no further growth has taken place, the volume of the G.S. will be = $I \times \frac{r}{2} - \frac{I}{2}$

For all practical purpose, the mid-season formula is generally used.

Applying the above reductions to the particular case of *Eucalyptus* plantations, worked on 10 year rotation, on 10 ha area, one ha under each gradation, the volume of 10 year gradation being 500 m^3, the N.G.S. will be:

(a) $I \times \frac{r}{2} = 500 \times \frac{10}{2} = 2500$ m3 at the middle of growing season.

(b) $\left[I \times \frac{r}{2} + \frac{I}{2} \right] = 2500 + \frac{500}{2} = 2750\ m^3$ at the end of the growing season.

(c) $\left[I \times \frac{r}{2} - \frac{I}{2} \right] = 2500 - \frac{500}{2} = 2250\ m^3$ at the beginning of the growing season.

This N.G.S. at the mid season, i.e. 2500 m^3, is standing on r ha area; so the average N.G.S. per ha in this case is = $\frac{2500}{10}$ = 250 m3. We substitute age-class of 10

Years for the age- gradations, it will represent a normal series of age-classes of, say, *chir* pine crop, 1 – 10, 11 – 20, 21 – 30 …… 91 – 100 years old for a 100 year rotations.

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. FORM 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 accurately determine by plotting the yield table data on a graph paper, drawing a smooth curve and computing the area below the curve either by a *plani-meter*, area-square or by counting the squares. This is however, a cumbersome procedure.

If we assume that during each Yield Table interval, say five years, the rate of increment is uniform (although it may vary from interval to interval), the trend of the growth curve from one measurement to the next is smooth either rising or falling, and the increment put on by the crop changes in equal quantities annually, or in an arithmetical progressing. Though this assumption is not quite correct, but as the period between tow successive measurements is usually mathematically by regarding the two successive entire in the yield table as the first and the last terms of an arithmetical progression.

Let n be the Yield Table interval, and A, B, C, and D the volumes given in the yield table at ages n, 2 n, 3 n and 4 n, respectively. Then:- Sum of volumes of age-gradations from *Zero* to n years (inclusive) = $(0 + A) \times \left(\frac{n+1}{2}\right)$ similarly, sums of volumes of age- gradations from n to 2 n, 3 n and 3 n to 4 n years, *inclusive*, are respectively.

$$(A + B) \times \frac{n+1}{2}, \; (B + C) \times \frac{n+1}{2} \text{ and } (C + D) \times \frac{n+1}{2}$$

Addition of these gives twice the volumes of age-gradations n, 2 n and 3 n plus that of 4 n gradations; in general terms, in the summation all the yield table entire, except the last one are included twice. Hence their values, i.e., A, B, and C, the volumes of n, 2 n and 3 n age- gradations, must be deducted. Summing up, the N.G.S. volume will be:

$$= \frac{n+1}{2} \times (A + A + B + B + C + C + D) - (A + B + C)$$

$$= (n+1)\left[A + B + C + \frac{D}{2}\right] - (A + B + C) = n\left[A+B+C+\frac{D}{2}\right] + \frac{D}{2}$$

This is the calculation for the end of the growing season, before the felling of the oldest age-gradations is felled after the growing season, the G.S. must be reduced by D to obtain its value for the beginning of the growing season. Thus, the G.S. at this stage will be

$= n\left[A+B+C+\frac{D}{2}\right] - \frac{D}{2}$. The N.G.S. at the mid-season is the average of these two

Value, i.e., N.G.S. $= n\left[A+B+C+\frac{D}{2}\right]$. In practice, this mid season formula is

Generally used. It must however, be clearly understood that this result applies to an area of as many units of area (acres / hectares, on which Yield Tables are based) as the age of the oldest (rotation-year old) age- gradation (4 n in the above case). For other areas, the results will have to be worked out by rule of proportion.

GRAPHICAL ILLUSTRATION OF THE ABOVE FORMULA

Assume a yield table showing only four entries at intervals of *n* years (as in the above case); the volumes in the years n, 2n, 3n and 4n being A, B, C and D. The volumes are plotted against age and a smooth curve ELMNP drawn through the plotted points. Total volume of mid season or summer NGS for the rotation r = 4n or r hectares, will be the area below the curve, i.e., area EKPNMLE = Triangle ELF + Trapeziums (FGML + GHNM + HKPN).

