FOREST MANAGEMENT

By

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FOREWORD

The forests of India exhibit as much variety and variability as its climate and soil, with a wide variation in crop composition, structure and stocking. Unlike advanced countries, where the population is mainly concentrated in the urban areas, a large majority of Indian population resides in the villages. This rural population draws a variety of products from the forests to meet its day-to-day requirements. In addition, the forest areas provide grazing and leaf-fodder for the livestock. The forest management in India thus gets very much complicated.

The principles and practices of forest management evolved in the advanced countries, with temperate forests composed of a few important species and free from the biotic pressures as experienced in India, may be out of step with the realities of the situation in our country. The need for a book on forest management written on Indian experience was for long being felt. Forest mensuration and forest management constitute an important component of the forestry syllabus in all the forest colleges of the Government of India and the State Governments, as also in the forestry education programme of the agricultural universities The students have been awaiting a comprehensive text book on forest management. The author, Shri Ram Parkash, I.F.S. (Retd.), ex-Lecturer, Indian Forest College and ex-Principal, Northern Forest Rangers College, has done a good job in bringing out this book on forest management to meet the long felt need of the forestry students. This book also incorporates a section on Working Plans without which the work would have been incomplete, as it is the Working Plans which familiarise the students with the process of application of forest management principles to the forest estate and thus form an integral part of the forest management course. The book becomes all the more valuable because of wide field experience of the author and his long association with the training at the forest colleges.

(Sd/-) R. V. Singh

AUTHOR'S PREFACE

Forest Management is one of the important forestry subjects prescribed in the curricula of forestry education and training, for Indian Forest Service and State Forest Service probationers, as well as the Forest Ranger trainees at the Forest Colleges. It also forms a component of *forestry*, now being offered as one of the elective subjects at various Agricultural Universities in India. It is not only the forestry students but also the practising foresters as well who need to have clear ideas of the basic principles and their application in planned management of forests.

Most of the books written on the subject, by various European and Indian authors, are out of print. To meet the requirements of an ever-increasing number of forestry students, the author felt that there was a need for an updated text book on the subject and took up the job of writing a book on Forest Management, primarily for use by forestry students at various forestry institutions. Particular care has been taken to cover the syllabii prescribed for both the Forest Ranger and Officer level courses. It is hoped that it will serve as a useful reference text book for Forestry Course students at the Universities, and the practising foresters as well.

The subject of *Working Plans* in general, and the practical exercise for field work and writing up a typical Working Plan in particular, is a very important part of training of the I.F.S. and S.F.S. probationers. However, the author felt from his practical experience in conducting the exercises, that the probationers are handicapped for want of a handy and precise reference material as to what exactly to do, and how to set about the arduous job. For their benefit, this topic has been covered in great detail giving a, more or less, standardised procedure and format for reference.

The author has no pretension to the originality of the subject matter. The only credit he might claim is that with his practical experience in teaching the subject for several years, both at the Indian Forest College and Northern Forest Rangers College, Dehra Dun, he has taken pains to collect, sift, compile and present the basic concepts of Forest Management and their application in a simple and readable form, for the benefit of forestry students. He will feel amply rewarded for his endeavour if the book meets the requirements of those for whom it has been written.

The author gratefully acknowledges the valuable help he received from a number of Working Plans, articles in the *Indian Forester* and the following publications, to which he frequently referred for write up and sketches for this compilation :—

1. A Text Book on Forest Management —M.R.K. Jerram
2. Planned Management of Forests —N.V. Brasnett
3. Planning and Control in Planned Forests —H. Knuchel
4. The Management of Forests —F.C. Osmaston
5. Forest Management —V.P. Mathur
6. Silvicultural Systems and Forest Management —A.B. Lal
7. Forestry in India. —A P. Dwivedi
8. Manual of Forestry, Vol. III —Schlich
9. Foresty in India—A Critical Study —G.S. Padhi
10. Managing the Forests. —A.R. Maslekar
11. Forester's Companion —A.R. Maslekar
12. Theory and Practice of Silvicultural Systems —Ram Parkash & L.S. Khanna
13. Glossary of Technical Terms in Forestry—FRI Publication
14. Preparation of Forest Working Plans in India —W.E. D'arcy.
15. Working Plan Codes of U.P., Maharashtra, Punjab (Forest Manual Vol. III) and draft "All India Working Plan Code" (F.R.I. & Colleges, Dehra Dun).
16. Lecture Notes on Forest Management—C.R. Ranganathan
17. "Growth and Yield Statistics of Common Indian Timber Species. (Vol. I and II)—(F.R I and Colleges, Dehra Dun)

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LIST OF ABBREVIATIONS USED

A.C.F.	—	Assistant Conservator of Forests
A.P.O.	—	Annual Plan of Operations
B.C.F.T.	—	British Commonwealth Forestry Terminology
C A.I.	—	Current Annual Increment
C C F.	—	Chief Conservator of Forests
C.F.	—	Conservator of Forests
C.F. (T)	—	Conservator of Forests (Territorial)
C.F. (W.P.)	—	Conservator of Forests (Working Plans)
Cpt.	—	Compartment
D.C.F.	—	Deputy Conservator of Forests
D.F.O.	—	Divisional Forest Officer
D.F.O. (T)	—	Divisional Forest Officer (Territorial)
D.R.	—	Deputy Ranger
F.C.	—	Felling Cycle
F P.B.	—	Floating Periodic Block
F.R.	—	Forest Ranger
F.R.I.	—	Forest Research Institute & Colleges, Dehra Dun
F.S.	—	Felling Series
G.S.	—	Growing Stock
Glossary	—	Glossary of Technical Terms—F R.I. & C.
L.I P.	—	Linear Increment Plot
M.A.I	—	Mean Annual Increment
N.G.S.	—	Normal Growing Stock
P.B.	—	Periodic Block
P.R.	—	Preliminary Report
R.F.	—	Reduction (or Reducing) Factor
W.C.	—	Working Circle
W.P.	—	Working Plan
W.P.O.	—	Working Plan Officer

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PART I

FUNDAMENTALS OF MANAGEMENT

CHAPTER I

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 organisation of a forest property for management and maintenance, by ordering in time and place the various operations necessary for the conservation, protection and improvement of the forest on the one hand, and the controlled 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" (Roth). *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 Silviculture, Ecology, Geology, Pedology, Botany, Mensuration, Pathology, Economics, 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 therefrom.

Management of forests broadly involves three main tasks, viz., (i) control of composition and structure of the growing stock,

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**Forester* : "Primarily a person engaged in the profession of forestry." (Glossary)

(ii) **harvesting** and marketing of forest produce, and (iii) administration of forest property and personnel. It is, unlike any other commercial enterprise, complicated; 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 bio-aesthetic, with one use dominant, viz., most often the production of wood, as illustrated in Fig. 1.1.

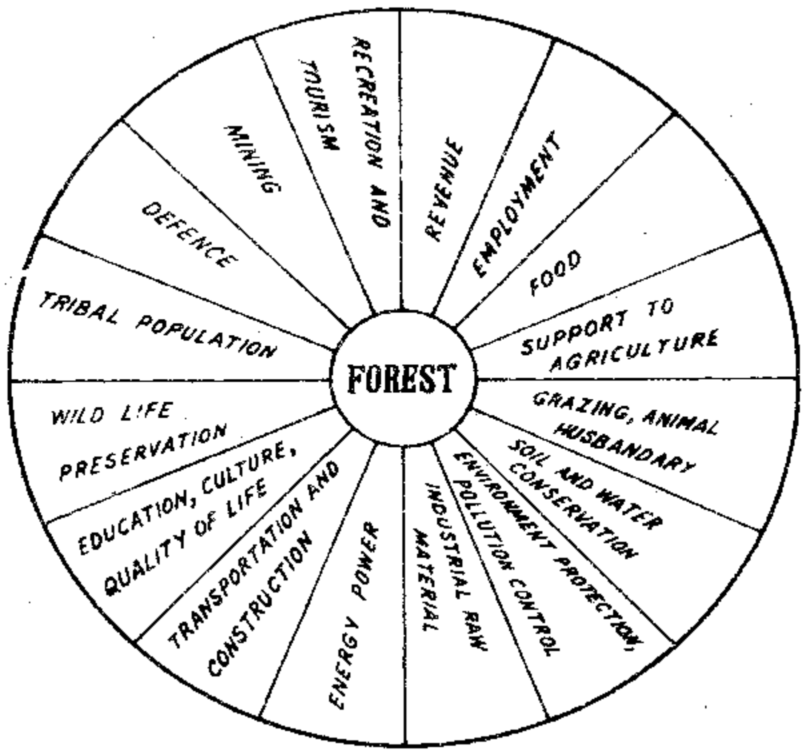

Fig. 1.1. Multiple Uses of Forests.

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 be 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 organisation
   - (ii) Management of Personnel
   - (iii) Monitoring and control of works
   - (iv) Labour management and welfare

(v) Financial control and economy efficiency
(vi) Fulfilment of social obligations
(vii) Record for present and future reference.

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 forests bestow. 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 socio-cultural.

PRINCIPLES OF FOREST MANAGEMENT — NATIONAL FOREST POLICY :

Fundamental principle of sound management of any enterprise is the fulfilment of the owner's objectives to the maximum extent possible. In case of the State forests, the objects are embodied in the National Forest Policy and the concerned State Forest Policy (see Appendix I — Directive Principles.)

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 from 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 complimentry 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 realisation of maximum amount of revenue in perpetuity, consistent with the fulfilment of the needs enumerated above.

The Policy advocated a functional classification of India's forests, apart from legal classification, to focus attention on the specific object of management in each case, into :—

(a) Protection forests
(b) National forests
(c) Village forests
(d) Tree-lands.

The Policy also suggested to keep a minimum of one third of the country's total land area under forests, with 60% in the Himalayas and other hilly tracts 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

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**Minor Forest Products* : "All forest produce, other than major forest produce, including grass, fruit, leaves, animal products, soil and minerals." (Glossary)

Major Forest Produce : Comprises "timber, small-wood and firewood." (Glossary) permitted on sufferance on residual land not required for any other purpose.'

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

The N.C.A. constituted in 1970, suggested the need for a revised Forest Policy, in their Report of 1976.

The N.C.A. concluded that National Forest Policy should rest on two important points, viz :—

(i) Meeting the 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) recognises the following vital needs of Forest Management :—

(i) For providing maximum goods and services for the public well-being and economic progress of the country.

(ii) Need for checking denudation and erosion in the mountainous region, tree-less river banks and waste-lands.

(iii) Need for realising 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 fulfil these needs, the policy suggests that, on an average, 33% of the land area should be dedicated to forest—comprising of 60% in the hills and 20% in the plains. The 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 influences—specially soil and water conservation. Forests purify the air we breathe, temper climate, cushion the rain and storms, protect the soil from the ravages of floods and erosion and help in regulating stream flow.

(ii) **Production :** to meet the demands 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 :

Realising 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 Wild Life on the Concurrent List in Seventh Schedule. This has enabled the Central Govt. to play a 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 forest land 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 usually short, and thereafter the 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 there is no confusion between the two. In forestry, however, this danger is very real and has to be carefully guarded against 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 cor-relate 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 fore-going 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.

**Normal Forest :* "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 by reason of its normalcy in these respects serves as a standard of comparison, for sustained yield management." (Glossary)

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 guide-lines 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 realise 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.

**Working Plan :* It is defined variously, as :—

(i) "A written scheme of management aiming at continuity of policy, controlling the treatment of a forest." (Glossary)

(ii) "It is a forest regulation prescribing the application of certain cultural rules, and the execution of certain works, in order to produce the given desired results." (DARCY)

(iii) "Working Plan is the simplest possible statement of what is known about the Working Plan area; its configuration, soil, climate, vegetation, its possibilities; what has been done in the past, what should be done in future, how it should be done, and what records should be kept."

***Sustained Yield :* "The material that a forest can yield annually (or periodically) in perpetuity." (Glossary)

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 i. 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 fulfil 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 fulfil distinctly separate functions ; e.g., Wild-life 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 fulfil 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 plan, thereby providing a broad framework for management

**Forest Type* : "A category of forest defined generally with reference to its geographical location, climatic and edaphic features, composition and condition." (Glossary)

(see Appendix II & III—Extracts from Chakrata & East Dehra Dun Division Working Plans) :-

(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 of rights of the right holders in respect of timber, firewood, grazing, etc., in particular, and to meet the bona-fide 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 objects may be laid down for different regions/locations, with different site factors and forest types, more suited for specific purposes. Accordingly, our Working Plans invariably specify general objects for the entire Working Plan area and, in addition, special objects of management of each Working Circle*, which is characterised by a distinct vegetation type, more suited for certain purposes as compared to others (see Appendix II & III for examples). 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

**Working Circle* : "A forest area (forming a part or whole of a Working Plan area) organised with a particular object, and under one Silvicultural System and one set of Working Plan prescriptions. In certain circumstances Working Circles may overlap." (Glossary) 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 'magnificient playgrounds for tired mankind seeking peace and spiritual strength' (V.S. Rao).

(iv) Mixed miscellaneous open forests, heavily grazed and felled in the past, with low proportion of valuable timber and industrially important species are clearfelled 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 Circles in plains and terai areas of U.P. and West Bengal, Bihar, Orissa, with a view to meeting increasing demand for industrial raw material for pulp, match 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 addition, 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 of material as well as intangible goods and services. However, the immediate interest of the private owners is limited, which is mainly financial and, therefore, naturally focussed on products which will bring direct monetary returns. Unlike public ownership, their management is *market-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 enactments (Acts, Rules, etc.) 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 uncomputible 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 (or profit) 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 (intangible ones) 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 cost of administering the service (Osmaston).

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 two 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 words *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 December, 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 challange 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 development."

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 services and serving the mankind in multifarious ways.

The National Commission on Agriculture report (1976) high-lighted the importance of the socio-economic role of forests for the rural communities, and in the management of the forest resources of the country. It has defined *Social Forestry* to 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 for 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 longifolia* Var. *latifolia)*, paper pulp from *Saijna (Moringa oleifera)* and *August (Sesbania grandiflora)*. These, and other similar forest-based cottage industries, can go a long away in providing employment to the landless poor. In addition, leaf fodder species like *Su-babul (Leucaena leucocephala), Saijana (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 only 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 tonnes 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 tonnes 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 for rural housing and agricultural implements, fodder for cattle of rural population living far away from the forest areas, protection of agriculture by creation of diverse ecosystem and arresting wind and water erosion, and creation of recreational forests for the benefit of 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 on Agriculture (1976), has embarked on a large scale Social Forestry Programme, through State organisations. 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, boundaries of fields, along roads, canals, around ponds, school 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 organisations, 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 Agriculture : A redeeming feature of the modern industrial civilization is the recognition of the importance of forests to our national economy. Our revised National Forest Policy (1952 : and the draft for next revision) 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 recognised and forestry is no longer to be viewed as a mere *hand maiden* of agriculture, but its promoter and protector as *foster-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 in 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, immobilise 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 the conventional forest areas for achieving social objectives for the benefit of rural and urban communities. This is a new dimension added to the concept of forestry and encompasses, within 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, promotor of 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 Organisational) and (vi) Management (or Silvicultural).

GEOGRAPHICAL AND CLIMATIC (ECOLOGICAL) CLASSIFICATION :

Under this, forests are divided into different forest types. Five major groups are recognised in India, viz., Tropical, Montane Sub-Tropical, Montane Temperate, Sub-alpine and Alpine Scrub. These major groups have been further divided into sixteen type-groups, or simply groups, on the basis of climatic data and vegetation. Most of these 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 types - climax, edaphic, seral, etc.

(For details refer to *Forest Types of India* by Champion H.G., and Seth, S. K., 1968).

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 Agriculture (1976) has suggested a modified functional classification as Production Forests (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-classed 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 are subject to complete protection. Villagers have no rights whatsoever 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. excercises 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 numerals 1, 2, 3, etc.).* It is the smallest permanent Working Plan unit of management, location of works and record; as such, its boundaries are carefully chosen on the ground and marked on the map. The boundaries are formed either by natural features such as ridges, valley bottoms, streams or artificial lines such as 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 (preferably 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, Karnatka, 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 Forests (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 States. 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 Directors. In some States, there are General Managers, 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 are 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 are Territorial as well as Functional Divisions, such as Silviculture, 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., 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 *Sections*, each manned by a Sub-Range Officer, Range Assistant (R.A.), Block Officer (B.O.) or Section Officer (S.O.) of the rank of a D.R. or a Forester. Each Sub-Range or Block is divided into *Beats*, each under the charge of a Forest Guard for protection and execution of field operations. *Beat* is the smallest functional territorial Unit, and is the foundation of Indian forest administration.

Summing up, heirarchy of the State Forest Department is, generally, of the following pattern :—

	Administrative Unit	*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.F.O./S.D.O. (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 Sections, (iv) Coupes, and (v) Periodic Blocks.

Working Circle : The Unit 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 a 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 (i. e., different Silvicultural Systems prescribed) 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) organised 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 it 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 kinds over one or more ranges, a W. C. may by divided into *Felling Series* (F.S.). A F.S. is defined as : *a forest area forming the whole or part of a Working Circle and delimited so as : (i) to destribute felling and regeneration to suit local conditions and (ii) to maintain or create a normal distribution of age-classes.* The yield is calculated separately 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. Division of a W. C. into several F. S. enables effective control and distribution of work in different ranges. When a W.C. is not divided it is, of course, one Felling Series.

Coupe : In Clear-felling System,** a F.S. (or W.C., if undivided) is divided into a number of *Annual Coupes**** (annual felling areas), equal to the number of years in the rotation, say R, size of each coupe being equal to the area of the F. S. (or W. C., as the case may be), say A hectares, divided by R, i.e. A/R hectares. Each F. S. will have all the R age-gradations. Figure 3.1 (a) shows diagrammatically in plan an undivided W.C. containing only one F. S. of 20 age gradations (for illustration), in equal annual coupes. The profile diagram, Fig 3.1 (b), shows the arrangement of age-gradations, but only for the first five years. It should be noted that fellings should take place against the direction of prevailing wind so as to produce a profile as shown, i.e., with the smallest trees on the windward

**Age-Class Distribution, Normal* : "A complete series of age-classes in such proportion as will permit equal volumes from annual or periodic fellings under the given rotation and Silvicultural System." (BCFT)

***Clear Felling System ;* "A silvicultural system in which equal or equi-productive areas are sucessively clear-felled in one operation to be regenerated, most frequently, artificially but sometimes naturally also." (Glossary)

****Coupe :* "A felling area, usually one of an annual series unless otherwise stated. Preferably numbered with Roman numerals I, II, III, etc." (Glossary)

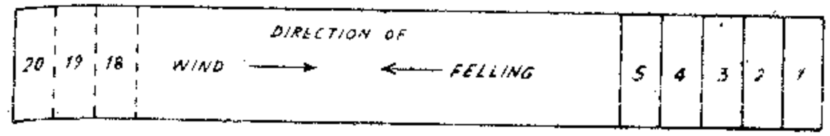

Fig. 3.1(a) Plan of an undivided Working Circle with twenty coupes

Fig. 3.1(b) Profile of regeneration after felling of the above five annual coupes

Fig. 3.1. (a) and 3.1. (b)

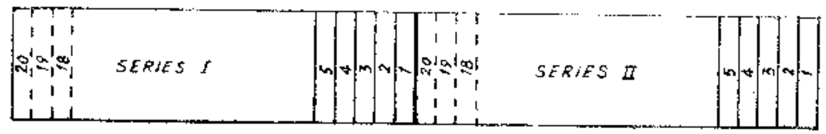

Fig 3.2 (a) Plan of the same Working Circle divided into two equal Felling Series, with twenty coupes in each

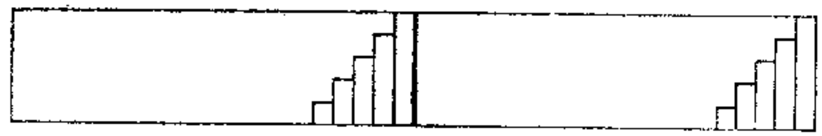

Fig. 3.2(b) Profile of regeneration after felling of five annual coupes in each Felling Series.

Fig. 3.2. (a) and 3.2. (b)

side, when the series has been established. The younger age-classes thus break the force of wind and protect the older ones behind. Figures 3.2 (a) and 3.2 (b) depict, in plan and profile, a W.C. divided into two equal F.S., each one worked simultaneously for sustained annual yields, as illustrated in Fig. 3.1 for an undivided Working Circle.

Cutting Section : Sometimes it may be desirable to avoid fellings in contiguous coupes in successive years for silvicultural considerations, such as danger from fire and/or insect attack. In such cases, a F. S. is sub-divided into a number of *Cutting Sections*; a Cutting Section being defined as : *a sub-division of a F. S. formed with the object of regulating cuttings in some special manner* : a planned separation of fellings in successive years. Figures 3.3 (a) and 3.3 (b) illustrate, in plan and profile, the division of a F.S. into

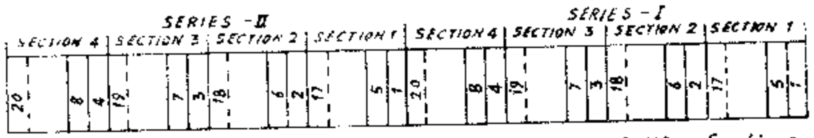

Fig. 3.3(a) The same Felling Series(I&II) divided into four Cutting Sections each. Plan of the first eight coupes shown.

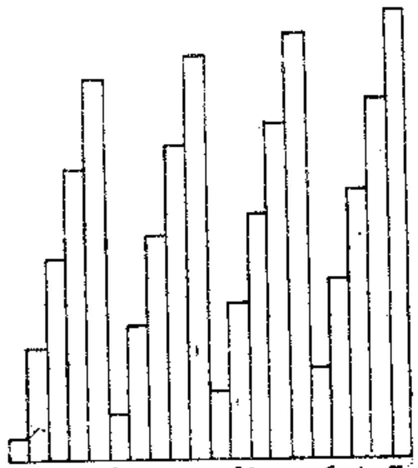

Fig. 3.3(b) Profile of completed regeneration of Series I after 20 years. Series II is also felled and regenerated at the same time as Series I.

Fig 3.3 (a) and 3.3 (b)

four *Cutting Sections*, so that fellings in each will take place at four years interval.

These management units have been described with reference to Clear-felling System, which is the simplest form of silviculture to understand and to illustrate.

PERIODIC BLOCKS : FELLING SERIES IN UNIFORM SYSTEM :

Under the Regular Shelterwood (or Uniform) System* of

**Regular Shelterwood (or Uniform) System* : "A kind of Shelterwood System aiming at concentrated regeneration in which the canopy is uniformly opened up over the whole area of a compartment to obtain uniform regeneration." (Glossary)

natural regeneration, age-classes take the place of age-gradations, and periodic blocks (P. Bs.) take the place of annual coupes, each containing one age-class instead of 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)

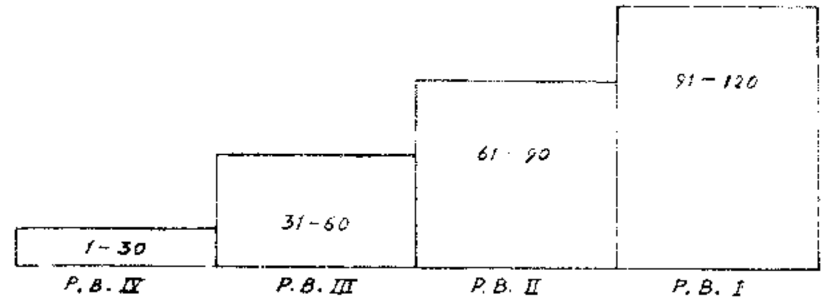

Fig. 3.4. Arrangement of age-classes/P. Bs. in a F. S. worked under Uniform System.

Taking a typical case of *Chir pine (Pinus roxburghii)* forests worked under Uniform Shelterwood System on a rotation of 120 years and regeneration period* of 30 years, the arrangements of P. Bs. in the F.S. is illustrated in Fig. 3.4. The number of P. Bs. in the W.C. or F.S. (as the case may be) is found by dividing the rotation by the regeneration period; in the above example of *Chir forest* it will be $\frac{120}{30}=4$, and the normal area of each P.B. is the area of the W.C. or F.S. divided by the number of P.Bs. The regeneration period varies, of course, with species and the climatic and edaphic factors of the site. Each P.B. is regarded as approximately evenaged**; the fewer the number of age-gradations included in the age-class in a P. B. (i.e., shorter the regeneration period and larger the number of P.Bs.) the more nearly it is evenaged. Woods

**Regeneration Period* : "The period required to regenerate the whole of a P. B." (BCFT)

***Evenaged Forest* : "Applied to a stand consisting of trees of approximately the same age. Difference upto 25% of the rotation age may be allowed in cases where a stand is not harvested for 100 or more years." (Glossary) in which the age of the trees varies more than 30 years are, by convention, not regarded as evenaged. Thus in Fig. 3.4, the first thirty annual coupes or age-gradations might be grouped together to form a Periodic Block to be felled and regenerated gradually by seeding, secondary and final fellings during the period of first thirty years. This would result in P. B. of 1–30 years age-class and, at the end of a 120 year rotation, the whole W. C. would have, similarly, been converted into four P. Bs. containing age-classes 91–120, 61–90, 31–60 and 1–30 and designated as P. B. I, P. B. II, P. B. III and P. B. IV, respectively.

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 Cycle* (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 (or, more evenaged in groups) the resultant regeneration and the crop, and *vice-versa*. The number of coupes will obviously be equal to the number of years in the F.C., and they may be made up of one or more compartments.

If 100 years is the rotation and 10 years the F.C., there will be 10 felling coupes, each being one tenth of the area of the F. S. (or the W. C., as the case may be) and worked at intervals of 10 years, i. e., ten times in the rotation, as illustrated in Fig. 3.5, taking out at each felling, in theory, the trees 95 to 105 years old and thinnings amongst the younger trees. It is not difficult to appreciate that the intensity of felling will be heavier in this case of a *Modified or Periodic Selection System*, as compared to that of an *Ideal Selection System* wherein the whole area is gone over annually.

*Selection Forest : (a) "An unevenaged crop containing many, theoratically all, age-classes or gradations. (b) A Forest managed under Selection System." (Glossary)

Theoratically, if the F.C were to be increased to, say about 30 years (virtually the regeneration period of several principal species), it would approach Uniform Shelterwood System : and, if F.C. is increased to rotation period, it would tantamount to Clear-felling.

I	II	III	IV	V
1, 11......91	2, 12......92	3, 13......93	4, 14......94	5, 15......95
VI	VII	VIII	IX	X
6, 16......96	7, 17......97	8, 18......98	9, 19......99	10, 20......100

Fig 3.5. Felling Series in a Selection Forest : Worked on 10-year Felling Cycle.

(*Note* : Numerical figures denote the years of working)

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-gradations in overwood (Standards) is the same as in theory in Selection forests,

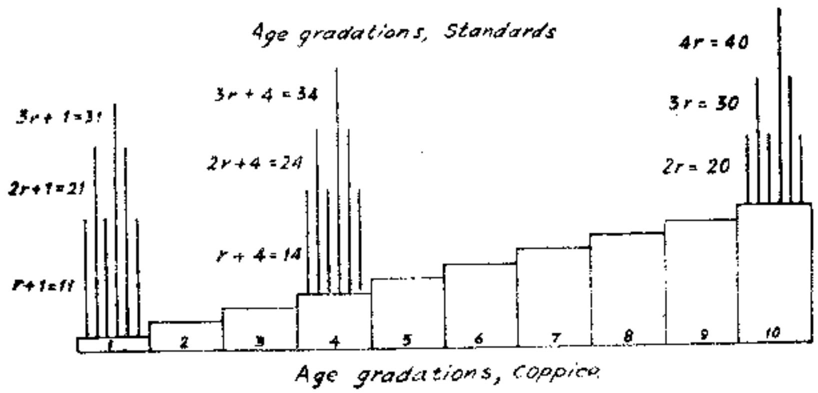

Fig. 3.6. Felling Series in C.W.S. System.

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 overwood (Standards), R, is a multiple of the rotation of the underwood (Coppice), r. Fig. 3.6 represents C.W.S. Felling Series, where $r=10$ years, $R=40$ years, immediately before the felling of the tenth annual coupe. The yield of the Standards will depend on the number of standards of each age retained when felling each coupe. Taking a concrete example: if number of Standards to be retained of ages 10, 20 and 30 years (in the above case where $r=10$ years and $R=40$ years) is 100, 60 and 30, then when the coppice is felled 100 trees will be left to grow into Standards and the annual yield of Standards, if there are no intervening casualties, will be :

$100-60=40$ of 20 years ($2r$) age.
$60-30=30$ of 30 years ($3r$) age.
$=30$ of 40 years ($4r$) age.

The yield of the Standards (overwood) is regulated by the number of trees, as illustrated above, and that of Coppice (underwood) by area.

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 Policies of all progressive countries of the world.

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

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

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

(iii) "The yield of timber or other forest produce 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

**Age-Gradation :* "An age class with one year as the interval." (BCFT) maintain a complete series of age-gradations; in such cases 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 organised for continuous production.* (Glossary)

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

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 utilisable 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 organised 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 visualised in two respects, viz., continuity of growth and continuity of yield or harvest. The two 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

**Growing Stock*: "The sum (by number or volume) of all the trees growing in the forest or a specified part of it." (Glossary)

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, means continuity of harvest, indefinitely, without impairment of the productivity of the soil.

Pre-requisites for Sustained Yield Management — Its Scope and Limitations:

Considering forestry from the economic point of view, investment in forestry should yield continuous return in terms of definite class of produce, and in greatest possible quantity within a reasonable time and to the best financial advantage. The simplest method of achieving this objective of sustained annual yield is to maintain a complete succession of equal areas of crops of all ages from one year old upto the age of maturity (say 10 years, for illustration) and remove the 10 year old wood annually, and plant up the area again.

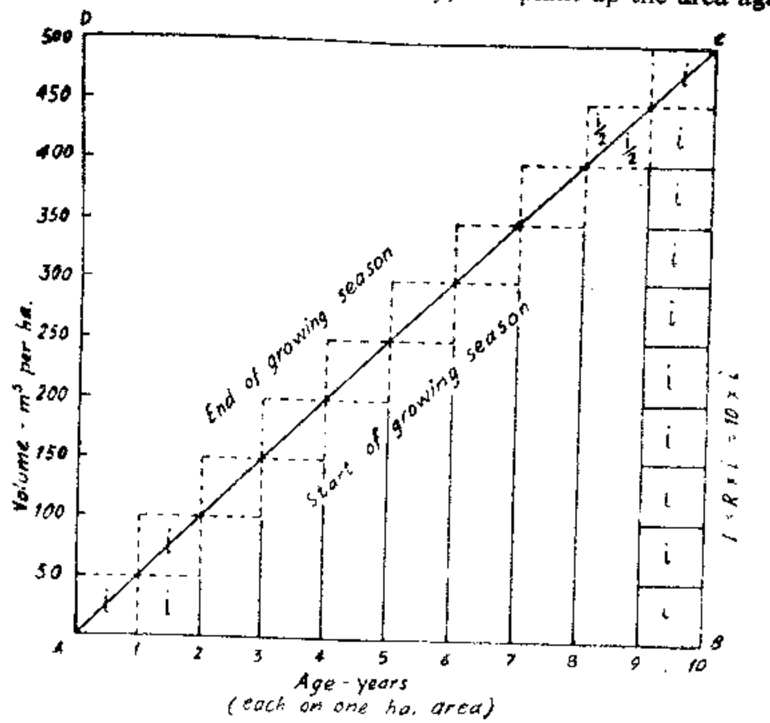

Fig. 4.1. Theoretical Normal Growing Stock in a Series of R (10) equal Age-gradations (one hectare each).

This 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 accumulated production of 10 hectare on 1/10th part of the total area, as illustrated in Fig. 4.1. Such a series of trees or crops of all ages, from seedling to maturity, so as to enable the removal of the oldest is known as a *complete series of age-gradations.*

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* (or *Sustension/Sustenance*) 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 (as in *Clear-felling* and *Coppice System*) 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 area instead of growing each year's crop on separate area (Chapter III page 28) 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 sechemes 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 occassions, 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 Kulu and five per hectare of *Chir*, in Chir Working Circle of Kangra 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-weigh 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 rerult of experience and research, which is considered as an important ingredient of scientific management. The concept of *Progressive Yield* envisages raising the productivity of soil, and of the crop, by silvicultural treatments, judicious tending, enrichment of the forest by changing the crop composition and by replacement of the original inferior forest by valuable forest species. It also stipulates avoidance of loss of increment by effective protection and tending and adoption of quick and efficient regeneration techniques. The new concept signifies a dynamic outlook in Man to build up and maximise productive enterprises through technological efficiency. It connotes a synthesis of ecological and economic considerations, and a long range view of forest products requirement for economic self sufficiency.

The principle of *Progressive Yield* as against the *Sustained Yield* principle was discussed at the VI Indian Silvicultural Conference held in Dehra Dun in 1939 and the III World Forestry Conference held in Helsinki in 1948, and adopted. Some foresters consider that the principle of *Progressive Yield* is embodied in the principle of *Sustained Yield.* Foresters, who advocate the principle of *Progressive Yield,* 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 practised in a stagnant economy, it has no justification in a growing or a developing economy." No individual or Organisation, 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. In case 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 the subject was considered at the VI Silvicultural Conference that in the first stages of development 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 in the latest definition of *Sustained Yield* (Page 33, BCFT def.). 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 the *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 in greater 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 any yield to be maximum must be the yield of the required kind of produce in the shortest period of time. Therefore, the principle of production of maximum quantity of the kind of produce in market demand that can be produced by the soil, in the shortest possible time, would cover 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. The word *perpetuity* itself signifies its static nature. It 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 in forest management practices, but now when forest research is given an important place in any forest policy, the dynamic principle of *Progressive Yield* should be the aim of all scientific managements. As remarked by Smith (quoted by N. J. Joshi). '*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 PRINCIPLE :

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, sustained Volume Yield does not necessarily mean sustained revenue as well, due to fluctuations in price.

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

(iii) Staff employed is fully and permanently engaged. It affords scope for systematic work and equal employment continuously. Organisation 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 summarised as follows :—

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

(ii) It ignores the costs involved in produciug a fixed quantity, 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 in 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 yields 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 realise 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 maldistribution 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 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 harvested 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 values 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 years between the formation or regeneration of a crop and its final felling. In the case of a selection forest, the average age at which a tree is considered mature for felling." (Glossary)

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

(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." *(Knuchel)*

(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." *(Osmaston)*

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

CONCEPT OF ROTATION IN REGULAR AND IRREGULAR CROPS :

The term *Rotation*, strictly speaking, is correctly applicable to regular crops only. In ***Clear-felling System*** and ***plantations***, rotation is a definite period of interval between the year of formation and final felling. In these, and regular forests in general, entire crops of trees of a sizeable area are felled at a time (as in clear-felling) or during a comparatively short period (regeneration period in ***Regular Shelterwood System***) when ready for felling. There is, more or less, a clear *production period* which can be planned in advance to give timber which satisfies the object of management. In the latter case, *rotation* is fixed for the whole Working Circle as a unit, as the average length of time between the establishment of crops and their harvesting. Though this system facilitates better planning and organisation 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, wind-throw may happen, necessitating felling 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 felled 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 the *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 romoval of some parts thereby increasing the tendency to break up uniformity of original crops into smaller segments, until they start approaching the structure of unevenaged forest.

In unevenaged (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 thinnings. 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 fulfil 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 removed. Maturity in *selection forests* is related to size, and exploitable size is fixed for removal of individual trees. Correct term expressive of maturity in selection forests is, as stated above, *exploitable* (or *utilizable*) *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 kind of *Yield Regulation** than 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 recognised in forestry are :—

1. Physical Rotation
2. Silvicultural Rotation
3. Technical Rotation
4. Rotation of Maximum Volume Production
5. Rotation of Highest Income
6. Financial Rotation.

1. Physical Rotation :

It is the *rotation which coincides with the natural lease of life of a species 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 cases roadside avenues. It is very variable, fairly long and also indefinite. Another interpretation of *Physical Rotation* is the age upto which the trees remain sound, or produce viable seed in high forests and, in coppice crops, can put forth reliable coppice shoots. This rotation is not of any relevance to economic forestry.

2. Silvicultural Rotation :

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

**Yield Regulation* : "A term generally applied to the determination of yield and the prescribed means of realising it. *Syn.* Yield Prescription." (Glossary)

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 (BCFT modif.)*. 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 may 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 prupose 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 age at which the Mean Annual Increment* (M.A.I.) culminates.*" (Glossary). The M.A.I. referred to is that of the stand (as from the Yield Table**) and not that of individual trees.

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

The length of this rotation will coincide with the year when the average rate of growth, or volume increment per unit area,

**Mean Annual Increment (M.A.I.) :* "The total increment upto a given age divided by that age." (Glossary)

***Yield Table :* "A tabular statement which summarises on a unit area (acre/hectare) all the essential data relating to the development of a fully stocked and regularly thinned even-aged crop at periodic intervals covering the greater part of its useful life *Syn. Volume Yield Table.*" (Glossary)

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 volumes of thinning at various ages V_a, V_b, V_c etc. then the age at which :—

$$\text{M. A. I.} = \frac{Yr + \Sigma v}{r}$$

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

The following table shows the ages 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, fibre-

**Current Annual Increment (C.A.I.) :* "Strictly speaking the increment in a specific year. Usually taken as the periodic annual increment over a short preceding period." (Glossary) board and particle-board industries based on disintegeration 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 :—

$$\text{Mean annual net revenue per unit area} = \frac{Y_r + \Sigma T_r - C - \Sigma e}{R}$$

Where Y_r = Value of final felling (final yield) per unit area.
T_r = 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, —do—.
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 prodution. Thus the mean annual net volume production (i. e., M.A.I.) is also $= \frac{Y_r + \Sigma T_r}{R}$ where Y_r and ΣT_r 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 the *rotation which yields the highest net return on the invested capital*. It differs from the *Rotation of Highest Net Income* in that all items of revenue and expenditure are calculated with compound interest at an assumed rate, usually the rate at which the Govt. is able to borrow money. It is also defined as :

(i) "the rotation which gives the highest discounted profit, usually at its commencement."

(ii) "the rotation which is most profitable." (Hiley).

(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 (Brasnett).

There are several methods of determining the *Financial Rotation* but as there are no agreed criteria for assessment of profit, they do not give the same result (for detailed account refer to books on *FOREST VALUATION*). The two prominent methods, however, may be summarised 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*. (Hiley sugsested *Land Expectation Value* to be the more appropriate term).

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

**Money Yield Table* : "A table constructed from a Volume Yield Table in which yields are expressed in terms of money instead of volume." (Glossary)

***Soil Expectation Value* (S_e) : "The discounted present value of all future returns from a property minus the discounted present value of all future expenses necessary to earn these returns, the discounting done at a given rate of interest at compound interest."

Mean Annual Forest Percent (M. A. F. %), which the forest enterprize 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 (afforestation, etc.) the first *rotation* should be, as nearly as possible, the financial rotation, i.e., the one which 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 India, 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, $S_e = \dfrac{X}{0{\cdot}0p}$; where p = rate of interest, percent $\left(\text{because } X = S_e \times \dfrac{p}{100} \text{ or } S_e = \dfrac{X}{0{\cdot}0p}\right)$. But if the land produces income periodically, instead of yearly, such as coppice forest, the present discounted value of that return $= Y_r/(1{\cdot}0p^r - 1)$ where Y_r is the net periodic income every *r* th year for ever. Consequently a formula can be derived to calculate the expectation value of land by discounting to the present all fore-casted future net incomes, whether collected yearly or at regular intervals, and subtracting from the sum the discounted fore-casted future expenses calculated in the same way. Such a formula, known as *Faustmann's Formula*, is as :—

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

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 values 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 $E = e/0{\cdot}0p$, 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, Y_r, is received at the end of r, 2r, 3r years etc., for ever and the sum of the infinite series of discounted values of $Y_r/1{\cdot}0p^r$ equal $Y_r/1{\cdot}0p^r - 1$. (Osmaston)

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 *rot tion* is in practice the *age range* within which the major crop will be harvested and 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-sized timber — though not economically sound to grow large-sized timber over a long rotation.

