FRM 503 LECTURE NOTES
FOREST MANAGEMENT TECHNIQUES

DR. MICHAEL FEMI ADEKUNLE
ASSOCIATE PROFESSOR

AND
PROFESSOR S A OLUWALANA

DEPARTMENT OF FORESTRY AND WILDLIFE

MANAGEMENT, UNIVERSITY OF AGRICULTURE,

ABEOKUTA, OGUN STATE,NIGERIA.

MANAGEMENT OF FOREST RESOURCES
INTRODUCTION

The forests make up one of the earth's greatest reservoirs of renewable resources. Properly managed, they can provide essential products indefinitely and at the same time remain a home for wildlife and a vital source of water supplies. Forest management is the process of organizing forest stands/ecosystems so that they produce a continuous stream of whatever resources are desired from that forest-timber, wildlife tourism, recreation, or any conceivable combination of the resources of the forest. The forester's task then, is to facilitate the production of resources from the forest in a manner that ensures that they will be forever available. The management techniques for accomplishing these purposes vary from the extraordinary simple to the exceedingly complex.

FOREST MANAGEMENT

DEFINITION:
(1)   Forest Management is the practical application of the scientific, technical and economic principles of forest.
(2)   It is that branch of forestry whose function is the organization 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 hand.
(3)   It is the application of business methods and technical forestry principles to the operation of a forest property.
(4)   The task of forest management is to build up, put in order, and keep in order a forest business.
(5)   The practical application of scientific, economic and social principles to the administration and working of a forest estate for specified objectives.
(6)   It is that branch of forestry concerned in broad sense with the overall administrative, economic, legal and social aspects and in strict sense with technical and scientific aspects, especially silviculture, protection and forest regulation.

Forest regulation concerns with the technical aspects of organizing and maintaining a forest to fulfill the objects of forest management.

Management of Forest Resources

Thus, forest management 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.

In its restricted sense, it is more especially concerned with the organization of a forest for the purpose of securing a sustained yield from it and for realizing the objects of management.

OBJECTS:

The objectives of forest management are embodied in National Forest Policy of the country. The National Goals and Directive Principles as set out in the Constitution provide the basis for forest policy. In Nigeria the forest policy formulation is guided by and draws strength from the Nigeria which states:

"... for Nigeria's natural resources and environment to be conserved and used for the collective benefit of the people, and to be replenished for the benefit of future generations".

The chief objectives of the National Forest Policy of Nigeria are twofold:

(1) To ensure the sustainability of forests, i.e. through proper management practices, the forests may be used and are retained as renewable resource; and
(2) Forests are harvested in order to bring about economic growth, job creation, increased participation of Nigerians in the forest industry and further domestic processing.

Careful use without changing the character of the forest, and successful regeneration after harvest ensure the sustainability of forests. This is the principal essence of forest management.

Management of forests broadly involves:

- Control of composition and structure of the growing stock.
- Harvesting and marketing of forest produce.
- Administration of forest property and personnel.

It is, unlike any other commercial enterprise, complicated; as forests are managed for a multiplicity of purpose, with one use dominant, viz., most often the production of wood.

Productive and protective functions of the forests cannot be bifurcated. Scientifically managed forests perform both these, simultaneously. It is, therefore, essential that forest resources are maintained in a state of maximum production for all time, consistent with their subsidiary or even the other main functions.

PRINCIPLES OF FOREST MANAGEMENT

The forest policies of many countries carry the following sentence:

"To manage the forest in such a way as to ensure a sustained yield of timber and other forest products in perpetuity."

The most celebrated principle of forest management all over the world is the "Principle of Sustained Yield". This being criticized as static one, was replaced by the "Principle of increasing yield" in the recent past. But this new concept covers only those forests which are in the early stages of their development. Yet another concept known as "Principle of Progressive Yield" emerged in Helsinki World Forestry Congress in 1948, but this is applicable to fast growing, short rotation species responding readily to the scientific methods. Thus for long term forest the "Principle of Sustained Yield" remains unchallenged.