(Note: Segments EL, LM, MN and NP of the curve may assumed to be straight lines).

$$\text{NGS} = \frac{n}{2}(A) + n\left(\frac{A+B}{2}\right) + n\left(\frac{B+C}{2}\right) + \left(\frac{C+D}{2}\right)$$

$$= \frac{n}{2}(2A + 2B + 2C + D) = n\,(A + B + C + D/2)\ 2$$

For the sake of convenience only four values have been taken in the above example; if the rotation is *r* years, n the yield table interval, and V_n, V_{2n}, V_{3n}, …. V_{r-n} and V_r the volumes at ages n, 2n, 3n, ……. r – n and r years, then the general formula can be written as:

$$NGS = n(V_n + V_{2n} + V_{3n} + \ldots V_{r-n} + V_r)$$

Over r units of area (acres/hectares)

NGS at the end of growing season (autumn NGS) and at the beginning of the growing season (spring GS) will, similarly, be:

$$n\left(A + B + C + \frac{D}{2}\right) + \frac{D}{2}, \text{ and } n\left(A+B+C+\frac{D}{2}\right) - \frac{D}{2}, \text{ respectively.}$$

COMPARISON OF REAL AND THEORETICAL NGS – FLURY'S CONSTANT

If the MAI and CAI curves are plotted against age, the age at which they intersect is the one at which the MAI culminates. The real NGS, for any rotation is represented by the area below the curve to a point on the curve vertically above rotation age. On the diagram are also shown the theoretical NGS triangles, according to equal annual increment conception for rotations of 10, 16 and 20 years. At 16 years, which is several years after the MAI has culminated, the triangle AHD and the area under the curve AHDEFA are about the same; that is, volume indicated by the final MAI and the actual yield table figures are nearly equal. Later on, say, at 20 years, true NGS indicated by the curve ABCDEFA is greater than the theoretical NGS (I x r/2) as indicated by the triangle ABC. The data is tabulated below:

Age (Years)	**Theoretical NGS by MAI triangle (m^3)**	**Real NGS under the YT curve (m^3)**	**On area (ha)**
10	500	366	10
16	1118	1105	16
20	1486	1615	20

Note that the yield table volume curve does not change its course but remains unaltered; it is the MAI formula curve which changes with each change of rotation, which changes the Mai as well. At some particular rotation, the excess as shown by formula curve during the earlier part of rotation is exactly made good by the deficit during the rest of the rotation, it is about 16 years. At this rotation age, the formula will also give the correct volume of the NGS just as the yield table does. It is easy to see that the nearer the rotation is to the time at which the growth of the wood is most active, that is to the time at which the CAI culminates, the greater will be the volume of the oldest age-class and more exaggerated will be the volume of the GS as calculated by the formula.

The volume of the true NGS will not attain equality with that obtained from the formula GS = I x r/2, until some considerable time after the CAI has fallen below the final MAI, i.e., until after the MAI has reached its maximum – the rotation of maximum volume production. Since it is seldom economical to work with rotations longer than this, and the modern tendency is to work on still shorter ones, this means that formula will, generally (not always, as illustrated above) given higher values for the NGS.

As the GS obtained from the yield table (real NGS) is more accurate than that obtained from the MAI formula (theoretical NGS), 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 MAI formula, which would allow for varying conditions under different systems of management. Amongst them, flurry (Swiss Forest Service) is the more prominent. He suggested that in the mid-season formula, GS = I x r x 1/2, a variable constant C (different for each rotation) should be substituted for ½, to obtain more correct results and the formula would read, GS = I x r x C, wherein C is known as Flury's constant. Flury actually calculated values of G at various ages to substitute for ½ in the formula, for various species, various rotations and varying sets of growing conditions.

DETERMINATION OF ACTUAL GS WITH PAST DATA ARE NOT AVAILABLE

Wherever yield tables are available, these figures may be applied to actual forest, by applying reduction factors for density. In case the yield tables are not available, as also the past data of the forest, the forester proceeds to enumerate the oldest age-class (on which the fellings will impinge) assuming that the volume of this age-class represents the increment of the forest and calculate the GS from it.

NGS IN UNIFORM REGULAR SHELTERWOOD SYSTEM

Under this system, theoretically, regeneration of a crop, compartment or a block (PB) extends over a period of time during which the old crop is removed progressively, and is replaced by the young crop. There is always an area under regeneration during the period; in the regeneration block (PBI) there will be found both old trees and young regeneration. The period over which the regeneration of the area goes on the regeneration period is the combined period required for recruitment of new seedlings and their establishment.

It is considered that for uniform crops to result from the uniform system, the regeneration period should not be more than a quarter of the rotation, in actual practice it varies from 15 to 30 years. Sometimes, when full reliance is placed on advance growth for regeneration, a period equal to the estimated age of the advance growth is deducted from the regeneration period.