(v) **Social Conditions :** Socio-economic and employment policy of the State.

Climate and topography may necessitate long, protective rotation or the adoption of unevenaged 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 thinning practice. The *Stand Table** should also be consulted to find out the percentage of trees above or below the average diameter at the rotaion age.

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

(a) Forests are meant to fulfil larger 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 silviculture 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.

**Stand Table* : "A table showing the distribution of stems by diameter classes for each of a series of crop diameters, often auxiliary to a Yield Table." (BCFT modif.)

ROTATIONS OF SOME IMPORTANT INDIAN SPECIES

The following table 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 Special Teak W.C. Conversion to Uniform and Selection-cum-Improvement.
	—do—	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.)	—do—
	Nilambur (Kerala)	60 (Teak F.S.)	Clearfelling and planting.
Sal	South Raipur (M.P.)	180	Sal High Forest W.C. Conversion to Uniform.
	—do—	40	C.W.R. ; Coppice rotation.
	Gorakhpur (U.P.)	75 & 90	Sal Taungya W.C.
	East Dehra Dun (U.P.)	120	Uniform
	Haldwani (U.P.)	150	Irregular Shelterwood W.C.; Floating P.B.
Blue Gum *Eucalyptus globulus*	Nilgiris South (T.N.)	10	Simple Coppice.

(Contd.)

Species	Locality-Division/State	Rotation/Conversion Period (Years)	Remarks
Eucalyptus hybrid (E. tereticornis)	U. P., Punjab, Haryana	8 to 12	Simple Coppice.
Wattle *(Acacia mearnsii* Syn. *A. mollissima)*	Nilgiris South (T. N.)	10	Clearfelling 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 Floating P.B.
Fir	Kulu (H. P.)	90	Modified Clearfelling (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 Rotations.*

(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 *Rotation of Maximum Gross or net Income* and the *Financial Rotation.*

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

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

(ii) The second view is that more important than the financial aspects is the general usefulness of products—specially in case of State-owned forests.

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

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

Where the objects are commercial, the rotation adopted is a compromise between *Silvicultural* and *Technical Rotations*, tempered by some economic considerations and financial test. The mistake is often made of working timber forests on the rotation of maximum volume production, 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 stated, 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 Table* 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 wihch 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 one 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 minimise sacrifice. For the purpose of managemet 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 than 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 contempleted 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

GENERAL 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 a forest which has an ideal growing stock, an ideal distribution of age-classes of the component crop and is putting on an ideal increment. From such a forest, annual or periodic yields equal to the increment can be realised indefinitely, without endangering future 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 19 th 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." (Glossary)

(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." (Schlich)

(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." (Osmaston)

(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, is 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." (Darcy)

(v) "A normal forest is an ideally constituted forest with such volumes of trees of various ages so distributed and growing in such a way that they produce equal annual volumes of produce which can be removed continuously without detriment to future production." (Brasnett)

(vi) "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 equalisation of the annual or periodic yields." (Jerram)

(vii) "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." (Knuchel)

BASIC FACTORS (ATTRIBUTES/CHARACTERISTICS) OF NORMALITY:

The above definitions stipulate 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.
and (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 age limits occur mixed together on the same area, they form an *age-class*. In very irregular forests there

may neither be age-gradations nor age-classes ; in such cases the sign of normality is the proper distribution of 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* represents 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 visualise the conception of a *Normal Forest* (a *fully-regulated forest*, as Davis designated it) is to consider it as a series of even-aged plantations of equal area, each of one age-gradation, worked under Clear-felling or Coppice System as illustrated in Fig. 4.1. A plantation of one hectare was planted every year for ten years (rotation age). There 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 (the annual coupe). At the end of tenth year, the plantation planted first of all is cut and regenerated by *Coppice*, natural seeding, sowing or planting. At the end of next year, this regenerated coupe becomes one-year old age-gradation ; the series is complete again and the oldest plantation (coupe) is now ten years old and due for felling. This arrangement is shown in Fig. 4.1 where the age-gradation areas are shown along the base-line AB, with the theoratical volumes standing on each, assuming hypothetically (though not correctly) that each hectare of plantation lays on an equal volume of wood in each year of its life. In the diagram, ten-year old plantation has grown 500 m^3 volume of wood so that M.A.I. at that age$=500/10 = 50$ m^3, and this is shown as the volume on the one-year old hectare as i. The volume on the two year-old hectare is shown as $2i$, and so on, upto the volume of rotation (r) year old hectare as $r \times i$ (or $10i$) in which r, the rotation, is shown as 10 years in the diagram. This $r \times i$, which is the volume standing on the oldest age-gradation at the end of r years (in this case, Fig. 4.1, $50 \times 10 = 500$ m^3), is also the sum of M.A.Is. of all the r (10) age-gradations and may be called I to represent the increment of the whole series. Therefore, by felling the rotation age hectare each year, the normal increment of this normal series for that rotation, i.e., 500 m^3 is being felled. Taking a general case, if A hectare is the area of the Felling Series, r the rotation, annual felling coupe in such a forest would be A/r ha (rotation-age coupe); cleanings and thinnings, if any, are provided in other age-gradations. Each operation will be done on A/r ha area.

An area operated on such a basis, with all age-classes represented and with uniform conditions of increment and stocking is a *fully-regulated forest* or a *Normal Forest.*

It is not at all necessary that each gradation/class may be distinctly seperated 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.

Fig. 4.1 illustrates plantations of one to ten years age, each on one hectare area. With crops worked on a longer rotation of, say 100 years, it is more convenient to distinguish age-classes of say ten years and the same Fig. 4.1 would, in that case, illustrate ten year age-classes (0–10, 10–20, 20–30, ... 80–90, 90–100 years) and classified by their average ages (5, 15, 25,.........85, 95 years), by substituting age-classes of ten years each for the age-gradations; an age-class being merely a group of age gradations (say, 10 in this case) and is more often used than the age-gradations because of the small growth of a tree in one year.

NEED FOR AN IDEAL STANDARD :

As stated already, a normal forest is an ideal model after which we aim to mould our forest. Attaining that ideal is within practicable possibilities but the requirements are such that some of these

may not be found over the whole of the series, or they may get disturbed quickly and cannot be maintained in that condition for long. This is, however, not to suggest that the ideal condition of normality should not be the aim under the apprehension of its likely failure at some stage. Such an attitude would not only be defeatist but will also leave us without a goal. We 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 our forests. To be able to improve his forests, the Forester must know its deficiencies, hence the conception of an ideal forest as standard for comparison is essential. This is also necessary for proper appreciation of the principles of Yield Regulation.

NORMALITY CONCEPT NOT ABSOLUTE : RELATED TO TREATMENT AND ROTATION :

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

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

KINDS OF ABNORMALITY :

Forests may be abnormal usually in the following ways :—

(i) They may be *over-stocked.* A forest past the age of maturity, or having excessive distribution of older age-classes, will have more volume per unit area than the normal, as illustrated in Fig. 6.1.

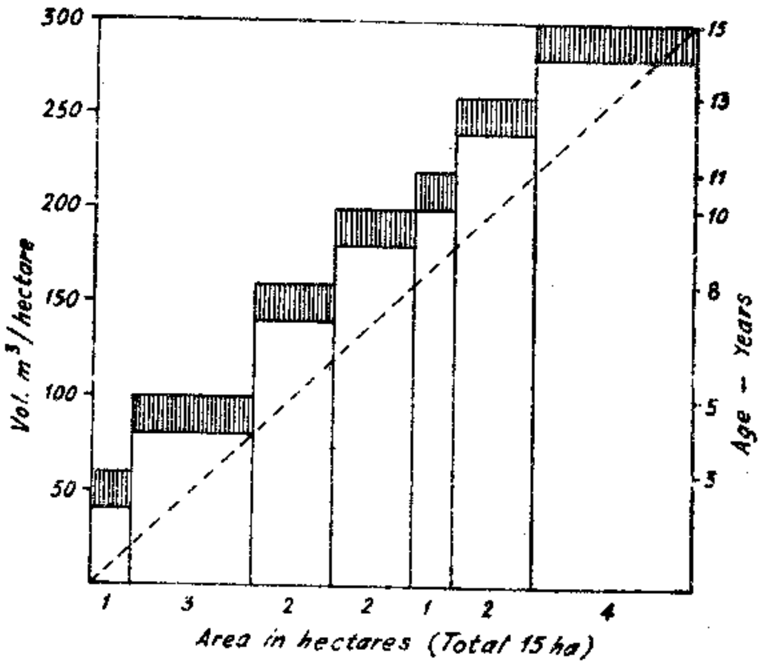

Fig. 6.1. Abnormal Growing Stock of 15 years on 15 hectare (shaded portion represents C.A.I. of various age-gradations).

This condition may also be brought about by a reduction in the rotation. Reverting back to Fig. 4.1, if the rotation were reduced from ten to eight years, the surplus nine and ten year old age-gradations would have to be cut gradually, until there were 1·25 ha of each age-gradation to be felled at eight years age every year. Reduction in rotation, thus, results in surplus growing stock to dispose off.

(ii) They may be *under-stocked.* This condition may be caused due to preponderance of younger age-classes , poor density or extension in rotation. For example, if in the illustration, Fig. 4.1, rotation is increased from ten to twelve years, we shall not be having a normal series of age-gradations from one to twelve, wherein the felling of the oldest at twelve years could result in sustained yield. The series would have to be adjusted, for instance, by stoping felling for two years to make it normal for twelve years 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 (estimated sustained yield).

(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 (allowing a variation of about 20 years). 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 Systems — e.g., Clear-felling, Coppice and Uniform.

(ii) Uneven-aged Systems — 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 of 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 af 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 *sizes* — 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 (as illustrated in Fig. 4.1). If *A* hectares is the area of the F. S., the normal annual coupe would be *A*/*R* hectares (assuming the site conditions to be uniform) — 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 difference 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, preferably but not necessarily in equal yearly quantities. A degree of flexibility is thus introduced 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-year (or one twenty-year) age-classes for a rotation of one hundred years. Each P.B. would be felled and regenerated, in turn, during twenty years regeneration period in as regular a manner as possible.

Similarly, as illustrated in Fig 3.4, the rotation of 120 years for Chir has been divided into four periods of 30 years each, viz., 1-30, 30-60, 60-90 and 90-120 years, each P.B. having a 30 year age-class. The oldest age-class (P B I.) will be felled and regenerated in thirty years. These P.Bs. may or may not essentially be compact and self-contained; however, area of each P.B. should, preferably, be equi-productive.

This kind of organisation is not only simple but provides some flexibility, which is both useful to meet market fluctuations 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 ege-class range and less even-aged the stand Therefore, whereas the short rotation plantations of *Eucalyptus*, worked under aunual 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-years regeneration period and 30-year age-classes, are only more or less even-aged.

In each case of the forests worked under Clear-felling, Coppice, Coppice-with-Standards (under-wood only) or Uniform Systems, the stands are even-aged and the test of normality is the presence of all age-gradations/classess, 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 (and sizes) 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 ages of trees can be known, nor the area occupied by each class.

Fellings, therefore, cannot be distinguished by either area or age; nor can thinnings (intermediate yields) be separated from final fellings and yields. Consequently, definite areas cannot be set aside every year either for final felling or intermediate yields (unlike in regular crops). All fellings are, in fact, a continuous process of thinning a perpetual forest by selection of individual trees for felling. Theoretically, in true Selection System, the entire F.S. is gone over 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 each gone over during the felling cycle, which may be 5, 10 or 15 years.

Large, 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 (exploitable) trees is obtained, on the general assumption that, on an average, size indicates 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

**Exploitable Size*: "The diameter or girth decided upon as the normal size for felling in order to fulfil the objects of management." (Glossary)

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 unevenaged 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 evenaged forests (e.g., triangle ABC in Fig. 4.1) 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 visualise 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 *(Methode du Controle)*. This is possible by keeping exact comparable records, frequently and periodically compiled, of the standing Growing Stock, its distribution in each size-class and of similar figures 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 (about 70%) are 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 so 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 :

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

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 researchers 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, 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 follow De Liocourt's law, which was hitherto known to hold good for temperate forests. (ii) A set of 'empirical Yield Tables' for Selection *Sal* forests 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 forests would remain unscientific till the problems of composition and growth are 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. class.

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

e=2.71828, the base of Napierian Logarithms.

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

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

Theoretical Selection forest is supposed to have all diameter classes intermingled in balanced proportion. Uneven-aged crops are continuous in nature and have no point of termination; when mature trees are removed a new crop of the next order is started. Growth data of unevenaged forests cannot be presented in the form of Yield Tables. Age of the crop is usually difficult to determine. Mathauda studied the distribution of number of stems in different dia. classess in uneven-aged sal forests in Ram Nagar Forest Division (U.P.), average results of which are tabulated (per hectare) below (Ind. For. May, 1958) :—

PROVISIONAL STAND TABLE—UNEVEN-AGED SAL CROPS

Dia. Class (cm)	Quality I		Quality II		Quality III		Quality IV	
	No.	%	No.	%	No.	%	No.	%
20–30	153	58.3	101	56.4	67	53.3	44	51.1
30–40	64	24.5	44	24.8	32	25 6	22	25.3
40–50	27	10.3	19·5	10 9	14 8	11.8	11.1	12.8
50–60	11 4	4.3	8.6	4 8	6.9	5.5	5.4	6.2
60–70	4.7	1.8	3.9	2.2	3.2	2.6	2.7	3.1
Over 70	2.0	0.8	1.7	1.0	1.5	1.2	1.2	1.4
Total (per ha.)	262.1	—	178.7	—	125.4	—	86.4	—

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 forest—a *Normal Forest*—and that of *Sustained 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—DFEINITIONS :

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 teatment (tending operations) 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 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 C.A.Is., which, of course, vary considerably from year to year. The C.A.I. is, so to stay, a Chapter in the history of the tree The mean or average of all C.A.Is. is known as *Mean Annual Increment* (M.A.I)., 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 M.A.I. 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 Percent.*

The *increment* of a crop may be expressed in the form of its C.A.I., M.A.I., or *Increment Percent.* Glossary definitions of these Technical terms connected with increment (explained 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 (C.A.I.)** : "Strictly the increment in a specific year. Usually taken as the periodic annual increment over a short preceding period."

(iii) **Periodic Annual Increment (P.A.I.)** : "The average annual increment for any short period ; sometimes referred to as *periodic mean annual increment* (deprec)".

(iv) **Mean Annual Increment (M.A.I.)** : "The total increment upto a given age divided by that age."

(v) **Final Mean Annual Increment** : "The M.A.I. at rotation age."

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

CURRENT AND MEAN ANNUAL INCREMENTS : (C.A.I & M.A.I.) :

C.A.I. is small in early stages (seedlings and saplings), increases 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 C.A.Is. laid on for the entire period gives the total volume, which when divided by the age gives the M.A.I.--the average of the past production. It is an arithmatically derived value and coincides with actuality 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 C.A.I. 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 or M.A.I. upto that year. The rising C.A.I. raises the M.A.I. also ; but the curve of the latter cannot show as steep a rise as that of the C.A.I., since the effect of the increasing growth each year is spread over all the previous years. When the C.A.I. curve reaches its culmination and begins to decline, the successive average increments, i.e., the M.A.I. 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 C.A.I. for the year finally falls to an amount equal to the average or mean for the entire period, the curve of M.A.I. has reached its highest point, i.e., has culminated. During the following years, the C.A.I. is less than the mean, hence the M.A.I. curve begins to drop but only to the extent that it is pulled down by the effect of this lesser C.A.I. for single years, spread over the age. Hence, as before, the M.A.I. curve shows a fall, more gradual than the C.A.I. curve. Unless the stand is felled, the losses in the stand will finally exceed the growth, and the C.A.I. will then become negative. But until the entire stand is destroyed, the curve of the M.A.I. will still be positive.

This trend is exemplified by the C.A.I./M.A.I. data for II Quality crops of chir, teak, deodar and sal tabulated below, and illustrated in Figures 7.1, 7.2 and 7.3.

M.A.I. AND C.A.I. IN SITE QUALITY II CROPS

Stem Timber & Small wood — m³/ha.

Age	CHIR		DEODAR		TEAK		SAL	
	M.A.I.	C.A.I.	M.A.I.	C.A.I.	M.A.I.	C.A.I.	M.A.I.	C.A.I.
10	0.25	0.50	—	—	9.37	9.69	1.75	4.78
20	3.60	8.10	0.49	0.97	9.22	9.09	3.15	5.88
40	6.36	8.50	5.31	13.78	7.41	5.95	5.32	9.51
60	7.24	9.00	8.53	15.74	6.79	5.18	6.99	10.77
80	7.37	7.30	9.79	13.21	6.16	3,99	7.56	9.91
100	7.17	5.50	10.35	12.03	—	—	8.11	8.40
120	6.74	4.30	10.28	9.37	—	—	7.96	6.86
140	6.30	3.10	10.07	7.32	—	—	7.69	5.32
160	5.80	1.90	—	—	—	—	—	—

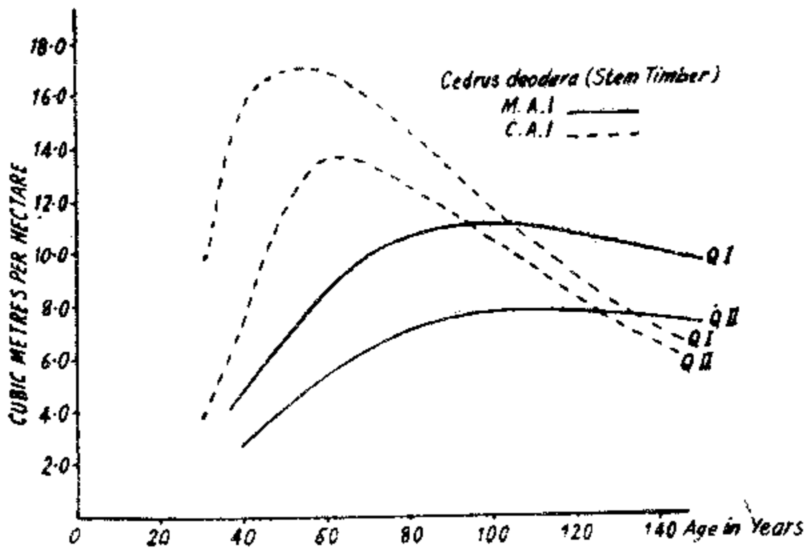

Fig. 7.1. M.A.I. and C.A.I. Curves for different Site Qualities of Deodar.

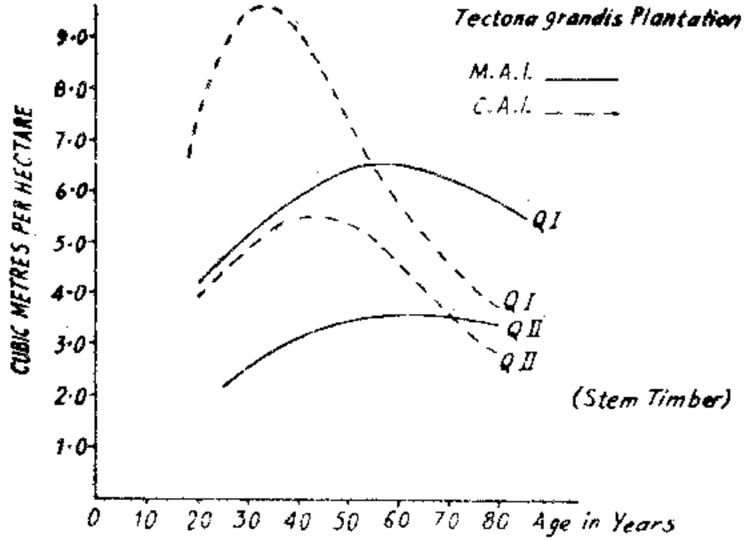

Fig. 7.2. M.A.I. and C.A.I. Curves for different Site Qualities of Teak.

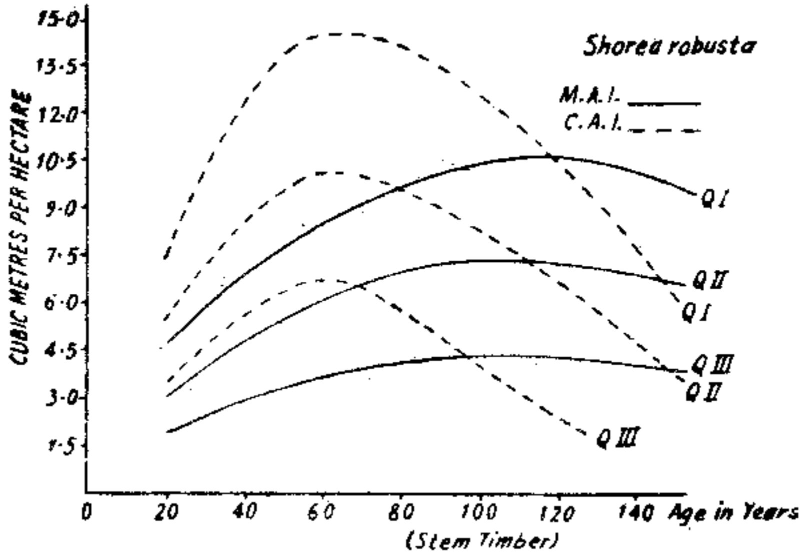

Fig. 7.3. M.A.I. and C.A.I. Curves for different Site Qualities of Sal.

Conclusions from the above description, tabulated data and trends of the M.A.I. and C.A.I. curves may be summed up as :—

(i) To begin with the M.A.I. keeps below the C.A.I.

(ii) While the C.A.I. is more than M.A.I., the M.A.I. is rising.

(iii) The C.A.I. attains the maximum before the M.A.I.

(iv) The C.A.I. is falling when the M.A.I. is still rising.

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

INCREMENT PERCENT

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

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

Periodic Increment Percent : 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 Percent : is the percent ratio which the M.A.I. for a given age bears to the total volume at that age.

The main purpose for which the increment percent is utilised 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 percent 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 a Pressler's Increment Borer, by repeated direct measurements or is taken from the Yield Tables. The increment percent of average sample trees is often assumed to be that of the crop (though not strictly correct).

Increment percent is the C.A.I. percent and is usually computed from Yield Tables by Pressler's Formula.

Pressler's Formula for Increment Percent : If 'V' is the Volume of the crop at present, and v the volume n years ago, and if n is fairly short (not more than ten years), then the C.A.I. will be $\frac{V-v}{n}$.

The average volume of the crop producing this increment is $\frac{V+v}{2}$.

Therefore *Increment Percent* (p) will be :

$$\frac{\text{Increment}}{\text{Volume}} \times 100 = \frac{V-v}{n} \times \frac{2}{V+v} \times 100 = \frac{V-v}{V+v} \times \frac{200}{n}$$

This is known as ***Pressler's Formula***. It is based on the assumption that the increment is laid on in equal annual instalments.

If any felling has been made in the intervening period, its volume must be added to 'V' to obtain correct result.

Example 1 : If the volume at the age of 50 years = 2500 cft., and at the age of 60 years = 3500 cft., and a thinning at the age of 55 years gave 300 cft., then *increment percent (p)* by Pressler's Formula will be :

$$= \frac{3500+300-2500}{3500+300+2500} \times \frac{200}{10} = 4.13$$

Example 2 : Let the volume at the age of 70 years be 100 m^3 and the volume ten years ago be 70 m^3, while a thinning carried out 5 years ago yielded 10 m^3. Then *increment percent (p)* will be

$$= \frac{100+10-70}{100+10+70} \times \frac{200}{10} = 4.44$$

Increment percent is very large in the early life of the crop but decreases very rapidly thereafter ; as illustrated in Fig. 7.4.

This is very obvious too when we imagine the percent growth rate of young seedlings, saplings and poles and then of older trees as they approach maturity.

Pressler also discovered a law of great importance in Forest

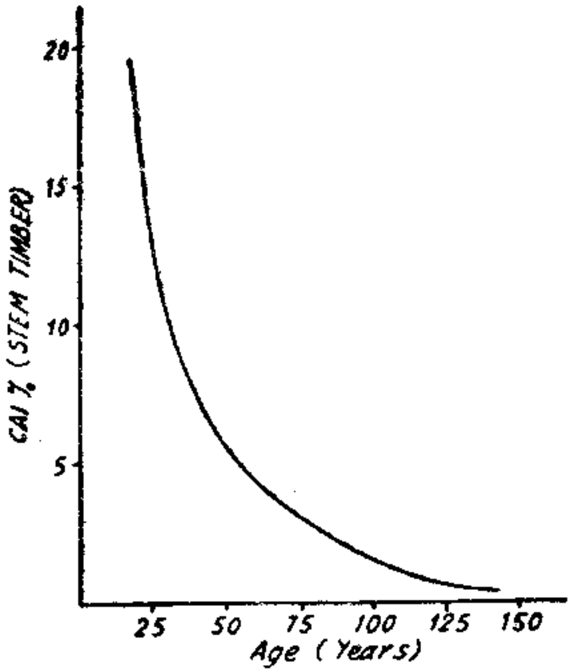

Fig. 7.4. C.A.I. Percent in Sal (Q. II.)

Management that the increment percent for the year r, in which the M.A.I. culminates, can be expressed by the formula $p=\frac{100}{r}$

Proof: $p=\frac{V-v}{V+v}\times\frac{200}{n}$ (Pressler's Formula)

$=\frac{V-v}{n}\times\frac{200}{V+v}$. In the year r, when the M.A.I. culminates, C.A.I.=M.A.I., therefore

$$\frac{V-v}{n}=\frac{V+v}{2}\times\frac{1}{r}$$

or $$p=\frac{V+v}{2}\times\frac{1}{r}\times\frac{200}{V+v}=\frac{100}{r}$$

Another formula which may be used is Schneider's Formula, which is applicable to ring porous trees.

SCHNEIDER'S FORMULA FOR INCREMENT PERCENT:

The most convenient formula for finding the increment percent (p) of standing trees is that developed by Professor Schneider in

1853. This formula is based on the determination of the diameter at breast height, and the number of rings in the last centimetre (or inch) of the radius as found by the Pressler's Borer. If D (*cm* or inches) is the diameter at breast height at present, and n the number of rings in the last centimeter or inch (same unit as that of d.b.h. measurement) and p the volume increment percent, then $p=\frac{400}{nD}$.

Proof of the Formula: If D=d.b.h. at present, then the dia. last year was$=D-\frac{2}{n}$, and the diameter next year will be$=D+\frac{2}{n}$ $\left(\text{as periodic annual radial increment is}=\frac{1}{n}\right)$. Let the corresponding radii be $\frac{D}{2}=r$; $\frac{1}{2}\left(D-\frac{2}{n}\right)=r_1$ and $\frac{1}{2}\left(D+\frac{2}{n}\right)=r_2$, respectively.

Present Volume of the tree$=\pi r^2hf$ (where h is the height in metres or feet and f the form factor).

Volume of the tree last year was$=\pi r_1^2hf$

Increment during the last year $=\pi r^2hf-\pi r_1^2hf$

$$\text{Increment percent } (p)=\frac{\pi r^2hf-\pi r_1^2hf}{\pi r^2hf}\times 100$$

Substituting values of r and r_1 and simplifying,

$$p=\frac{400}{nD}-\frac{400}{n^2D^2}$$

If increment is calculated on the basis of $r_2\left[=\frac{1}{2}\left(D+\frac{2}{n}\right)\right]$ instead of $r_1\left[=\frac{1}{2}\left(D-\frac{2}{n}\right)\right]$, increment percent p would be

$$=\frac{400}{nD}+\frac{400}{n^2D^2}$$

Taking the average of the two results,

$$p=\frac{400}{nD}$$

Increment percent data worked out for different diameter classes of Fir and Spruce and reported by R.V. Singh in his article "Management of Fir through the Century", published in January 1975 issue of *Indian Forester*, is reproduced below :—

Dia. Class (cm)	Increment % Spruce	Silver Fir
20–30	3.08	2.34
30–40	2.56	2.08
40–50	1.97	1.69
50–60	1.54	1.30
60–70	1.21	1.13
70–80	0.95	0.91
80–90	0.83	0.73
Above 90	0.65	0.49

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.

Fast growing species suffer from the following *disadvantages* :—

(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 10m³/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 utilise the maximum productive capacity of the site. *Eucalyptus* hybrid (*E. teretricornis*) 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. Their rates of growth are tabulated below :—

SOME INDIGENOUS FAST-GROWING SPECIES

Sl. No.	Name of Species	Age (Years)	Stem and small wood vol. m³/ha	M.A.I. m³/ha
1.	*Duabanga sonneratioides*	47	889.484	18.925
2.	*Alnus nepalensis*	22	357.907	16.269
3.	*Michelia champaca*	8	146.000	18.250
4.	*Casuarina equisetifolia*	5	75.300	15.060
5.	*Shorea robusta* (Coppice Q.A.)	30	329.700	10.990
6.	*Cedrela toona* (Syn. *Toona ciliata*)	14	235.200	16.800
7.	*Trewia nudiflora*	13	165.300	12.720
		18	175.100	9.728
8.	*Artocarpus chaplasha*	14	276.600	19.760
		19	294.100	15.480
9.	*Gmelina arborea*	06	137.800	22.960
		11	168.700	15.340
10.	*Tectona grandis*	10	122.450	12.245
	(Fully stocked : Q. I)	20	225.300	11.265
		40	417.000	10.425

(*Source* : "The concept of fast growth in forestry" : article by I.M. Qureshi, Indian Forester, Jan. 1968 ; quoted by Dwivedi.)

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

Some of the exotic species introduced in India have shown fast rates of growth in many localities. Growth data available in respect of some of these in some localities is tabulated below :—

M.A.I. OF SOME IMPORTANT EXOTIC SPECIES

Sl. No.	Species	Age (Yrs.)	Standing Vol. m³/ha	M.A.I. m³/ha	Locality
1.	*Eucalyptus globulus*	30	1107.10	36.90	Nilgiris
		10	151.00	15.10	Many areas
2.	*E. tereticornis*	10	205.00	20.50	—do—
	(hybrid)		135.00	13.50	—do—
3.	*Cryptomeria*	10	84.92	8.49	—do—(W.B.)
	japonica	20	339.72	16.98	—do—(„)
		30	601.17	20.04	—do—(„)
4.	*Ailanthus grandis*	30	520.00	17.33	Many areas
5.	*Populus spp.*	10–20	—	15.20	U.P.
6.	*Lagerstroemia flosreginae*	30	380.00	12.67	Many areas

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, P. elliottia.*

POSITION OF GROWING STOCK AND INCREMENT IN INDIA :

India has about 35 million hectares 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. Comparative figures of average Growing Stock in Commercial Forests are tabulated below :—

(Source : "World Wood Review, 1973".— Anon ; quoted by Dwivedi).

Sl. no.	*Country*	*Growing Stock m^3/ha*
1.	Canada	97.04
2.	Federal Republic of Germany	143.40
3.	*India*	*43.30*
4.	Italy	120.00
*5.	Pakistan	87.24
6.	U.K.	82.08
7.	Sweden	103.17
8.	U.S.S.R.	118.10

The position of M.A.I. 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. Comparative figures with some other countries are tabulated below :—

MEAN ANNUAL INCREMENT IN FORESTS

Sl. no.	*Country/Region*	*M.A.I. m^3/ha*
1.	Europe	2.5
2.	U.S.S.R.	1.9
3.	North America	2.3
4.	Africa	0.8
5.	Asia	2.6
6.	*India*	*0.5*
7.	World Average	2.1

(Source : "India's Forestes — 1974 — Central Forestry Commission, Ministry of Agriculture, New Delhi : quoted by Dwivedi)

INCREMENT IN TREES AND CROPS : SOME DISTINCTIVE FEATURES :

The M.A.I. 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 an 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 percent 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 Percent* can be determined and expressed in the same way as *Volume Increment Percent*. By using Pressler's method the expression will be :—

$p = \frac{K-k}{K+k} \times \frac{200}{n}$, where p is the *increment percent*, 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 economies. 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 percent for price may also be determined in the same way as the increment percent 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 percent 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 C.A.I., on which the mathematical relationship between the C.A.I. and the M.A.I. 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 C.A.I. 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 C.A.I. and the M.A.I. 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 C.A.I. and M.A.I. 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 C.A.I. and M.A.I. But information regarding the yield from thinnings throughout the life of a crop is not always available. In such cases, either both measurements should be taken before thinning, or both after thinning, for purpose of comparison of the M.A.I. with the C.A.I.

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 percent in value of the tree

v = annual increment percent in volume of the tree

p = annual increment percent in price per m^3.

DETERMINATION OF THE INCREMENT :

It is relatively easy to determine the C.A.I. 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. Yields 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 M.A.I.* :

Increment of the Felling Series, or the Yield, can be determined from the final M.A.I. In a normal Forest, the annual yield, or increment of the series will be = M.A.I. (at rotation age) $\times$ area of the F.S. If the forest is under-stocked or over-stocked, the yield must be reduced or increased, accordingly, by an amount equal to the difference between the actual and the normal growing stock, divided by the equalisation period (Heyer's formula : to be described later).

(b) *Increment From C.A.I.* :

The increment can also be estimated from the C.A.I. 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, c_3 c_4, etc., the C.A.I. per tree in the dia. classes. Then the total increment =

$$n_1v_1c_1 + n_2v_2c_2 + n_3v_3c_3 + n_4v_4c_4$$

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 C.A.I. in each dia. class is obtained from graph; the C.A.I. per tree being equal to C.A.I. per hectare divided by the number of trees.

(iii) **By Increment Percent Method :** The increment % 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, $\frac{400}{n\,D}$ (described already). The increment per-cent method can be used both for regular and irregular crops by determining the growth percent 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 % method : total standing volume in each dia.class is known (from enumeration data), with the calculation of increment % 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 (F.S.) or the Yield. From this, the average increment % of the entire F.S. can also be worked out as :—

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

The C.A.I. and Increment Percent 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, M.A.I. 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 enumerations 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 M.A.I. would be $\frac{G_a}{A}$, 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 *Methode 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 M.A.I. during the period is $=\frac{(V_2-V_1)+N-P}{n}$

Biolley's *Check Method* will be described in detail in Chapter X—YIELD REGULATION.

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". (Also refer to CHAPTER-VI : THE NORMAL FOREST, under the sub-heading ***Normality in Regular and Irregular Forests***).

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 year 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. Same 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 complate 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 interrupted.

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 difference being that due to the difference in a 30 year old tree and one 29 year old) : in the 11th year from now the yield would be normal and in the 12th 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 nor 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 a sustained yield should be produced from a forest ; this is easy enough from any forest, however, abnormal. It is necessary that the Sustained Yield produced 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 later 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 somewhat simpler method is to compare the total basal area of the age-class with the Yield Table figure.

Where the several age-gradations 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* (discussed in detail in Chapter–IX) 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 Area*.

Examples of forests 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 (i.e., reduced 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 af 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-GRADATIONS/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 Systems* :
(Refer to CHAPTER–III : Figures 3.1, 3.2 and 3.3)

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*, as is illustrated in Chapter–III, Figures 3.1, 3.2, and 3.3. The figures show diagramatically 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 Systems* :

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. Fig. 3.4 (Page 29) illustrates the arrangement of age-classes/P.Bs. in a *Chir* F.S., worked on 120 years rotation and 30 years regeneration period. 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. (For discussion of the topic and illustration, refer to CHAPTER–III, page 31 ; Fig. 3.5). 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. So 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 ; it may be twice, thrice, or four times as illustrated in Fig. 3.6 (CHAPTER–III, page 31). 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).

Arrangement of Coppice and Standards

$3r+1$,	$3r+2$,	$3r+3$	.. $4r$	Standards rotation	$4r$ years.
$2r+1$,	$2r+2$,	$2r+3$	.. $3r$	—do— —do—	$3r$ years.
$r+1$,	$r+2$,	$r+3$	.. $2r$	—do— —do—	$2r$ 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 arrangement 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 (G.S.) 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 (G.S), is immediately reflected in the income (increment/yield). Just as in a business enterprise, the investment may be over-capitalised, normally-capitalised or under-capitalised, in forestry enterprise also the G.S. (capital) may be over-stocked, normally-stocked or under-stocked. An over-mature and/or very densely stocked crop may have an excess G.S. to the extent that it is over-crowded, and not only the increment is retarded but even the excess G.S. may also gradually be lost by decay.

Besides the volume of the G.S. 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, regularisation of the G.S., 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 (G.S.) 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 (N.G.S.) is defined as : "The total volume of trees in a fully stocked forest with normal distribution of age-classes for a given rotation." (Glossary)

DETERMINATION OF ACTUAL GROWING STOCK

Measurement of 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; practised 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, *Aeriel Photography* is being increasingly used. These methods have been exclusively adopted by the Directorate of Forest Resources of India for estimation of G.S. in various regions of the country (details of these methods are beyond the scope of this publication).

The importance of determination of the actual G.S. and its composition by age-gradations/classes cannot be over-emphasised. However, it will not in itself indicate whether the G.S. volume is at its optimum and putting on optimum increment. Even frequent enumerations will only indicate the direction in which the G.S. 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)*.

As has been pointed out in Chapter VI, it is necessary to have a concept of an '*ideal* forest for maximum production—that ideal is a *Normal Forest*.

DETERMINATION OF NORMAL GROWING STOCK

Normal Growing Stock (N.G.S.) of forests worked under various representative Silvicultural Systems may be determined as follows :—

(A) *N.G.S. IN CLEAR FELLING SYSTEM*:

(a) *Based on Final M.A.I.*: The simplest example may be taken of a firewood Eucalyptus plantation of ten hectares, one hectare of which has been planted annually for ten years—the proposed rotation period, as has been illustrated in Fig. 4.1. 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 and 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, as diagrammatically illustrated in Fig. 4.1. Age-gradation areas are shown along the base line 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 $i, 2i, 3i \ldots\ldots 9i$ and $10i$, as illustrated in the diagram. The volume of 10-year old gradation on one hectare area has grown 500 m³, so the final M.A.I. at this rotation age $=\frac{500}{10}=50$ m³, and this is shown as the volume on one-year old hectare as i.

The volume $r\times i$ standing on the oldest age-gradation at the end of r years (in this case, $10\times 50=500$ m³) is also the sum of the M.A.Is. 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 (page 35) brings out that the volume of the oldest or rotation (r) age-gradation is equal to :—

(i) $r\times i=\mathrm{I}$

or (ii) Final M.A.I. of any one age-gradation i multiplied by rotation r.

or (iii) The sum of C.A.Is., i, of all the r age-gradations.

or (iv) The total M.A.I. 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 G.S. on r age-gradations, one to r year old, is the sum of the series $i, 2i, 3i \ldots (r-1)i, ri$, in arithmetical progression, at the end of the growing season and before the oldest, r-year old, plantation is felled. This sum is $=(i+ri)\frac{r}{2}=\frac{ri}{2}+\frac{r}{2}(r\times i)$. Substituting I for ri, it is $=\left(\mathrm{I}\times\frac{r}{2}\right)+\frac{\mathrm{I}}{2}$. Similarly, with the removal of oldest plantation (volume $=r\times i=\mathrm{I}$), the increment I of the whole series is removed and the volume at the beginning of the next growing season will be $\left(\mathrm{I}\times\frac{r}{2}\right)-\frac{\mathrm{I}}{2}$.

Therefore, the volume of N.G.S. in the middle of the growing season is the average of the two values $=\mathrm{I}\times\frac{r}{2}$. This is also graphically illustrated by the diagram (Fig. 4.1) as well, wherein r is 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$=\mathrm{I}\times\frac{r}{2}$; whereas at the end of the growing season, it will be—Triangle ABC $+\,r$ small triangles above the triangle ABC $\left(\text{each}=\frac{i}{2}\right)=\mathrm{I}\times\frac{r}{2}+\frac{i\,r}{2}=\left(\mathrm{I}\times\frac{r}{2}\right)+\frac{\mathrm{I}}{2}$.

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 $=\left(\mathrm{I}\times\frac{r}{2}\right)-\frac{\mathrm{I}}{2}$.

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

Applying the above deductions to the particular case of *Eucalyptus* plantation, worked on 10-year rotation, on 10 ha area, one ha under each gradation, the volume of 10-year gradation being 500 m³, the N.G.S. will be :

(a) $\mathrm{I}\times\frac{r}{2}=500\times\frac{10}{2}=2500\ \mathrm{m}^3$ at the middle of growing season.