SCOPE OF FOREST MANAGEMENT

Though forest management is an integration of silviculture, silvicultural systems, protection, economics etc., each of which is a separate subject itself; "Yield Regulation" remains the core subject of forest management. It involves the study of sustained yield, normal forest, management units, rotation, increment, yield calculation, and serves as a tool in answering to the questions when to cut, how much to cut, and what to cut, i.e. for establishing sustained yield forest management plans.

SUSTAINED YIELD

DEFINITION:

(i)   (a)   The material that a forest can yield annually or periodically in perpetuity.

         (b)   As applied to policy or plan of 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.

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

(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 the presence of age classes of trees in the forest. It ensures continuous yield and safeguards against extinction of forest property.

Where the forests are small with incomplete age classes, the crop is worked for Intermittent Yield, which is the material or clash return obtained from time to time from a forest not organized for continuous production.

Concept of sustained yield is 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 envisages that a forest should be so exploited that the annual or periodic feelings do not exceed the annual or periodic growth. It is expressed as the allowable cut almost equal to net increment.

Sustained productivity may be visualized in two respects:

-       continuity of growth, an
-       continuity of yield/harvest.

Management of Forest Resources

Sustained yield management, therefore, means the continuity of harvest, indefinitely, without impairment of the productivity of the soil. For Sustained Yield Management the forest must conform to an ideal normal forest. Principle of sustained yield achieves 'Normality'

NORMAL FOREST

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, normal forest has an ideal growing stock, an ideal distribution of age-classes of the component crop and is putting on an ideal increment. From such a forest, annual or periodic yields equal to the increment can be realized indefinitely, without endangering future yields and without detriment to the site.

In forestry, concept of Normal Forest envisages an ideal state of perfection, serving the purpose of good scientific management. It is an ideal condition in the context of forestry. Normal Forest is a conception of forest management based on the principle of Sustained Yield. The term was evolved in early 19th century by German Foresters.

DEFINITION

(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 yield. It serves as a standard of comparison for sustained yield management.

(ii) 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 the produce which can be removed continuously without detriment to future production.

(iii) A forest which corresponds in every way to the objects of management. Normal state of a forest include in it:

6

- A normal increment,
- A normal age-class distribution,
- A normal growing stock.

(iv)   Normal forest is that forest which has reached and maintains a practically attainable degree of perfection in all its parts for the full satisfaction of management.

(v)   Under a given method of treatment and rotation, a forest is termed a normal forest which has:
(a)   a normal series of age-gradations or age-classes,
(b)   a normal increment, and consequently,
(c)   a normal growing stock.

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

(vii)   A forest which contains a regular and complete succession of age-gradations or classes in correct proportion so that an annual or periodic felling of the mature woods results in an equalization of the annual or periodic yield.

(viii)   Normal forest is one in which growing stock is so distributed by size and age classes as to provide a sustained yield of nearly equal annual volumes through growth.

Attributes of Normal Forest

The main attributes of a normal forest are:

-        presence of normal series of age gradations or age classes,
-        accrual of normal increments, and
-        having a normal growing stock.

Normal Series of Age-gradations, Normal Growing Stock and Normal Increment form the 'Trinity of Norms' in forestry.

Normal series of age-gradations or age classes: This means presence in a forest in appropriate quantity, the trees of all ages from one year old to rotation age.

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, there are mature trees or mature crop available to give the

calculated sustained yield. This stipulates the establishment of a normal series of age-gradations or age-classes.

    (i)   Age gradation: When the trees of each age occur on separate area, they constitute a series of age-gradations. This is achieved in man-made forests.

    (ii)   Age class: When trees falling within certain age limits occur mixed together on the same area, they form an age-class. It is found in even-aged, regular or uniform, natural forests.