Generally, regeneration in the regeneration block comes up in the first few years of the regeneration period and the rest of the period is for gradual removal of the old crop and establishment of the new. However, sometimes, recruitment may continue throughout the regeneration period; in such cases there is a great difference between the ages in the new crop (= the regeneration period).

Generally, regeneration in the regeneration block comes up in the first few years of the regeneration period and the rest of the period is for gradual removal of the old crop and establishment of the new. However, sometimes, recruitment may continue throughout the regeneration period, in such cases there is a great different between the ages in the new crops (= the regeneration period).

Whatever the regeneration interval for a coupe or a compartment, it is necessary that the whole PB should be regenerated within the regeneration period, so that regeneration PB has one age-class in it, corresponding to the length of the regeneration period. When all the overwood has been removed from a PB., and no advance growth has been retained to form part of the future crop (or if retained, has been cut back as in case of teak and sal), the G.S. may be considered as normal as in the case of Clear-felling System, the age-classes replacing the age-gradations.

The N.G.S. is usually determined from the suitable yield table in the same way as for Clear- felling system. However, it does not give a correct picture due to the difficulty in defining the duration of regeneration correctly.

Fischer evolved a formula for a condition when part of the G.S. has been removed under regeneration fellings. The N.G.S under such working would be $= (V+V1) \times \frac{P}{2} \times D$

Where: V is the initial G.S; V1 is the G.S at the end of regeneration period; P is the regeneration period and D is the crown density.

(C) N.G.S. IN SELECTION SYSTEM:

As we already know, yield tables prepared from even-aged crops are not applicable to the selection forests and, in the present state of our applicable to the selection forests and, in the present state of our knowledge, we cannot precisely describe the constitution of an ideal / normal selection forest, as regards age-class distribution, etc. Very little work has been done in India on this subject, though some empirical yield tables have been constructed but their use is very restricted. In the meantime N.G.S. in selection forest will continue to be determined by the old methods. Due to the assumed similarity between the G.S. in a normal even aged forest and a selection forest, the N.G.S has often been determined by the use of the M.A.I.; this is also more easy to apply.

A formula evolved by Munger (U.S.A) is based on C.A.I.; be considers that the N.G.S. in a selection forest can be better found on the basis of C.A.I. rather than the M.A.I. His normal G.S. $(C_n) = \frac{i \times \text{f.c.}}{2}$ + reserved timber per felling area x the number of areas. In this *i* is the C.A.I. over the whole reserved timber and F.C. is the felling cycle suppose, total area = 100 ha, I = 500 m^3; f.c. = 10 years ; Reserved Timber = 25000 m^3 over the whole area (or 250 m^3 / ha).

Then G.S. = $\left(\frac{500 \times 10}{2} + 25000 \right)$ m3 for 100 ha; or 275 m3 per hectare.

COMPARISON OF G.S. IN EVEN-AGED AND SELECTION FORESTS:

Comparative data for G.S (total volume) in even-aged and selection forests are not available, to the extent and precision necessary for drawing any general conclusions. However, on theoretical considerations it is quite understandable that an uneven-aged stand with maximum utilization of soil and air space should carry a larger volume of G.S per ha as compared to an even-aged crop on the same site.

Result obtained in respect of uneven-aged sal forests of Ram Nagar Forest Division, U.P. (as reported by Mathauda in his article; "The uneven-aged Sal forest of Ram Nagar Division, U.P.", in Indian Forester, May 1958), substance the above. These are as follows.

Site quality (1)	**Even-aged Sal forest: Rot 125 years (cft / acre) (2)**	**Selection Forest (cft / acre) (3)**
I	2969	2880
II	2095	2180
III	1216	1480
IV	590	800

(**NOTE:** Divided figures in col. 2 and 3 by 14 to obtain *approximate* corresponding figures in m3 / ha)

RELATIONSHIP BETWEEN G.S. AND YIELD:

A complete picture of the N.G.S. at the end of the first rotation is given in figure. The 10 year old crop will be felled at the beginning of the next rotation and will be immediately regenerated by planting or coppice. Similarly, even plantation will reach maturity and, in its turn, felled to give annual yield. Thus the G.S. remove during a rotation period of *r* years will be:

I (annual coupe / yield) x (rotation) = I x *r,* as represented by rectangle ABCD, which is twice the triangle ABC, the N.G.S. triangle. 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 (rotation); in other words, during a rotation, half the yield is provided by the exciting G.S and the other half by increment. Only half the increment occurring 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 only is felled during the rotation (i x r) 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.