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

(c) $\left(\mathrm{I}\times\frac{r}{2}\right)-\frac{\mathrm{I}}{2}=2500-\frac{500}{2}=2250\ \mathrm{m}^3$ at the beginning of the growing season. This N.G.S. at the mid season, i.e. 2500 m³, is standing on r ha area; so the average N.G.S. per ha in this case is$=\frac{2500}{10}=250\ \mathrm{m}^3$. If in the diagram (Fig. 4.1, page 35), 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 rotation.

The sum of age-gradations/classes in a forest is then the G.S. of the forest ; the sum of the normal such series is the N.G.S.

(b) *Calculation of N.G.S. From Yield Table* :

If a Yield Table gives data for intervals of one year, that is, it gives the volume of each age-gradation, the G.S. volume can be readily calculated by adding up the volumes of successive years. But the Yield Tables usually give data for intervals of five or ten years. In such cases, the volume of N.G.S. can be accurately determined by plotting the Yield Table data on a graph paper, drawing a smooth curve and computing the area below the curve either by a *planimeter*, 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 progression. Though this assumption is not quite correct, but as the period between two successive measurements is usually short, the error is insignificant. Then the G.S. can be calculated mathematically by regarding the two successive entries 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, 2 n to 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 gradation ; in general terms, in the summation all the Yield Table entries, 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-gradation. If the oldest age-gradation 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 values, 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, 2 n, 3 n

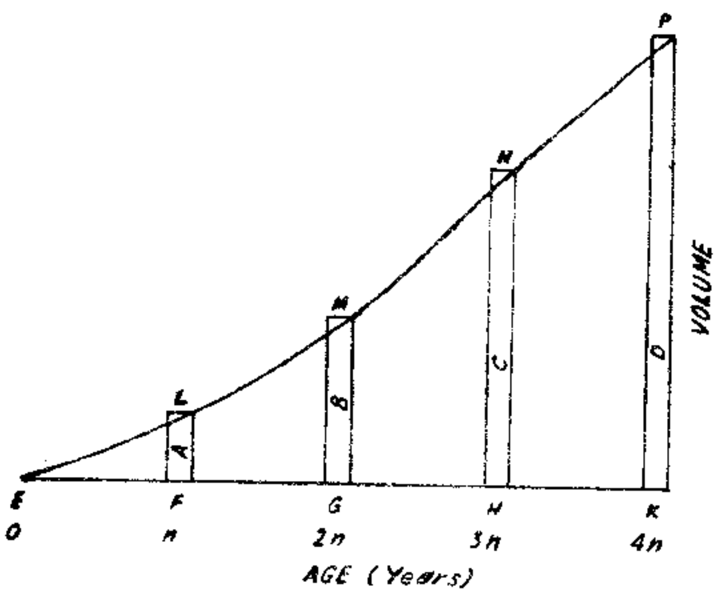

Fig. 9.1.

and 4 n being A, B, C, and D, as shown by rectangles in Figure 9.1 overleaf. The volumes are plotted against age and a smooth curve ELMNP drawn through the plotted points. Total volume of mid season or summer N.G.S. for the rotation r=4 n on 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 be assumed to be straight lines).

$$\text{N.G.S.}=\frac{n}{2}(A)+n\left(\frac{A+B}{2}\right)+n\left(\frac{B+C}{2}\right)+\left(\frac{C+D}{2}\right)$$

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

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, 2 n, 3 n... r−n and r years, then the general formula can be written as :

$\text{N.G.S.}=n(V_n+V_{2n}+V_{3n}+\ldots\ldots V_{r-n}+V_r)$;

over r units of area (acres/hectares).

N.G.S. at the end of growing season (autumn N.G.S.) and at the beginning of the growing season (spring G.S.) will, similarly, be :

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

respectively.

NUMERICAL EXAMPLES ON CALCULATION OF N.G.S.:

Example 1 : Following is an extract from Yield Table for *Deodar*, Site Quality II.

Crop Age (years)	Final Yield (Stem timber and small wood m^3/ha)	Crop Age (Years)	Final Yield (m^3/ha)
10	—	60	490.50
20	9.80	70	574.47
30	74.17	80	656.34
40	210.62	90	734.01
50	347.06	100	806.77

(i) N.G.S. by M.A.I. formula, for rotation of 100 years over 100 hectares$= I \times \frac{r}{2}$, where I is increment of the whole series and= Volume of r year old age-gradation$=806.77$ m³.

Total N.G.S.$= \frac{806.77 \times 100}{2} = 40338.5$ m³; or average N.G.S per hectare$=403.39$ m³.

(ii) N.G.S. over 100 ha as calculated directly from the Yield Table figures, by the formula derived above :

$$=10\left(0+9.80+74.17+210.62+347.06+490.50+574.47+656.34 +734.01+\frac{806.77}{2}\right)=35003.6 \text{ m}^3$$

or, average N.G.S per hectare$=\frac{35003.6}{100}=350.04$ m³

It is seen that in this case the N.G.S. calculated by the M.A.I. is greater than that calculated from Yield Table figures for 100 years rotation.

Example 2—Calculate the average N.G.S. per hectare in a teak plantation of Site Quality II, worked on a rotation of 40 years, to which the following Yield Table figures apply.

Age (Years)	Final Yield (Stem Timber : m³)	Age (Years)	Final Yield (Stem Timber : m³)
5	—	25	51.43
10	0.70	30	73.82
15	8.40	35	94.81
20	27.99	40	114.75

(i) By M.A.I. formula, N.G.S. on 40 ha$=I \times \frac{r}{2}$

$=114.75 \times \frac{40}{2}$; or average N.G.S. per ha$=114.75 \times \frac{40}{2} \times \frac{1}{40}$

$=57.38$ m³.

(ii) By Y.T. formula, N.G.S. on 40 ha$=n\left(A+B+C+\frac{D}{2}\right)$

$$=5\left(0+0.70+8.40+27.99+51.43+73.82+94.81+\frac{114.75}{2}\right)$$

$=5 \times 314.53$ m³; or average N.G.S. per ha$=\frac{5 \times 314.53}{40}=39.31$ m³.

In this case also M.A.I. formula has given higher result for 40 year rotation.

We may now study the progress of G.S. through the rotation in the above two methods to see when, if ever, the two will give the same result

COMPARISON OF REAL AND THEORETICAL N.G.S.—FLURY'S CONSTANT :

As already stated, and illustrated in Figs. 7.1, 7.2 and 7.3, if the M.A.I. and C.A.I. curves are plotted against age, the age at which they intersect is the one at which the M.A.I. culminates. In Fig. 4.1, progress of volume production with age was shown as a straight line AC, depicting the final M.A.I. (i). If the actual volumes produced at each age are plotted over age, the result is a curve as shown in Fig. 9.2.

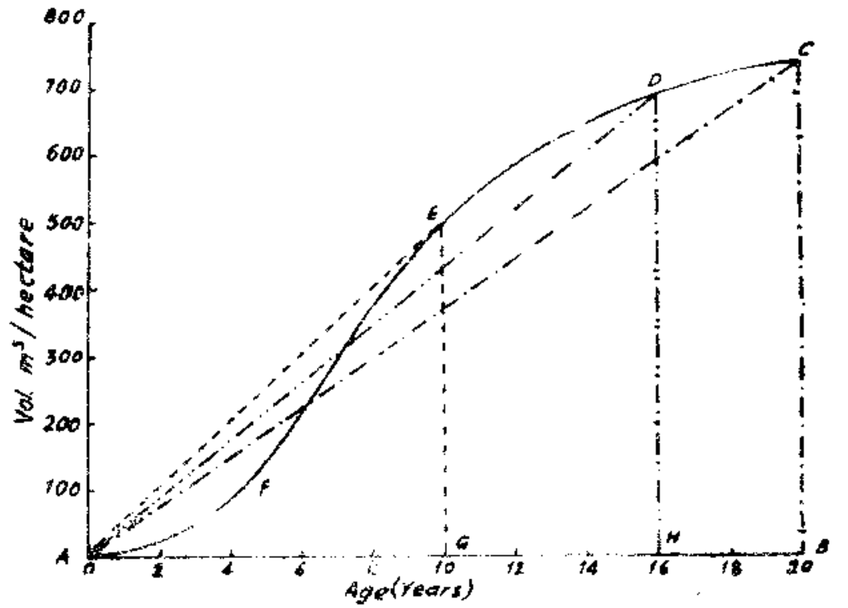

Fig. 9.2. Yield Table G.S. compared with that from Final M.A.I.

In this figure, the real N.G.S. 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 N.G.S. triangles, according to equal annual increment conception for rotations of 10, 16, and 20 years. For the 10-year rotation the triangle AGE is the same as in Fig. 4.1, and is obviously considerably larger than the real N.G.S. as shown by the area under the curve AGEFA. At 16 years, which is several years after the M.A.I. has culminated, the triangle AHD and the area under the curve AHDEFA are about the same; that is, volume indicated by the final M.A.I. and the actual Yield Table figures are nearly equal. Later on, say, at 20 years, true N.G.S. indicated by the curve ABCDEFA is greater than the theoretical N.G.S. $\left(I \times \frac{r}{2}\right)$ as indicated by the triangle ABC. The data is tabulated below :—

Age (years)	Theoretical N.G.S. by M.A.I. Triangle (m^3)	Real N.G.S. under the Y.T. Curve (m^3)	On Area (Hectares)
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 M.A.I. formula curve which changes with each change of rotation, which changes the M.A.I. 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; in the above illustration, Fig. 9.2, it is about 16 years. At this rotation age, the formula will also give the correct volume of the N.G.S. 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 C.A.I. culminates, the greater will be the volume of the oldest age-class and more exaggerated will be the volume of the G.S. as calculated by the formula.

The volume of the true N.G.S. will not attain equality with that obtained from the formula $G.S. = I \times \frac{r}{2}$, until some considerable time after the C.A.I. has fallen below the final M.A.I., i.e., until after the M.A.I. 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) give higher values for the N.G.S.

As the G.S. obtained from the Yield Table (real N.G.S.) is more accurate than that obtained from the M.A.I. formula (theoretical N.G.S.), the former is ordinarily the method employed for its determination. Since the Yield Tables are not always available, it has led many foresters to find some modification to the more convenient M.A.I. formula, which would allow for varying conditions under different systems of management. Amongst them, FLURY (Swiss Forest Service) is the more prominent. He suggested that in the mid-season formula, $G.S. = I \times r \times 1/2$, a variable constant 'C' (different for each rotation) should be substituted for "1/2", to obtain more correct results; and the formula would read, $G.S. = I \times r \times C$, wherein 'C' is known as *Flury's Constant*. Flury actually calculated values of 'C' at various ages to substitute for "1/2" in the formula, for various species, various rotations and varying sets of growing conditions.

The value of 'C' will be less than '1/2' for short rotations, and more than '1/2' for long rotations, as has been discussed above and illustrated in Fig. 9.2.

DETERMINATION OF FLURY'S CONSTANT 'C' :

We shall take up the two numerical Examples (Ex. 1 and Ex. 2—on pages 103/104) in which N.G.S., real and theoretical, were determined by Yield Table and M.A.I. formula methods. Since the Yield Table method is the more accurate method, we shall equate M.A.I. formula results with variable 'C', to the Yield Table method results, and find the value of variable 'C'.

Example 1 : From Example 1 on page 103, the real/correct N.G.S. by Yield Table Method $= 350.04\ m^3/ha$. By M.A.I. formula this is $= I \times r \times$ 'C' over r ha, or $I \times$ 'C' per ha, where $I = 806.77 m^3$.

Therefore, $'C' = \frac{350.04}{806.77} = 0.43.$

Example 2 : From Example 2 on page 104, by similar procedure we have : $\frac{I \times r \times 'C'}{r} = 39.31\ m^3/ha$; or $114.75 \times 'C' = 39.31$

or $'C' = \frac{39.31}{114.75} = 0.34.$

DETERMINATION OF ACTUAL G.S. WHEN 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-classs (on which the fellings will impinge) assuming that the volume of this age-class represents the increment of the forest, and calculate the G.S. from it. In doing so he pictures his G.S. as in Fig. 4.1 and assumes that his $G.S.=I \times \frac{r}{2}$, where I is the volume of the oldest class, and r the rotation.

(B) *N.G.S. IN UNIFORM REGULAR SHELTERWOOD SYSTEM* :

Under this system, theoretically, regeneration of a crop, compartment or a block (P.B.) 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 (P.B.I.) 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).

Whatever the regeneration intarval* for a coupe or a compartment, it is necessary that the whole P.B. should be regenerated

**Regeneration Interval* : "The period between seeding felling and final felling on a particular area, usually a compartment or a sub-compartment under one of the shelterwood systems. On the other hand, regeneration period is the period required to regenerate the whole P.B." (Glossary)

within the regeneration period, so that regeneration P.B. has one age-class in it, corresponding to the length of the regeneration period. When all the overwood has been removed from a P.B., 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 Tables 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 $=(V+V_1) \times \frac{P}{2} \times D$,

where : V is the initial G.S ; V_1 is the G.S. at the end of regeneration period ; P is the regeneration period and D is the crown density.

Example ; A *Chir* pine forest contains 600 m^3 per hectare at the age of 100 years. In the regeneration fellings over 20 years period, 75% of the volume was removed, the rest was left as a part of the future crop. The density was reduced to 0.25.

Substituting values in Fischer's formula, the

$$G.S.=(600+150) \times \frac{20}{2} \times 0.25 \text{ m}^3$$

or 1875 m^3 for $\frac{20}{2}$ (or 10) years, or 187.5 m^3/ha/year. Another formula was conceived by Strzeleckis, which is : $G.S.=1/2r\ (V+V_r)$, where V is volume at half rotation age., V_r volume at rotation age. Using this formula with the following Deodar Yield Table, Site Quality II, for a rotation of 100 years :

Final Yield/ha at 100 years=806.77 m^3 (Stem timber and Small wood)

Final Yield/ha at 50 years=347.06 m^3 (—do—)

$$G.S. \text{ for } 100 \text{ years rotation} = \frac{100}{2}(806.77+347.06)\text{m}^3$$

$$=57691.5 \text{ m}^3 \text{ over } 100 \text{ ha, or } 576.92 \text{ m}^3/\text{ha}.$$

The G.S from Yield Table for a similar rotation for a normal forest worked out to 350.04 m^3/ha (*Example 1*, page 104).

(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 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. ; he 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. $(G_n) = \frac{i \times \text{f.c.}}{2}$ + *reserved timber* per felling area × 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 m³; f.c. = 10 years ; Reserved Timber = 25000 m³ over the whole area (or 250 m³/ha). Then $\text{G.S.} = \left(\frac{500 \times 10}{2} + 25000\right)$ m³ for 100 ha; or 275 m³ per hectare.

(**Note :** *Reserved Timber*, or the *Residual G.S.* is the G.S. below the exploitation diameter left standing after the fellings are over, usually under a felling cycle).

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.

Results 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 forests of Ram Nagar Division, U.P.", in Indian Forester, May 1958), substantiate 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 :** Divide figures in col. 2 and 3 by 14 to obtain *approximate* corresponding figures in m³/ha).

The data in respect of sal Selection forests was obtained from the crops which were not fully stocked, and it is presumed that with complete stocking much higher figures would have been obtained for sal Selection forests in col. (3) of the above table.

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 4.1. 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, every plantation will reach maturity and, in its turn, felled to give annual yield. Thus the G.S. removed during a rotation period of r years will be :—

I (annual coupe/yield) × r (rotation) = I × 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 excisting 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 × 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 $\frac{Y_n}{N.G.S.} \times 100$, where Y_n 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 modifed area* is meant that area which would produce the same yield with uniform quality and/or density, as is 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*.

Yield Tables are prepared from data collected on normally stocked forests, which are seldom found in our forests. Two most important factors in which conditions are likely to differ are *density* and the *quality*. Yield Tables are constructed 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 Table figures directly.

As regards *quality*, separate Yield Tables are usually constructed for each recognised 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-gradations/classes, where

**Sample Plot*: "A plot chosen as representative of a larger area. In forestry, sample plots are used mainly in enumeration surveys and for studies of growth (e.g., preparing Yield Tables or determining the effect of thinning treatments on the rate of growth)." (Glossary)

occupying separate areas in even-aged crops, occupy equi-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 (or 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 the equivalent area in terms of crop with normal density (1.0). (Assessment of crop density is dealt with in detail in *Forest Mensuration*).

Thus, if in Example 2 (page 104) the density of 40-year old teak plantation is 0.8, the volume per hectare would be $114.75 \times 0.8 = 91.80 m^3$. 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 equalised yields in the next. However if, theoratically, 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.

Example: Let the area of a Felling Series (F.S.) in Clear-felling or Coppice System be = 1000 ha, of this 300 ha have normal density, 200 ha 0.75, 400 ha 0.5 and the remaining 100 ha have 0.25 density. If the total area is to be divided into 25 equi-productive coupes, area of each will be worked out as :—

Reduced (modified) area of the F.S. in terms of unit (normal) density :

$= 300 + (200 \times 0.75) + (400 \times 0.5) + (100 \times 0.25)$

$= 675$ ha (fully stocked).

Modified area of each annual coupe of normal density (1.0)

$= \frac{675}{25} = 27$ ha.

In distributing crops to 25 equi-productive coupes, area of each coupe in various density crops will be ;

27 ha in density 1.0 crop
36 ha in density 0.75 crop
54 ha in density 0.50 crop
108 ha in density 0.25 crop.

The number of coupes which will be laid in different density crops will be as follows :—

Crop density	Area in hectares			No. of Coupes laid	Balance taken over to next crop (ha)
	Actual	Recd from Col. 6	Total		
1.	2.	3.	4.	5.	6.
1.00	300	Nil	300	11	3
0.75	200	$3 \times \frac{4}{3} = 4$	204	5	24
0.50	400	$24 \times \frac{3}{2} = 36$	436	8	4
0.25	100	$4 \times 2 = 8$	108	1	—
Total	1000			25	

REDUCTION (OR MODIFICATION) FOR QUALITY :

Variation in G.S. 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 M.A.I. For example, in case of plantation teak, the yield capacity (M.A.I.) for total wood for a rotation of 60 years is : (from Yield Tables)

Quality I — 9.38 m^3/ha
Quality II — 6.79 m^3/ha
Quality III — 4.20 m^3/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., M.A.I. Reduction may be made in either of the three ways :—

(i) reduction to the most prevalent quality
or (ii) reduction to the mean quality of the whole area
or (iii) reduction to any suitable quality — whether present in the area or not.

In Chakrata Forest Divison, 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 M.A.I. 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 (see Appendix II).

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 M.A.I.

Reduced area : actual area = M.A.I. of the quality : M.A.I. of the Standard Quality. The factor :

$\frac{\text{M.A.I. of the quality to be reduced}}{\text{M.A.I. of the standard quality}}$ is known as the ***reducing factor for quality***.

Taking the following example of a plantation teak felling series, of 1000 ha worked on 60-year rotation, the reduced area in terms of the Standard II quality will be worked out as follows :—

Quality Class	Actual Area (ha)	M.A.I. (m^3/ha)	Reducing Factor	Reduced Area (ha)
I	300	9.38	$\frac{9.38}{6.79} = 1.38$	414
II	500	6.79	$\frac{6.79}{6.79} = 1.00$	500 (Standard Quality)
III	200	4.20	$\frac{4.20}{6.79} = 0.62$	124
Total	1000			1038

The mean quality is that which, if it existed throughout the entire area, would produce the same total yield as that would be produced by the several existing qualities in its different parts.

Example : From the above figures, M A.I. of the mean quality would be :—

$$\frac{(300\times 9.38)+(500\times 6.79)+(200\times 4.20)}{1000} = 7.05 \text{ m}^3/\text{ha.}$$

The reduced area of each of the various qualities will be $= \frac{\text{actual area} \times \text{its M.A.I.}}{\text{M.A.I. of mean quality}}$ as :—

(i) Reduced area of 300 ha, Q. I. $= \frac{300\times 9.38}{7.05} = 399.1$ ha

(ii) „ „ „ 500 ha, Q. II $= \frac{500\times 6.79}{7.05} = 481.5$ ha

(iii) „ „ „ 200 ha, Q. III $= \frac{200\times 4.20}{7.05} = 119.1$ ha

999.7 ha

or 1000 ha.

Total reduced area should be equal to the actual area, i.e., 1000 **ha** as all areas have been reduced to the *mean quality*. The difference of 0.3 ha is due to rounding off decimal fractions.

PART II

YIELD & ITS REGULATION

CHAPTER X

YIELD REGULATION — GENERAL CONSIDERATIONS

PRINCIPLES—OBJECTS—DEFINITIONS :

The management of forests for production and supply of wood, requires continuous (or periodic) cutting of individual trees or crops of trees. The chief object of Forest Management may, therefore, be stated as the regulation of this production and supply, i.e., the *Yield*. Before it can be regulated, it has to be determined or calculated.

Yield Regulation, therefore, involves two separate functions, viz., :—

(i) Calculation/determination of what the amount of *yield* should be, i.e., the amount of material which may be removed annually or periodically from a forest over a stated period and prescribing the means of realising it ; in brief, ***how much, where*** and ***when to cut*** the calculated quantity from the forest.

(ii) The construction of a cutting (felling) plan which determines the identity of the stands to be cut.

How precisely or rigidly each one of these should be prescribed, will depend on the circumstances in each case. Cutting plan may indicate annual coupes, or leave it to be chosen by territorial officers.

Correct regulation of yield is one of the main functions of sound forest management. Its general function is, however, to control the rate of removal or the progress of fellings of the existing crop, to institute safe-guards to ensure yield in prepetuity and, subject to these, to satisfy the main objects of management, primary one of which being the production of timber on sustained basis in perpetuity.

Broadly, yield regulation is the estimation of, what the French call, *possibility*, i.e., the productive capacity of an area, deciding as to how much of this could be removed, how much re-invested in the wood capital of the area, or how much of the excess (from normal) wood capital could be removed in addition, and how much and from what portion of the growing stock the fellings should be made.

In a normal forest the entire annual increment could be removed each year, and the same capital would always be left undisturbed. If the growing stock is not normal, but consists of young trees only, obviously the wood capital is too small and the increment must be left un-cut to build it up. If the bulk of the growing stock is old, there will be excess of wood capital and the rate of increment will be low. The capital will have to be reduced by cutting more than the increment to make room for young trees In a production forest, the object of management is usually to obtain a fairly steady yield, while aiming to bring it to a condition so as to give maximum sustained yield from the wood capital invested in the soil.

Definitions of some of the terms pertaining to *yield* may be recapitulated ; these are reproduced below (from Glossary) :

Yield : "The volume or number of stems that can be removed annually or periodically, or the area over which fellings may pass annually or periodically, consistent with the attainment of objects of management."

Final Yield : "(a) All the material that counts against the prescribed yield and which is derived from the main fellings in a regular forest.

(b) As shown is the Yield Table, it is the sum of the main crop and the subsidiary crop figures for the given crop age."

Intermediate Yield : "All material from thinnings or operations preceding the main felling in a regular forest, or its cash equivalent. *(Syn. Subsidiary Crop).*"

Normal Yield : "The yield from a normal forest."

Sustained Yield : "The material that a forest can yield annually (or periodically) in perpetuity."

Total Yield : "The standing volume of a crop plus the total volume removed in thinnings since its establishment as a more or less even-aged stand; or the sum of the *final* and *intermediate yields.*"

Yield Capacity : "The total quantity of material per annum, of given species, that an area is capable of producing under normal conditions, so long as the factors of locality remain unchanged."

Yield Determination : "The calculation of the amount of

material which may be removed from a forest, annually or periodically over a stated period, or of the annual or periodic area over which fellings may be made, consistent with the treatment prescribed."

Yield Regulation : "A term generally applied to the determination of the yield and the prescribed means of realising it." It means the fixing in advance, usually for a short period—the Working Plan Period—the amount of timber or other produce which may be removed from the forest, annually or periodically.

The objects of regulating yield, in short, are -—

(i) to cut each crop or tree at maturity ;

(ii) to obtain maximum yield of the desired produce ;

(iii) to cut, approximately, the same quantity of material annually or periodically ;

and (iv) to limit the area to be felled to that which can be regenerated.

The achievement of the above objects is quite easy in the second and subsequent rotations by which time the forests are, more or less, converted/regulated ; in the first rotation of scientific forest management the first and second objectives are difficult to achieve and some compromise has to be made. The aims and objects should, however, remain the same.

In the first rotation difficulty arises due to : -

(i) In virgin forests, crops are generally over-mature and decrepit, necessitating early removal ; regeneration conditions therein are also not favourable.

(ii) The crops are usually irregular, both in density and composition.

(iii) Growth and composition data are not available for quite a few decades. In case of even-aged systems, the yield is regulated by area in the first rotation, so as to build up equal age-gradations/classes for sustained yield in subsequent rotations, rather than equalising yield in the current rotation.

The yield is usually regulated for the period of the Working Plan, which is generally ten years. It is neither possible, nor desirable, to fell annually the exact quantity prescribed in the Working Plan. Unfore-seen contingencies, silvicultural or economic, often necessitate variation ; however, it would suffice to restrict the yield within the prescribed yield for the Working Plan period - i.e., we aim at sustained yield over the period if not over each year; this is quite a practicable proposition.

Broadly, the yield is determined on the basis of area, volume or both the parameters; the chief bases for which are the growing stock, increment, objects of management and the silvicultural system. Proper regulation of yield must take into consideration volume, age and also the area of a crop. Volume alone is insufficient, and regulation purely by area lacks flexibility. Frequent revision of Working Plans is essential for check on previous regulations.

The determination of yield does not merely consist of mathematical calculations based on crop inventories, the records or the Yield Table. The result of any such calculations would, at best, give only a preliminary figure. The permissible yield may be more or less than the calculated yield, taking into consideration the growing stock and composition of the age-classes. These may be in such condition as may require harvesting less or more than the calculated yield.

TYPES OF YIELD—INTERMEDIATE AND FINAL:

(The two terms have been defined already).

In even-aged forestry, there are two types of yield—the ***final*** or ***main yield*** and the *intermediate yield* from cleanings, thinnings and improvement fellings. In general, one can say that the ***final yield***, i.e., removal of stands and their regeneration, controls the proportional distribution of age-classes whereas the ***intermediate yield*** from thinnings, etc., controls the economy by providing early returns, influencing the length of rotation and controlling the quality of timber. Silvicultural operations, such as cleanings and thinnings, by well-timed removal of the suppressed and dominated stems, do not decrease, but rather increase the ***final yield*** and, at least, qualitatively improve the yield. These yields, therefore, represent a ***bonus***, as it were, but do not generally form a part of the prescribed or regulated yield. The regulation is, usually, in respect of final fellings only, as the intermediate fellings are silvicultural operations, which cannot (and should not) be circumscribed within any quantitative limitations. Under systematic working and favourable market conditions, yields from thinnings also tend to be, more or less, uniform and can be estimated with reasonable precision.

In pure, even-aged, normally stocked crops, treated with ordinary C-grade thinning, the relationship between the two yields may be determined by means of Yield Table. Intermediate Yield may constitute anything from one third to one half of the *total yield.*

Yield Regulation and Silviculture*:** It may be reiterated that silvicultural treatment of a crop should be so planned that it does not run counter to the fundamental concept of *sustension*, and the annual cut should be equal to the annual increment. If the annual fellings exceed the annual growth, the growing stock or the ***working capital is reduced, resulting in reduced fellings for several years to make up the deficiency. On the other hand, if the fellings are less than the annual growth, it will result in over-stocking of the growing stock which depreciates the increment. Over-capitalizing of the growing stock also generally indicates an untended forest and deficiency of reproduction.

The relative importance of ***Yield Regulation*** and ***Silviculture*** in the practice of forestry has been a debated issue on the continent. There are two divergent views based on the relative degree of emphasis. The German School holds a more or less rigid concept on ***Regulation***; claims of ***sustained yield*** are considered paramount and govern all aspects of organised forestry practices and management. The French School, on the other hand, does not place so much emphasis on *Yield Regulation* and considers it only as subservient to good *Silviculture*. French Forester, Broilliard, was inclined to think that mathematics and formulae 'never take into consideration the secrets of the living forest' and may lead silviculture into serious errors.

The over-riding role of *Silviculture* is being appreciated more and more; it is being realised that every silvicultural operation, resulting in a cut of some sort is to keep the ***wood producing apparatus***, the Growing Stock, at the highest level of production. Silviculture and management should not run couuter to each other, and a close and harmonious relationship has been achieved in BIOLLEY's ***Check Method***. Under Indian conditions, with difficult regeneration conditions prevailing in moist *Sal*, *Teak* and ***Deodar*** forests, flexible methods of *Yield Regulation* are indicated, with greater stress on silvicultural aspects.

SILVICULTURAL SYSTEMS IN RELATION TO YIELD:

Most methods of yield calculation and regulation originated on the European Continent which was the birth-place of scientific forestry. These methods were designed and applied by foresters to suit local conditions. In the process it so happened that a particular method of *Yield Regulation* came to be associated, broadly, with a particular method of management and Silvicultural System. But it would be incorrect to consider this association between Silvicultural Systems and methods of yield calculation and regulation as sacrosanct and inviolable; it would be particularly dangerous for a forester dealing with conditions so different from those found on the continent. The best course to adopt would be to understand the principles underlying such applications, and apply the knowledge so acquired for building up a scheme of silviculture and management best suited to the forests we are concerned with. Some methods of yield regulation imply a certain method of yield calculation and, some methods of yield regulation or calculation are particularly applicable to, or in some cases only applicable to, certain types of Silvicultural Systems. We shall examine such cases of limited applicability also.

For the purpose of considering the effect of *Silvicultural Systems* on *Yield Regulation*, the following three broad types of systems will be recognised.

I—*Clear-felling* : resulting in regular, even-aged forests, in which age-gradations are recognised by area.

II—*Regular Shelterwood* : resulting in regular even-aged forests in which age-classes are recognised by area.

III—*Irregular Shelterwood and Selection* : resulting in irregular forests, in which neither age-gradations nor age-classes are recognisable by area.

Yield regulation methods applicable in each of the above broad categories will be dealt with in later paragraphs.

BASIS OF YIELD REGULATION

As stated in a previous paragraph, there is no recognised correlation between a method of *Yield Regulation* and a *Silvicultural System*; several methods of *regulation* have been applied to crops and *Systems* other than those for which these were originally evolved. It would be more appropriate to classify them according to their underlying basic principles.

The yield can, broadly, be prescribed in three ways, viz., by area, by volume or by area and volume combined. In case of yield

by area, the entire area, irrespective of the growing stock, forms the basis of calculation. In case of yield by volume, the volume of growing stock (either whole or part thereof), the increment or both volume of growing stock and its increment, may form the basis. We shall study the following methods of yield calculation classified according to the above parameters :—

	Basis	Method
A.	*Area only*	A1—Annual coupe by gross area A2—Annual coupe by reduced area
B.	*Volume only* (Growing Stock Volume)	B1—Von Mantel's Formula B2—Howard's modification B3—Simmons' modification B4—Smythies' modification B5—Burma modification.
C.	*Area and Volume*	C1—Permanent P.B. Method ; allotment by :— (i) equalising area (ii) equalising volume : Hartig's method (iii) equalising area and volume C2—Revocable P.B. Method C3—Single P.B. Method C4—Floating P.B. Method C5—JUDEICH'S Stand Selection (Management) Method.
D.	*Increment*	D1—Increment Method D2—Swiss Method D3—Biolley's "Check Method" or *Methode du Controle* (comparison of successive inventories and volumes removed).
E.	*Volume and Increment of whole Growing Stock*	E1—*Formula Methods* (comparison of actual and normal G.S.) (i) Austrian (ii) Heyer's (iii) Hundeshagen's (iv) Karl's (v) Breymann's E2—Hufnagl's Method (Variation I and II)

Basis	Method
(Dia. classes)	E3—(i) French Method of 1883
	(ii) 1894 Modification or Melard's Method (Regeneration Area Method)
	(iii) Symthies' Modification
	(iv) Chaturvedi's Modification
	E4—Hufnagl's Diameter Class Method
	E5—Brandis' Diameter Class Method (or the Indian Method)
(No. of trees)	E6—Volume Unit Method
	E7—Symthies' Safe-guarding Formula (or U.P. Safe-guarding formula).

Of the above methods, B2, B3, B4, E5 and E7 are purely of Indian origin; these were evolved to deal with special situations and problems of *forest management* in India.

CHAPTER XI

YIELD REGULATION IN REGULAR FORESTS

I. *YIELD REGULATION IN CLEAR-FELLING SYSTEM*:

(a) *Annual Coupes by Gross Area (A1)*: This is the oldest and simplest form of regulating yield from a forest; first applied in France in the 14th century, when the need for some control on felling was realised. It was initially applied to coppice crops worked on short rotations, upto twenty years. Subsequently, with the introduction of Coppice-with-Standards System, the same method of area control continued to be applied, wherein a certain number of *standards* was reserved for two, three or four coppice rotations. This method is applicable to coppice forests and also to *high forests* worked on a system of Clear-felling and artificial regeneration as in Nilambur (Kerala), Bori and Betul (M.P.) teak plantations. In Europe, regulation by area is also applied to fairly regular coniferous forests wherein conditions for natural regeneration are favourable and can be assured in a year. A well known example is that of Maritime Pine *(Pinus pinaster)* of Landes (France), where natural regeneration comes up profusely after clear-felling, from the seed already lying on the ground.

In India, this method is widely adopted in plantations, particularly those coppiced for fuel. It is also adopted in Coppice-with-Standards and Coppice-with-Reserves Systems. It regulates the *Final Yield*, i.e., fellings in areas to be finally felled at rotation age and regenerated; it does not take into account *Intermediate Yield* from cleanings and thinnings in the younger crops.

In its simplest form, the area of the forest or the *Felling Series* (say, A ha) is divided into a number of *annual coupes* equal to the number of years in the rotation (say, *r*), and one coupe felled every year—A/*r* ha in area. Usually, the sequence of annual coupes is laid down in the Working Plan and shown on the map, and sometimes demarcated on the ground as well, but there should be no objection to felling a coupe, nearly mature but damaged by fire, in advance of its prescribed date, and making suitable adjustments in the felling order.

This method of *yield regulation* will ensure equal sustained yield in the second and subsequent rotations (if there are no unforeseen accidents), though it *may not* in the first. Annual coupes so formed, and equal in the area on the ground, are known as ***equi-extensive*** coupes. A typical example of this case is illustrated in Fig. 4.1 (Page 35).

(b) *Annual Coupes by Reduced Area (A2)* : Since the density and site quality may vary from coupe to coupe, reduction factors should be applied for equalising annual yields and areas allotted to each coupe made equi-productive, rather than equi-extensive. As already explained (in Chapter IX), reduction for density is seldom made, as this variation may be only a temporary feature and full stocking may be expected after regeneration operations, and this factor will not affect future yields. However, yield variation due to site quality may be a permanent feature of the locality, and is taken into account by determining and applying suitable ***reduction factors*** before formation of equi-productive coupes (as described and illustrated in Chapter IX).

Advantages of Yield Regulation by Area :

(i) It is easy to apply.

(ii) Leads to absolute regularity of age-gradations.

Disadvantages :

(i) It is very rigid, every change of rotation will necessitate re-division of the coupes.

(ii) Prescribes fellings without consideration of the crop condition.

Limitations :

(i) In unmanaged forests, it is not possible to lay out equi-productive coupes.

(ii) In mixed natural forests, regulation by area is only a crude method ; it was given up in Europe in early 19th century in favour of regulation by area and volume.

II. *YIELD REGULATION IN REGULAR SHELTERWOOD SYSTEMS* :

(a) Yield Based on Area Allotment by Periods :

This is similar to regulation by fixed area, but is less rigid. It

differs in that the felling areas are not permanently fixed on the ground in the order of felling, but instead compartments and/or sub-compartments are allotted to various periods of rotation. Rotation is divided into a number of convenient periods (depending on regeneration period; 10 to 30 years); areas allotted to various Periods (P) are known as P.Bs. All P.Bs. are of equal or equi-productive areas. This method is also known as ***Periodic Block Method.*** Final yield is obtained from the mature regeneration block (P.B.I.), and this may be regulated by :—

(i) Area (gross or reduced) or (ii) Volume, or (iii) Area and Volume.

Allotment to P.Bs. may be ***permanent*** (fixed P.Bs.), ***revocable, single*** or ***floating*** (floating P.Bs.).

PERMANENT ALLOTMENT METHOD (C1) :

(i) ***Regulation by Area (C1-i)*** : In its simplest form the method of area allotment by periods consists in permanent allocation of areas in all the P.Bs. In other words, the actual forest or the felling series is made, by adjustments and compromises, to fit into a pre-conceived pattern. This arrangement is possible in forests where regeneration presents no difficulty and accidents do not upset the time schedule.

Area of each P.B. of the Felling Series (or the forest, as the case may be) is $= \frac{A}{R} \times P$; where P is the regeneration period, A the area of the F.S. and R the rotation. This may be gross area, where crop and growth conditions are uniform in regular forests, or reduced, for quality. Areas may also be reduced for age, as suggested by Hufnagl.

The P.Bs. may be self-contained or scattered, as the provisional allotment will be on the basis of the condition and maturity of the crop in various compartments and sub-compartments after inspection (paricutilarly so in the first rotation). It abnormal forests, considerable shifting and/or adjustment may be necessary to allot equi-productive areas to all the P.Bs.

In this method, instead of annual coupes we have periodic coupes and annual yield is fixed by volume.

Hufnagl's Variation or Modification : For sustension of annual yields during the rotation, Hufnagl suggested a modification that the area (of the annual coupe in Clear-felling system, or P.B. in Shelterwood System), should be multiplied by : (average age : 1/2 r).

The actual average age is determined by multiplying the area of each age class in the series by *average age* of that age-class, summing up the products and by dividing the sum by the total area of the Felling Series. If there is an excess of older age-classes, the actual average age of the series would be higher than the normal average (or half rotation) age and, consequently, the coupe (or P.B.) would be larger than the normal; conversely, if there was an excess of younger age classes, the calculated area of the coupe (or P.B.) would be smaller than the normal. This modification is applied more often to areas under Shelterwood Systems on long rotation, with Periodic Blocks, rather than annual coupes worked on shorter rotations. Application of this modification is illustrated in the following example :—

Example : Area of the F.S $=1000$ ha ; Rotation $=80$ years ;

Period $=20$ years ; No of P.Bs. $=\frac{80}{20}=4$

Normal area of each P.B. $=\frac{1000}{4}=250$ ha.

Distribution of age-classess is as follows :—

Age-class (years)	Area of the class (ha)	Average age of the class × area	Actual average age of the series (Years)
1–20	200	10 × 200 = 2000	
21–40	150	30 × 150 = 4500	
41–60	350	50 × 350 = 17500	$\frac{45000}{1000}=45$
61–80	300	70 × 300 = 21000	
	1000	45000	

Normal average age of the F.S. $=1/2$ rotation $=40$ years.

Therefore, modified area (in respect of age) of each P.B. would be *equivalent* of $\frac{1000}{4}\times\frac{45}{40}=281$ ha instead of the normal 250 ha. This is due to the excess of the older age-classes over the normal distribution.

Annual yield is calculated only for the P.B.I., the area to be felled during the first period of rotation. Standing volume in P.B.I is determined by enumeration or computed from Yield Table. Since

the area is putting on increment, as the fellings proceed from year to year in the P.B., increment for half the period (average period of growth) is also added to the Standing Volume and divided by the period (P), which gives the average annual volume yield from the P.B.I. Thinning Yield (Intermediate Yield) may be dealt with separately. Sometimes allowance for increment is ignored while calculating the annual yield, so as to provide a reserve against unfore-seen emergencies such as fire, insect/fungal epidemics. Agarwal's Kulu Division (H.P.) and Misra's Dehra Dun Division Working Plans omitted this allowance while calculating yields from Regular Working Circle and Sal Conversion Working Circle, respectively.

The formula for annual yield may be written as :—

$$Y_a=\frac{V+Pi/2}{P} \quad \text{or} \quad Y_a=\frac{V}{P}+\frac{i}{2} \qquad \text{(Cotta's Formula)}$$

where Y_a is the annual yield, P the period, V the standing volume in P.B.I, i the annual increment of the P.B.I.