    (iii)   In uneven-aged, very irregular forest there may neither be age-gradation nor age-classes; in such cases the sign of normality is the proper distribution of trees of all ages. Selection forests are the true examples.

By age-class distribution is meant: "the local occurrence, or proportionate representation, of different age-classes in a forest".

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 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 feelings, under the given rotation and silvicutural system. The presence of a complete series of age-gradations/classes, is a sine-quo-non for obtaining sustained yields from a forest.

Normal increment: It means the best or maximum increment attainable by a given species per unit area on a given site. It always denotes the volume increment only, the product of height and girth increments.

Management of Forest Resources

An abnormal increment may be caused by faulty formation, faulty treatment, injurious external influences and also unequal distribution of age classes.

Normal growing stock: It is the volume of stands in a forest with normal age classes or age gradations and a normal increment. In practice, this is taken to be the volume indicated in Yield Tables of each age-class. The abnormalities common in growing stock are of four types:

(i)   Overstocked: A forest may be overstocked on two accounts:
    - When a forest past the age of maturity have more volume per

hectare than the normal.

- A forest also becomes overstocked when the rotation already fixed is reduced.

In both the cases, there will be surplus growing stock due to excessive distribution of the older age classes. This surplus has to be gradually removed to achieve normalcy.

(ii)   Understocked: Understocking arises in three situations:

- due to preponderance of the younger age classes, the volume per ha will be less than the normal,
- due to previous mis-management or bad protection, the forest may have poor density than the normal condition, and
- through the increase or extension of the rotation period.

This is remedied by conservative fellings and building up a proper reserve of growing stock.

(iii)   Volume normal but age classes abnormal: The whole forest may contain of single age class against the normal proper distribution of all age classes. This is the worst form of abnormality and conversion of such forest to normalcy is very difficult. In such situation, suspension of sustained yield may be necessary and sacrifice of material due to decay and unsoundness may be unavoidable.

(iv)   Sub-normal increment: This situation may arise due to the effect of fire, disease etc. or because of poor density or due to excessive over-mature timber. Normalcy under such situations can not be achieved without sacrifice of material.

(v)   Volume increment normal in an abnormal forest: Annual increment may be 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.

INSTRUMENT OF FOREST MANAGEMENT

Forestry is a long term enterprise. Plan of forest management therefore needs proper written document for guidance of the forest manager. It will also serve as an instrument for execution of operations decided upon to achieve the desired objectives. A Working Plan of a forest is such an

instrument which discusses and prescribes the management of a forest so as to realize the objects of management.

WORKING PLAN

(i)   It is a written scheme of management aiming at continuity of policy, controlling the treatment of a forest.

(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 results.

(iii)   It is he 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.

Working Plans are invariably based on the principles 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. It 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 is the unit of forest management, usually covering an administrative area or areas forming compact manageable block of forests.

MANAGEMENT UNITS

From the point of view of Silvicultural management and yield regulation, the forests are organized into working circles, felling series, cutting sections, coupes, periodic blocks and felling cycles.

Working Circle (W.C.): A forest area (forming the whole or part of a Working Plan) organized with a particular object and subject to one and the same silvicultural system and the same set of Working Plan prescriptions. In certain circumstances Working Circles may overlap.

Felling Series (F. S.): A forest area forming the whole or part of a Working Circle and delimited so as:
(i)   to distribute felling and regeneration to suit local conditions, and
(ii)   to maintain or create a normal distribution of age classes. The yield is calculated separately for each felling series which should have an independent representation of age classes.

When concentration of fellings in any one place is considered undersirable for silvicultural, social or economic reasons, 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 areas, a working circle may be divided into felling series. It enables effective control and distribution of work in different administrative units.

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

A Felling Series or Working Circle is divided into a number of Annual Coupes equal to the number of years in the rotation, especially in Clear-felling System.

Cutting Section: A sub-division of a felling series formed with the object of regulating cuttings in some special manner: a planned separation of fellings in successive years.