Utilization Percent: It is the percent ratio of normal yield to the N.G.S. It is expressed as $\frac{Yn}{N.G.S} \times 100$, where Yn is the normal yield. The term is also applied to the percentage ratio between volume as estimated from the standing tree, or the log, and the actual merchantable out-turn.

REDUCING (OR REDUCTION) FACTORS – REDUCED (OR MODIFIED) AREAS:

Over large areas of forest crops, the soils and sites are seldom uniform, and the consequent variation in fertility results in variation of growth rates. Consequently, even equal annual coupes will yield different volumes of wood and not *sustained yield*. This variation can be offset by adopting *equi-productive* or reduced areas instead of *equi-extensive* areas.

By *reduced or modified* area is meant that area which would produce the same yield with uniform quality and / or density, as it produced by the existing areas with their various qualities and / or densities; and the factors, by which each class must be multiplied to reduce it to the standard quality and / or density, are known as *Reducing Factors.*

Yields tables are prepared from data collected on normally stocked forest, which are seldom found in our forests. Two most important factors in which conditions from measurements in *Sample plots* with normal stocking, i.e. fully stocked, expressed as Unity (1.00). In practice we may find density varying within a very wide range from a virtual blank to full stocking; it would, therefore, be incorrect to apply yield rable figures directly.

As regards quality, separate yield table are usually constructed for each recognized quality, but the quality of the locality may vary frequently within the same compartment with the result that it may not be practicable to correctly apply yield table figures for any particular quality. Since the potential volume production of different site qualities varies considerably, it is essential for sustained yield management that various age- gradation / classes, where occupying separate areas in even-aged crops, occupy equip-productive areas. For this reason both density of stocking and quality of the locality have to be brought on to a common basis before allotment to the annual coupes or periods is made.

Reduction (of modification) for density: In order that yield table be correctly applied to determine of volume of any crop, it is necessary to assess its density as compared to that of a fully stocked forest, which is represented by the numeral 1.0 – the normal density. Density of a stand which is not normally/fully stocked is expressed by decimal, e.g. 0.6, etc. It is usually assessed by comparison of actual basal area with that of yield table basal area, per hectare. The area occupied by the crop is multiplied by its density of stocking to get equivalent area in terms of crop with normal density (1.0) (Assessment of crop density is dealt with in detail in forest mensuration).

The density of 40- year old teak plantation is 0.8, the volume per hectare would be 114.75 x 0.8 = 91.80 m^3. Thus 0.8 is a reducing (or modifying) factor for density; it should not be confused with that for quality. The former may relate to a variable and temporary condition of the crop; e.g. if a crop has a density of 0.7 it may, in course of time, become 0.9, or normally stocked as a result of regeneration operations. Thus, the stocking factor is not a permanent one; it will also vary from age to age and rotation to rotation. In such cases, there is no need for applying the reducing factor for density, though in the first rotation annual yields will be unequal, but with prospects of normal equalized yields in the next. However if, theoretically, the causes for variation in density are inherent – i.e., permanent, reducing factor for density will also have to be applied, to bring all areas to a common basis of normal density.

Correct assessment of density in our usually irregular forests may involve complete enumeration of the G.S., in that case reduction for density may not be practicable.

REDUCTION (OR MODIFICATION) FOR QUALITY

Variation in GS due to yield capacities of different site qualities is, more or less, a permanent factor of the locality and has to be taken into account. For all important species, yield tables are usually available separate for different site qualities.

Indication of different qualities is given by the MAI. For e.g., in case of plantation teak, the yield capacity (MAI) for total wood for a rotation of 60 years is (from yield tables):

Quality I	-	9.30 m^3/ha
Quality II	-	6.79 m^3/ha
Quality III	-	4.20 m3/ha

In order to determine the areas under different qualities which will produce the same yield, a reduction or modification of the area will have to be made on the basis of their production capacity, i.e. Mai. Reduction may be made in either of the three ways:

i) Reduction to the most prevalent quality

ii) Reduction to the mean quality of the whole area

iii) Reduction to any suitable quality – whether present in the area or not

In Chakrata Forest Division, U.P., the most prevalent quality of forest included in Deodar Working Circle is II. Taking this as the standard quality, reduction factors of other site qualities based on their MAI at rotation, are worked out as 1.37, 1.20, 1.00 (standard), 0.83 and 0.63 for qualities I, I/II, II, II/III and III respectively.

The quality most represented is called the standard quality, in which the reduction of other qualities is usually made. This is done by applying the inverse proportion of their MAI.

Reduced area: actual area = MAI of the quality: MAI of the standard quality. The factor:

$$\frac{\text{MAI of the quality to be reduced}}{\text{MAI of the standard quality}}$$ is known as the reducing factor for quality