(ii) *Regulation by Volume (CI–ii)* : This method was evolved by Hartig in 1795 In this case also the area of the forest, or the Felling Series, is divided into P.Bs but instead of equalising the area, or reduced area, the volumes of the various P.Bs. are equalised. To start with, the allotment is made by age-classes, then volumes of crops allotted to various P.Bs. are determined from the Yield Table for the middle of the period when each P B will be due for final felling. The volume of the P.B I is determined by actual enumeration. The late P.Bs are allotted a slightly more volume. If age-class allotments do not give equal volumes, shiftings are made for adjustment, but this will involve re-calculation of the final yield with every shifting. This method attempts to equalise the yields during the present rotation, but the yields in subsequent rotations may not be equal from period to period.

A great disadvantage of this method is that it depends for its use on the Yield Tables which may not be available Another disadvantage is that it attempts to regulate the yield for the whole rotation. This method is of very little practical application.

(iii) *Regulation by Area and Volume (CI–iii)* : This method is the combination of area and the volume methods ; the object being that all P.Bs have equal volume and equal area. After making the allotment according to the age-classess, preliminary equalisation is made either for area or for volume. When the allotment has been made for one (area or volume), shiftings are made to fix the other (volume or area), so that both areas and volumes are equal, or approximately equal, in all the P.Bs. This is a very laborious and difficult work, especially in the more or less irregular forests. This method was evolved by Cotta in 1804; it was modified by Klipstein in 1823 according to which the areas and volumes need be equalised for the oldest two P.Bs. only, and in the other P.Bs. only areas may be equalised.

This method has the advantages of both the methods which it combines.

The permanent allotment method was found to be very rigid, and is not in common use outside France. The crops do not respond to a pre-determined plan. Sometimes, final fellings have to be postponed as regeneration has not appeared, or a compartment has to be taken up for final fellings out of turn. The whole rotation is too long a period to expect crops to continue to behave as they were behaving at its beginning.

REVOCABLE ALLOTMENT METHOD (C2).

Since the method of permanent allotment was found to be rigid, it was replaced by the method of *Revocable Allotment*. In this case also, the rotation is divided into periods (suitable regeneration period) and the F.S. into corresponding P.Bs. The compartments are allotted, according to their average ages, to various P.Bs. and, if necessary, adjustments are made to equalise the areas of various P.Bs. Only the regeneration block (P.B.I.) is of immediate importance and it is definitely allotted, whereas the other P.Bs may be re-allotted at each revision, if necessary, according to crop conditions at that time. For allotment to the regeneration block, compartments are selected on the basis of following order of priority :—

(i) Wherein regeneration fellings had been started, but not completed during the previous period.

(ii) Which need to be taken up early due to severe damage by fire, storms, epidemics, etc.

(iii) Wherein the crop is mature and advance growth is already present under it.

(iv) Wherein the crop is mature, but without any advance growth.

At the time of each revision, the area of the carried over compartments (partially regenerated) is reduced for its reduced density in the overwood, in terms of the density of the mature compartments in which regeneration fellings have not yet started, for purposes of the revised allotment.

The chief feature of this method is that the allotment of P.Bs. made in one period may be changed in the next; it is more realistic and flexible.

Sometimes the P.B. II is also allotted as carefully, and simultaneously, so that it could be given special treatment for preparing it for regeneration during the next period. It is, however, not necessary that it may then definitely be allotted to the P.B. I; some more suitable area may be selected instead.

For obvious reasons, Periodic Blocks may not necessarily be self-contained; they may sometimes be scattered.

SINGLE ALLOTMENT METHOD (C3) :

In the previous method, it was considered that allotment to only the regeneration block was of importance, and in case of others it was revocable. It was only a step further that only the compartments to the regeneneration block may be allotted; there being no necessity of allotting the rest to various other P.Bs., as this is likely to be upset by un-foresee-able natural causes and may have to be modified at each revision. The French evolved this modification to the fixed P.B. method and called it *Single P.B. Method,* in which areas are allotted to the current regeneration block only. In this case the period, as also the area of *Single P.B.*, is still fixed. The only gain in elasticity lies in the fact that the remaining P.Bs. are not allotted. From the method of *Single P.B.*, it is only a step to the method of *Floating P.B.*, in which neither the area of the P.B. nor the period is fixed in advance.

FLOATING PERIODIC BLOCK (F.P.B.) METHOD (C4) :

This method consists in the allotment of areas ripe for regeneration and exploitation to one P.B. There is no pre-determined limit as to the size of the P.B. as formed, nor to the length of the *period*. All woods which are over-mature, mature or nearly so, and are ready for regeneration or in which regeneration has already appeared, may be included in the F.P.B. In an even-aged forest, which is normal or nearly normal, the extent of woods requiring inclusion in the F.P.B. will be of correct proportion corresponding to the regeneration time required. In abnormal forests, a very large proportion may require to be included in the F.P.B. on account of the presence of a large extent of over-mature woods, and the presence of advance growth over a large part of the forest. In such circumstances the area of the F.P.B. is limited on grounds of practical convenience.

The gradual evolution of the F.P.B. System from the fixed P.B. System may be summed up as follows :—

(i) Fixed self contained P.Bs. with permanent boundaries.

(ii) Fixed scattered P.Bs. with permanent boundaries.

(iii) P.Bs. scattered or self-contained, with boundaries subject to revision at intervals—Revocable Allotment Method.

(iv) Single P.B., scattered or self-contained, with fixed period.

(v) Floating P.B., passing gradually over the whole forest.

Each step aimed at greater freedom and elasticity in selection of areas for regeneration according to silvicultural requirements, without sacrificing the basic principles of forest management.

The F.P.B. Method was evolved in France under the name of ***Quartier Bleu Method,*** since the F.P.B. was coloured blue on the maps; the rest of the area, which was subject to thinnings was left uncoloured and called the ***Quartier Blanc.*** At each Working Plan revision the compartments are allotted to ***Quartier Bleu*** as follows :

Group–I : Compartments already under regeneration.

Group–II : Compartments which should come under regeneration during the Working Plan period.

The volume of timber in each compartment of the F.P.B. is found. The annual yield is determined by dividing this volume (with or without increment allowance) by the length of time expected to regenerate each compartment.

The Working Plan period may be any convenient time and has no special relation to regeneration period. It is often based on the thinning cycle, i.e., if the thinning cycle is 10 years, the Working Plan period may be 10, 20, or 30 years. Thus, in this method there is no regeneration period which must be a sub-multiple of rotation, as in Fixed P.B. system.

For calculating the annual yield, Duchaufour devised a method particularly applicable to the ***Quartier Bleu*** method of regeneration. He applied the following formula :—

Period of Exploitation : Rotation = Area of Cpts. in F.P.B. : Area of F.S.

or P : R = F.P.B. : F.S. ; or $\frac{P}{R} = \frac{F.P.B.}{F.S.}$

Therefore $P = R \times \frac{F.P.B.}{F.S.}$

The area of the F.P.B. is ascertained by adding the full (reduced) area of Group II compartments, i.e., compartments newly brought into F.P.B., and the area of Group I compartments (which have already had regeneration fellings partly) ***modified*** to allow for previous fellings; i.e., reduced according to present density of the crop, since final fellings had already commenced. The Group II forests are the standard for density purposes and represent 1.0 density, or fully stocked woods.

The modified or the reduced area (C) is found by the famous Duchafour's Crown Cover Method, as follows :—

$C = K^2g^2n$ or K^2d^2n, where

g = Mean girth of the trees in Group I (partly felled compartments).

d = Mean diameter of the trees in Group I.

n = Number of trees in Group I.

K = Coefficient by which the girth (or diameter) of the mean tree must be multiplied in order to obtain the side of the square occupied by the crown.

Thus K^2g^2 (or K^2d^2) gives the area occupied by the mean tree and K^2g^2n (or K^2d^2n) gives the reduced area of the compartment in Group I in terms af normal stocking of Group II compartments.

The effective area of the F.P.B. having thus been determined, the equivalent period of exploitation 'P' is calculated by the above formula. The total volume standing in the F.P.B. (found by enumeration or from the Yield Tables) is divided by 'P', the period, and this gives the annual yield; allowance for increment may or may not be given.

A separate calculation is made for yield from each Felling Series.

The Coefficient 'K' may be ascertained as follows :—

A convenient area, say 200 m × 200 m is laid out in Group II (unfelled area of F.P.B.), which is considered fully stocked for all practical purposes. The trees are enumerated and measured.

Let n = number of trees

g = mean girth

D = average side of the square occupied by the crown of the average tree.

Then 'D' is calculated from the formula :—

$$nD^2 = 200 \times 200' m^2$$

Since $Kg = D, K = D/g$.

Advantages of the F.P.B. Method :

(i) The method closely relates fellings to the silvicultural requirements of each crop. Only those crops which are in need of regeneration, or in which regeneration fellings have already been started, are put in F.P.B.

(ii) No artificial *period*, in the sense of the time limit for completion of regeneration, is laid down in any area. The period 'P' found by calculation is for the purpose of regulating the annual yield, and has no bearing on the intensity or frequency of fellings in any particular crop; these will depend entirely on the progress of regeneration.

Disadvantages :

(i) It works satisfactorily only in those forests which have a more or less normal distribution of age-classes. In abnormal forests, it leads to considerable diffusion of operations.

(ii) It is not suitable for irregular forests.

JUDEICH'S STAND SELECTION METHOD (C5) :

This method was practised by Judeich in Germany, long before the F.P.B. method was developed in France. The principle in both the cases is same, i.e., treatment of each crop according to its needs. It was originated by Cotta in 1841 and perfected by Judeich. The basis of Judeich's method is the fact that no method of yield regulation over long periods can be accurate, if it is not frequently revised. He, therefore, regulates yield for a period of, say, 10 years at a time and at the end of that period the Working Plan is revised.

The essence of this method is the careful selection of mature stands (maturity being technical, financial or silvicultural, depending on the object of management), and the allotment of, a more or less, proportionate area of such stands to be felled and regenerated during the Working Plan (W.P.) period.

The procedure is as follows :—

(1) The forest is divided into a number of compartments of suitable size.

(2) The compartments are inspected and described with

reference to the treatment they require during the next Working Plan Period, say 10 years.

(3) The rotation and the Working Plan period are fixed.

(4) The compartments are selected for felling and regeneration during the W.P. Period on the following principles :—

(i) Stands which must be felled to meet the necessary silvicultural or protective necessities.

(ii) Mature and over-mature stands ; maturity being related to objects of management.

(iii) Stands of doubtful maturity, whose felling may be desirable for reasons of convenience; e.g., one occurring between two mature stands.

(5) The size of the mean annual coupe and the area to be felled during the W.P. period is determined $\left(\text{it is} = \frac{F.S.}{R} \times P\right)$.

(6) If the total area of the compartments selected for felling under 4(i), (ii) and (iii) is within, say 10% of the mean periodic coupe as calculated in (5) above, no further adjustment is necessary. If it is larger than this, then some of the areas brought in under 4 (iii) may be omitted. If it is smaller than the calculated minimum area, then some more compartments, even though not quite mature, will have to be included.

The following example illustrates the procedure.

Example : Area of the F.S. 1000 hectares rotation 80 years and Working Plan period 10 years. Age-class distribution is as follows:—

Age-classes (years)	Normal distribution (ha)		Actual distribution (ha)	
1–20	250	500	200	350
21–40	250		150	
41–60	250	500	350	650
Over 60	250		300	

As there is an excess of old woods, the areas to be felled during the Working Plan period should be more than $\frac{1000}{80} \times 10$, or 125 ha. For the next two periods (20 years), it may be desirable to fell 150 ha in each period of 10 years, to balance the younger age-classes which will follow fellings of old wood.

The distribution of age-classes at the end of first period (10 years) and the second period (20 years) will be as follows :—

Age-classes (years)		Area now (ha)		Area after 10 years (ha)		Area after 20 years (ha)		Remarks
Young	1–20	200	350	250	425	275	487.5	$\frac{1}{2}$ of 200+150 =250 $\frac{1}{2}$ of 200+$\frac{1}{2}$ of 150=175
	21–40	150		175		212.5		$\frac{1}{2}$ of 250+150 =275 $\frac{1}{2}$ of 175+$\frac{1}{2}$ of 250=212.5
Old	41–60	350	650	250	575	212.5	512.5	Calculated similarly as above.
	Over 60	300		325		300		
Total			1000		1000		1000	

After that, 125 ha might be felled during each of the successive periods and the age-class distribution will become progressively more normal. Age-classes at the end of 30 years (three periods of 10 years each) will be as follows :—

Age-classes (years)		Area after 30 years (ha)		Remarks
Young	1–20	262.5	506	$\frac{1}{2}$ of 275+125=262.5
	21–40	243.5		$\frac{1}{2}$ of 212.5+$\frac{1}{2}$ of 275=243.5
Old	41–60	212.5	494	$\frac{1}{2}$ of 212.5+$\frac{1}{2}$ of 212.5=212.5
	Over 60	281.5		$\frac{1}{2}$ of 212.5+(300−125)=281.5
Total			1000	

Judeich did not specify any particular method of prescribing the yield. It may be either by area or by volume, depending on whether the crop is reasonably regular or irregular. The main object is the attainment of normality in the distribution of age-classes.

(7) The annual yield by volume may be prescribed by dividing the total standing volume in the compartments taken up for fellings (with or without an allowance for increment) by the period

Advantages :

(i) The method is simple and elastic ; working is firmly based on the actual condition of the crop.

(ii) It can be freely applied to all regular forests, even if abnormal.

Disadvantages :

(i) Crops may become mixed, as regards age-class distribution, owing to freedom allowed in selecting them for felling.

(ii) Sustained yield may not be possible if too much freedom is given in selection of crops for felling entirely on silvicultural considerations.

(b) Yield Based on Volume and/or Increment of Growing Stock (G.S.) :

(These methods are generally applicable to Irregular Shelterwood Systems also)

Methods of Yield Regulation based on volume (of G.S. and/or Increment) are generally referred to as *Formula Methods*. These should rarely be relied upon as the sole basis of yield regulation, as these are liable to inaccuracies even when applied to normal forests. In case of abnormal forests – as most of our forests are – they are particularly dangerous, as they are based on abstract quantities and pay little or no attention to the distribution of age-classes and the condition of the crop. The fact that a certain forest has a certain volume, and a certain increment, does not indicate whether any part of the forest is of exploitable size and, if so, how much. The use of an area check, when using formula methods, is essential. Inspite of their obvious defects, *formula methods* are widely used due to their convenience and, in some cases, to the impossibility of applying a more suitable and accurate method. Their use is justified provided the yield so calculated is not prescribed blindly, but is modified as necessary to suit the actual conditions in the forest, and the Working Plan is frequently revised and the yield re-calculated on the basis of measurements of the G.S.

Methods Based on Volume of the G.S. only :

(i) *Von Montel's Formula* (B1) :

It has already been shown in Chapter IX (Page 100) that the volume of the normal G.S. is equal to the m.a.i. of the F.S. multiplied by half the rotation, i.e., $N.G.S. = I \times \frac{r}{2}$, where I represents the volume of the oldest age-gradation (and also the total annual increment of the F.S.) and is the normal annual yield. I is, therefore, equal to $\frac{N.G.S.}{r/2} = \frac{2\ N.G.S.}{r}$. Von Mantel's simple formula derived from the above relation is :

$$\text{Annual Yield} = \frac{\text{Actual Volume of G.S.}}{\frac{1}{2}\text{ rotation}} = \frac{2\text{ G.S.}}{r}.$$

This is Von Mantel's Formula, sometimes known as the *formula of glorious simplicity.*

According to Von Mantel, the annual yield from any forest must bear the same proportion to the actual growing stock as normal increment bears to the normal growing stock.

$$\frac{\text{Actual Yield}}{\text{Actual G.S.}} = \frac{\text{Normal Yield}}{\text{Normal G.S.}} ; \text{ or } \frac{Y_a}{V_a} = \frac{Y_n}{V_n}$$

Von Mantel's formula may be written as :

$$I \times r = 2\text{ G.S., or } Ir = \text{G.S.} + \left(I \times \frac{r}{2}\right)$$

Therefore, yield during the rotation is equal to twice the G.S. The existing G.S. supplies the yield for half the rotation ; yield for the other half of the rotation coming from the increment.

The main merit of Von Mantel's formula is its simplicity and the fact that is requires only the determination of actual volume of the G.S. It, or its modifications, are therefore widely used. On the other hand, since it is based on the volume of the G.S. only, it suffers from the worst defects of the *formula methods.* It will indicate the same annual yield for a forest consisting of immature woods as for a forest containing a large number of over-mature ones, provided the G.S. volume is same in both the cases.

Since the method is based on actual measurement of the G.S., it is possible to find out the actual increment by compariug successive measurements. The real increment thus found should be compared with the *formula yield.*

This formula is best applicable to regular, even-aged or nearly even-aged normal forests ; it is definitely not suited to markedly irregular forests to which it is, however, frequently applied because of its simplicity.

Advantages :

(1) It is easy to apply ; requires determination of G.S. and rotation only. It is handy.

(2) It regulates the yield according to actual G.S. Over-stocked forests will be heavily felled and under-stocked forests lightly felled.

(3) It is useful as a preliminary step in yield regulation, specially in irregular forests.

(4) It gives conservative yield and helps in enrichment of the G.S.

Disadvantages :

(1) It does not take into consideration the difference between the actual and the normal G.S., nor of the composition of G.S. which may vary from forest to forest.

(2) It is in-elastic because the surplus or deficit in the G.S. is spread over half the rotation; frequent re-calculation of yield on the basis of new enumeration can overcome this objection to some extent.

(3) It involves complete enumeration of the G.S., which is not always practicable.

(4) It neglects the age-class distribution and rate of growth of the crop.

(5) It gives only the final yield and is useful where natural forests are being brought under regulation. Where thinnings constitute an important part of the yield, the formula gives very low figures.

(6) The assumption that all age-gradations put on equal increment throughout is wrong—this is why Flury introduced a Constant C in place of '½' in 'r'.

Masson's Formula : Exploitation Percent / Masson's Ratio

Masson's Formula is identical with that of Von Mantel. The French claim that this was derived independently by Masson

It will be observed that if Von Mantel's formula is accepted as a correct basis on which to calculate the yield, the increment (M.A.I.) percent is proportionate to the rotation. From the formula $Y = \frac{2\text{G.S.}}{r}$, if G.S.$=100$, the yield is $200/r$ or $2/r$ percent. This is known as *Exploitation Percent* or *Masson's Ratio.* For a 80 year rotation, it would be 200/80 or 2½%, and similarly for other rotations. This is a useful fact to bear in mind. In case of forests for which accurate information is not available, this percentage may usefully be employed as a temporary measure to indicate the maximum permissible annual felling of mature crop.

Modifications of Von Mantel's Formula :

Application of Von Mantel's formula requires measurement of the entire G.S. There is, however, a limit below which it is practically impossible to measure. Measuring down to a very low limit would eliminate any appreciable error (as un-enumerated seedlings and saplings contribute only a very small proportion of the total volume), but it is very expensive and time-consuming. But when the lower limit of enumeration is fairly high for reasons of economy and convenience, say 20 cm (stem timber limit in India), considerable error is likely to result by treating the volume above this limit as the volume of the G.S. Several modifications have, therefore, been evolved to meet these contingencies. The object in each case is to relate the measured volume of part of the G.S. to the volume of the total G.S.

(ii) ***Howard's Modification*** (B2) :

This modification was evolved to meet the special case of selection forests in which enumerations were done down to half the exploitable girth; assumption being made that girth was directly proportional to age. The only data required are :—

(i) Rotation—corresponding to the exploitable girth.

(ii) Determination of girth corresponding to half rotation age.

In the absence of more accurate data, this can be assumed to be half the exploitable girth.

(iii) Enumeration of trees down to half rotation age.

Howard's formula for yield is : $Y=\dfrac{V}{\left(\frac{3}{8}\right)r}$ or $\dfrac{8\,V}{3\,r}$, where

V is the volume of G.S. enumerated down to half rotation age. This can be proved either arithmatically or graphically. The latter is simpler.

In Fig. 11.1, triangle ABC represents the total G.S. of the forest on a rotation of 'r' years. The figure BCEF represents the part of G.S. which was enumerated down to half rotation (i.e. half the exploitable girth/dia. as assumed). Triangles marked 1, 2, 3, 4, and 5 all being equal, it is obvious that enumerated G.S. is 3/4 of the total G.S. If 'V' is the enumerated G.S. volume, the total G.S.

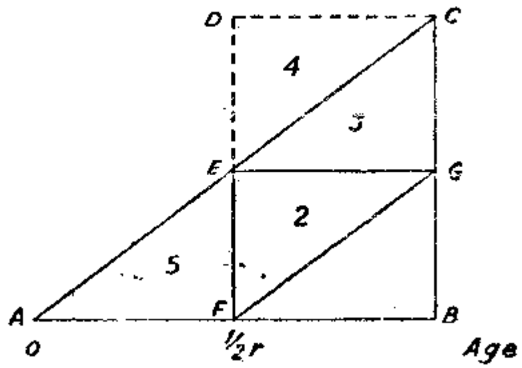

Fig 11.1. Howard's Modification.

volume will be 4 V/3. Substituting this in Von Mantel's formula $Y=\dfrac{2\text{ G.S.}}{r}$, Yield $Y=\dfrac{2(4V)}{3\,r}=\dfrac{8V}{3\,r}$ or $\dfrac{V}{(3/8)\,r}$.

The difficulty in its application is that the limit of enumeration will change every time that the rotation is changed. The limit will also change with any change in the quality class.

(iii) ***Simmons' Modification*** (B3) :

Howard's formula applies only to the special cases in which enumeration is carried out down to the diameter corresponding to half the rotation. A more general formula was evolved by Simmons, which is applicable to all fractional enumerations of G.S., down to girth/dia equivalent to 1/n th of the rotation.

Let G = Volume of total G.S.

V = Volume of G.S. enuumerated

a = Volume of G.S. *not* enumerated

$$n=\frac{\text{Rotation}}{\text{Age of oldest class in 'a'}}=\frac{r}{x}$$

x = age down to which ennumerations were done. In Fig. 11.2, triangle ABC represents the normal G.S. triangle. The G.S. was enumerated down to age 'x'; $Ax=\frac{r}{n}$. (For practical illustration, take 'r'=120 years; 'x'=20 years; 'n'=120/20=6. It means that rotation is divided into 6 parts, and G.S. is enumerated down to 1/6 th the exploitable girth/dia., corresponding to 1/6th rotation, i.e., 20 years). The rotation is divided into n parts $\left(\text{each}=\frac{r}{n}\right)$; perpendiculars and parallels are drawn as shown. From Fig. 11.2 it is clear that G.S. volume measured is represented by the figure BCDx $=V$; and the triangle AxD$=a$, the volume of un-enumerated part, and that all the triangles marked "a" are equal (triangles on equal

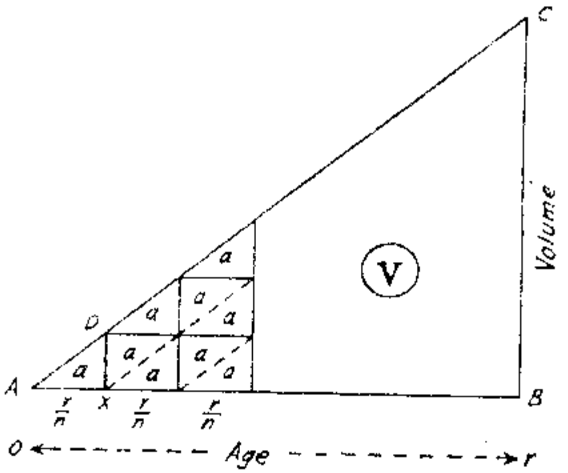

Fig. 11.2. Simmons' Modification.

bases and between the same two parallels). Total G.S.$=$G$=$triangle ABC$=a+3a+5a$ .... $(2n-1)a$; the rotation being divided into 'n' parts and corresponding volumes of each part are in arithmetical progression (A.P. Series) as shown in Figure 11.2 above.

Thus, summation of Volume $G=\frac{n}{2}\left[\ a+(2n-1)a\ \right]=n^2a$

Therefore, $V=G-a=n^2a-a=a(n^2-1)$;

and $\frac{G}{V}=\frac{n^2a}{a(n^2-1)}=\frac{n^2}{n^2-1}$; or $G=V\times\frac{n^2}{n^2-1}$

Annual Yield $Y=\frac{2G}{r}=\frac{2\,n^2}{r\,(n^2-1)}\times V$ .. (i)

This formula may also be expressed in terms of 'r' and 'x'. Since $n=\frac{r}{x}$, substituting this value of 'n' we get Annual Yield

$Y=\frac{2\,r}{r^2-x^2}\times V$ .. (ii)

It can be shown that Howard's formula is a special case of this general formula where $x=1/2\ r$.

Substituting the value of 'x', we get annual yield :

$$Y=\frac{2\,Vr}{r^2-r^2/4}=\frac{8V}{3\,r} \quad \text{(Howard's Formula)}$$

Example 1 : Rotation $-$ 100 years; G.S. down to diameter equivalent to 20 years age enumerated and measured, i e.,

$x=20$ years, and $n=\frac{100}{20}=5$;

Volume measured (i.e., V)$=2400\ m^3$

Applying the formula in the form (i),

$\text{Yield}=\frac{2n^2}{r(n^2-1)}\times V=\frac{2\times25}{100(25-1)}\times2400\ m^3=50\ m^3$

Applying the formula in form (ii),

$\text{Yield}=\frac{2\ r}{r^2-x^2}\times V=\frac{2\times100}{10000-400}\times2400\ m^3=50\ m^3$

Example 2 : Rotation$=$120 years and corresponding diameter $=$60 cm. Enumeration and volume measurement made down to 20 cm diameter, corresponding to 40 years age. Volume measured$=$ **12000 m^3.**

Substituting values of 'r' ($=$120 years), 'n' ($=$3), 'x' ($=$40) and V($=12000\ m^3$),

Annual Yield by formula in form (i)

$Y=\frac{2\times9}{120\ (9-1)}\times12000\ m^3=225\ m^3.$

Annual yield by formula in form (ii)

$Y=\frac{2\times120}{(120\times120)-(40\times40)}\times12000\ m^3=225\ m^3.$

(iv) *Smythies' Modification* (B4) :

Smythies provides for a still more restricted G.S. than Howard or Simmons did. The volume which he fits into Von Mantel's formula is only timber which not only excludes crops below a certain diameter but also the portion of the tree (in volume calculation) which is below that diameter (in India, standard timber limit is down to 20 cm dia. over-bark).

Let V$=$Volume of G S. enumerated and measured (triangle xBD in Fig. 11.3).

r$=$Rotation

x$=$Age down to which enumeration and measurement is done (corresponding to the girth/dia. down to which the volume is measured).

In Fig. 11 3, ABC represents the normal G.S. triangle. If xD is drawn parallel to AC, and the rectangle ExBD be completed, then the part of the G.S. neither enumerated nor measured is represented by figure AxDC, and the enumerated and measured G.S., V, is represented by triangle xBD. The Yield in $r-x$ years = rectangle ExBD = twice triangle xBD = 2V, and the annual yield

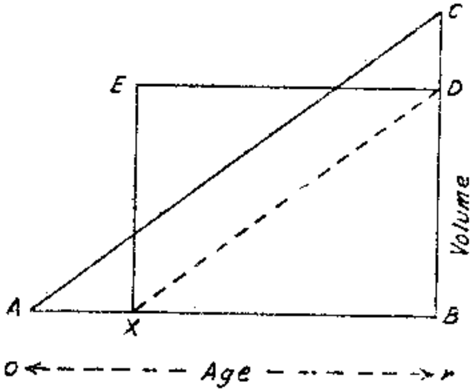

Fig. 11.3 Symthies' Modification

$Y=\frac{2V}{r-x}$. This is Symthies' modification of Von Mantel's Formula.

This pre-supposes the existence of normal G.S. below the age 'x' to supply the yield during the remaining 'x' years of rotation, which is a risky assumption.

(v) *Burma Modification* (B5) :

Like Howard's Modification, Burma Modification was also evolved as a special case in which enumeration and measurement of the G.S. was done down to one third rotation (corresponding to 1/3 exploitable girth/diameter as assumed), instead of half the rotation in Howard's.

Let V = Volume of G S. measured down to r/3 years

r = Rotation

Then the annual yield $Y=\frac{V}{4/9\,r}=\frac{9V}{4\,r}$

This can be proved geometrically as Howard's, or derived from Simmons' general formula :

$$Y=\frac{2Vn^2}{r\,(n^2-1)} \quad \ldots(i) \quad \text{or} \quad Y=\frac{2Vr}{r^2-x^2} \quad \ldots(ii)$$

In this special case $n=3$; $x=r/3$. Substituting values of 'n' in (i), we get :

$$Y=\frac{2\times V\times 9}{r\,(9-1)}=\frac{9V}{4\,r}$$

or, substituting value of 'x' in (ii) above, we get the same result, i.e.;

$$Y=\frac{2\times Vxr}{r^2-r^2/9}=\frac{9V}{4\,r}$$

Methods Based on G.S. and Increment (E)

Formula Methods (E1) :

(i) *Austrian Method or the Austrian Assessment Method* (E1–i) :

This method is reported to have originated in 1788, when an Austrian tax collector concerned with the assessment of woods for purposes of taxation, suggested a principle which came to be known as Austrian Formula. The broad-outline of the method is :—

(1) If the normal G.S is present in a forest then the *actual increment* should be removed as yield.

(2) If the actual G.S. is more than the normal, the excess over the normal should be removed over a period.

(3) If the actual G.S. is less than the normal, then less than the actual increment should be removed so as to bring the G.S. to normal over a period.

This period may be an *equalisation period*, to be determined with respect to local exigencies by the Working Plan Officer, or a *rotation*. The earlier the abnormality is removed the better ; it should certainly not be carried over to the next rotation. This idea is embodied in the following formula :—

$$Y=i+\frac{V_a-V_n}{r} \text{ : where}$$

Y = the annual yield

i = the increment

V_a = the actual G.S.

V_n = the normal G.S.

r = the period during which the difference between the normal and the actual G.S. is to be adjusted (it may be upto a rotation).

For use in this formula, the normal annual increment was taken to be the actual volume of the rotation-age age-gradation, the 'I' of Von Mantel's formula, and the normal G.S. was calculated from it as : N G.S. $=I\times\frac{r}{2}$. This, of course, suffers from a drawback that if the final age-gradation was excessive in relation to the rest, both the normal increment and the normal G.S. would be over-estimated.

In modern practice, the normal G.S and the increment may be obtained from the Yield Tables, and the actual G.S. from sample areas and the increment is taken as the sum of final m.a.i. of all the age-classes.

Historically, it was the first method which based the yield on a knowledge of increment and G.S. Its usefulness, however, depends on how this increment and G.S. are determined. It is based on the following premises :—

(a) If the stand is normal $V_a = V_n$, and Y=M.A.I.

(b) If the G.S. is normal, but the distribution of age-classes is irregular, the formula can still be used provided after felling the area is promptly regenerated, either naturally and/or artificially.

(c) If the actual M.A.I. is less than the normal M.A.I., and the G.S. is normal, only actual M A.I. and not the normal M.A.I. should be felled.

(d) If the G.S. is abnormal, it can be brought to normal by either cutting less than the normal M.A I., if V_a is too small, or cutting more than the M.A.I. if V_a is too large.

This method is applicable to both the regular and irregular forests. In its application to irregular forests, this method has the great disadvantage in that it assumes both the increment and normal G.S. as constants, while both are constantly changing according to the treatment given.

In regular forests, the normal G S. may be calculated from the Yield Tables, but in case of irregular forests, these figures are of doubtful value. Calculation with $I \times \frac{1}{2}$ is unsatisfactory in either case. This method does not take the age-class distribution into account.

(ii) *Heyer's Modification or Heyer's Formula* (E1–ii) :

In 1841, Karl Heyer of Bavaria suggested that calculation be based on actual mean annual increment (M.A.I. calculated over a short period of, say, 10 years) rather than on theoratical normal increment and also that the G.S. be brought to normal in a shorter period *(x)* than that of rotation—usually less than half the rotation. To do this, he estimated the increment of each age-class for a short period of, say, 10 years and recalculated his yield at the end of each such period. The formula reads : $Y = I_a + \frac{V_a - V_n}{x}$ or

$$\text{M.A.I.} + \frac{V_a \sim V_n}{x} ;$$

where I_a = actual increment of the forest, and 'x' the number of years in which the surplus or deficit is to be adjusted.

Later, Huber further modified this formula by substituting the C.A.I. for the M.A.I.

In Switzerland, the normal G.S. is calculated by the formula $I \times \frac{r}{2}$, or preferably $I \times r \times c$, where 'c' is Flury's Constant for the species, locality and rotation, and I the sum of measured C.A.Is. of various age-classes.

The length of the equalisation period 'x' is fixed with reference to local exigencies. If the timber is overmature, the tendency is to reduce the surplus rapidly. If a deficit exists, obviously the equalisation period cannot be shorter than the period necessary for the sum of annual increments during the period to balance the deficit.

Advantages :

(i) It is elastic, as there is a wide choice as regards the period over which the surplus or the deficit is distributed.

(ii) The ideal of the normal G.S. is kept clearly before the Working Plan Officer.

(iii) It is applicable both to regular and irregular forests; it clearly distinguishes between the *capital* (G.S.) and *income* (increment).

(iv) Its main use is as a check on other methods.

Disadvantages :

(i) As it disregards age-class distribution, it may lead to anomalous results ; it is artificial.

(ii) It ignores area and age, hence un-realistic.

(iii) Determination of actual M.A.I. in irregular forests, and for species which do not have distinct annual rings, is difficult, especially when successive enumeration data are not available.

Under Indian conditions the formula has to be suitably modified, as V_a represents the volume of G.S. enumerated over a diameter corresponding to a particular age (say, *p*) ; similarly the normal G.S., V_n, should be computed by deducting the volume of age-class 0-*p* years old. For irregular forests, under Indian conditions, $\text{M.A.I.} = \frac{V_a}{\text{mean age}}$. Mean age is computed by multiplying the number of trees enumerated in each dia. class by the corresponding ages, adding these and dividing by the total number of trees.

Heyer used his modification not for calculating the yield but for modifying his felling plan, which was made under the area allotment methods. His formula is largely used in unworked American forests, where V_a is more than V_n and its reduction to normal is important.

This formula was tried in Thano forests of Dehra Dun by M.P. Bhola in Thano Working Circle, covering Ram Nagar and Lambirau Blocks.

(iii) ***Hundeshagan's Method*** (E1–iii) :

It is based on the supposition that actual yield (increment) bears the same proportion to the actual (real) G.S. as the normal yield does to the normal G.S., i.e., $Y_r : G_r = Y_n : G_n$, where Y_r is the real yield, G_r the actual G.S., Y_n the normal yield and G_n the normal G.S.

$Y_r = G_r \times \frac{Y_n}{G_n}$. The quotient $\frac{Y_n}{G_n}$ is called ***Utilization Factor*** by **Hundeshagan**. *Utilization Percent* $= \frac{Y_n}{G_n} \times 100$.

G_r is determined by actual measurements, G_n and Y_n are obtained from the Yield Table. It differs from the Austrian Method in that there is no distinction between increment and the surplus G.S. in the calculation of yield.

If G_n is calculated from M.A.I., i.e., $G_n = \frac{r \times i}{2}$, and $Y_n = i$,

then : $Y_n/G_n = i/\left(\frac{ri}{2}\right) = 2/r$, or $Y_n = \frac{2G_n}{r}$ (same as Von Mantel's Formula).

If $G_r = 100$, then $Y_r = 200/r$ or $2/r$ percent—same as Masson's Ratio (Page 141).

Advantages and Disadvantages : Scope and Implications :

(i) The assumption, that the actual increment bears the same ratio to actual G.S. as the normal increment bears to the normal G.S., is doubtful and generally incorrect, as the rate of increment is determined *not* by volume of G.S., but its age, vigour and age-class distribution. A larger G.S. of over-mature trees may give smaller increment than a smaller G.S. of younger trees.

(ii) As in Austrian Method, and in Von Mantel's Formula, this method will give a yield even if there is no mature crop to fell, as it does not take age-class distribution into consideration; if the latter are fairly normally distributed, it will give satisfactory results.

(iii) It also does not take into consideration the surplus G.S., which may drag on indefinitely.

(iv) Under certain conditions an abnormal G.S. is likely to become more abnormal under this method; e.g., if the G.S. and the actual rate of increment are both deficient, a yield in the proportion of normal increment will still be obtained and, if prescribed, the G.S. will further be depleted

(v) For use in the even-aged forests, it requires the use of Yield Tables, which may not exist.

(vi) As with Von Mantel's Formula, a great advantage of the method over the Austrian Method is that it does not require the determination of the present real increment. This formula can be of great value if the yield is calculated annually or periodically, and altered according to actual conditions of the G.S.

(vii) It is mostly used as a check on other methods in irregular uneven-aged forests; its use in regular even-aged forests pre-supposes normal regulated Yield Table condition, which is not found in our forests.

(iv) ***Karl's Method*** (E1–iv)

In the Austrian Formula with Huber's modification, Karl made a further modification and considered the annual yield as equal to the C.A.I. ± the surplus or deficit of the actual G.S. over (or below) the normal G.S. distributed over a period of years 'a', instead of over the rotation; 'a' depending on silvicultural considerations.

$$Y = C.A.I. \pm \frac{G_a \sim G_n}{a}$$

The formula makes use of the actual C.A.I., which is difficult to determine in irregular forests and for species which do not possess distinct annual rings. Further, the C.A.I. varies from year to year. The above formula would be accurate only for the first year and would suffer from the same drawback as the Austrian, if the yield is not determined annually (which is impracticable) or at very short intervals (which is expensive). To avoid this difficulty, Karl introduced a third expression in the formula and, consequently, the formula reads as :

$$Y = C.A.I. \pm \left(\frac{G_a \sim G_n}{a}\right) \mp \left[\frac{C.A.I.\ (Actual) - C.A.I.\ (Normal)}{a}\right] \times n$$

where 'n' is the number of years which has elapsed since the last measurement was made. Karl proposes the adoption of 10-year periods for re-assessment of the yield and gives the value 5 to n (i.e., n=5) the middle of the period to get the average of the period. Judeich considers the third (last) expression in the above formula as not only incorrect but redundant in view of the 10-year revisions envisaged. Moreover, there is no justification for assuming that with an increase or a decrease of the G.S., the increment should also increase or decrease. On the other hand, when over-mature crops are replaced by vigorous young crops, the increment increases with the reduction of the G.S.

If the third expression is removed from the formula, it reduces to the Austrian formula, using C.A.I. instead of the M.A.I. for increment, with the suitable period for removal of the surplus. C.A.I. gives 10 to 20% more increment than the M.A.I., and a conservative removal of the G.S. demands the use of M.A.I.

(v) ***Breymann's Method*** (E1–v) :

This method is based on the same principle as Hundeshagan's formula It assumes that the actual yield bears the same proportion to the normal yield as the average age bears to the normal age of the crop; i.e., :

$\mathbf{Y : Y_n = A : A_n}$, or $Y = Y_n \times \frac{A}{A_n}$, where A=average age of the F.S.; A_n=Normal age of the F.S., i.e., ½ rotation; Y_n=Normal Yield (i.e. M.A.I. of the F.S.).

Average age can be determined in two ways :

(i) By considering the area of various age-classes and their respective average ages, as :

A (Average age)$= \frac{x_1a_1+x_2a_2+x_3a_3 \ldots}{x_1+x_2+x_3 \ldots}$, where x_1, x_2, x_3... are the areas occupied by various age-classes, and a_1, a_2, a_3 ..... their respective ages.

or (ii) By considering the volumes of various ages or diameter classes and their respective ages as :

A (Average age)$= \frac{V_1+V_2+V_3}{V_1/a_1+V_2/a_2+V_3/a_3}$, where V_1, V_2, V_3, etc., are volumes of various age/dia. classes and a_1, a_2, a_3 etc., their respective ages (i.e., total volume divided by Σ volume/age for each class).

Disadvantages :

(i) The surplus or deficit is distributed over the whole rotation, whereas its condition may necessitate early removal of the surplus; in case of deficit, it is always necessary to bring the crop to normal as early as possible.

(ii) The formula will give the same yield even if the younger age-classes occupy proportionately more area than older ones, or the latter ones even absent.

(iii) The data required is difficult to ascertain correctly in the irregular forests for which it was originally devised.

The formula is of little practical value.

HUFNAGL'S METHOD (E2) :

Variation I : Hufnagl's formula for yield is :

$Y = \frac{V+(a \times i \times r/4)}{r/2}$, where V is the volume of the crop of the age half rotation and over, 'a' the area occupied by that crop, 'i' is final m.a.i. (per unit area) and 'r' the rotation. For increment c.a.i. can also be used; in that case c.a.i. for each year over r/2 years is measured (or taken from the Yield Tables) and their sum gives the increment. The m.a.i. gives more conservative yield than the c.a.i.

This is based on the premises that if to the volume of the crop above half the rotation age is added the increment over a quarter of the rotation (average of the period, i.e., one half of r/2 years), a sustained yield can be obtained for half the rotation (r/2 years). In this case, yield is calculated by taking the volume and increment of crops above r/2 years age.

This method is applicable to regular or semi-regular crops, such as we generally have in India. The differentiation between the crop of half rotation and above, and the rest, is simple and the increment can be determined easily.

Variation II : In this case also the annual yield is equal to the volume of r/2 years old trees and over, *plus* their increment for r/4 years, and the result divided by r/2. It is expressed as a formula as :

$Y = \frac{V+(V \times i \times r/4)}{r/2}$, where 'i' is the c.a.i. per unit volume (*not* per unit area as in Variation I), and V the volume of the half rotation age crop and above. The theory behind this is the same as in Von Mantel's Formula. It can be shown that during half the rotation, the yield which is removed consists of 3/4th in the existing G.S. and 1/4th in the increment put on by it in r/4 years.

Diameter at breast height corresponding to half the rotation is determined by Stump/Stem Analysis, or in any other way, and all the trees of and above this diameter are measured in suitable diameter classes and their volume computed with the help of Volume Table.

This method is suited more to irregular forests where trees of all ages are mixed together. It was used by Trevor for calculation of Yield in the Selection forests of Kulu Forest Division (H.P.).

Methods Based on Diameter Classes

(i) *French Method of 1883* (E3–i) :

This method is sometimes called the ***Quartier bleu*** method of yield regulation in irregular forests. It was primarily designed for regulating the yield of tolerant species, serving a semi-protective purpose. It is based on the conception that a normal selection forest is like a normal even-aged forest, the only difference being that the various ages, instead of occupying separate areas, were intermingled. In other words, the normal G.S. of a Selection forest can also be represented by a triangle, say ABC, as in Fig. 11.4. The procedure is as follows :—

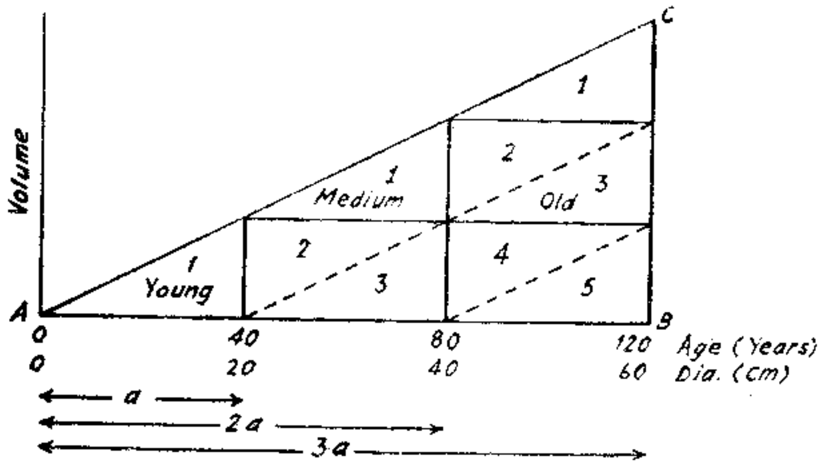

Fig. 11.4. "French Method of 1883"

(i) Determine the exploitable diameter, in accordance with the objects of management.

(ii) Ascertain the rotation corresponding to this diameter, by Stem Analysis, or otherwise, adding a few years for establishment of regeneration.

(iii) Divide the G S. into three dia./age classes ; the *Old* class with trees corresponding in diameter from 2/3 to full exploitable diameter, the *Medium* class with trees ranging in diameter from 1/3 to 2/3 of the exploitable diameter and the *Young* class with trees less than 1/3 of the exploitable diameter.

(iv) Enumerate the first two classes of the G.S , i.e., the *Old* and *Medium* woods.

Then if the volumes of *Old* and *Medium* classes are in the proportion of 5 : 3, the forest was to be considered as normal and the two classes were like the first two P.Bs. of an even-aged forest divided into 3 P.Bs., in which the average of the ages is in the proportion of 1 : 3 : 5 (in Fig. 11.4, these are 20, 60, 100 years). The base AB representing the age (0–120 years) is divided into three equal parts (0–40, 40–80 and 80–120 years), instead of two in Howard's Modification of Von Mantel's formula. Draw perpendiculars and parallels to AB and AC as shown, dividing the N.G.S. triangle into three parts, representing the volumes of *Young*, *Medium* and *Old* crops, which are 1/9th, 3/9th and 5/9th of the whole, respectively, or in the proportion of 1 : 3 : 5, as illustrated geometrically in Fig. 11.4. Then, if the volumes of *Old* and *Medium* classes are 5 : 3, the proportion may be considered normal (the *Young* crop is not enumerated), and the *Old* class could be removed during 1/3rd of rotation. For illustration (Fig. 11.4), rotation is 120 years, exploitable diameter 60 cm, the volume of *Old* wood, 80–120 years class (40–60 cm dia. class), with or without increment, could be removed in 40 years ; just as in case of Van Mantel's formula we found that half the crop (r/2 to r year class) was removed in half the rotation. This is expressed as a formula :

$$\text{Yield in } r/3 \text{ years} = V_o + \frac{V_o \times t_1 \times r/3}{2}, \text{ or}$$

$$\text{Annual yield } Y_a = \frac{V_o}{r/3} + \frac{V_o \times t_1}{2}, \text{ where}$$

Y_a = Annual Yield ; V_o = Volume of *Old* class.
t_1 = Increment per unit volume per annum of old class.
r = Rotation.

This method of yield regulation could be applied to forests worked under Selection System, and also those worked under Irregular Shelterwood with a long regeneration period, extending over 1/3rd of rotation ; and even to regular forests as well.

Discussion of the Method : As already stated, this method is based on the conception that a normal Selection forest is just like a normal even-aged forest, except that the age-gradations are intermingled ; and it can also be represented by a N.G.S. triangle (Fig. 11.4). In case of Selection forest, however, annual yield can be only in terms of mature trees scattered all over the area, without any limit of the area; hence the yield has to be regulated by volume. In theory, the volumes of *Young*, *Medium* and *Old* classes (corresponding to below 1/3r, 1/3 to 2/3r, and 2/3 to r years ages, respectively) in a normal Selection forest are in the proportion 1 : 3 : 5 ; and while enumerating these classes an assumption is made (though not necessarily correct) that diameter is directly proportional to the age.

Although the proportion of the volumes of *Old* and *Medium* classes, V_o and V_m, may be normal (i.e , 5 : 3), the total volumes of these classes may be too large or too small (than the normal). This must be compared with the Yield Table figures or checked by other means.

The method is simple when the proportion of the *Old* and the *Medium* wood is 5 : 3, or nearly so, but this is seldom found in practice. Moreover, in several cases their volumes may not be normal. Let us examine the various situations. Suppose V_o is the volume of old class and V_m the volume of medium class. The various possibilities are :—

(1) V_o+V_m normal ; and

(i) $V_o : V_m=5:3$. In such a case, the yield may be determined directly, i.e., volume V_o and its increment during one-sixth of rotation divided by 1/3rd of rotation.

or (ii) $V_o : V_m \gtrless 5:3$

(a) If V_o is greater in proportion than V_m, the crop in V_o is examined and by transferring the lower diameter trees to V_m the proportion of 5 : 3 is adjusted.

(b) If V_o is less in proportion to V_m, the medium crop V_m is examined and by transfe ing the upper diameter trees to old crop, V_o, the proportion of 5 : 3 adjusted.

(2) $V_o+V_m<$normal ; and

(i) $V_o : V_m=5:3$. In this case the whole G.S. is deficient and needs to be built up. Therefore, in the first third of the rotation only very old and decrepit trees from V_o may be removed. The trees which would last through the period should be left standing. If the deficiency is not very great, it may be possible to bring the G.S. to normal just by not removing the increment.

(ii) $V_o : V_m \lessgtr 5:3$. Volume V_o or V_m may be deficient. Practically nothing should be removed from V_o except the dead and dying trees ; of course nothing will be removed from V_m.

(3) $V_o+V_m>$normal. The only possibility in this case is that V_o is greater in proportion to V_m than 5 : 3. In this case the excess in the G.S. (V_o+V_m) over the normal has to be removed from the old crop. This surplus has to be removed in addition to the normal calculated yield for one-third of the rotation.

Originally, the increment put on by the crop during the period of its removal was not added to the yield. It was, however, felt that ignoring the increment made the yield too conservative, and the increment put on by the old crop (V_o) during half the period of its removal (1/2 of r/3=1/6th r) was added to the yield, as shown in the formula above.

The original instructions of the French Foresters stipulated that in Selection working : (i) the length of the felling cycle should be a sub-multiple of rotation, (ii) the number of coupes should be equal to number of years in the felling cycle, (iii) the local forester should be free to allot the annual yield to each coupe according to local requirements at the time of felling, and (iv) the yield should be revised at the end of each felling cycle.

In Shelterwood Working, the area occupied by the old crop was to be further divided into sub-periods, each a sub-multiple of the one third of the rotation. The Working Plan was to be revised at the end of this sub-period ; therefore, the period was to be neither too long nor too short. The area containing the largest proportion of over-mature and deteriorating trees was to be worked first. This *period* was to be further sub-divided into Units, each capable of giving the annual yield.

(ii) *1894 Modification of French Method--Melard's Formula* (E3–ii) :

In the formula already given, we have considered only the final yield, i.e., the yield from the old wood, V_o. But in a Selection forest it is impossible to distinguish between the *final yield* and the *intermediate yield* by area, since both classes of yield are obtained from the same area, simultaneously. Thinnings being a silvicultural operation, great caution and elasticity are needed in prescribing their yield. To the final yield is added a fraction of the increment on the *Medium* wood (Volume of the *Young* wood, V_y, being ignored for thinning yield prescription as being too small).

Intermediate Yield $= 1/n\ (V_m \times t_2)$ where :

V_m = Volume of the *Medium* class

t_2 = Increment per unit volume per annum on V_m

n = A factor varying according to circumstances.

The French official instructions suggested the following values for the coniferous forests to which the formula was usually applied :

$t_1 = 0.01;\ t_2 = 0.03;\ n = 3$

So the formula for the total yield comes to :

$$Y = \left(\frac{V_o}{r/3} + \frac{V_o \times t_1}{2}\right) + \frac{1}{n}\ (V_m \times t_2).$$

This 1894 Modification of French Method was suggested by Melard, and is also known as Melard's Formula.

While the original method was primarily designed for Selection forests, the revised formula (1894 Modification) is applied to forests worked under Shelterwood System, with a long regeneration period extending to 1/3rd of rotation.

The French deprecate any large transfers involving silvicultural sacrifice in order to adjust the proportion between the *Old* and the *Medium* woods. The co-efficients t_1, t_2 and n, which are derived from knowledge of the forests, provide the necessary variables, in the calculation of yield and may be taken advantage of to bring the forests to normality.

When marking for felling, thinnings and improvement fellings are first marked (from *Medium* class) and the volume of these *plus* that of any windfalls deducted from the possibility. The balance is then marked in final fellings from the *Old* class, or regeneration fellings in Shelterwood System, in the *Old* block (Regeneration Block : ***Quartier bleu***). This method is, sometimes, known as ***Regeneration Area Method*** also. This method is probably less suitable for Selection forests than those based on C.A.I. It differs from the formula methods (given under E1) that it does not strictly follow any theory of relationship between G.S. and Yield. It is elastic and

gives free hand to the Silviculturist within the limits of the prescribed yield.

An example of its application in a French Forest, quoted by Jerram, is given below :

Example : Species Beech and Silver Fir ; Worked under Selection System—on a rotation of 150 years ; Area of the F.S. 376 hectares.

VOLUME INVENTORY—ACTUAL AND NORMAL

	Actual (m^3)	*Normal* (m^3)	(+)	(−)
Old wood (V_o)	63,523	75,200	——	11,677 m^3
Medium wood (V_m)	48,217	45,120	3,097 m^3	——
Total	1,11,740	1,20,320	——	8,580 m^3

The forest is abnormal ; *Old* wood is considerably deficient and *Medium* wood slightly in excess. In this case, however, the method of *transfer/shifting* was not adopted ; instead, increment on V_o was placed at a low figure of 0.75% per annum (p.a.) and the *Medium* wood being in excess and of vigorous growth, its increment was placed at 2.5% p.a., and 'n' was placed equal to "2" instead of "3". The formula for calculation of the yield gives the following result :

From *Old Wood* *Medium Wood*

$$\text{Annual Yield} = \left(\frac{63{,}523}{50} + \frac{63{,}523 \times 0.0075}{2}\right) + 1/2\ (48{,}217 \times 0.025)$$

$$= (1{,}270.5 + 238.2) + 603 = 1509 + 603 = 2{,}112\ m^3.$$

By the Alternative Method :

Place n = 3 and transfer (if possible) 3,097 m^3 from *Medium* to *Old* class, so that $V_o = 66{,}620\ m^3$ and $V_m = 45{,}120\ m^3$, then : Annual Yield works out to :

$$= \left(\frac{66{,}620}{50} + \frac{66{,}620 \times 0.0075}{2}\right) + 1/3\ (45{,}120 \times 0.025)$$

$$= (1{,}332 + 250) + 376 = 1{,}582 + 376 = 1{,}958\ m^3$$

Let us compare these results with that given by Simmons' Modification (B3) of Von Mantel's formula : $Y = \frac{2\ V\ r}{r^2 - x^2}$ (Page 144) where 'V' is the volume of the enumerated G.S. down to 1/3rd rotation, i.e., 'x' = r/3. Substituting values of 'V', 'r' and 'x' :

$$\text{Yield} = \frac{2\times 111{,}740\times 150}{(150\times 150)-(50\times 50)} = 1676\ m^3.$$

The same result would be obtained by Burma Modification of the formula (Page 146) which is a special case of Simmons' general formula, where the G S. is enumerated down to one-third of rotation, i.e., 'x' = r/3. Annual Yield $= \frac{9}{4}\frac{V}{r} = \frac{9\times 111{,}740}{4\times 150} = 1676\ m^3$.

Since this formula does not take into account the intermediate yield from thinnings, consequently, the result is comparable only with the yield from *Old* wood in the French Method. Moreover, unlike the French Method, it takes into account only the quantity of G.S. and not the proportion of classes

ADVANTAGES OF THE FRENCH METHOD (1883) AND ITS MODIFICATION (1894)

Advantages :

(1) Yield is in accordance with the condition of the crop.

(2) The method leads the forest to normality.

(3) It is elastic and quite accurate; has worked well in practice.

Disadvantages :

1. Measurements have to be carried out down to 1/3rd rotation and, therefore :—

   (i) In short rotations these may have to be taken down to diameters which are very small.

   (ii) Sometimes these may result in taking measurements down to decimal fractions of centimetres.

   (iii) Diameters corresponding to 1/3rd rotation may not fit into standard dia classes (5 or 10 cm) in which measurements are usually taken

2. Dia. limit will change with site and change in rotation.

3. Diameters are not exactly proportional to ages, as has been assumed, specially in Selection forests.

(iii) *Smythies' Modification—1925* (E3–iii) :

In the French Method, 'r' was divided into three equal parts (Young, Medium and Old), and if volumes of *Old* and *Medium* crop were in the ratio of 5 : 3, the crop was considered to be normal and annual yield could be fixed as : $Y = \frac{V_o}{r/3}$ + increment

on V_o for one year. If the proportion was abnormal, yield was calculated the same way after bringing the proportion nearer to normal after necessary shifting. While discussing disadvantages, it has also been mentioned that since enumerations had to be taken down to 1/3rd rotation, the limit would change with every change in rotation, and will be different for different qualities. It would be impossible to work in practice with varying odd diameter limits. Smythies felt that in French Method of 1883, fixing of unmerchantable (un-exploitable) volume at upto 1/3rd rotation was purely arbitrary. In most of the U.P. Sal forests, 30 cm dia. limit is considered the limit of unmerchantable volume and this diameter will be obtained (in regular crops) in 27, 37 or 47 years, in site qualities I, II, or III, respectively. Smythies tried to put the underlying idea of the French Method (1883) into general terms and find the proportionate volumes of three classes of wood (*Old, Medium* and *Young*) where the young (or unexploitable/unmerchantable) is upto any fraction of rotation 'r', instead of '1/3 r'. We can then enumerate down to a standard diameter (irrespective of rotation or quality) and yet ascertain whether the proportion between the *Old* and *Medium* wood is normal or not (proportion will be constant for a normal forest, whatever the Site Quality or Rotation), and yield calculated accordingly.

In Fig. 11.5, ABC represents the normal G S. triangle, representing a forest worked on rotation 'r' and enumerated down to any unexploitable/unmerchantable diameter limit corresponding to age, say, 'x' years. AB represents the age 0 to 'r' years. and AE the age-class 0 to 'x' years (young/unexploitable wood). EB represents the age (r − x) of the rest of the G S., which Smythies divided into two equal parts, EG and GB, each $\frac{r-x}{2}$ years. Perpendiculars DE and FG are drawn on AB. Let DE = y. Now the G.S. is divided into three age-classes as :—

(i) Volume of Young Wood (V_y) represented by triangle ADE $= \frac{1}{2}$ xy.

(ii) Volume of Medium Wood (V_m) represented by figure DEGF.

(iii) Volume of Old Wood (V_o) represented by figure FGBC.

Triangles AGF and AED are similar, therefore :

$$\frac{FG}{AG} = \frac{DE}{AE} = \frac{y}{x}\ ;\ \text{or}\ FG = AG\times\frac{y}{x} = \left(x+\frac{r-x}{2}\right)\times\frac{y}{x} = \frac{y}{2x}(r+x)$$

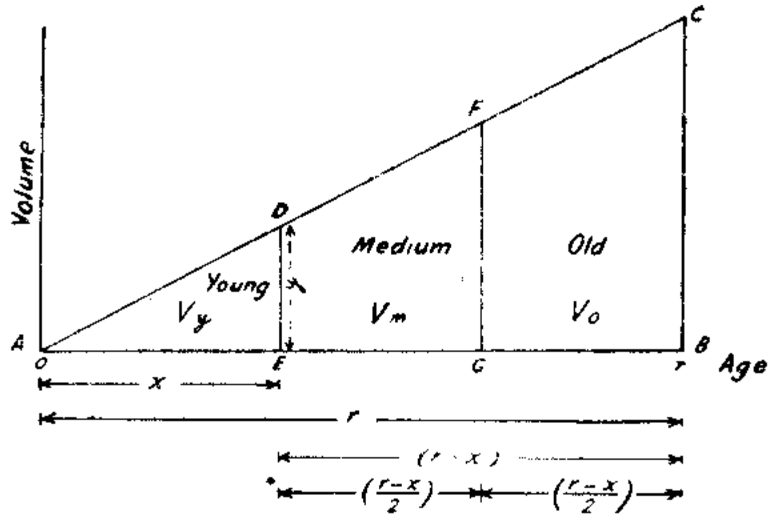

Fig. 11.5. Smythies' Modification of French Method

Similarly $BC = AB \times \frac{y}{x} = \frac{r\,y}{x}$.

$$AG = AE + EG = x + \frac{r-x}{2} = \frac{r+x}{2}$$

$$\text{Triangle } AFG = 1/2 \times FG \times AG = 1/2 \left[y/2x\ (r+x) \times \frac{(r+x)}{2} \right]$$

$$= \frac{y\ (r+x)^2}{8\ x}$$

$$\text{Triangle } ABC = 1/2 \times BC \times AB = 1/2 \left(\frac{r\,y}{x} \times r \right) = \frac{y\,r^2}{2x}$$

$$\text{Figure } DEGF = \triangle AFG - \triangle ADE = \frac{y(r+x)^2}{8x} - \frac{x\ y}{2}$$

$$= \frac{y}{8x}\ (r+3x)\ (r-x)$$

and Figure $FGBC = \triangle ABC - \triangle AFG$

$$= \frac{y\,r^2}{2\,x} - \frac{y\ (r+x)^2}{8x} = \frac{y}{8x}\ (3r+x)\ (r-x)$$

Hence the proportion of three classes is :

$$\triangle ADE : \text{Fig. } DGEF : \text{Fig. } FGBC = \tfrac{1}{2}xy : \frac{y}{8x}(r+3x)\ (r-x) :$$

$$\frac{y}{8x}\ (3r+x)\ (r-x) = 4x^2 : (r+3x)\ (r-x) : (3r+x)\ (r-x)$$

This is a simple proportion **in terms of two known quantities** '**r**' **and** '**x**'.

If $x = 1/3r$, this proportion becomes 1 : 3 : 5 (French Formula)
If $x = 1/2r$, this proportion becomes 4 : 5 : 7 : and if
$x = 1/5r$, it will be 1 : 8 : 16.

Advantages of Smythies' Modification :

We need not define exploitable wood as proporsional to 1/3 rotation and enumerate accordingly. We can enumerate down to what is actually exploitable in a locality ; and having determined 'r' and 'x' of our enumeration limits, we can divide the enumerated G.S. into two portions and calculate the normal proportion between them. If the actual forest is more or less normal, the calculation of the yield becomes the volume of *Old Wood* divided by the period of exploitation, i.e., $\frac{r-x}{2}$ years, ***plus*** **its increment for half of that period** ; i.e. $Y = \frac{V_o}{\frac{r-x}{2}} + 1/2\ (V_o \times i)$, **where i = annual increment per unit volume for V_o, the old wood.**

(It may be noted that Smythies' Modification of Von Mantel's formula, in which case G S. is enumerated down to 'x' years age also stipulates the yield as $Y = \frac{2\ V}{r-x} = \frac{V}{\frac{r-x}{2}}$, **same as above except that in the above case 1/2 of the increment for the year has also been added).**

Disadvantage :

It is not convenient in the field. The highest dia. limit for the *Old* wood is fixed by rotation, and even if the lower limit is fixed at, say, 20 cm, it is not possible to fix the next dia. limit of enumeration for calculation of volume of *Medium* wood, i.e., V_m. Moreover, neither of these two limiting diameters may coincide with 10 cm, the dia. class in which we usually carry out enumeration.

Example : Rotation = 90 years **and corresponding dia** = **50.4 cm. Lower dia. = 20 cm. According to modification, the** *Medium* wood is 20 cm to 35.2 cm dia. class, and *Old* wood 35.2 cm dia. and above.

The dia. limit does not fit in standard dia. classes.

4. ***Chaturvedi's Modification*** — 1927 (E3–iv) :

Chaturvedi showed that in a normal forest, ratio between V_y (vol. of young crop), V_m (vol. of medium crop) and V_o (vol. of old crop) is given by the following relationship (Fig. 11.6).

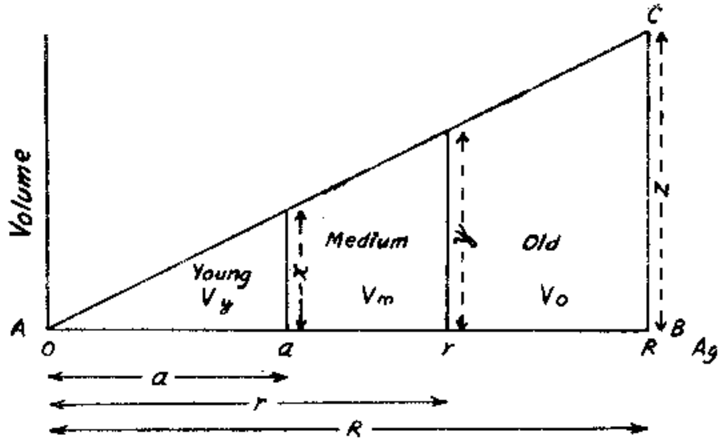

Fig. 11.6. Chaturvedi's Modification of French Method

$$V_y : V_m : V_o = ax : ry - ax : RZ - ry$$

Because $V_y = \frac{ax}{2}$; $V_m = \frac{ry}{2} - \frac{ax}{2}$ and $V_o = \frac{RZ}{2} - \frac{ry}{2}$

Since $\frac{x}{a} = \frac{y}{r} = \frac{Z}{R} = c$ (say), because of similar triangles, $x = a\,c$; $y = r\,c$ and $Z = R\,c$ Substituting these values in the above : $V_y : V_m : V_o = (a \times ac) : (r^2c - a^2c) : (R^2c - r^2c) = a^2 : (r^2 - a^2) : (R^2 - r^2)$.

Chaturvedi contended that if this relationship exists, the forest will be normal, whatever the values of 'a' and 'r'. Thus the enumerations could be taken down to whatever limits considered profitabe—the age corresponding to this would be 'a'. The value of 'r' may be made to correspond with any age to retain the 10 cm dia. class enumeration. The youngest wood, V_y, is not measured. If the proportion between V_m and V_o (*Medium* and *Old* wood) is normal—after making adjustments, if necessary—the annual yield is given by the formula :

$Y = \frac{V_o}{R - r} + 1/2\ (V_o \times i)$, where 'i' is the increment per unit volume per annum of the old wood, V_o.

Example : Rotation = 150 years, corresponding dia. = 60 cm.

Enumeration carried out down to 20 cm dia. limit, corresponding to 40 years age. Distribution of G.S. in various dia. classes is as :

Dia. Class	*Volume*
20–30 cm	V_1 m³
30–40 cm	V_2 m³
40–50 cm	V_3 m³
50–60 cm	V_4 m³

The position of 'r' may be fixed anywhere to coincide with one of the 10 cm classes. Let 'r' be the age corresponding to 40 cm dia. and let it be = 90 years. The normal proportion between the *Medium* crop (V_1+V_2) and the *Old* crop (V_3+V_4) can be determined by substituting the values of 'a', 'r' and 'R' in the general formula :

$a^2 : r^2 - a^2 : R^2 - r^2$ or $40^2 : 90^2 - 40^2 : 150^2 - 90^2$ or $16 : 65 : 144$. Omitting the young crop, the rest of the G.S. is normal if $(V_1+V_2) : (V_3+V_4) = 65 : 144$ (say, 4 : 9, roughly).

The annual yield $= \frac{V_3+V_4}{R-r}$ + annual increment on (V_3+V_4) for half the year.

CHAPTER XII

YIELD REGULATION IN IR-REGULAR FORESTS

(a) Yield Based on G.S. only (B) :

1. ***Von Mantel's Formula and its Modifications*** **(B1–B5) :**

These have been discussed alre.. y in Chapter XI—***Yield Regulation in Regular Forests*** (Page 139). The formula (without modification) was applied in Selection Working Circle of Mt. Stuart forests; wherein exploitable girth was $=7\frac{1}{2}$ ft., corresponding rotation$=$ 160 years ; felling cycle$=$40 years ; 2/5th of the crop was mature or over-mature, and removal of over-mature timber was spread over the entire rotation. The yield was calculated as : $Y=\frac{V_o}{R}+\frac{V_r}{1/2\ R}$,

where V_o=volumes of G.S.$>7\frac{1}{2}$ ft. girth,

V_r=volume of remainder of the enumerated stock ;

R=Rotation.

Simmons' Modification (Yield$=\frac{2\ V\ r}{r^2-x^2}$; page 143) was applied in Sal forests of North Kheri (U.P.) and fir forests of N.W.F.P. by Gotley ; Yield was estimated as check, in terms of percentage of G.S.

2. ***French Method of 1883 (E3–I)*** **:**

This has also been dealt with in detail already in Chapter XI–***Yield Regulation In Regular Forests.*** There is difficulty in tallying of trees down to 1/3rd exploitable diameter. It is best adopted to high diameter limits, in long rotation Selectio nforests. It is elastic.

1894 Modification of French Method (E3–Ii) **:**

(Also refer to page 157)

Original method of 1883 did not provide for removal of increment on Old and Medium classes of trees ; this resulted in accumulation of surplus G.S. This modification provided for removal of total increment on *Old* wood (V_o) and a fraction of the increment

on *Medium* wood (V_m) to be removed in thinnings. With usual connotations, the formula is :

$$Y=\left(\frac{V_o}{r/3}+\frac{V_o t_1}{2}\right)+1/n\ (V_m \times t_2).$$

The method is elastic. All removals count towards yield. It can be adopted in Irregular Shelterwood System and Floating P.B., ***Quartier bleu*** ; it includes thinnings in *Q.* ***blanc.***

(b) Yield Based on Increment only (D) :

1. *Increment Method* **(D1) :**

This method is based on the premise that the yield must be cor-related with the increment throughout the life of the crop. The formula is :

$$Y=\frac{V+a-V_n}{n}$$

where ; Y=Annual Yield ; V=Present volume, V_n=Volume 'n' years ago ; 'a'=Volume removed during the previous 'n' years.

The yield will be equal to the increment, if the forest is normal in all respects ; not so in an abnormal forest. If the proportion of young and middle-aged classes is abnormally high or low, as compared with mature or over-mature classess, the c.a.i. will be correspondingly high or low, respectively. This situation will call for modification of yield according to conditions of the crop, not on the basis of any formula but on the basis of local knowledge and experience. If this is neglected, an abnormal G.S. may become more and more abnormal, both as regards volume and age-class distribution.

The method is applicable to ir-regular forests of small extent where the entire G.S. can be measured frequently, say every fifth or tenth year, and the crop condition examined correctly. Following example quoted by Jerram from Schlich's Manual of Forestry, Vol. III, will illustrate the application of this Method.

(This is a simplified form of Biolley's *Methode-du-Controle*, page 171), which distinguishes between the apparent and the real increment of each class, obtaining the latter by deducting from the former the increment resulting from the trees which have moved up from the class next below. Brandis' and Hufnagl's methods, described subsequently, are also based on the measurement of the current increment).

INVENTORY PER ACRE IN A SELECTION FOREST

Dia. class (Inches)	1st Inventory: No. of trees	Average Vol. per tree (cft.)	Total Vol. (cft.)	2nd Inventory after 10 years: No of trees	Total Vol. standing (cft.)	Vol. of trees cut during 10 yrs. (cft.)	Total Vol. (cft.) (6+7)	Increment (cft.)
1	2	3	4	5	6	7	8	9
(IV) 6–12	90	10	900	90	900	200	1,100	200
(III) 12–18	40	25	1,000	41	1,025	400	1,425	425
(II) 18–24	15	60	900	21	1,260	120	1,380	480
(I) 24–30	5	140	700	9	1,260	140	1,400	700
	150	—	3,500	161	4,445	860	5,305	1,805

The proportion of volume in higher dia. classes being too low, it will be necessary to make a conservative estimate of yield. 860 cft. has been cut out, representing only 2% per annum on the average volume, whereas the new inventory indicates that the increment has been about 4 1% per annum, as follows :—

From *Pressler's Increment Formula* :

$$\text{C.A I. \%} = \frac{V-v}{V+v} \times \frac{200}{n} = \frac{1{,}800 \times 200}{10\,(5{,}300+3{,}500)} = 4.1\%$$

The distribution of age-classes is now better proportioned, but still short in higher diameter classes, indicating that the policy of building up G.S. by cutting less than the increment and conserving trees in the higher dia. classes, must be continued. It will be noted that the number of trees cut in the last 10 years are : I Class, 1 ; II Class, 2 ; III class, 16 and IV Class, 20.

2. *The Swiss Method* (D2) :

According to this method, only the annual increment is to be removed from the oldest diameter classes as the yield. No particular method of determining the increment is prescribed. The formula is :

$$\text{Annual Yield} = \frac{Y+Z}{c.c.}, \text{ and } c.c. = \frac{Y+Z}{Xi+Yi+Zi}$$

where X = Volume of the diameter classes *below* the fixed dia. limit.

Y = Volume of the dia. classes *above* the dia. limit and upto the limit upto which the c.a i. is considered satisfactory.

Z = Volume of the dia. classes above the satisfactory dia. limit (i.e , the surplus G.S.).

i = The c.a i. of various dia classes.

c.c. = The period during which the volume of the oldest dia. classes should be removed, or the *cutting cycle*.

Since 'Z' is surplus G.S , it should not be taken into consideration in calculation of the c.c , nor should its increment. Therefore $c.c. = \frac{Y}{Xi+Yi}$, and $\text{Yield} = \frac{Y+Z}{c.c.}$ or $\frac{Y+Z}{Y} \times (Xi+Yi)$. As the c.c. will be small due to leaving out 'Z', the yield will increase. In addition to the increment of 'X' and 'Y' trees, something more will be removed and that would be out of 'Z'.

The c.a.i. can be determined by Pressler's or any other formula.

For the application of this method, essential requirements are :—

(i) Stand and Volume Table.
(ii) Measurement of the G.S. and increment at short intervals of 5 to 10 years, in the same manner.
(iii) Exact determination of the c.a.i.
(iv) The composition of the dia. classes should be as near normal as possible.
(v) Any increase or decrease in the G.S. at each revision must be offset by increasing or decreasing the yield for the next period.

The method is applicable to Selection forests of comparatively small extent where frequent measurements are possible.

Example : From the data in Treror's Revised Working Plan for Kulu Forest Division, Yield may be calculated (for *Deodar* in *Selection* W.C.) as follows :—

The Volume and increment data for deodar are :—

Dia. class (inches)	Volume (cft.)	C.A.I %	Increment (cft.)	Classification (in ii case of example).
12–17	554,620	4.2	22,748	
18–23	737,424	2.2	16,225	X
24–26	531,825	1.9	10,106	
27–29	554,434	1.1	5,999	
30–32	589,176	0.26	1,531	Y
33–35	563,310	0.20	1,127	
36–38	591,221	0 15	886	
39 and over	1,852,500	0.10	1,852	Z

(i) Trees of 12″ dia. and over count towards yield, and 17″ is the dia. limit.

Volume of 12–17 inch dia. class (X)=554,620 cft.
c.a.i. on 'X' (from table)=22,748 cft. (Xi).

$$\left.\begin{array}{l}\text{Volume of 18–23 inch dia class}=737{,}424\\ \text{Volume of 24–26 inch}\ ,,\ \ ,,\ =531{,}825\end{array}\right\}=1{,}269{,}249\text{ cft (Y)}$$

If c.a.i. upto 26″ dia is considered satisfactory, increment on 'Y' from the above table=26,331 cft. (Yi)

Volume of trees 27–39 inch dia. and over=4,150,641 cft (Z)

$$\text{c.c.}=\frac{Y}{Xi+Yi}=\frac{1{,}269{,}249}{22{,}748+26{,}331}=25 \text{ years (rounded off).}$$

$$\text{Annual Yield}=\frac{Y+Z}{\text{c.c.}}=\frac{1{,}269{,}249+4{,}150{,}641}{25}=216{,}796 \text{ cft.}$$

or 216,800 cft.

(ii) If the dia. limit is 26″ and c.a i. percent is taken as satisfactory upto 35″, then "X", "Y", and "Z" would be as indicated in the above table, and the calculation will be :—

$$\text{c.c.}=\frac{Y}{Xi+Yi}=\frac{1{,}706.920}{49{,}079+8{,}657}=30 \text{ years (rounded off)}$$

$$\text{and the Annual Yield}=\frac{Y+Z}{\text{c.c.}}=\frac{4{,}150{,}641}{30}$$

=138,354 cft., or 138, 350 cft.

(iii) If the dia. limit upto which c.a.i. is considered as satisfactory is taken as 29″, then the c.c. works out to 10 years and the annual yield three times of that calculated above in case (ii).

It is obvious that the yield depends not only on the diameter limit but also, to a great extent, on what dia. limit the increment is considered satisfactory.

3. *Biolley's "Check Method"—Methode-du-Controle (D3)* :

Check Method of control is, really speaking, no separate method, but merely a more precise and specific procedure. It is considered an improved kind of Forest Management by which all parts of a forest are brought to the highest state of productivity, and in perpetuity. The check lies in reviewing the yield by estimating the increment of the crop periodically. It is a method which endeavours to lead a crop to highest production by *silviculture* and *increment* combined. This revolutionary method in the management of Selection forests is associated with the name of Henri Biolley. It was Gurnaud who first conceived the idea which was later developed by Biolley. Favre (1943) calls this method "a management-plan procedure applied to the treatment of forests."

The principle behind the method is that the composition and distribution of the G.S. can be moulded ; and, by correct harvesting the timber production can be improved. To be precise, all fellings must be cultural operations. Every time the fellings are due, it has to be checked whether the composition has to be altered, and G.S. increased, decreased or maintained so as to have it in a state of maximum productivity. The yield is of secondry importance and only regulates the income to the owner, and not the cultural operations which may be necessary in the forest. It provides a check on fellings, but does not prescribe the nature of fellings.

In Biolley's Method, *Silviculture* is given paramount importance and a balanced distribution of all age-classes is envisaged in Selection forest (for an ideal distribution of size classes, he considered that the volumes of small, medium and old classes should be, approximately, in the ratio of 20 : 30 : 50). Biolley considered *Silviculture* to be the king-pin and as such it should not be relegated to a position subordinate to that of management. On the other hand he considered *Management* subservient to Silviculture, though he regarded both these as two facets of Forestry, with the common objective of securing *sustained yield.*

This is also a method which is described as a *Silvicultural System,* with an indication/prediction of yield ; it is a method primarily of *yield prediction,* rather than of *yield prescription.*

A great deal has been written about this *Check Method*—Biolley's *Method of Control* As a complete application of Selection System it can only be applied to forests of species which thrive in an all-aged composition, but the method of yield control, or rather of yield prediction, which he devised as part of it can be used with any form of forest treatment, except those involving clear felling.

Biolley was obsessed by the idea that trees of all sizes growing together all over a forest can make better use of all levels of soil for water and salts, and of all levels of the atmosphere for carbon assimilation, than even-aged stands on different parts of it. He also believed in measuring the increment of his forests rather than calcuting it from formulae. Biolley, in fact, rejected all conventional ideas of rotation, exploitable size and normal G.S. distribution, and decided to leave all well-shaped, vigorous trees to grow as long as they remained vigorous and did not have potentially better replacements. He regarded the forest as a *laboratory* and management as the study of results obtained therein, and that a Working Plan should incorporate periodic conclusions drawn from experiments by frequent revisions.

Biolley (1890) sub-divided the forest (Couvet, Series I) into compartments, or *Check Units* : carried out complete enumeration (subsequently on 6 to 10 years cycle) in 5 cm (2 inches) dia. classes, down to a minimum of 17. 5 cm (7 inches) dia., and formed them in three broad groups as follows. The point of measurement on each tree was marked with a scribe.

Group	*Dia.-Classes* *inch*	*cm*	*Dia-limits of Group* *inch*	*cm*
Small timber	8, 10, 12	20, 25, 30	7 to 13	17.5 to 32.5
Medium timber	14, 16, 18, 20	35, 40, 45, 50	13 to 21	32 5 to 52.5
Large timber	22 and over	55 and over	21 >	52.5>

(20 cm dia. class stands for 17.5 to 22.5 cm range ; 25 cm for 22.5 to 27.5 cm range, and so on).

Diameter classes 10 cm (7.5 to 12.5 cm) and 15 cm (12.5 to 17.5 cm) are classed as *Optional Group.* Volume of growth (increment)=Volume of G.S. at second enumeration *plus* the volume removed during the intervening period *minus* the volume at the first enumeration ; that is :

$I=V_2+N-V_1$, where I=total increment during the period ; N the volume of trees cut ; V_1 and V_2 the volumes of the measured G.S. at the beginning and the end of the period (first and second enumeration, respectively).

Biolley recognised two possible sources of error, which he tried to guard against, viz. :—

(i) The volume cut must be measured exactly the same way as for standing trees, i.e.; by a *volume table* and not with tapes on the ground. Special Volume Tables (called *Tariff Tables*) were used, sometimes simple Local Volume Tables (Dia./Vol.) or General/Regional Volume Tables (Dia.-ht./Vol.) To avoid confusion between the volumes read from the tables, and actual volumes measured on the ground after felling, Biolley adopted a special term for its Volume Table Unit, and called it *Silve* (*sv*). A *Silve* is, of course, approximately a m^3 to which its relationship can be determined at any time by measuring on the ground a number of felled trees already measured standing by the Tariff Table. The relationship may vary from cpt. to cpt., and also in the same area from time to time as the taper of the stems increases or decreases (in some forests the ratio *m³/silve* was found to vary betweea 0.97 and 1.00).

(ii) The increment put on by the previously enumerated trees must be kept distinct from the volume of the new recruits to the lowest measurable class, 8 in. (7 to 9 in.)/20 cm (17.5 to 22.5 cm) recorded at the second enumeration. This should not be important in a well-balanced all-aged forest, in which recruitment is always roughly the same in all increment periods so that increment calculation is not influenced by it; but if the forest is under conversion from a partially even-aged forest (as Biolley's was), whole regeneration strip or group in a compartment may cross the threshold of calliper measurement and attain enumeration size between the first and the second inventory; and none in the next. For this reason, and to determine the growth rates of the different size-groups, the *Stand Table* is checked off in descending order, from the largest to the smallest dia. class, and the number of trees in each group is made equal to the original number of the group (as is illustrated in the tobulated data, to follow in TABLE—A).

For Working Control, it is not so much a question of finding out the absolute volume of a stand as of determining the changes in the magnitude and distribution of volume from one enumeration to the next (between two *inventories*); hence the stipulations in the paragraphs (i) and (ii) above.

Passage or recruitment of trees from one dia. class to another is of three kinds, viz. :—

(i) From one dia. class to the next higher class within the same group.

(ii) From higher dia. class of one group to the lower dia. class of the next higher group.

(iii) From the un-enumerated dia. class (Optional Group) to the lowest of the enumerated class.

Increment is calculated for each group, and only those trees are enumerated in the next cycle (second inventory), which bear a scribe mark, in testimony of their having been enumerated previously (first inventory). As for the recruitment, only the increase in the volume of recruited trees should be recorded as increment and not their full volume. Since there is no satisfactory method of assessing this increment, it was considered appropriate that calculations of increment are based on the trees which were already

enumerated in the previous enumeration. The recruitment would, however, be adjusted in the lower groups and their increment ignored. In other words, it is preferable to substract the whole volume of recruitment from the total increment during the measurement interval. Thus :—

$Z = V_2 - V_1 + N - P$, where ;

Z=Increment ; V_2=present G.S. Volume—2nd inventory ;

V_1=G.S. volume 'n' years ago—Ist inventory ;

N=Volume of trees cut ; P=Volume of recruitment in 'n' years (from lower storey to the main stand).

Or, Increment=G.S.$_2$—G.S.$_1$+Fellings—Recruitment.

There are various ways of determining 'P' ; viz.,

(i) By recording separately in second inventory all trees that do not bear scribe marks, i.e., which were not measured in the first inventory ; these trees will be of the lowest class/category.

(ii) It can also be determined arithmatically, as is illustrated in the data tabulated in TABLE—A.

In Biolley's Method, fellings are made strictly on silvicultural considerations, and in all age-groups, and not in the *Large Group* only.

Yield prediction serves as a check against over felling; the increment being calculated on the number of trees that existed in the previous enumeration, and excluding the recruitment to that group.

$$\text{Annual increment or yield} = \frac{Z}{n} \text{ or } \frac{(V_2+N)-(V_1+P)}{n}$$

If G.S. is more or less than the normal, a factor should be introduced to the increment (in yield prediction), to remove the surplus G.S. or build up a normal G.S.

Annual Yield prediction (based on data tabulated in TABLE—A)

$$=\frac{(883.31+158.43)-(906.28+31.56)}{6} = \frac{103.90}{6} = 17.32 \text{ m}^3.$$

The yield may be modified, if the G.S. is not normal. Modified Annual Yield would then be :

$$Y=\frac{Z}{n}(\text{as above}) \pm \frac{(G_a \sim G_n)}{A} \text{ ; where,}$$

G_a=Actual G.S. ; G_n=Normal G.S. ; A=Period of adjustment.

A concrete example of Increment Calculation by Dia. Class/Size Groups according to Biolley's Check Method, from the actual data of Couvet Comptt. 6B, area 2.63 ha, quoted by Kunchel

("Planning and Control in Managed Forests"—pages 191 and 193) is reproduced in TABLES—A (enclosed) & B (below).

Increment calculations by size-groups, based on the number of trees only, from the same data, would be as tabulated below :—

TABLE—B

Size class (cm)	Number of trees				Trees of V_1, appearing against in V_2+N, increased by their increment	Addition to Higher Group
	V_1	V_2	N	V_2+N		
1	2	3	4	5	6	7
85	1	1	—	1	1	—
75	—	2	1	3	3	—
70	3	5	1	6	6	—
65	10	11	—	11	11	—
60	16	13	2	15	15	—
55	21	27	3	30	15	15
Large Trees	51	59	7	66	51	
Recruitment into large-trees group					15	—
50	40	32	3	35	35	—
45	55	66	11	77	77	—
40	82	69	11	80	80	—
35	115	117	26	143	85	58
Medium trees	292	284	51	335	292	
Recruitment into medium trees group					58	—
30	188	142	40	182	182	—
25	219	199	60	259	259	—
20	215	215	25	240	123	117
Small Trees	622	556	125	681	622	
Total	965	899	183	1,082	(965 (+117 (Recruitment into the main stand).	

The prescribed yield need not necessarily be fixed equal to the increment. It will be limited to that much which can be taken out without deterioration of the G.S. Several factors will have to be

considered, such as the balanced proportion of various size-classes, increment, etc. If recruitment is more, only the calculated yield may be prescribed; if less, more than the increment may be prescribed as yield as the crop may need opening out. The vigour of the trees is also to be noted; if increment is low, crop may be too old and yield removed may be more than the increment, and *vice versa*.

Biolley's Check Method leads an ir-regular forest gradually to normal. Optimum G.S. and size-class distribution is checked by periodical total enumeration. There is no rotation, nor any exploittable diameter. Trees of any size may be removed, provided their removal benefits the remaining crop in improving the increment or size-class distribution. This method was found to be successful in the hands of experienced foresters, who had intimate knowledge of their forests, by virtue of long association as Biolley had.

This method with suitable modifications, may be adopted for valuable Selection forests of Sal and Teak in India

(c) Yield Based on G.S. and Increment (E) :

1. ***Hufnagl's Diameter Class Method***—(E4) :

While considering the method of yield calculation based on volume of G.S. and Increment, we have already studied another method postulated by an Austrian forester, Hufnagl, with two Variations (page 153), viz, Variation I : $Y_a = \frac{V+(a \times i \times r/4)}{r/2}$,

where V=Volume of crop of 1/2 rotation age and above, and
a=area occupied by V; i=final m.a.i. and
r=rotation. This was for calculation of yield in more or less even-aged crops.

Variation II : $Y_a = \frac{V+(V \times i \times r/4)}{r/2}$. In this case i=increment per unit volume and V=volume of crop>1/2 r age. This was for use where the crop was ir-regular and different ages did not occupy separate areas. Theory behind both these variations was the same as in Von Mantel's Formula, that during 1/2 r years, the yield that is removed consists of 3/4th in the existing G.S. and 1/4th in the increment put on by it in r/4 years.

In 1893, Hufnagl devised another method on the basis of diameter at which trees are marketable, instead of age, for use in remote Selection forests, which is known as Hufnagl's Diameter

Class Method. Hufnagl proposed that all trees of such diameter and above may be removed during a period of years which is required by the next lower class/classes to produce the same number of marketable trees to replace those that have been removed. The formula that he used for calculating the annual yield was as follows :—

$$Y_a=\left(\frac{n_4}{a_4-a_3}\times V_4\right)+\left(\frac{n_3-n_4}{a_4-a_3}\times V_3\right)+\left(\frac{n_2-n_3}{a_3-a_2}\times V_2\right)$$
$$+\left(\frac{n_1-n_2}{a_2-a_1}\times V_1\right), \text{ where :}$$

(i) n_1, n_2, n_3 and n_4 are the number of trees in the lowest to the highest dia. classes (in ascending order).

(ii) a_1, a_2, a_3, and a_4 are the mean ages of trees in each dia. class.

(iii) V_1, V_2, V_3 and V_4 are the volumes of average trees in each dia. class (these may be found from Volume Tables, or otherwise).

Hufnagl considered that the period of exploitation should be, approximately, equal to a_4-a_3 years; the formula will be incorrect if this period exceeds the time taken by any class to pass into the next. Hufnagl also contemplated checking the yield obtained with that obtained by the c.a.i. method (Increment Method—D1, page 167).

Salient Features of the Method **:**

(i) a_4-a_3, a_3-a_2, etc., will give the length of time required to pass from the middle of one class to the middle of the next higher; in contrast to Brandis' Tree Unit Method (described later, page 180) which determines the time required to pass *through* each class, i.e., the difference between the lowest ages of trees in two consecutive age-classes. Hufnagl's Diameter Class Method, and the Brandis' Tree Unit Method, when used to calculate the number of trees which reach the higher class during a certain period will give slightly different results, but the difference is not important, and the Brandis' age limits could be substituted for the average ages, if desired.

(ii) The first expression in the formula will clearly result in the removal of the first class trees in the period in which they will all be replaced by second class trees.

(iii) The second expression will result in the removal of those second class trees which are not required to replace the first class trees, in the period required for the second class trees to become first class; similarly for the subsequent expressions.

(iv) It is, therefore, clear that the application of the formula, without modification, will result, in theory, in the maintenance of the classes in the exact proportion in which they are at present.

(v) The formula assumes that the trees in each class, not required to recruit to the higher class, will be available in the yield; i.e., none will die and rot between the felling operations. Intensive management and a short felling cycle may justify this assumption.

Hufnagl's method is preferable to Brandis' for most types of Selection forests. It is clear from (iv) above, that it would not be correct to apply it, as it stands, to any forest which is not approximately normal, and from (v) above, in many cases it may be necessary to make allowance for un-merchantable trees, as in Brandis' Method (mortality % provided for).

Yield may be usefully checked with the yield obtained by Simmons' Formula.

Any trees below the merchantable size (i.e., below the lowest class enumerated), which may have to be felled for silvicultural reasons, may or may not be saleable and will not be counted against the yield. It may, however, be considered desirable to enumerate a class below that ordinarily merchantable, to obtain additional information regarding the distribution of G.S. within the rotation.

This method was primarily designed for Selection forests worked on a Felling Cycle (f.c.) and it required that the f.c. should approximately be$=a_4-a_3$. Another important requirement is the frequent revision of the Working Plan.

Yield arrived at by this method should be checked with other methods and, if found excessive, only the first one or two expressions of the formula should be used.

This method is specially suited for ir-regular virgin forests, where we require the removal of over-mature stock soon, and also Selection forests

Example :

Dia. class (cm)	No. of trees	Av. dia. (cm)	Av. Age (years)	Vol. per tree (m^3)
20–30	3480 (n_1)	25	42 (a_1)	0.34 (V_1)
30–40	2320 (n_2)	35	67 (a_2)	0.74 (V_2)
40–50	1110 (n_3)	45	92 (a_3)	1.90 (V_3)
50–60	340 (n_4)	55	122 (a_4)	3.40 (V_4)

$$\text{Annual Yield}=\left(\frac{340}{122-92}\times 3.40\right)+\left(\frac{1110-340}{122-92}\times 1.90\right)$$
$$+\left(\frac{2320-1110}{92-67}\times 0.74\right)+\left(\frac{3480-2320}{67-42}\times 0.34\right)$$
$$=\left(\frac{340}{30}\times 3.40\right)+\left(\frac{770}{30}\times 1.90\right)+\left(\frac{1210}{25}\times 0.74\right)+\left(\frac{1160}{25}\times 0.34\right)$$
$$=38.53+48.77+35.82+15.78=138.90\ m^3,\ \text{or, say}\ 140\ m^3.$$

In the above example, the minimum diameter limit at which trees are marketable is fixed at 20 cm, and the maximum diameter upto which it is desired to grow the trees is fixed at 60 cm; trees between these two diameter limits were enumerated in 10 cm dia. classes as above. Trees above the maximum dia. are considered to be surplus and do not enter into yield calculation and are to be removed over the cycle, rapidly or slowly, depending on other considerations.

2. *Brandis' Diameter Class Method or the Indian Method*—(E5) :

This is a method of Yield Regulation by Volume, based on Tree as a Unit. As in Hufnagl's Diameter Class Method, described above, and in Smythies' Safe-guarding Formula (described hereafter, on page 194), yield in Brandis' Method is based on the number of trees in various dia./girth classes, and time taken to pass from one to the next, with or without consideration of volume.

This somewhat rough and ready method was devised by Brandis in the middle of 19th century, to meet the need for exploitation of large areas of tropical forests; it must, therefore, be assessed against the background that practically nothing was known about these forests then. Brandis was faced with the problem of regulating the yield from extensive Pegu forests in Burma (in 1856) over which concessionists had been granted felling rights. These forests contained only about 10% of teak which was the only valuable timber of commercial importance, and that too was saleable only if above 6′ girth. As in many untouched and virgin tropical forests, where scientific management was introduced during the middle of 19th century, there was excess of large trees over the medium and small sized trees. If all the merchantable trees were to be removed by the concessionists as rapidly as they could it would have been a long time before the forests would be productive again, even

assuming that regeneration of valuable species, mainly teak, appeared and could establish itself and compete successfully with all stages of the growth of useless species. Brandis wanted to ascertain, as quickly as possible, the number of teak trees of exploitable girth (Class I trees) which might be removed annually without endangering future yield. He evolved a method which was really to be only a temporary expedient, till full growth statistics and data could be collected and more reliable method of yield regulation applied.

Following steps were adopted by Brandis :—

(i) A girth limit (6′) was fixed below which no teak trees were to be felled.

(ii) Systematic strip enumerations were carried out in 18″ girth classes down to a minimum of 18″ girth (i.e., 1½′—3′, 3′—4½′, 4½′—6′, 6′ and over girth-classes).

(iii) Rate of girth increment for each girth class was found by stump analysis on a number of available stumps in the forest (teak having distinct growth rings), and the period of transition from each class to the next above (i.e., the period of *passage through* the class, namely, the difference between the lowest and highest ages of the trees in the class—or the *transition period*) was ascertained.

(iv) By adding the *transition periods* and allowing some years extra (establishment period) the rotation corresponding to the exploitable girth was worked out.

(v) Survival coefficient, i.e., the percentage of trees of each class surviving to the exploitable class was estimated, on the basis of extensive observations of the G.S.

(vi) A *felling cycle* (f.c.) was fixed, which was a sub-multiple of rotation (r) and was not less than the period of transition from Class II (next below the exploitable Class I) to Class I.

The annual yield was then fixed by the number of trees as :—

Yield=Average number of trees reaching exploitable size annually *plus* a fraction of surplus number of trees of over the exploitable girth/size, if any.

This surplus of Class I trees may be harvested (liquidated) in a variety of ways, depending on the circumstances, viz. :

(i) During the first felling cycle only;

or (ii) During the first two felling cycles;

or (iii) Part removed and part kept as reserve—*Working Stock* (or Working Capital)—by leaving equivalent number of trees that pass into Class I during half the f.c. This may even be necessary, since whereas the existing I Class trees are available for felling, only *half* of the total recruitment is available for felling during a f.c., as fellings proceed from one end of the F.S. to the other (average of *nil* and *full* increment during the first and the last year of the f.c. in the respective coupes).

Following example will illustrate the application of Brandis' Method.

Example 1 : Data from Rodger's Working Plan of a forest in Burma (quoted by Schlich) to which this method was applied, is as follows :

Girth Class (ft.)	No. of trees enume-rated	Age on entry in class (years)	Years in class—transi-tion period	Survival Co-effi-cient (to Class I) %	No. of poten-tially exploi-table trees	Potentially exploitable trees Class II–V.
I >7	31,523	156	—	95	29,947	
II 6–7	18,114	130	26	85	15,397	1,33,932
III 4½–6	42,768	93	37	70	29,938	
IV 3–4½	1,01,737	60	33	50	50,869	
V 1½–3	1,50,910	31	29	25	37,728	
VI <1½	Not counted	—	31	—	—	
Total	3,45,052	—	156	—	1,63,879	

Notes :—(i) Transition period = years to pass through the class.

(ii) Ages on entry in various classes in the above table are, 0+31=31; 31+29=60; 60+33=93, and so on.

(iii) Minimum exploitable girth = 7′ (Class I).

(iv) Though I Class trees do not have to pass through a class to a higher one, there is bound to be some mortality within the class during the period; hence 95% provided as survival coefficient (and not 100%).

Rotation adopted was 160 years; felling cycle 32 years—a sub-muliple of rotation; rotation being thus divided into 5 felling-cycle periods

The yield may be calculated on the basis of :

(i) Average recruitment rate for the whole period during which the smallest enumerated tree (Class V) will reach Class I (125 years in the above example).

or (ii) Average recruitment rate from the upper classes to Class I during the first felling-cycle period only.

CALCULATIONS IN EACH CASE WILL BE AS FOLLOWS :

(i) Total number of potentially exploitable trees in Classes II to V is = 1,33,932.

Total period of transition from Class V to Class I = 125 years. Average number of trees passing from the lower enumerated classes into Class I, annually, is therefore = 1,33,932 ÷ 125 = 1,071.

Working Stock of class I trees required to be kept as *reserve* = Annual recruitment × ½ f.c. = 1071 × 32/2 = 17,136 trees.

Surplus of Class I stock = 29,947 − 17,136 = 12,811 trees. If this surplus of Class I stock is to be harvested in the very first f.c. (it could as well be done in 2 or more felling cycles, or even the entire rotation period : we shall deal with such cases later); the annual yield of these *surplus* I Class trees = 12,811 ÷ 32 = 400 trees. Therefore, total annual *possibility* or *yield* = 1071 + 400 = 1,471 trees. However, in order to preserve mature trees for regeneration, and in view of price increment on trees of 8′ and 9′ girth, the actual yield was reduced to 1,000 trees only in the Working Plan.

(ii) In this case, yield is based on the recruitment into class I in the first f.c. only. This is a more realistic approach than the above case (i), as in the first f.c. actually trees of class II and, possibly, some of Class III only will move into Class I. Thus, in a f.c. of 32 years, during the first 26 years all the 15,397 Class II trees would reach Class I : the exploitable size. During each of the next six years the average number of Class III trees which have been reaching Class II each year will also pass into Class I. Therefore, the number of Class III trees passing into Class I in the first

32 years f.c. $= \frac{29,938}{37} \times 6 = 4,855$ trees (as an average Class III tree takes 37 years to reach Class II).

Therefore, total recruitment to Class I in 32 years (i.e., the Yield) $= 15,397 + 4,855 = 20,252$ trees.
Annual Yield $= 20,252 \div 32 = 633$ trees, and *not* 1,071 trees.
This obviously indicates a big deficit of Class II trees.

Rodgers also provided for removal of the *surplus* Class I trees in the very first f.c., as follows :

Recruitment to Class I (from Classes II and III) during the f.c. $= 20,252$ trees. Surplus of Class I trees, after reservation of Working Stock equal to recruitment during half the f.c. will be

$$= 29,947 - \frac{20,252}{2} = 19,821 \text{ trees.}$$

Therefore, total possibility in 32 years (first f.c.)
$= 20,252 + 19,821 = 40,073$ trees.
Or , Annual Possibility (Yield) $= 40,073 \div 32 = 1,252$ Class I trees. (Actually the yield prescribed was only 1,000 trees)

In the above examples (i) and (ii), it will be noted that after allowing for some reserve *(Working Stock)*, the rest of the Class I trees—the surplus—are being removed during the course of one f.c. only. It is always better to remove the surplus in more than one f.c., so as to even off the difference between the yield during the first and second felling cycles.

In the above example, if the surplus is removed during two felling-cycle periods, the annual yield will be $= 633 + \frac{19,821}{64} = 943$ trees (instead of 1,252 trees).

It is usually not necessary to equalise the yield over more than two felling cycles, or to expect the same yield from cycle to cycle over the whole rotation—or force the yield to be sustained over this period. In fact, the equalisation of yield for the second f.c. may not be necessary if the Working Plan is revised by the end of the first f.c.—as it should be—resulting in fresh enumeration and fresh yield calculation. It is for this reason that many foresters recommend carrying out of actual enumeration for the upper two or three dia. (girth) classes only; this reduces the cost also.

Example 2 : Calculation of yield for sal forests of Bastar by

Brandis' Formula is as follows (growth figures taken from Sal Yield Table by Griffith and Sant Ram). Area under sal forests $= 32,426$ acres. (From S.D.N. Tiwari's article "The Working Capital and other Formulae for Yield Regulation in Selection Forests" in *Indian Forester*, November, 1955).

MATLA FELLING SERIES—BASTAR

Class	Dia (inches)	No. of Trees	Years in Class	Survival % to Class I	Nett no. of harvestable trees
I	20 & >	54,946	—	95	52,199
II	16–20	1,38,621	50	64	88,717
III	12–16	2,88,714	38	37	1,06,824
IV	8–12	5,57,301	32	20	1,11,460
			120		3,59,200

Felling cycle $= 40$ years.

Average annual increment during the first f.c. $= \frac{88,717}{50}$ $= 1,774$ trees (Class II to Class I).

Average annual increment during the next 120 years

$$= \frac{88,717 + 1,06,824 + 1,11,460}{120} = 2,558 \text{ trees.}$$

Working Stock/Capital (WC) required $= 2,558 \times \frac{40}{2} = 51,160$ I Class trees. By prescribing 2,558 trees per year as yield, the surplus Stock (as per formula worked out in previous Example I) comes to $52,199 - 51,160 = 1,039$ trees. If this surplus is to be liquidated over two felling cycles, this will give additional $\frac{1039}{2 \times 40} = 13$ trees annually.
Therefore, total annual yield would be $= 2,558 + 13 = 2,571$ trees.

Discussion of the Working Capital (WC) formula :

As per the formula for WC used above (as given by Jerram as well as Brasnett), WC $=$ Annual recruitment $\times$ 1/2 f.c. $= 2558 \times \frac{40}{2}$

=51,160 trees. If the forests are to be felled at the rate of annual yield as calculated above, $2,571 \times 40 = 1,02,840$ trees are required during the f.c. to be removed, while the total number of trees that will be available $= 52,199 + \frac{1,774 \times 40}{2} = 87,679$.

Similar situation would have arisen in *Example I*, if the total permissible yield of 1471 was adopted. There would have been a clear deficit of I Class trees even during the working of the first f.c.; the situation was saved by arbitrary reduction of yield from 1,471 to 1000 trees. The fore-going formula is, therefore, *not* workable in *all* cases. A new formula suggested by Tiwari is :—

WC = Y − 1/2 I, where Y is Yield during the f.c., and I = total recruitment to Class I in the f.c.

Or $WC = Y_1 \times f - \frac{R \times f}{2} = f(Y_1 - R/2)$, where f = f.c., Y_1 = annual yield, R = annual recruitment to Class I during the f.c.

From this formula it is clear that if the rate of recruitment is low during the f.c., large WC is required to get the prescribed yield. Similarly, if WC is small, and if rate of recruitment is very high in comparison to 'Y', it may be possible to get the prescribed yield in certain cases, depending on the distribution of WC in the Felling Series.

From the above formula, the WC in Matla F.S. should be $= (2,558 \times 40) - \frac{1,774 \times 40}{2} = 66,840$ (instead of 51,160) I Class trees.

As the WC of 66,840 trees is not available, it can straight away be said that this F.S. cannot be worked on 40 year f.c. if the annual yield of 2,571 trees is to be extracted

In *Example I* above, the WC should be $= (1071 \times 32) - \frac{20,252}{2} = 24,146$, as per previous calculation and the surplus stock should have been shown as : $29,947 - 24,146 = 5,801$, and *not* 12,811.

(The above illustrations bring out the inconsistencies in Brandis' Method as, explained in the two books by Jerram and Brasnett).

Example 3 : Enumeration data and information collected from stump analysis is tabulated below :

Class	Dia.-range (cm)	No. of trees enume-rated	Age on entry in Class (years)	Transi-tion period (years)	Survival Coeffi-cient %	No. of potentially exploitable trees
I	>50	15,000	88	—	90	13,500
II	40–50	12,250	74	14	80	9,800 } 72,000
III	30–40	27,000	56	18	60	16,200
IV	20–30	60,000	32	24	40	24,000
V	10–20	88,000	16	16	25	22,000
Total		2,02,250		72		85,500

Rotation was fixed at 100 years and the f.c. at 20 years. Since the total recruitment from lower classes to Class I in 72 years is 72,000, the average annual recruitment for the entire period is 1,000 trees. This may be checked with the progress of recruitment during the first f.c. (20-year period). During the first 14 years all 9,800 Class II trees would reach Class I, the exploitable size. During each of the next six years the average number of Classs III trees which have been reaching Class II each year will also pass into Class I. Therefore, the number of Class III trees that will pass into Class I during the first 20 years f.c. $= \frac{16,200}{18} \times 6 = 5,400$.

Therefore, total recruitment from Classes II and III to Class I during the first f.c. $= 9,800 + 5,400 = 15,200$ trees.

Average annual recruitment $= 15,200 \div 20 = 760$ trees, instead of 1,000 trees calculated from the total figure for the entire transition period, thereby indicating a deficit of class II trees.

Therefore, where Brandis' Method is to be applied, it should suffice if the yield is equalised for the first f.c., and for that purpose the average number of trees passing from the lower class/classes into Class I during the first f.c should be taken into account for yield calculation.

Existing Class I trees (already available) = 13,500

Working Stock reserved (= recruitment during half f.c.) = $760 \times 20/2 = 7600$ trees.

Surplus stock af Class I trees available during the f.c.= 13,500−7,600=5,900 trees

Therefore, total possibility (yield) $=760+\frac{5900}{20}=1{,}055$ trees.

This may be rounded off to 1,000 trees, allowing for mortality, retention for seed production and/or extra price increment. If the yield is equalised and surplus Class I stock is removed during two felling cycles instead of one, calculation based on the above data would be as follows :—

If surplus stock is distributed over one f.c., yield would be about 1000 trees annually, as explained above.

The position in the second f.c. (at the end of 40 years, would be :—

(i) Remaining 10,800 trees (16,200−5,400) of Class III will move into Class I during the first 12 years of the second f.c.

(ii) During the remaining 8 years of the f.c., 8/24 of the 24,000 Class IV trees, i.e., 8,000 trees wil also move to Class I.

Total recruitment to class I in 20 years=10,800+8,000= 18,800 trees, or 18,800÷20=940 trees annually. To fell this number we shall need a Working Stock reserve of 940×20/2= 9,400 trees, but actually only 7,600 trees will be available (kept as reserve stock in first f c.). There is, therefore, no surplus stock of Class I trees to fell. Only 760 trees can be felled annually and, therefore, 700 or 750 trees could be fixed as yield, as against 1,000 in the first f.c.

If the surplus stock is distributed over two felling cycles, the yield in the first cycle will be $=760$ *plus* $\frac{5900}{40}=907$ trees (instead of 1,055 calculated previously, when *surplus* stock was to be removed in just the first f.c. only); giving a safety margin, yield may be fixed at 850 trees, annually.

In the second cycle, recruitment to Class I=940 trees annually (as calculated above). For this, a Working Stock of $940\times\frac{20}{2}=$ 9,400 I Class trees is required; against this we have only 7600 trees left as Working Stock in first f c., and 2,950 $\left(=\frac{5900}{2}\right)$ left out of the surplus (after the first f.c. and for the second f.c ; because 5,900 surplus trees are being distributed over two felling cycles—40 years). Total I Class stock=7,600+2,950=10,550 trees (or, directly, No. of I Class trees is 13,500 *minus* 2,950 felled in the first f c.=10,550). After retaining 9,400 as Working Stock, it leaves a balance of 1150 trees, which may be removed in addition to 18,800 trees during the second f.c. ; i.e., $\frac{18{,}800+1{,}150}{20}=997$ trees annually, or, say 950 trees annually during the second f.c.

In the third f.c yield will be different again. Brandis' method of yield calculation was applied to ir-regular teak forests of Bhima Ram F.S. Allapalli (Maharashtra) and Bori (M.P.), Selection forests of Chanda (Maharashtra); it is being applied in Fir Selection Working Circles of Kamraj, Langet and Pir Panjal Divisions (Kashmir) also.

Summing up, the data required for the application of Brandis' Method, is as follows (based on enumeration, Yield Tables and Stump Analysis) :

(i) Number of Class I, II, III, etc.. trees.

(ii) Transition period (years required to pass through various classes).

(iii) Percentage of trees in each class, likely to survive till in Class I ; and the net number of harvestable trees in each class.

(iv) Annual recruitment to Class I

(v) Working Stock (=Annual Increment×1/2 felling cycle).

(vi) Surplus of Class I trees, i.e., existing number of Class I trees *minus* the Working Stock.

(vii) Period during which the surplus of Class I Stock is to be liquidated.

Merits of Brandis' Method :

(i) Gives a free hand to the marking officer who can mark according to Silvicultural requirements of the crop.

(ii) Suitable for extensive tropical forests where only one or two species (such as teak) are saleable and where *Selection fellings* are the rule

(iii) Admits of enumeration in broad dia./girth classes ; an advantage where illiterate labour is to be employed.

(iv) Where Volume Tables exist, it is possible to convert number of trees into volume.

De-merits :

(i) It is necessary to revise enumeration and calculation at the end of each f c., which is an expensive operation.

(ii) Survival co-efficients, an essential part of calculation, are mere guesses.

(iii) In mixed forests, satisfactory regeneration of desired species is doubtful, as undesirable species are left unfelled.

(iv) Takes no account of the fact that in most of the mixed ir-regular forests, silvicultural requirements do not permit of restrictions on felling of trees of a certain dia. only; lacks elasticity.

(v) It is complex ; liable to error. It requires as much data as better and more reliable methods

(vi) Natural regeneration may not come up in many cases; this important management practice was left merely to chance.

3. *Volume Unit Method* (E6) :

Volume Unit Method is not a standard and accepted term ; it is used for convenience to cover two methods which resemble one another (viz., Hufnagl's Diameter Class Method as applied to Selection forests, and the one applied to forests under Conversion to Uniform) and to contrast them with Brandis' Tree Unit Method ; it is a further development on the latter. One of the serious defects noticed in Brandis' Method was that it does not take into account the fact that, in majority of the ir-regular forests, silvicultural requirements do not permit of restrictions that trees of a particular size (Class I trees) only may be felled. If, however, the yield is to be regulated by numbers, it is obviously unnecessary to prescribe in advance numbers of trees to be felled in each class in such forests. Moreover, while fixing mortality percent one may take the loss in thinnings and silvicultural non-availability into consideration, but at best it can still be only a guess.

To improve upon Brandis' Method, and to arrive at a method of calculating yield which will make it possible to cut the increment from any class according to silvicultural requirements, a method was devised to substitute for numbers a *Unit*, in which it will be possible to represent the proportionate volume in each class.

In Selection working, as well as in working for Conversion to Uniform, where in order to minimise sacrifice, poles aud saplings upto a certain size are retained as advance growth to form a part of the future crop, a minimum dia. or girth is fixed for enumeration. Upper dia. or girth corresponds to rotation in case of forests under *Conversion*, and to exploitable dia. in case of *Selection*. The two diameters (upper and lower limits) having been fixed, enumerations are carried out as in Brandis' Method in the *Regeneration Block* in case of forests under *Conversion*, and in the whole *Felling Series* in case of *Selection* forests.

Enumerations having been carried out, volume of an average tree in each *size class* is determined and a *Volume Table* prepared. Comparative volumes of trees of different classes are expressed in the form of multiples of a common unit. Taking the minimum volume (that of the lowest class) as *Unit* (1.00), the volumes of the average trees in the other classes are given proportional values in terms of *Volume Units*, and total volume units of each class are calculated. Average age of the tree at the lower limit of each class is also determined and the data calculated, as illustrated hereafter.

A. Application of Volume Unit Method to Forests under Conversion to Uniform : The procedure is as follows :—

(i) The total G.S., except that below the minimum dia., will be removed during the regeneration period.

(ii) In addition to the above, increment put on by the enumerated crop during half the period will also be removed ; this increment is determined by following the progress of each class during the regeneration period.

Suppose regeneration period is 25 years, and the difference in the ages at the lower limit of the adjacent classes is 20 years, then during the regeneration period, all the trees of the lowest class will pass into the next higher class and, in addition, 5/20 of these trees will also pass into the class next above.

Example : (Based on Working Plan data of Pine forests of Rawalpindi Division, now in Pakistan, worked under conversion from Group Selection System to a Regular System ; as quoted by Jerram).

INVENTORY OF P.B.I.

Girth Class	No. of Trees	Average vol. per tree (cft.)	Vol. Unit	Total Vol. Units	Av. age at lowest limit (years)	Difference in ages (years)
1	2	3	4	5	6	7
I Over 7′–6″	8,500	250	5.0	42,500	140	20
II 6′–6″ to 7′–6″	16,300	165	3.3	53,790	120	20
III 5′–6″ to 6′–6″	33,500	122	2.44	81,740	100	20
IV 4′–6″ to 5′–6″	49,200	85	1.7	83,640	80	18
V 3′–6″ to 4′–6″	57,800	50	1.0	57,800	62	
Total				3,19,470		

1. The woods allotted to P.B.I. are to be regenerated in 25 years.
2. They contain trees of all dimensions.
3. Trees below 3′–6″ girth are not merchantable, and when felled for silvicultural reasons will not count towards yield. They are left as advance growth to form a part of the future crop.
4. Figures in Col. 6 of the table were determined from age-diameter curve prepared from a number of ring countings.
5. Total volume available for felling in 25 years period is 3,19,470 Vol. Units *plus* 1/2 increment laid in each class during the period.
6. No increment is to be calculated for I Class trees, since the yield of trees above 7′–6′ girth has been arbitrarily fixed as 5 Vol. units
7. As regards the other classes, the increment can be determined on the assumption that each class contains as many age-gradations as the number of years which a tree in the class takes to pass through the class (i.e., V class has 18 age-gradations and in other classes there are 20 in each).

Thus starting from Class V, during the period 25 years will be added to each age-gradation, so that V Class trees will move from 62–80 years to 87–105 years. In other words, all the 57,800 trees of this class will not only pass into class IV, 5 of its upper-most age gradations, (5/18 of the class), will pass further into Class III, and the remaining 13 age-gradations (13/18 of the class) stay in Class IV. Thus the increment of those V class trees which pass into III will be 2.44 *minus* 1.0=1.44 Vol. units per tree; the increment of the remainder 13/18 of V class trees=1.7 *minus* 1.0=0.7 Vol. units per tree; similarly for other classes, the whole of class II becoming Class I.

Total increment during 25 years period will, therefore, be calculated as follows :—

Class V (5/18 of 57,800×1.44) *plus* (13/18 of 57,800×0.7)
=52,340 Vol. units.
Class IV (5/20 of 49,200×1.6) *plus* (15/20 of 49,200×0.74)
=46,990 Vol. units.
Class III (5/20 of 33,500×2.56) *plus* (15/20 of 33,500×0.86)
=43,050 Vol. units.
Class II =16,300×1.7=27,710 Vol. units.
Total increment=170,090 Vol. units.

Therefore, *theoretical* increment for half the period available for felling during the period 'P' $=\frac{170,090}{2}=85,045$ Vol. Units. In case of forests under Conversion to Uniform System, the whole of the crop above 3′–6″ girth will be removed during the regeneration period 'P' and, in addition, half the increment for the period. The annual yield will be calculated by the formula (in Vol. units) :

$$Y=\frac{V+I/2}{P}$$

In practice, actual theoretical increment as determined by calculation is not taken for yield calculation for various reasons, viz., (i) Many trees may not be putting on the normal increment due to damage by fire, etc. (ii) Certain percentage of exploitable trees may not be silviculturally available due to gaps, etc., or may have to be left beyond the regeneration period for seed or protection of seedlings. Usually, only about 50% of the theoretical increment is taken into account. The annual yield, by the above formula, will then work out to :—

$$Y_e = \frac{V + 50\% \text{ of } 1/2}{P} = \frac{3,19,470 + 50\% \text{ of } 85,045}{25} = 14,480 \text{ units.}$$

In the above calculation of increment, we have not taken into consideration the increment, during the period, of trees below 3′-6″ in girth as represented by their progressive advance into the higher classes. As stated already, majority of such trees may be retained as part of the future crop ; but a number of these, particularly when occurring as single trees or in small groups, may have to be felled for silvicultural reasons, but they are not to be counted against yield. In order, therefore, to ensure that trees which have not been enumerated shall not be counted against the prescribed yield when marking for felling, a table is drawn up from age-girth graph to show the minimum girth which will entitle a tree to be counted against yield in each year of the period, e.g., :

First year	... 3′-7″	;	Second year	...	3′-8″
Third year	... 3′-8″	;	Fourth year	...	3′-9″
Fifth year	... 3′-10″				

This indicates that in the fifth year a tree below 3′-10″ girth had a girth of less than 3′-7″ when enumerations were made, and was therefore not enumerated.

B. Application of Volume Unit Method to Selection Forests :

When applied to a Selection forest, only the increment and the surplus G.S. will be taken into consideration. In that case this method will be more elaborate than Hufnagal's Method, as it considers the increment of each girth-class separately ; in fact, it will, in principle, resemble the *French (Biolley's) Methode du Controle.* In addition to the exploitable size-trees, some trees from lower sizes may also have to be felled in thinnings, or other silvicultural reasons, and all these will count towards the yield.

4. *Smythies' Safe-guarding Formula* (E7) :

This is also known as U.P. Safe-guarding Formula. It was evolved by Smythies in the thirtees, mainly for the sal forests of U.P., which were worked under Selection System and where the chief object of Management was the production of trees of large size. Smythies found that in most of the Working Plans there was a tendency to regard everything above the *Selection* limit as *surplus stock* ; this tendency had been responsible for decrease in the yield from Selection trees in many areas. He, therefore, considered it essential to maintain sustained yield, mostly from *Selection*

Class of trees, which he termed as *Selection Yield.* His method stipulates :—

(i) Sustained yield of Selection trees (above the exploitable limit) and not total yield of large and small timber.

(ii) No method of yield calculation could by itself safe-guard the Selection Yield, including methods of area yield.

(iii) Area yield with a check on the Selection trees can be applied to all types of forests, and eliminates most of the objections of Indian Management Systems.

The formula is based on the following assumptions :—

(i) That exploitable (Selection) trees already exist and are being recruited everywhere (and not in any particular compartments only) and that fellings pass regularly through the forests in consecutive annual coupes in a felling cycle of 10, 15, 20, 25 or 30 years.

(ii) The basic object of management is to ensure, as far as possible, sustained or increasing yield of exploitable trees above the exploitation limit at every felling cycle.

(iii) The middle-aged and younger dia. classes are well represented, and the present rate of recruitment into the two highest dia. classes (I and II) will not decrease for quite a few decades.

(iv) Sustained yield of Selection trees is adequately safeguarded if, in any area, the number that may be felled is limited to the number that will pass up from below by the time fellings come round again.

Procedure : The Working Plan Officer (W.P.O.) proceeds as follows :—

(i) Fixes the felling cycle and exploitable dia.

(ii) Fixes the diameter classes—these are indicated by symbols I, II, III, IV, etc ,—Class I standing for trees above the exploitable dia., and others successively below it to the youngest.

(iii) Carries out enumerations in various dia. classes (I and II necessarily; though the other classes do not enter into yield calculation, but still Class III, and perhaps IV also, are also enumerated to verify the assumption that the middle and younger age-classes are also well represented, to ensure Sustained Yield in subsequent felling cycles also). The youngest dia. class, usually below 20 cm dia., is not enumerated.

(iv) Every Selection tree is prescribed for felling subject to the limitation fixed by the W.P.O. to safe-guard the Selection Yield; this limitation is the number of II Class trees which pass into Class I during the felling cycle 'f'—let this number be 'x' per hectare.

This number 'x' is determined from the formula :

$$'x' = \frac{f}{t}\ (II - Z\%\ II), \text{ where}$$

'f' = felling cycle (f.c.)

't' = time taken by a II class tree to pass into I class

'Z' = percentage of II class trees that do not pass into I Class in 't' years; due to mortality or removal in thinnings, etc.

Values of 't' and 'Z' can be obtained with reasonable accuracy by re-enumeration of large sample areas, statistical sample plots, from Yield Tables or even by considering the normality of the existing distribution of dia. classes. Preferably, a number of Linear Increment Plots may be laid out along the fertility gradient, in various parts of the forest to determine these values for different dia. classes.

(v) After calculating 'x', the area of the Working Circle, or the Felling Series (F.S.), is subdivided into 'f' annual coupes, made as equi-productive as enumerations and W.P.O.'s knowledge of the forest permits. The W.P.O. may prescribe the annual yield of I Class trees by any of the two alternative methods, viz. :—

1. Fix a volume yield of 'x' trees per hectare area of the coupe, per annum, i.e., $x \times \frac{\text{Total area of F.S.}}{\text{f.c.}}$. This is similar to Brandis' Method, without providing for removal of surplus trees > the exploitable dia. If the data are correct, this ensures no reduction of I Class trees at the end of the felling cycle. However, this alternative has all the disadvantages of a volume yield—viz., cumulative error due to inaccurate data.

2. The second alternative (and a better one) is to prescribe an area yield, by dividing the forest into 'f' annual coupes, and limiting the removal of I class trees to a percentage 'p' of their number per ha ('N') in the coupe of the year at the time of marking. The number 'N' is ascertained by the marking officer at the time of marking the year's coupe and can also be expressed in terms of 'I', the number of I Class trees per ha at the *beginning* of the f.c., and 'x'.

The number of I class trees per ha at the *end* of the f.c. = I + x. Therefore, the *average* number of trees, i.e., 'N' during the f.c. $= I + \frac{x}{2}$.

The percentage of I Class trees to be removed in any year's coupe then becomes (taking average value of 'N', which is strictly true of the 'f'/2 year's coupe only; it will be an over-estimate for the earlier coupes and an under-estimate of subsequent coupes) :

$$\text{Yield} = \left(\frac{x}{I + x/2} \times 100\right)$$

In order to allow for the influence of various factors, which may affect the realisation of the full calculated yield (e.g., silvicultural non-availability, allowance for low-density of I Class trees requiring to be increased, need for sustaining average yield and revenue, etc., and also to round off the percentage, an arbitrary allowance of ± A is given and the formula becomes :

$$Y = \left(\frac{x}{I + x/2} \times 100 \pm A\right) \%\ N.$$

Of the two formulae involved in this method, the principle underlying the equation :

$x = \frac{f}{t}\ (II - Z\%\ II)$, gives the measure of recruitment of Selection trees from the next lower class, and forms the basis of the *Safe-guarding Formula*. The actual yield is prescribed as a percentage of the exploitable trees found in the course of the year, as given above.

The essential difference between this and the other formulae is that the annual yield is a percentage of I Class trees found by the marking officers and not a yield by volume, basal area or number of trees.

Limitations and Disadvantages of the Method :

(i) Formula can be used to calculate yield, for those species for which I, II, and III Class trees have been enumerated, and for which values of 't' and 'z' are known. However, as in Brandis' Method, values of 't' and 'z' cannot be accurately determined.

(ii) It holds good only if 'I' is within certain reasonable limits and not in general. Thus if I=0, yield will be 200% of 'N' which is absurd. Similarly, if value of 'I' is comparatively very high, that of yield percent (of 'N') will be very small: in that case these trees will be deteriorating, and it should be permissible to remove a larger percentage of these. If 'I'=x/2, yield will be 100% of 'N'—again an impracticable situation. It is, therefore, clear that it is not possible to apply the above formula unless 'I' is greater than x/2.

(iii) Since the removal of Class I trees depends on silvicultural availability, and the extent to which regeneration is present, yield is bound to vary.

(iv) Yield in the second f.c. will depend on the number and behaviour of III Claas trees as in Brandis' Method; if its proportion is less, yield is bound to fall.

(v) This method of yield regulation, like Brandis' Method, is essentially a method of yield by area (equi-extensive coupes), and Smythies only introduces a check on the number of trees to be removed. To have an equal yield of I Class trees, there must be even distribution of I and II Class trees throughout the F.S., and there should be no bar, silvicultural or any other, to the removal of the calculated number.

(vi) The formula bears no relation to the increment of the forest as a whole; it takes only I and II class trees into calculation.

(vii) It requires as much data from enumeration—and more statistical data for estimating 't' and 'z'—than volume formulae, and is, therefore, liable to go wrong.

(viii) This formula is merely a modification of Brandis' Method, wherein yield regulation is based only on the stocking of Class II trees and liquidation of the surplus G.S. is not provided for.

Smythies' formula is now very widely used in Selection forests of India.

Example 1 : Following data pertains to Selection and Improvement Working Circle of Balaghat Forest Division of Madhya Pradesh (from an old Working Plan), wherein *sal* yield was regulated by Smythies' Safe-guarding Formula. Exploitable dia.=50 cm; Felling Cycle ('f')=25 years. Two F.S. were formed, each with 25 approximately equi-productive coupes. Trees were classified as :—

50 cm dia. and over =Selection Tree (I Class)

(i) 50–60 cm dia. =Mature } (I Class)
(ii) 60 cm and over dia.=Over-mature }

40–50 cm dia. =Pre-selection Class (II Class)

Yield was prescribed, according to Smythies' Formula (usual connotations) ;

$$x=\frac{f}{t}\,(\text{II}-Z\%\ \text{II}) \quad \ldots \quad \ldots \quad \text{(i)}$$

$$Y=\left[\frac{x}{I+x/2}\times 100\pm A\right]\%\ \text{of 'N'} \quad \ldots \quad \text{(ii)}$$

Values of 't' and 'Z' were found to be 50 years and 33⅓ percent (from Yield Tables/Linear Increment Plots), respectively.

From enumeration data of Sondhar F.S.,

No. of II Class trees =16,677
No. of I Class trees =7,804

$$x=\frac{25}{50}\,(16{,}677-33\tfrac{1}{3}\%\ \text{of}\ 16{,}677)=5{,}559\ \text{trees.}$$

$$Y=\frac{5{,}559}{7{,}804+5{,}559/2}\times 100\pm A\ \text{percent of 'N'}$$

$=52\pm A\%$, or 50 percent of trees of the Selection Class present at the time of marking.

Example 2 : Sal Selection Working Circle of Pilibhit Forest Division (U.P.) was being worked under Selection System, and Yield was regulated by Smythies' Safe-guarding Formula (1971–72 to 1980–81 Working Plan by A. C. Gupta). The yield was calculated as follows :—

Felling cycle ('f')=10 years ; Exploitable dia.=50 cm
't' (time taken for an average II Class tree to reach I Class) =30 years

'Z' (mortality percent) =45%

(Values of 't' and 'z' have been worked out from Yield Table and L.I.P. data).

No. of I Class trees (50 cm dia. and above) as per enumeration. =18.3 per ha
No. of II Class trees (40–50 cm dia. class). =22.5 per ha

$$\text{'x'}=\frac{10}{30}\,(22.5-45\%\ \text{of}\ 22.5) \qquad =4.1\ \text{per ha}$$

Yield, Y, expressed as percentage of I Class trees present at the time of marking $= \frac{x}{1+x/2} \times 100 \pm A = \frac{4.1}{18.3+4.1/2} \times 100 = 20.1$ or, say, 20%.

On this basis, yield has been prescribed as 20% of the *sal* Selection trees (i.e., one out of five), provided silviculturally available.

Fir and Spruce forests of Chakrata Forest Division are being worked under Selection System (1977–78 to 1986–87 Working Plan) and yield is regulated by Smythies' Safe-guarding Formula. (Refer to *Appendix II* for yield calculation and prescription).

PART III

WORKING PLANS

CHAPTER XIII

WORKING PLANS — GENERAL CONSIDERATIONS

INTRODUCTION :

A forest is a *Continuum*. The building up of a regulated and a productive forest is a complex problem, usually requiring many years to work out—but once established, it is perpetual in nature. It can be modified and changed in many ways, but unless destroyed, it goes on indefinitely in one form or the other. Decisions made and actions taken now may have effects decades later. To look and plan ahead for periods of time, that may span several human generations, is a characteristic of the forestry profesison, as the forester has to deal with forest—a long term natural resource. Few foresters can reap what they sow, or see the full fruition of their work.

At the same time a practising forester has to live and function in the present, with all its ups and downs and dynamics of an ever-changing economic society. It is not enough to plan well ahead for the future—the present has also to be faced. It is thus imperative to provide for both long and short term planning in the field of *forestry*. Timber crops take a long time to grow; foresters, like other people, come and go. Fundamentally, therefore, there is a need for continuity and a reasonable consistency in the operation or working of forests; that requires planning.

A plan for working of a forest should, however, not be thought of as something *set* or *rigid*. It is only an operating base, that must be sufficiently flexible to meet the changing conditions. In fact, one of the best arguments for framing an operational plan is that it can be changed, if and when need arises.

A Working Plan (W.P.) document is a means of enforcing systematic, obligatory and mandatory regulations for continuous management of a given forest property. It is not confined to silvicultural and management aspects of the forest only, but it also covers other activities such as general administration, grazing and watershed management, permanent improvement, preservation of environment, forest production, soil and water conservation, Wildlife and recreation, etc. In other words, a *Working Plan* is a complete forest plan for the next Working Plan period.

A good *Working Plan* will :—

(i) Be simple and brief, exact and definite, for the subordinate staff to follow the prescriptions clearly.

(ii) Be based on the thorough knowledge of the tract to be dealt with.

(iii) Aim at achieving realistic and not idealistic objectives; workable in practice.

(iv) Avoid limiting the discretion of the executive staff to an ir-rational degree, particularly in silvicultural matters.

(v) Recognise practical difficulties in respect of marketing and transport problems, limitations of the technical abilities of the staff; co-ordination of administrative resources in men, money and equipment.

(vi) Provide a work of reference, containing all relevant information and a foundation on which all subsequent management plans can be built up.

Definition : Glossary defines *Working Plan* as: "A written scheme of management aiming at continuity of policy and action and controlling the treatment of a forest (BCFT). The instrument of forest management. *Syn* Management Plan". A forest, in this definition, means : "an area which for the most part is set aside for production of timber and other forest produce, or which is maintained in order to exercise climatic or protective influences on the adjoining areas."

The long term of working involved in forestry, and the inevitable changes in personnel necessary for its management, make it imperative that the management plan is reduced to writing, and not left to the personal whims or inclinations. A recorded scheme ensures continuity of policy over the whole term of working—hence the need for forest *Working Plans*.

Objectives and Scope :

The management of a forest depends, in the first place, on the objectives that the owner has in view, in so far they are not limited

by the laws of the country. These objects may differ widely according to nature of the forests and the local conditions. *Forest Management*, as we know, is not a subject by itself—it is the practical application of science, technology, economics, business acumen and statesmanship—all combined together, as applied to a forest area for the production of desired results. It is an activity—a duty which only a trained forester can perform. It consists in assessing the potentialities of a given area, organising the achievement of the objects to the maximum extent (consistent, of course, with the well-being of the soil), planning the operations and executing them from day-to-day.

The primary objective of a meaningful W.P., as one would appreciate as a professional forester, would be the creation of an *ideal* condition of the forest which meets the aims of the owner (the State, in case of Indian forests) to the fullest extent. This aim, in case of public-owned forests, would naturally be the *maximum benefit to the greatest number of people for all time*. This ideal condition is afforded by, what is known as, a *normal forest* (already discussed in Chapter VI), the realisation of which should be the forester's aim. He may not succeed in every respect, but the aim should be in that direction—that of bringing his forest as near to the normal state as may be possible—and then keeping it in that condition.

In actual practice, as already stated and explained in an earlier Chapter, the forest may differ from the normal in several respects, and the forester has to determine which of these are of greater importance. Some of these may be :—

(i) Abnormal increment (ii) Abnormal proportion of age-gradations/classes (iii) Abnormal Growing Stock.

A question would, therefore, arise as to which of these the forester should take in hand first ? Just as a capitalist's first concern is to make his capital yield him an appropriate interest, so must the forester see that a full increment takes place in the forest. The increment, above all considerations, renders the invested capital active; it replaces, year by year, that part of the Growing Stock (G.S.) which has been removed by fellings. Without it the G.S. will diminish, until it finally disappears. Hence, it would be the forester's foremost concern to bring the increment to its full or normal amount. This he can do by regulating the cuttings in a suitable manner, followed by efficient regeneration and accompanied by rational tending of the G.S. Rational forestry demands that, if not all, at least the greater part of the useless material should be removed and replaced by more valuable one.

Next, a proper proportion and distribution of age-classes has to be aimed at in all cases, when a regular and sustained return is desired. This realisation is possible if both a full increment and a proper proportion of age-classes, as well as their suitable distribution over the forest, have been achieved. When this has been established, it has been found that such forests also contain normal G.S. ; this follows as a corollary if the first two conditions are satisfied.

Considering the above, it would be clear, that a proper plan—a proper W.P.—must determine and devise, according to time and locality, the entire management of the forest so that the objectives, for which it is maintained, may be realised as fully and as economically as possible; extravagance has no place in forestry.

A W.P. will deal both with long-term planning, at national or State level to ensure continuity of purpose and policy, as well as short term planning for each forest—an action plan for about ten years or so, specifying *how much to cut, where and when* ?

Broadly a W.P. involves :

(i) Survey and assessment of the past results, present facts, resources and constraints.

(ii) Analysis of facts, with respect to prospects leading to conclusions on policy, objects of managements—for a long term plan.

(iii) A plan for future action in a definite period in conformity with the long-term-plan, i.e., a short-term-plan.

(iv) Provision for control of prescriptions, for maintenance of records and collection of new facts by research and new techniques (e.g., aerial photography, mechanised logging, sophisticated inventory methods, etc.).

The W.P. should be prepared within the frame-work of national policy, five-year development plans and other considerations of national and regional level planning. For efficient management of forests, it has to be flexible and not rigid, dynamic and not static.

Unit of a Working Plan :

There is difference of opinion as to whether the unit should be an individual forest or a group of forests which can be worked together, or the administrative charge of a forest officer, such as a Division or a District ? In Europe, individual forest is taken as a unit, but in India we generally combine the forests of a Division into a single W.P. with several Working Circles, as may be necessary and convenient. Working Plan area tends to change with the stage of forest development and intensification of forestry operations, e.g., creation of East Dehra Dun and West Dehra Dun divisions out of a single Dehra Dun Division (U.P.), carving out of two additional Hamirpur and Una Divisions out of Kangra Division, and Lahaul and Logging additional Divisions out of the parent Kulu Forest Division in Himachal Pradesh. It would, however, be preferable if the W.P. is prepared on a regional basis or within the framework of regional planning. It would be highly desirable if consultations are provided between the adjoining Units/States for pooling up resources to supply raw materials to the industries in a common catchment area. Co-ordination at the inter-state level is also necessary.

Who should draw up the Working Plan ?

There are two schools of thought ; one that advocates a Special Duty Officer, Divisional Forest Officer (D.F.O.), i.e., a Working Plan Officer (W.P.O.), and the other the Territorial Staff. Argument in favour of the territorial officer is that he has detailed knowledge, both of the forests and the needs of the people, and is able to plan the most practical organisation for the general good. This is certainly true of officers in Europe where foresters stay in their posts for long periods—but it is not so in India. Local Officers are here so busy with administrative and routine work that it is almost impossible for them to devote un-interrupted attention to the W.P. work, and cover extensive areas within reasonable time.

Special Duty D.F.O., (W.P.O.), on the other hand, although he would not have the local knowledge and back-ground information, would be able to devote more time and attention and do a quicker job. The ideal would, of course, be if he continues to operate the W.P. that he has prepared so as to ensure its workability.

In some countries a combination of both methods exists. The local Forest Officer is given the supporting additional staff for collection of data, preparation of maps, etc. In any case, whoever may prepare the W.P, it is desirable that there is full co-ordination, consultation and discussion about the objects of management, silvicultural methods, etc., between the territoriol D.F.O. and the W.P.O., before a plan is prepared.

Period of the Working Plan :

Working Plan period is "the period for which detailed prescription are laid down in a Working Plan." There has to be some general basis for long term development in a plan; e.g., if a forest has to be worked, provisional decisions will have to be taken about *Rotation*, or the size of produce intended to grow, sustained or intermittent yield desired, and so on. On the other hand, the idea that the whole future of the forest can be mapped out and ordered for long periods has proved to be fallacious, because nature cannot be regulated to a machine-like precision. Poor seed-years, periods of drought, storms, fluctuations of market, size and species in demand and all such considerations make it unwise to plan for long periods. At the same time, the process of revising a W.P. involves time, labour and money which should not be expended too frequently. Sometimes there may be some inherent factors of the management prescribed which may determine the period, such as regeneration period, e.g., 30 years in Aggarwal's Kulu W.P. and Romesh Chandra's Kangra (H.P.) W.P., and 20 years in Sinha's Saranda (Bihar) W.P.; with provision for intermediate revision after expiry of half the period. A 20-year regeneration period may well be split up into two W.P. periods of 10 years each. A period of 10 years is generally found to be convenient for detailed planning in India, and has been suggested in the proposed *All India Working Plan Code* as well. It may, however, be increased or decreased, according to exigencies of circumstances, such as stability of markets, methods of treating the G.S. and its response, regeneration period and closure programme, availability of funds for revision, natural calamities and emergencies which disturb yield regulation, etc. Circumstances change and markets vary; plans should, therefore, be prepared for limited periods only.

Annual Plan of Operations (A.P.O) :

An A.P.O. is : "A tabular statement showing the order and extent of all works to be carried out during the year. Such a plan is based on the prescriptions of the W.P. where it exists, otherwise on general silvicultural principles as modified by financial provisions." (Glossary).

It is a short term plan, within the framework of a W.P., dealing with thinnings, cultural and other forestry operations, correlated with funds—annual Budget Estimates for Revenue and Expenditure. The D.F.O. sanctions the A.P.O. of the Ranges, keeping in view the distribution of work to range staff, supplies to various consumer industries, etc.

WORKING PLAN ORGANISATION

Constitution of a W.P. Division is generally decided by the Conservator of Forests, Working Plans Circle (C.F., W.P.) in accordance with the set programme of preparation and/or revision of W.Ps. drawn up by him and approved by the Chief Conservator of Forests (C.C.F.). Although in some States, W.P.Os. are appointed specially for revision of each W.P., there is an increasing tendency for appointment of a W.P.O. for each territorial Circle, or a combination of such Circles, so that after the revision, an effective control and review is possible Special W.P.Os. are also appointed, in addition to Circle W.P.Os, if and when required.

The headquarters of the W.P.O. is normally the same as that of the territorial division, of which the W.P. is to be prepared or revised. The entire touring season is spent in the field by the W.P. party, returning to headquarters only in the monsoon season for compilation of the field data and writing up of the W.P.

The W.P.O. is usually of the rank of a Deputy Conservator of Forests, assisted by one or two Assistant Conservators and two or more Forest Rangers, Deputy Rangers and Foresters for compartment description, enumerations, etc., and Surveyor/Draftsman for demarcation, mapping and checking of boundaries. This staff is generally made available by the territorial C.F. Special pay/allowances are admissible to the W.P. staff. The W.P.O. is also provided with adequate office staff, transport, equipment, etc. His budget is prepared by the C.F (W.P.), and got sanctioned by the C.C.F. For accounts purposes, the W.P.O. has the same powers as the territorial D.F.O. In some States, the accounting functions of the W.P.O. are attended to by the territorial D.F.O.

DIVISION OF FOREST AREAS

For Legal, Territorial, Administrative and Management subdivisions (the four main and distinct ones) of the forest areas, refer to Chapter III—"Forest Organisation".

CHAPTER XIV

PREPARATION OF WORKING PLANS

(Note : The procedure and the format outlined here-under is based mainly on the Working Plan Code of the U.P. Forest Department, and the draft All India Working Plan Code, circulated by the Director of Forestry Research, F.R.I. and Colleges, Dehra Dun to the various States in November, 1983 for comments.)

Preliminary Working Plan Report :

The principal object of the W.P. Preliminary Report (P.R.) is to examine the result of the past working, to decide how far the prescriptions of the previous W.P. should be followed, and where and in what direction modifications are necessary. It is, therefore, an important document for the preparation and revision of a W.P.

First Preliminary Report : The C.F. (W.P.) asks the D.F.O. (Territorial), through the C.F. (T), at least six months in advance, for a preliminary reconnaissance report on the operation of the current W.P. This report briefly reviews for each Working Circle :—

(i) The results of management.

(ii) The success or failure of past prescriptions.

(iii) Suggestions for any changes that may be necessary.

This is followed by a discussion between the C.F. (W.P.), and the C.F.(T) and, if necessary, the C.C.F. is consulted to arrive at the greatest measure of agreement. In case of a new W.P., the first P.R. will contain a short description of the forest concerned, facts relating to their management, working and reproduction, the future treatment recommended alongwith reasons therefor, and also a sketch map showing, roughly, the proposed Working Circles.

In the following season, the C.F. (W.P.), inspects the forests and prepares the first P.R. This is submitted to the C.F. (T) for comments, discusssd and got approved by the C.C.F.

The Preliminary W.P. Report forms the basis of the W.P.O.'s immediate work. In some States, such reports are prepared by the

W.P.O. himself, after discussion with the territorial D.F.O. and the C.F., and submitted by him through the C.F. (W.P.) to C.C.F. for approval. In respect of the changes in management, generally only tentative proposals are made pending collection of further information by the W.P.O. during the course of the first years's field work.

This report also indicates the information to be collected, the maps to be prepared, the type and intensity of enumerations to be carried out, and so on.

Second Preliminary Report : In some States, e.g., U.P., a second P.R. is prepared by the W.P.O., after the first season's field work. In this report, Part II of the W.P. is written up as complete as possible, Chapter by Chapter, using the standard paragraph headings in their proper order and making it fully self-contained. The main outline is that of the first P.R., with such additions or alterations as considered necessary. This report is then submitted to the C.F. (W.P.), who forwards it to the C.F. (T) and the C.C.F. After considering the comments of the C.F. (T) and discussing it with him, the C.C.F. indicates such alterations as he considers necessary, and finally sanctions it.

The Director Forestry Research, F.R.I. and Colleges, Dehra Dun has suggested the constitution of a Working Plan Committee, comprising the C.C.F., C.F. (W.P.), C.F. (Research) and the C.F.(T), W.P.O., D.F.O. (T) and the Forest Utilization Officer to discuss the second P.R. in detail, before finalising and adopting the report.

Once the report is sanctioned by the C.C.F., no major alterations are ordinarily made.

FIELD WORK

1. *Working Season* :

The W.P.O. should commence field work immediately after the rainy season and normally continue upto summer. In hill divisions the work should continue till June.

2. *Examination of the Territorial Units* :

The W.P.O. should examine if the Blocks, Compartments and Sub-compartments are properly demarcated and adequately subdivided for the new plan. Boundaries cannot be changed except with the sanction of the C.F. (W.P.).

3. *Compartment Description* :

The W.P.O. will bring all the descriptions of compartments upto-date, by incorporating all important changes brought about by various factors. Descriptions should be concise, not verbose, and should convey an adequate idea of the composition, quality, age, density and general characteristics of the growing stock (G.S.). Where old compartment description does not exist, as much information as possible should be collected by the W.P.O.

The W.P.O. will make notes in a systematic manner, when he visits each compartment. These notes should be in a standard form prescribed by the C.F. (W.P.) or the State Working Plan Code. The importance of these notes cannot be over-emphasised as they form the basis of descriptions, which, in turn, constitute the foundations on which future management rests, e.g., allotment to Working Circles, P.Bs., etc.

The minuteness of description depends, as does the sub-division of area into compartments and sub-compartments, on the method of treatment adopted and the object in view. (A sample page of the Compartment Description format adopted by the U.P. Forest Department is appended—Appendix IV).

To obtain a good general idea about the compartment, it is advisable to traverse it in atleast two diametrically opposite directions, though this may not be practicable in a hilly country, wherein it would be best to keep to the ridges and spurs and make such excursions as necessary into the adjoining forests. At the same time, the slopes can be viewed and a good general impression of the composition and stocking obtained, if the types are well marked. Hilly areas must be traversed methodically, with a minimum of over-lapping, and each day's work planned ahead.

Special treatment required for regeneration, or for improving the crop, such as burning, shrub cutting, fencing, thinning, etc., should also be noted.

Boundaries : These are checked with entries in the *Compartment Histories* or the *Demarcation Register*, and any discrepancy or encroachment detected will be brought to the notice of the territorial staff.

Rock and Soil : Important facts about soil should be expressed in a few words, describing the underlying rock, surface, composition and depth.

Age-Classes : This is unimportant in Selection forests. In Uniform forests, the overwood should be allotted to a definite age-class, i.e., young, middle-aged or old.

Quality : The quality of crop is assessed by measuring heights and diameters of atleast 10 dominant trees in each compartment or sub-compartment ; selected trees should collectively represent the average of the whole area.

Density of Stocking : This is usually estimated ocularly by inspection, and checked with enumeration results, if any. Frequency of species is indicated by symbols : (*a*) for abundant ; (*f*) for frequent ; (*o*) for occasional ; (*r*) for rare and (*l*) for local.

Estimates of *Quality* and *Density* are of considerable importance if the yield is prescribsd by area reduced for *quality* and *stocking*.

Regeneration : The adequacy or otherwise of young regeneration, and also its condition, should be mentioned

4. *STOCK MAPPING :*

Glossary defines a *Stock Map* as : "A map showing distribution of different forest or stand types, which have a bearing on Management, with information about their composition, age-classes, etc."

Detailed descriptions of compartments are tedious and bulky in case of a large area. It requires as much minute care on the part of the writer, as steady attention on the part of the reader ; and, after all, it is very difficult to get any idea of the forest in its entirety from its perusal. A graphic representation of the nature and composition of the forest (i.e., a Stock Map) would probably give a better general idea of its condition and contents, and could be prepared with much less trouble.

The *Stock Maps* are generally prepared by the W.P. Rangers or the A.C.Fs., but the W.P.O. himself should also stock-map a certain number of the compartments and check in the field at least 20% of the maps prepared by the A.C.Fs./F. Rs. These maps are usually 1 : 15000 to 1 : 5000 scale. Field work is done in pencil ; this is inked and coloured the same day when back to office.

The additional details which should be shown in the *Stock Maps* will vary according to the intensity of management and the crop composition; these are indicated in the preliminary W.P. report.

Broadly the main categories to be distinguished are :

(a) **Crop Composition :** In case of gregarious species like sal, teak, deodar, classification may be done on the basis of % mixture with other species; for example :--

(i) 75% and over *teak* may be classified as *pure teak.*

(ii) 50–75% *teak* —do— —do— *mainly teak.*

(iii) 25%-50% *teak* —do— —do— *mixed teak.*

(iv) <25% *teak* —do— —do— *Misc. with some teak.*

In case of mixed dry or moist deciduous forest, not containing teak or sal, the components of misc. spp. may best be shown by adopting symbolic notations. In case of pure crops, only the specified colour wash (for the spp.) is given.

(b) **Density :** For all practical purposes, a three-fold classification of density serves the purpose; e.g., Poor ; Moderate ; Good. In U.P., and more commonly elsewhere too, it is represented by decimal fractions.

(c) **Quality :** This needs to be shown where there are more or less sharp or abrupt changes in variable terrain. This can be done by super-imposing hatching of lines on a conventional pattern.

(d) **Age-Class Distribution :** Young (Y) ; middle-aged (M) or Old (O) may be shown separately, specially in case of gregarious spp. which tend to occur in distinct age-groups.

(e) **Regeneration :** An accurate delineation of the extent of young regeneration and advance growth is specially significant in case of crops managed under the Conversion, Uniform or the Group System.

All blanks, tree-less grassy patches, water-logged areas are shown separately (if>2 hectares). For all practical purposes, stock-maps show the principal species, their purity and/or mixture; quality, density, age-classification by a pre-determined pattern of colours, hatchings, symbols, figures, etc. While inspecting the forest for compartment description and stock mapping, various relevant notes made in the field may be, in some such form as S/II/M/O.6 to show a middle-aged (M) *sal* (S) forest, II quality, with a density of 0.6.

A brief description accompanying a *stock map* furnishes a complete picture of the forest inspected.

In most cases, it may be necessary only to revise the old compartment descriptions and the Stock Maps. However, a more detailed study will be required for preparation of the new ones.

COLLECTION OF STATISTICAL DATA

Forest Inventories :

While designing a forest inventory, three factors, viz., cost, time and accuracy level should be kept in view

Except for a small area, every tree cannot be enumerated. Total enumerations should be avoided, as far as possible, and some sort of sampling technique should be adopted.

It is also useful to plan integrated surveys, of various resources at the same time, e.g., trees, bamboos, grasses, minor forest produce, etc. Use is being progressively made of new tools available for forest inventory work, viz., :

(i) New sampling techniques : Bitterlich's method of *point sampling* or *variable plot sampling.*

(ii) Wide variety of sampling designs (stratified sampling designs ; multi-stage sampling, etc.).

(iii) Dendrometry, i.e., measurement of trees and their volumes without felling; by the use of dendrometers.

(iv) Aerial photographs and *saetllite photography.*

(v) Electronic Data processing by the use of computers and electronic calculating machines to fit regression equations, etc.

Planning an Inventory :

A simple formula for estimating the size of sample needed to determine the intensity of sampling is :

$$n=\left(cv\%\times\frac{t}{e\%}\right)^2, \text{ where}$$

'n' = Number of samples needed.

't' = Students' 't' at a given level of probability ; for example, for 95% Confidence Limit 't' is equal to 2.

'cv' = Coefficient of Variation, i.e., $\frac{\text{Standard Deviation}}{\text{Mean}}\times 100$

'e' = Desired measure of accuracy, i.e., desired sampling error, or standard error expresed as percentage of the Mean.

Thus, if 'e' = 10% and cv = 100%, at a 95% Confidence Limit,

$$n=\left(\frac{2\times 100}{10}\right)^2=400$$; i.e., 400 sampling units are required.

Coefficient of Variation ('cv') for the most important parameter to be sampled (say, volume) should be chosen for the above calculation It may either be derived from a fresh random sample, or from old inventories, but it should be based on the same sampling scheme (i.e., plot size, etc.)

Type of sampling may be fixed radius plots or variable plots (Point-sampling), using Relaskope or Wedge Prism. In fixed radius plots, the size of the plot depends on many considerations, but a standard size of 0.1 ha may be used in most cases.

The lay out of samples may be by (i) Topographical Units, (ii) Strips of a definite width spaced apart, either in a systematic, random or systematic with a random start pattern, or (iii) Grid points, i.e., location of sampling units at the intersection of grid lines on maps. At each point, there can either be single or a cluster of plots ; the grid points may also be selected either at random, in a systematic sample or in a stratified random sample.

The techniques of sub-sampling, two-stage sampling, multi-stage or 3 'p' sampling *(probability proportional to prediction)* can also be used.

Use of Aerial Photographs :

If aerial photographs of the area are available (say, on a scale of 1/50,000), they can be used with advantage for the following purposes :—

(i) Preparing stock-maps and forest-type maps.

(ii) Stratification for sampling by species, density-classes, topography, etc.

(iii) Location of grid-points or other sampling units, particularly in accessible areas.

(iv) Area determination by using a suitable dot grid area calculator.

TREE ENUMERATIONS :

(For details of the methods, refer to any book on *Forest Mensuration*)

(i) Diameter Classes : All enumerations should, ordinarily, be in 10 cm dia. classes, or 30 cm girth classes, except when the exploitable dia. is so low that 5 cm classes, at least for the lower part of the range, are desirable. If the exploitable dia. falls within a dia. class, it may be necessary to sub-divide the class ; e.g., if the exploitable dia is 35 cm, it may be necessary to enumerate 30–40 cm dia. class in two parts, viz., 30–35 cm and 35–40 cm.

(ii) Species to be enumerated : The species to be enumerated and recorded will be given in the first Preliminary Report. In view of the increasing importance of miscellaneous species for major and minor forest products, it would be advisable to enumerate and collect statistics of as many important, and potentially important, species as possible. These may be lumped together in the final abstracts of the W.P., but should be shown separately in the Compartment Histories. It may however, be kept in mind that it is not possible to enumerate a large variety of species accurately ; and enumeration of more than six species simultaneously adds considerably to the cost of enumeration.

(iii) Classification : Trees should be classified into *sound* or *unsound*, *fit* or *unfit*, *saleable* or *unsaleable*, according to the local practice in vogue. In case of *Chir* forest where twist is prevalent, it is usual (in U.P.) to note upto 7° left-handed and upto 15° right-handed twist only, as beyond these limits the trees are unfit for sawing.

System of Enumeration :

The W.P. Conservator will decide the system of enumeration, in consultation with the Silviculturist, for each Working Circle, or part thereof, The factors on which the choice of the system will depend are : the extent of the area, topography, variation in species composition, density of valuable species, intensity of management and productivity of the forest.

(For a detailed study of the following aspects, it would be useful to refer to books on Mensuration ; one by Chaturvedi and Khanna by the same publisher is suggested).

(i) Choice between total and partial enumeration : based on factors of intensity of management, cost, time, labour, standard of accuracy required.

(ii) In case of partial enumerations : the intensity of sampling methods thereof (viz., stratified random or systematic sampling by whole compartments, sub-compartments or by topographical sampling units *or* systematic sampling by strips in plains forests).

Stock maps would be necessary for preliminary planning and selection of sampling units.

(iii) Stratification, i.e., the division of the area into a convenient pattern of blocks from each of which a certain number of samples is taken.

(iv) Enumeration staff and labour.

(v) Instructions to the Enumerators.

(vi) Check Enumerations.

(vii) Equipment required.

(viii) Norms of output.

(ix) Point Sampling—Horizontal and Vertical forms. Use of Wedge prisms and Relaskops.

(x) Lay out of grid for sampling.

BAMBOO ENUMERATIONS :

Due to the great importance of *bamboo* for paper pulp, bamboo survey/enumeration has become an essential part of Working Plans of Divisions where it is found in commercial quantities.

Method : (As commonly followed in U.P.) : Two stage stratitied random sampling method is generally used. In the first stage, sampling is carried out to estimate the number of clumps per unit area ; second stage sub-sampling is carried out to estimate the number of culms of various ages per clump.

In case of sampling by topographical units (say 20%), the total number of bamboo clumps is enumerated in the sampling unit concerned ; this constitutes the first stage. Simultaneously, as the second stage, every 20th clump is also sub-sampled (5%) for recording the number of culms. In this way, ultimate sampling intensity for culms is 1%. In case of strip sampling, first stage consists in enumerating all the clumps in the strip concerned (40 m, i.e., 2 chain wide) ; the second stage comprises detailed sub-sampling all the culms in 40 m×20 m rectangle formed along the strip at 200 m intervals. Strip sampling being 10% in intensity, the ultimate intensity of culm sampling is 1%.

Classification of Bamboos : The following classification is used for bamboos for the first stage sampling (*clump count*) :—

(a) *Thrifty* : healthy, undamaged and uncogested.

(b) *Culturable* : rather unhealthy and congested or partly damaged, but can be improved and brought to full production by cultural operations and cleanings, etc.

(c) *Degraded* : Badly congested ; severely depleted—lacking in vitality ; incapable of attaining normal productivity. These clumps may further be distinguished into :—

(a) *Un-established* : Culms less than ½ normal size (dia.) of seedling origin, having not yet attained clump form.

(b) *Im-mature* : A stage further beyond (a)—culms not yet full size ; clump small.

(c) *Flowering* : (i) Sporadically, (ii) Gregariously.

Culm Classification : for use in second stage sub-sampling (*culm count*) of every selected clump :—

(i) Total number of culms.

(ii) No. of culms of current year (1 year).

(iii) No. of culms of previous year (2 years).

(iv) Average dia. of young culms (based on 5 culms of classes ii and iii above, measured at the *third* internode above the ground level.

(v) Average height of young culms (as in case of iv).

It is essential to cor-relate the number of culms wit.. 'ry weight as this information is essential for estimating pulp yield. The constant dry weight of 100 trimmed culms is determined, both height and dia. class-wise, and for sample as a whole; the final averages being derived from atleast three such weighments.

Stock Maps of Bamboo : These are prepared, showing areas flowered gregariously as well.

REGENERATION SURVEYS AND MAPS :

These surveys are considered necessary, particularly in Sal forests worked under Shelterwood System, to determine the status of regeneration before allotment of the area to regeneration block (P.B.I/Floating P.B.), and then assess the progress of regeneration therein.

The procedure adopted in U.P. Sal forests is as follows :—

The survey is usually combined with partial enumeration by strips ; sub-sampling can be done, 2 to 5% of aggregate area. Regeneration is recorded in quadrats, 2 m×2 m formed on either side of the cruise lines. If 10% strip sampling is being done, in strips 20 m wide (200 m apart), and 2 m×2 m quadrats are laid on either of cruise line, regeneration survey will be 20% of strip, or 2% of the total forest area. Cruise lines should not be too far apart—not more than 200 m—to get a fairly complete picture of disposition of regeneration, and to make it possible to prepare an accurate stock map.

When regeneration survey data comes to be plotted, each surveyed strip is representative of a rectangle 20 m × 200 m in case of 2% sampling, and 20 m × 80 m in case of 5% sampling.

In regeneration surveys, it should suffice to record the occurrence of the most promising categories of plants (regeneration) only. In case of sal, it should suffice to concentrate on poles, saplings or other established plants, or on woody shoots on way to establishment, and on large whippy saplings—establishment height being taken as 2—3 metres (2.5 m in Dehra Dun) depending on local adverse factors.

Method of recording is as follows :—

No.	Symbol	Category of Regeneration	Remarks
1.	*e*	Woody shoots of estt. ht., or over. (Weightage Factor—W.F.=5)	*e* symbol indicates presence of atleast one such plant sufficient to stock the quadrat.
2.	*w*	Woody shoot, less than estt. ht., healthy and vigorous to become estd. (W.F.=4)	In the absence of (1), symbol *w* indicates at least one such plant to stock the quadrat completely
3.	$\overset{+}{u}$	Non-woody (whippy) old, unestd. regeneration (W.F.=2)	In the absence of (1) and (2), symbol u^+ indicates more than one such plant.
4.	*u*	—do—do —do— (W.F.=1)	—do— —do— one such plant only.
5.	*r*	Recruitment (W.F.=0.1)	In the absence of 1, 2, 3, and 4, *r* may be recorded.
6.	*o*	No seedlings : blank	—

The data may be classified for plotting on the basis of *weightage factors* (W.F.) given above. Taking a unit consisting of 20 quadrats (10 quadrats on either side of cruise line : 4 m wide × 20 m long), as a suitable stretch for preparing a regeneration map (in case of 2% sampling, it will represent a rectangle 200 m × 20 m, 0.4 ha in area), the maximum cumulative weightage will be 100 (all the 20 quadrats with *e* regeneration). The other commulative weightage values can then be graded as :

Cumulative Weightage Value	*Regeneration Status*	*Colour for Regen. Map*
81–100	Excellent	Green
61–80	Good	Blue
41–60	Moderate	Yellow
21–40	Fair	Red
0–20	Deficient	Blank

Black hatchings may be super-imposed on colour where smaller sub-divisions are considered desirable ; e.g., blue colour with hatchings will indicate 71—80 (Good) and only blue colour will indicate 61–70 (Infra Good) ; similarly for all other categories.

Symbols : The calculation of cumulative weightage value does not give information regarding the individual contribution of different categories of regeneration. Where there is much variation in this respect, exact make up of regeneration can be shown by printing symbols in each half of the assessment rectangle (say 100 × 20 m) in the following manner :—

There are 10 quadrats in each *half rectangle* ; the number of quadrats with *u*, u^+, *w* and *e* can be written as a four figure number, with *u* occupying the place of unity, u^+ that of tens, *w* that of hundreds and *e* that of thousands. Thus for 2 quadarats with *u*, 3 with u^+, nil with *w* and 5 with *e* (total 10), the symbol will be 5032. If all the 10 quadrats represent only one category of regeneration, the place should bear the letter symbol for that category ; e.g., if all the 10 quadrats contain *w*, the symbol will be 00*w*0.

This method can also be used to represent the make up of regeneration of any part of the area, the mean values of *u*, u^+, *w* and *e* being computed as parts of ten and then rounded to the whole numbers. Thus for part of the compartment in which regeneration is more or less homogeneous, and the mean values are : u=31.6 ; u^+=14.4 ; w=46.2 ; e=7.8, the corresponding symbol will be 1513.

MAPS

General : New maps are prepared, and copies of existing maps are supplied by the Director, Map Publications, Survey of

India, Hathibarkala, Dehra Dun (D.M.P.). Administrative instructions should be followed with respect to correspondence with the D.M.P. in such matters.

Preparation and Printing of new W.P. Maps : The procedure for preparation of new maps by the W.P.O. is as follows :—

(i) If the old W.P. map is available, an un-corrected copy will be corrected and brought upto-date. A list of changes and missing details will be submitted with the revised map.

(ii) If the old map is not available, new map will be prepared from the standard 1 : 50,000 (old 1″=1 mile) map, uncoloured Survey of India topographical sheets, which may be obtained from the Map Publication Office (M.P.O.); the index numbers of sheets being ascertained from the Survey of India Map Catalogue.

(iii) The tracing or the map will be prepared in duplicate and one copy sent to the M.P.O for reproduction and printing From this, Map Office will prepare a plate, print some proof sheets and send one copy to the W.P.O.

(iv) The M.P.O. will print the map, as far as forest details are concerned, according to "standard forest references" which are shown on all such maps. Change, if any desired, will be got approved by the C.F. (W.P.) and communicated to the M.P.O.

(v) Proof copy is corrected by the W.P.O. and sent to the M.P.O. for printing the required number of copies.

Printing of Divisional Maps : These are usually on 1 : 15,000 or 1 : 25,000 scale. Each territorial Conservator (C.F.,T) is responsible for the accuracy of maps pertaining to his Circle, though the W.P.O. assists him by pointing out inaccuracies at the time of periodic W.P. revision. Alterations/discrepancies in Divisional maps are reported by the D.F.O. (T) to the C.F.(T) annually; the latter sends these to the M.P.O. so that the latter's master set is kept upto-date.

When a W.P. is due for revision, it is the duty of the D.F.O. (T) to keep ready sufficient number of complete sets of Divisional maps, duly corrected upto-date, showing compartments, sub-compartments, etc., and send these to the W.P.O. as soon as he assumes charge; usually 2 sets are of cut and mounted maps, and the rest un-cut and un-mounted. These sets will be utilised by the W.P.O. for preparation of *Management*, *Stock* and *Regeneration* maps, and for field work.

PREPARATION OF MAPS BY THE W.P.O. :

(i) **Management Maps :** These are generally on 1 : 50,000 scale (corresponding to the old 1″=1 mile) showing new Working Circles, Felling Series, Periodic Blocks and other details of management.

Each Working Circle is coloured with a distinct colour wash; P.B.I. areas, if any, are usually given a deeper shade of the appropriate colour.

(ii) **Stock Maps :** These are generally prepared on 1 ; 15,000 (old 4″=1 mile) scale. These maps give, ordinarily, the distribution of forest types and main forest species, non-forest areas, blanks, etc. If the management is intensive, age-classes, quality-classes and density are suitably differentiated and super-imposed by hatchings, etc. If old stock maps are available, these are checked and brought upto-date.

(iii) **Regeneration Survey Map :** The procedure for carrying out regeneration survey (as followed in U.P.) has already been given in earlier paragraphs The result is plotted on a large scale map, 1: 5,000 or 1 : 4,000 scale Sufficient number of copies are made by the W.P.O., for the D.F.O. (T), C.F. (W.P.), Compartment History Files (C.H.F.) and supply to the Range Officers for field use, during marking, cultural operations, etc.

(iv) **Working Plan Map :** These are prepared on 1 : 60,000 (corresponding to old 1″=1 mile) to 1 : 30,000 scale (old 2″=1 mile); generally 1 : 50,000. These show all features which are reasonably permanent, such as physiographic features, territorial boundaries including pillars and their numbers, names of blocks, compartments, also showing Forest Rest Houses (F.R.H.), roads, railways, and main-features of the country around the reserved forests.

The W.P.O will prepare 2 complete copies, showing Working Circles, Felling Series, P.B.I areas, compartments, and sub-compartments, plantation areas, Range Headquarters, Range boundaries and other useful/important features.

(v) **Enumeration Map :** In case of partial enumerations, an enumeration map, on 1 : 50,000 scale, (sometimes upto 1=15,000 as in Dehra Dun W.P.) is prepared by the W.P.O. showing location of plots, strips, topographic units, compartments and sub-compartments actually enumerated. Tracings are also made on 1 : 1,5000 scale maps and deposited with the C.F. (W.P.) for future reference.

(iv) **Forest Type Map :** This is prepared on 1 : 50,000 scale showing forest types, according to the prescribed colour guide (as per State W.P. Code). The W.P.O. will prepare one copy in consulation with the State Silviculturist and get it approved by the C.F. (W.P.). Copies of the same are prepared and distributed as per prescribed practice.

To prepare such maps, it will, in most cases, be sufficient to distinguish climax types (Champion and Seth's classification) by flat wash of distinct colour ; seral and edaphic types could be shown by black patterns super-imposed as follows (draft suggestions for the All-India W.P. Code) :—

Primary Seral	—	Black horizontal lines
Secondary Seral	—	Black Vertical lines
Edaphic	—	Black dots
Degradation	—	Black cross-hatching

For each main group, the following colour scheme may be used. Sub-groups, sub-types, etc., may be distinguished by the super-imposed pattern given above.

	Group Designation		*Colour*
1.	Tropical Wet Evergreen	...	Violet
2.	Tropical Semi-evergreen	...	Purple
3.	Tropical Moist-deciduous	...	Cobalt blue
4	Littoral and Swamp forests	...	Prussian blue
5.	Tropical Dry Deciduous	...	Yellow
6.	Tropical Thorn	...	Red
7.	Tropical Dry Evergreen	..	Pink
8	Sub-tropical Broad-leaved Hill forests	...	Vermillion
9.	Sub-tropical Pine		Orange
10.	Sub-tropical Dry Evergreen	...	Burnt umber
11.	Northern Wet Temperate	...	Olive Green
12.	Himalayan Moist Temperate	...	Green
13.	Himalayan Dry Temperate	...	Yellow
14.	Sub-alpine	...	Burnt sienna
15 and 16.	Alpine	...	Sepia

(vii) **Reference Map : Each W.P. should have a small reference map on the inside of its back cover, of convenient size to fold.** It should show main boundaries of the forests, ranges, roads, canals, F.R.Hs, neighbouring towns and villages, etc. Scale of the map will depend on the size and shape of the Division. Details should not be over-crowded.

(viii) **Soil Map :** A Divisional map on a convenient scale should be made showing broad soil types, on the basis of data collected in the soil survey during the W.P. field work.

General : A register of maps will be kept in the W.P. Office in which a record will be maintained of the maps, alongwith their sheet numbering and the tracts covered by the maps.

WRITING UP THE WORKING PLAN

General : A W.P. is a comprehensive reference document for the concerned forest area ; as such, it should contain all relevant statistics and data in a very concise form.

It is necessary to reproduce, for ready reference, all Govt. orders, pertaining to the grant of rights and concessions to local population, regulation of grazing, etc., as also the legal position of the forests.

In the modern Working Plans, there should be more stress on the ecological, environmental and socio-economic aspects, water-shed management, wildlife management, recreational forestry, etc., rather than on mere commercial timbers exploitation, as hitherto-fore.

The effect of clear-felling and other forestry operations on soil and the environment should be studied and taken into consideration.

The W P. would consist of two parts, Part–I dealing with the factual information about the area, and Part II dealing with the prescriptive part (Future Management), followed by Appendices. In addition, the W.P.O. will also update the *Compartment Histories* and *Stock Maps*, and prepare *Control Forms*.

In case of revision of a W.P., the text of Part I should not be changed much from that of the expiring plan, except that all statistics for the intervening part would be added up, and the text modified so as to reflect the socio-economic conditions.

Format of the Working Plan :

Standard format for the write-up of the W.P., with some additional Chapters as suggested in the draft "All India Working Plan Code" is given in Appendix V.

CONTROL AND RECORDS :

System of Control : It will be through the control forms, which will be prepared to include each of the prescriptions as well as definite suggestions regarding other operations left at the discretion of the territorial staff. The W.P.O. will prepare a draft set of Control Forms to control all operations prescribed and suggested in his Working Plan. These forms will be submitted to the C.F. (W.P.) for approval and preparation of final copies. Deviations are got approved by the C.F (W.P.)/C.C.F.; if these can be foreseen, necessary advance sanction of the competent authority is obtained.

Control Forms : Format of the various Control Forms varies from State to State. Essentially these are prescribed to control :—

(i) Yield, (ii) Fellings – Departmental and Contractor's Agency, (iii) Subsidiary Operations, (iv) Tending Operations, (v) Plantations, (vi) Natural and Artificial Regeneration, (vii) Revenue and Expenditure.

Compartment Histories : The W.P.O. should bring all sets of Compartment Histories to date and hand these over back to the D.F.O. (T).

Plantation Journal : The W.P.O. should prescribe the maintenance of separate Plantation Journal for each plantation in an appropriate form, which he will prescribe.

Fire Records : This will be maintained in the *Register of Fires*, in which details of areas burnt, damage caused, etc., will be recorded alongwith the sketch maps of the areas burnt. D.F.O. (T) sends reports to the C.F./C.C.F. as per instructions.

Climate Register : Observations of temperature, rainfall, etc., at various stations will be maintained separately, as also regarding depth of wells and water-table. Occurrence of floods, drought, storms is also recorded in this register.

Flowering of Bamboos and Seed Years of Principal Species : These observations are recorded in a separate register.

Deforestation and Afforestation Records : These are recorded in a separate register.

Game Record : Record is maintained in a separate register, of the game shot, observations regarding regeneration of Wildlife, notifications for creation of Wildlife parks and sanctuaries, etc.

Cattle Census : It is recorded in a separate register, if and when the Census takes place.

APPENDICES

APPENDIX—I

NATIONAL FOREST POLICY OF INDIA (1952)

DIRECTIVE PRINCIPLES GUIDING MANAGEMENT OF FORESTS :

(i) The primary object of management of forests lying in the catchment of important rivers should be to utilise in full their protective influence on soil, the water regime and the physical and climatic factors of the locality Further, the interests to be so safeguarded are to outweigh all others which it may be necessary to restrict.

(ii) The village communities in the neighbourhood of forests naturally make greater use of these for the satisfaction of their domestic and agricultural needs. Such use, however, is not to be permitted at the cost of national interest. Further, it is more in the interest of the villagers that these forests should be properly managed, so as so be able to meet their legitimate requirements for fuel, fodder and timber in perpetuity.

(iii) The national forests, as defined in Article 13 of the National Forest Policy of India, are to be managed chiefly in the interest of the nation as a whole. Their management on scientific and commercial lines is essential for maintaining a sustained supply of wood for industry and timber for Defence, Communications and other national purposes To attain national self-sufficiency in these vital supplies, effort should be made to maintain and extend the forests over suitable areas.

(*Source* : Working Plan of Chakrata Forest Division 1977–78 to 1986–87, by P.C. Srivastava)

APPENDIX—II

WORKING PLAN FOR CHAKRATA FOREST DIVISION

(1977–78 to 1986–87)

(By P.C. SRIVASTAVA)

(Extracts only)

GENERAL OBJECTS OF MANAGEMENT:

(i) To conserve, improve and extend protective vegetal cover of forests and other perennial vegetation over the tract dealt with, thereby to ensure soil and water conservation and equitable and regulated flow of water in the streams and rivers.

(ii) Consistent with (i) above, to achieve progressively the maximum possible sustained yield of timber and other forest produce and maximum economic returns by :—

(a) Increasing the exploitation and productivity of the existing forests, in respect of all kinds of forest produce to the maximnm possible extent, by intensification of management and tapping of non-utilized and under-utilised potential.

(b) Progressing towards the best possible stocking of the existing forests, and towards normal forests with normal growing stock, i.e., normal distribution of age-classes and normal increment.

(c) Maximising the area under, and the proportion of, the species which have the highest value and which are in great demand for important national industries, in all localities suited to their growth.

(d) Maximising the productivity in terms of all kinds of forest produce by tending, developing and augmenting the forest resources to the extent possible.

(iii) Consistent with (i) and (ii) above, to provide for the bonafide domestic and agricultural requirements of the local people holding rights and concessions.

(iv) To foster and promote the utilisation, and to tend and develop the market and trade, of conifers like *Yew (Taxus wallichiana)*, the various broad-leaved species (including the Oaks), medicinal and other economic herbs, which have great potential for industrial and other uses but are practically unexploited at present.

(v) To conserve and develop the wildlife in the tract.

(vi) To promote peoples' enjoyment of, and involvement with, the forests by developing recreation forestry, outdoor recreation and tourism, and thus instil forest consciousness and goodwill among the public.

CONSTITUTION OF WORKING CIRCLES—

Chakrata Forest Division :

Keeping in view the general objects of management stated above, the following Working Circles have been constituted :

(1) *Chir*, (2) *Deodar*, (3) Fir and Spruce, (4) Oak, (5) Protection, (6) Industrial Timber, (7) Resin (Over-lapping), (8) Plantation (Over-lapping), (9) Minor Forest Produces (Over-lapping)

CHIR WORKING CIRCLE—*Special Objects of Management* :

(i) To convert the existing more or less irregular forests to uniform crops, and to progress in the direction of normal forests by obtaining a normal age-class distribution, to the extent possible, without sacrificing young stock.

(ii) To ensure establishment of *Chir* regeneration within the shortest possible time by tending the existing natural regeneration and by planting where necessary.

(iii) To get maximum possible sustained yield of *Chir* timber, pulpwood and resin to meet the requirements of trade and industry.

Silvicultural System :	Uniform System with Floating P.B.
Regeneration Period :	25 years
Rotation :	100 years
Conversion Period :	100 years
Allotment to P.Bs. :	Two P.Bs. recognised ; (i) P.B. last—including all converted areas, (ii) P.B. I.—including the rest of the area. It is further subdivided into two groups: A (wherein *seeding fellings* have already been done) and B (wherein

seeding fellings have not yet been done).

Yield from P.B.I. : It is based on available/removable volume in P.B.I. (assessed on silvicultural considerations; ignoring the increment) during the Working Plan Period (10 years).

DEODAR WORKING CIRCLE *Chakrata Forest Division* :

Reducing Factors (R.F.) : Normally areas are reduced for crown cover and quality for making equi-productive coupes. However, in this case, reduction factors for quality alone have been applied, for want of data for density. As majority of the compartments have II quality crops, the reduction factors for various qualities are worked out in terms of II quality (taken as Standard, its R.F. being taken as Unity), as in the following table :—

Quality	Height (m)	Mean height for which M.A.I. calculated (m)	M.A.I. at rotation (m^3)	R.F
I	above 42.4	42.4	4.39	1.37
I/II	39 4 to 42 4	40.9	3.79	1.20
II	36.4 to 39.4	37.9	3.20	1.00
II/III	33.4 to 36 4	34.9	2.68	0.83
III	Below 33.4	31.4	2.04	0.63

(*Note* : M.A.I. figures appear to have been worked out per acre ; it is immaterial for working out R.F.).

Rotation : 160 years.

Allotment to Periodic Blocks : As the Floating P.B. method has been adopted, the following 3 P.Bs., are recognised.

(i) *Quartier bleu* (or P.B.I.)—areas under regeneration fellings, or fit for these.

(ii) *Quartier rubrum* (or P.B. last)—young converted crop.

(iii) *Quartier blanc* : (or P.B. Unallotted)—Remaining area.

Yield from P.B.I. : P, the period of exploitation for P.B.I. is calculated as :—

$$P = \frac{\text{Reduced area of P.B.I.}}{\text{Reduced area of W.C}} \times \text{Rotation}$$

$$= \frac{4074}{11058} \times 160 = 59 \text{ Years}$$

The annual yield $= Y = \frac{V}{P}$ (where V is the total *removable* volume from P.B.I.) i.e., $\frac{371126}{59} = 6090$ m^3 (round) or say 6200 m^3 (round).

Increment has been ignored as the stocking is poor which needs to be built up.

FIR AND SPRUCE W C.—*Chakrata Forest Division*

Silvicultural System : Selection

Felling Cycle : 10 years.

Method of Calculating Yield : By Smythies' Safe-guarding Formula.

(a) $X = \frac{f}{t}$ (II—Z% of II)

Where X=No. of trees of Class II which pass into Class I during the felling cycle.

f=felling cycle (10 years)

t=the period that the trees in Class II (an average tree) takes to grow to exploitable size, i.e., Class I (25 years).

Z=the mortality percent, i.e., the percentage of Class II trees that disappear in 't' year (25%).

(b) Yield $Y = \left(\frac{X}{I + X/2} \times 100 \pm A\right)$ % of total Class I trees present at the time of marking.

Where I=no. of Class I or Selection trees already present at the beginning of the felling cycle (70 cm dia., and above.).

A=an arbitrary adjustment factor for rounding off the computed percentage yield.

The number of Class I trees actually present at the time of marking will depend on the year of marking. If markings are done in the nth year of Working Plan, then this number will be

$I+\left(\frac{n}{f}\times X\right)$. The above formula (b) pertains to the situation at the middle of the felling cycle

Concrete enumeration data and calculation of Yield :

No. of trees (fir and spruce) of Class I=66,138 (70 cm dia. and above)
No. of trees (fir and spruce) of Class II=36,499 (60–70 cm class)
Overmature trees =20,582

(Overmature trees are 2 dia. classes above the exploitable dia., i.e., 90 cm dia. and above).

Recruitment from Class II to Class I during the felling cycle 10 years, i.e. $X=\frac{10}{25}$ (36,499–25% of 36,499)=10,950.

Since the number of overmature trees is fairly large, which are likely to deteriorate if left for too long in the forest, it is advisable to remove them in 30 years. Thus the maximum yield that can be removed from any coupe during the felling cycle is $=X+\frac{f}{30}$ (no. of overmature trees) or $10{,}950+\frac{10}{30}(20{,}582)=17{,}811$ trees.

Which is roughly 20% of the number of I Class trees present at the time of marking (i.e., $66{,}138+20{,}582+\frac{10{,}950}{2}=92{,}195$ trees), hence the marking instruction would be to fell 1 out of 5 exploitable size trees.

INDUSTRIAL TIMBER (OVER-LAPPING WORKING CIRCLE)—
Chakrata Forest Division :

General Character of Vegetation : Mostly of pure temperate broad-leaved patches, or miscellaneous broad-leaved species occurring in suitable localities, mainly along *nalas* in Fir and Spruce, Oak and Deodar Forests The main species of industrial importance are Walnut, Ash (*Fraxinus* spp.), Maple (*Acer* spp., Horse-Chestnut *(Aesculus indica)*, Cypress *(Cupressus torulosa)*, *Carpinus viminea*, Himalayan hazel *(Corylus colurna)*. In Chir forests—*Alnus nitida*, *Celtis tetrandra* and *toon* *(Toona ciliata)* are found along nalas.

Special Objects of Management :

(i) To get maximum possible sustained yield of the industrial

timbers for various wood-based industries, which in turn feed important national industries.

(ii) To utilise the accumulated overmature stock.

(iii) To ensure adequate natural regeneration of these species through proper silvicultural practices and tending the existing natural regeneration and/or coppice regeneration.

(iv) To restock the depleted areas and to extend the area under industrial species by artificial means.

THE RESIN (OVER-LAPPING) WORKING CIRCLE—
Chakrata Forest Division :

Special Objects of Management : Apart from their traditional uses, rasin and turpentine (the two primary products of resin) are finding ever increasing uses in growing industries like plastics, synthetic rubber, explosives, adhesives, printing inks, pharmaceuticals, perfumaries and cosmetics; turpentine providing an unlimited scope for production of synthetic camphor.

The special object of management is, therefore, to obtain maximum sustained yield of resin for meeting the growing needs of the industry without losing the timber value of the trees, i.e., without prejudice to the special objects of management proposed under ***Chir Working Circle.***

APPENDIX III

WORKING PLAN FOR THE EAST DEHRA DUN FOREST DIVISION (U.P.)

(1979–80 to 1988–89)

(By K.N. SINGH)

(Extracts only)

GENERAL OBJECTS OF MANAGEMENT :

(i) To conserve and extend the existing forest and vegetal cover for soil and water conservation.

(ii) To attain, as for as possible, the normal forest and, where necessary, to supplement natural regeneration by artificial means.

(iii) To stock the under-stocked and blank areas so as to increase the percentage of valuable species, as far as possible.

(iv) To treat severely eroded areas and channelise priority *raus* (hill torrents).

(v) To conserve and enrich the forest fauna in variety and quantity.

(vi) To maintain and raise roadside avenues on P.W.D. roads transferred to this Division.

(vii) Consistent with the above (a) to meet the rights and concessions of the local population, and (b) to progressively achieve the sustained yield of timber, firewood and forest produce of marketable size and quality and to ensure maximum possible economic return.

CONSTITUTION OF WORKING CIRCLES—

East Dehra Dun Division :

Following Working Circles have been constituted :—

(1) The Sal Conversion (2) The Sal Selection
(3) The Protection (4) The Miscellaneous
(5) The Plantation (6) The Roadside Avenue
(7) The Grazing (partly Over-lapping)
(8) The Khair (Over-lapping)
(9) The Minor Forest Produce (Over-lapping)

(10) The Soil Conservation (Over-lapping)
(11) The Wild Life Management (Over-lapping).

SAL CONVERSION WORKING CIRCLE—*East Dehra Dun Division*

Special Objects of Management :

(i) To convert these Sal forests into uniform crop, as far as possible.

(ii) To attain a normal forest by obtaining normal distribution of age-classes as far as possible, by supplementing natural regeneration by artificial means, wherever necessary.

(iii) To maintain and improve the existing Sal eco-system.

(iv) Consistent with the above, to progressively achieve the maximum sustained yield of timber of Sal and its associates.

Silvicultural System : Conversion to Uniform under Shelter-wood ; strictly speaking it is Ir-regular Shelterwood System, but to avoid confusion old name is left unchanged till the *conversion* is completed.

Rotation : 120 years:

Conversion Period : 120 years.

Allotment to Periodic Blocks :

(A) *Unconverted Crop* : *P.B I* :—Includes areas where regeneration fellings were carried out during two previous plans but are still unregenerated, together with heavily opened P.B. II areas of previous plan.

P.B II :—Two categories distinguished, viz., P B. IIA—such areas which by virtue of advance growth and/or presence of whippy and woody regeneration are expected to pass on to P B.I. in the next plan; and P.B.IIB—the remaining uncoverted areas of Misra's (previous) Plan.

(B) *Converted Crop* : P.B III, IV and V have been allotted on the basis of average crop diameter and their corresponding ages read from the graph P B VI includes P B.VI areas of Misra's plan, adequately regenerated, but in some cases some overwood is still standing

Yield from P.B.I. : Since the areas allotted to P.B.I. have already undergone fellings, or heavy thinnings in P.B II in the name of *Preparatory Fellings* in the previous plans, no fellings are anticipated and the question of yield fixation does not arise.

SAL SELECTION WORKING CIRCLE—*East Dehra Dun Division* :

Special Objects of Management :

(i) To protect the hill slopes against erosion and to regulate local water supply by conserving and improving the forest stand.

(ii) To obtain a balanced uneven-aged crop with all age-classes adequetely represented over every unit of area, or at least in groups.

(iii) To obtain, encourage and nurse up natural regeneration of *sal* and other valuable species under best conditions of growth.

(iv) To improve the stocking of low density crops by planting species of economic and fodder importance without any felling of trees, and

(v) Consistent with the above, to obtain sustained yield of timber.

Silvicultural System : The U.P. Selection System, which is a system of Selection fellings and thinnings.

Exploitable Diameters :

For *Sal* and *Sain (Terminalia tomentosa)* ....40 cm
For *chir, tun (Toona ciliata), haldu (Adina cordifolia), gutel (Trewia nudiflora), sissoo (Dalbergia sissoo)* and *Siris (Albizia spp)* ....50 cm
For *Khair*.. .... 30 cm

Felling Cycle : 10 years

Yield Calculation : Yield is calculated by Smythies' Formula, in terms of the number of selection trees present in the coupe at the time of marking, which is as :

$$Y = \frac{X}{I + \frac{X}{2}} \times 100 \pm A$$

where $X = \frac{f}{t} (II - Z\% \; II)$

with usual connotations (as given in Appendix II, under Fir and Spruce Working Circle of Chakrata Forest Division). Values of 't' and 'Z' have been worked out to be 35 years and 45%, respectively.

From the enumeration data of Class II and Class I trees and the application of Smythies' formula, yield Y has been calculated as 16% of the Sal Selection trees (i.e., one out of six), provided silviculturally available.

PLANTATION WORKING CIRCLE—*East Dehra Dun Division* :

This W.C. includes four Planting Series, viz., Chir, Sal and Teak, Miscellaneous and *Eucalyptus* (including *Poplar*) Series

Special Objects of Management :

(i) To convert forest areas of low economic value into plantations of species of industrial importance, as also species suitable for leaf fodder.

(ii) To afforest the extensive scrub forests in the outer Mussorie hills with suitable species like *Chir* and its broad-leaved associates

(iii) To exploit mature plantations of miscellaneous species and of *Eucalyptus*.

GRAZING WORKING CIRCLE (PARTLY OVER-LAPPING)—
East Dehra Dun Division :

Special Objects of Management :

(i) To regulate the exercise of grazing rights and concessions as laid down in Govt. orders and settlement records

(ii) To control and regulate grazing and lopping by professional graziers.

(iii) To maintain and improve the area so as to ensure sustained supply of the required produce.

THE SOIL CONSERVATION (OVER-LAPPING) WORKING CIRCLE—
East Dehra Dun Forest Division :

Special Objects of Management :

(i) To take effective preventive as well as curative soil conservation measures in areas affected by severe erosion.

(ii) To prepare a detailed soil and water conservation project in Kansrau followed by afforestation of land so reclaimed.

(iii) To simultaneously envolve methodology for similar work elsewhere.

(iv) To collect quantitative data of run off and erosion in the Division to facilitate selection of priority *raus/nalas* for treatment during subsequent plans and also to help in monitoring the work done.

THE WILD LIFE MANAGEMENT (OVER-LAPPING) WORKING CIRCLE—*East Dehra Dun Division* :

Special Objects of Management :

(i) To identify problem of Wild Life Management in the Division and try to formulate guide-lines for its development, consistent with the requirements of forestry and environment.

(ii) To ensure collection of scientific data for the maintenance and development of viable population of fauna for scientific, aesthetic, cultural, ecological and economic purposes.

(iii) To optimise fauna in Motichur Sanctuary and to develop it as a recreation forest for attacting tourists.

(iv) To regulate shooting in game reserves.

APPENDIX—IV

COMPARTMENT DESCRIPTION

(Sample Page from Dehra Dun Working Plan)

Block .... **Compartment**..........

Working Plan/ Period	Kuber Nath (1959–60 to 68–69)	Misra (1969–70 to 78–79)	Singh (1979–80 to 88–89)
Working Circle			
Felling Series			
Periodic block			

1. *Area*	Give the area under each species or type ; blank ; unworkable portions ; as well as the total area.
2. *Situation*	If required, e.g., "lower slope or valley ; sheltered".
3. *Boundaries*	North, east, south and west ; mentioning boundary pillars ; ridges ; spurs ; streams ; roads ; etc., wherever possible.
4. *Altitude*	In the hills ; give limits.
5. *Aspect*	If pronounced variations occur, give these and the main aspect.
6. *Gradient*	Steep ; moderate ; gentle ; etc.
7. *Configuration*	Rugged ; undulating ; flat, etc.
8. *Rock*	Mention the main underlying rocks ; including alluvial deposits.
9. *Soil*	Give a general description, noting in particular the texture (sandy, loam, clayey, etc.); depth (in cm or metres in case of shallow soils ; otherwise as deep ; moderate ; etc.) ; permeability and drainage ; suface compaction ; humus content ; special features such

as presence of salts: *kankar* pan, etc. Erosion ; rock outcrops, etc., should also be noted so that a good idea of the potential fertility of the soil is conveyed.

10. *Growing Stock* General composition—Reference to Champion and Seth's classification to precede a full description of the crop (natural and artificial). Enough details regarding the distribution of economic species should be given although they may be occurring only sporadically, e.g., bamboos.

10. (a) *Overwood* Composition ; Age-class ; Quality ; Stocking (density).
 (b) *Underwood*
 (c) *Undergrowth* Shrubs, herbs, climbers, grasses.
 (d) *Regeneration* of principal species.

11. Proposed allotment to W.C., P.B.
12. Treatment proposed.
13. General information about damages, wildlife, etc.
14. Remarks The effect of biotic factors should be specially dealt with.

EXPLANATORY NOTES

Useful adjectives which may be utilised for correct understanding :—

1. *Canopy density*—For overwood—Closed : Dense : Thin ; Open (Meaning as per Glossary).
2. *Crop density* — (Generally with respect to yield table figures : applied to young crop).
 Over-stocked ; Complete ; Incomplete (Meaning as per Glossary).
3. *Crop* Old crop => Exploitable dia.
 Middle aged=< Exploitable dia-(approach class)
 Young crop =< Middle aged (It will also depend on the extent of advance growth retained).

 Seedling crop or Regeneration : Whippy; Sub-whippy; Established; Unestablished.

Sapling crop Pole crop	(Meaning as per glossary)
Pure Mixed	30% or more of Sal in overwood considered as pure Sal forest.

4. *Soil depth*

Very deep	—	Top soil+Sub soil=> 150 cm
Deep	—	Top soil+Sub soil=90–150 cm
Moderately deep	—	Top soil+Sub soil=45–90 cm
Shallow	—	Top soil+Sub soil=15–45 cm
Very shallow	—	Top soil+Sub soil=< 15 cm

5. *Topography*—Rugged ; Undulating ; Flat ; Rolling
6. *Slope*

Level	0°–5° ;	Gentle	5°–10°
Moderate	10°–15° ;	Steep	15°–25°
Very steep	25°–45° ;	Precipitous	over 45°

7. *Climber infestation*—Heavy ; Moderate ; Light ; Negligible.
8. *Under Storey*—Dense ; Moderately dense ; Sparse.
9. *Ground flora*—Dense ; Moderately dense ; Light.
10. *Undergrowth*—Impenetrable ; Dense ; Moderately dense : Light.

APPENDIX—V

WRITING UP OF THE WORKING PLAN—STANDARD FORMAT

INTRODUCTION

GLOSSARY OF BOTANICAL TERMS
LIST OF COMMON ANIMALS AND BIRDS

Part—I

SUMMARY OF FACTS ON WHICH THE PROPOSALS ARE BASED

CHAPTER I—THE TRACT DEALT WITH

Name and situation
Configuration of the ground
Geology : rock and soil
Climate
Water supply
Distribution and area
State of boundaries
Legal position
Rights and Concessions

CHAPTER II—FLORA AND FAUNA

Part A—Forest Flora

1. Occurrence and distribution of species
2. Composition and condition of the crop
3. General description of the growing stock
4. Injuries to which the crop is liable

Part B—Forest Fauna

1. General Description—
   (I) ANIMALS (MAMMALS)
      (A) Game Animals—
         (i) Carnivora
         (ii) Herbivora
            (a) Goat and sheep group

            (b) Bovine and Antelope group
            (c) Goat Antelope group
            (d) Deer Group
            (e) Others
      (B) Non-game Animals
   (II) BIRDS
      (A) Game Birds—
         (i) Land Birds—
            (a) Pheasants and fowls group
            (b) Partridges and quail group
            (c) Doves and pigeons group
            (d) Others
         (ii) Aquatic birds
   (III) REPTILES
   (IV) FISHES
2. Injuries to which the fauna is liable
3. Protection and management of the fauna.

CHAPTER III—UTILISATION OF THE PRODUCE

Agricultural customs and wants of the population
Markets and marketable products
Lines of export
Methods of exploitation and their cost
Past and current prices.

CHAPTER IV—STAFF AND LABOUR SUPPLY

CHAPTER V—PAST SYSTEMS OF MANAGEMENT

General history of the forests
Past systems of management and their results
Special works of improvement undertaken
Past yield
Past revenue and expenditure

CHAPTER VI—STATISTICS OF GROWTH AND YIELD

Part—II

FUTURE MANAGEMENT DISCUSSED AND PRESCRIBED

CHAPTER I—BASIS OF PROPOSALS

General objects of management
Method of treatment to be adopted
Working Circles, their area and distribution, reasons for their constitution

Blocks and compartments.
Period of Working Plan and necessity for intermediate revision.

CHAPTER II—WORKING PLAN FOR THE......WORKING CIRCLE

General constitution
General character of the vegetation
Blocks and compartments
Felling series and cutting sections
Special objects of management
Area and allotment
Analysis and valuation of the crop
- Stock maps
- Quality and age classes
- Density
- Enumerations and their results

Silvicultural System
Rotation and Conversion Period
Exploitable diameters
Reducing factors and reduced areas
Felling cycle
Division into periods and allotment to periodic blocks
Calculation of the yield
Table of fellings
Method of executing the fellings
Subsidiary silvicultural operations and their economics
- Cultural operations
- Cleanings and thinnings

Supplementary fellings
Artificial regeneration and their economics
- Treatment of existing plantations
- Nursery technique
- New plantations; method of establishment, etc.
- Choice of species
- Fencing and tending

Other regulations—
- Fire protection and control burning
- Grazing
- Exercise of rights and concessions

Economic Analysis
Effect of Prescriptions on the Environment and the Eco-system.

(CHAPTER III, IV, V etc.—ONE CHAPTER FOR EACH WORKING CIRCLE)

CHAPTER...RAW MATERIAL FOR FOREST INDUSTRIES

Allocation of raw material
Future outlook
Supply of timber to railways, defence, etc.
Fuelwood production and future outlook.

CHAPTER WILDLIFE MANAGEMENT

General constitution
Distribution of Wildlife in relation to Forest Types
Special objects of Management
Area and allotment
Management of National Parks and Sanctuaries
Exercise of Rights
Grazing
Development and improvement of Wildlife habitats
Development of tourist facilities
Scientific study, Wildlife Census, etc.
Miscellaneous regulations

CHAPTER WATERSHED MANAGEMENT AND SOIL CONSERVATION

General constitution
General character of the vegetation
Status of Soil Erosion
Special objects of Management
Area and allotment
Soil Conservation measures
Management of water yield
Meterological and hydrological stations
Economic Analysis
Misccellaneous Regulations

CHAPTER...MULTIPLE USE FORESTRY—OUTDOOR RECREATION AND ENVIRONMENTAL CONSERVATION

General
Scientific study
Bio-aesthetic planting
Tribal Welfare

CHAPTER MISCELLANEOUS REGULATIONS (Prescribed and suggested)

Petty fellings

Deviations
Roads, paths and bridges
Buildings
Water supply
Telephones
Fire protection
Maintenance of boundaries
Rights and concessions
Survey and maps
Research plots
Lopping schemes
Medical facilities
Development of forest industries

CHAPTER...ESTABLISHMENT AND LABOUR

CHAPTER...CONTROL AND RECORDS.

System of control
Control Forms
Compartment Histories
Plantation Journals
Divisional note book
Fire records
Forest records

CHAPTER...FINANCIAL FORECAST AND COST OF THE PLAN

Past yield
Future yield
Past revenue and expenditure
Future revenue and expenditure
Summary of financial forecast
Cost of enumerations
Cost of the Working Plan

CHAPTER...SUMMARY OF PRESCRIPTIONS

Appendices

APPENDIX—VI

POTENTIAL PRODUCTIVITY OF INDIAN FORESTS

Primary objective of scientific Forest Management is to obtain maximum possible production from forests. Various factors—edaphic, climatic and ecological—determine the *potential productivity* of a site. Of the various attempts made to assess the potential productivity of natural forests, one made by Paterson, a Swedish geographer, who estimated this on the basis of climatic factors, is probably the most useful one. He found the mean annual increments of suitably managed forests throughout the world strongly cor-related with climatic indices, which denote combined effects of temperature amplitude, length of the growing season, precipitation and solar radiation. He considered even soil as a reflection of the climatic factors.

Paterson (1956) evolved a formula, by giving due weightage to the climatic factors which mainly govern plant growth, to evaluate the ability of a site for forest growth in a particular climate, and to express it as an Index and then cor-relate it with site productivity. He proposed the following "CVP" (Climate, Vegetation and Productivity) Index, which has proved quite useful in giving an approximate estimate of forest productivity in various countries :

$$I \text{ or CVP Index} = \frac{TV \times P \times G \times E}{Ta \times 12 \times 100}, \text{ where}$$

TV = Mean temperature of the warmest month (C°)

Ta = Mean annual range of temperature (C°)

P = Mean annual precipitation (mm)

G = Length of the growing season in months, depending on precipitation and temperature

E = "Evapo-transpiration reducer"—a factor based on latitude and giving the generalised total annual radiation received, as percent of that at the equator.

Paterson termed the yield per hectare per annum, a convenient qualitative measure of productivity, as *site-class*; and when a forest is managed under ideal conditions so as to give the highest yield, the annual production is referred to as *ideal site-class*.

Cor-relation between the CVP index and the maximum ideal productivity for different regions of the world worked out by Paterson turns out to be significient at 95% probability, the variance of the CVP index contributing to about 80% of the total variance for the ideal site class. The equation for calculation of productivity is, thus :—

$Y = 5.2 \log X - 7.25$, where Y is the productivity in m³/ha/year, and X is the CVP index.

The CVP index thus derived, and the values of various symbols in the formula for some of the stations in India, as mentioned by Paterson, are given in the following table :—

CVP Index Range	Station	CVP Index	TV	Ta	P	G	E	Potential Production in m³/ha/year
1	2	3	4	5	6	7	8	9
25– 100	Bikaner	31	34.2	29.4	222	2	46	2.05
100– 300	Allahabad	248	33.60	18.3	900	4	45	3.60
300–1000	Jabalpur	485	30.0	13 5	1463	4	45	6.27
	Seoni	636	29.7	11.7	1367	5	44	6.90
	Ranchi	764	26.0	9.4	1473	5	45	7.73
1000–5000	Dhubri	1520	28.0	9.8	2362	6	45	9.12
	Sibsagar	1730	28.1	13.5	2369	9	46	9.29
Above 5000	Cherapunji	9210	20.3	8.4	10160	10	45	12.93

Actual annual production and potential productivity of India and some of its States, as reported by Seth, Kaul, and Sharma in their Paper "Potential Productivity of Indian Forests" (Proceedings International Symposium on Tropical Ecology"—New Delhi, January, 1971) are given below :—

State	Forest Area (million ha)	Average Annual Production 1961–65 (million m³)	Potential Productivity (million m³/year)
1. Himachal Pradesh, Punjab & Haryana	2.489	1.062	16 94
2. Kerala	1.041	0.469	12.74
3. Madhya Pradesh	17.299	4.215	108 50
4. Uttar Pradesh	4.571	3.063	27.62
5. West Bengal	1.183	0.908	9.33
6. Maharashtra	6.696	2.467	43.71
(Similar data furnished for other States and Union Territories)			
Total India	75.351	19.601	492.071

Thus, in India, from an area of 75.351 million hectares of accessible forests, with a potential productivity of 492.071 million m³, actual production is only 19 601 million m³, i.e., only about 4%. Future management should, therefore, aim at full utilization of natural resources of climate and soil, judicious choice of species employing modern techniques of planting, tending and harvesting so as to increase production to the highest possible level and meet the ever-increasing wood requirement of our rapidly developing economy.

Before concluding, an observation may be made about Paterson's *CVP Index*. Though the basic approach is good, the formula proposed by him needs modification to the extent that some other important variables, e g., soil factor, also need to be introduced, as his assumption that soil is a reflection of climatic factors is not always true, especially when biotic, chiefly human, influences operate adversely.

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