Sometimes it is desirable to avoid fellings in contiguous coupes in successive years for silvicultural considerations, such as fire danger or insect attack. In such cases, a felling series is sub-divided into a number of cutting sections.

Periodic Blocks (P.B.): The part or parts of forest containing one age-class, set aside to be regenerated or otherwise treated, during a specified period. The forests managed under uniform system are divided into periodic blocks, which may be "Floating" or "single" and "Fixed" of "Permanent". When only generation block is allotted, it is called floating periodic block. When all periodic blocks are allotted and retain their identity at working plan revision, they are termed fixed or permanent periodic blocks. Number and area of P. B. is calculated as under:

Number of P. B. = Rotation period / Regeneration period.
Area of P. B.   = Area of working circle / Number of P. B.

Felling Cycle (F.C.): In selection forests, it is the time that elapses between successive main fellings on the same area.

In an ideal Selection Forest the entire area is a complete and undivided F.S. which is to be worked every year. Such annual working of entire area of the Working Circle is neither practicable nor desirable. The usual practice is to divide the area into a number of coupes (cutting sections)

each of which is worked at an interval of a planned number of years, known as Felling Cycle (F.C.). It may vary from 5 to 40 years depending on the intensity of working. 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 forest compartments.

ROTATION

It is also known as Production period. It is the period which a forest crop takes between its formation and final felling. It is not common one to all forest crops, nor for the same crop in different regions. It expresses the rate of growth of the crop to produce the desired size and quality of crop.

DEFINITION

(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.

(ii)   The period of years required to establish and grow timber crops to a specified conditions of maturity.

(iii)   The number of years fixed by the working plan between the formation or regeneration and the final felling of a forest crop.

(iv)   The interval between successive crop regenerations.

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

(vi)   The interval of time between the formation of a young crop by seeding, planting or other means and its final harvesting.

(vii)   The period which elapses between the formation of a wood and the time when it is finally cut over.

ROTATION FOR UNIFORM AND SELECTION FORESTS

Strictly speaking, the term rotation is correctly applicable to regular crops only. In clear fellings, plantations and regular forests, entire crops of trees of a sizeable area are felled at a time or during a comparatively short period 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. Thus the rotation is associated with the final felling age or removal age which may vary with rate of growth. On better sites rotation will be shorter.

In selection (unevenaged/irregular) forests, trees of exploitable size are felled selectively. Here the rotation period is equal to that of the average age of the exploitable size trees removed – the exploitable age, at which they attain the size required to fulfill the objects of management. Correct term expressive of maturity in selection forest is exploitable or utilizable age, or size.

CRITERIA FOR ROTATION FIXATION

The salient features to be considered are that:

1. Rotation differs from species to species.
2. Rotation differs for same species from region to region.
3. Rotation is not a permanent one for a species at a particular site and can be increased or decreased.
4. Rotation may conform to "Maturity" of the species but it may not always conform to "Maturity".

Factors considered for fixing the rotation are:

(a) Owner's desire and policy.
(b) Financial aspects – business enterprise – maximum revenue.
(c) Productive capacity of land and tree species.
(d) Market demand for particular "form".
(e) Value of wood products.
(f) Capital investment – economic management.

CLASSIFICATION OF ROTATION

Based on the objects of management and also of "necessity", the rotation is classified as: Physical rotation, Silvicultural rotation, Technical rotation, Rotation of maximum volume production, Rotation of highest income, Financial rotation.

Physical Rotation: Rotation that coincides with the natural lease of life of a species on a given site. Trees are harvested only on their death. This is followed in protected forests, park lands, roadside avenues, recreation forestry etc.. It is not relevant in economic forestry.

Silvicultural Rotation: The rotation through which a species retains satisfactory vigour of growth and reproduction in a given site. This

rotation presupposes the crops which are regenerated by natural means and coppicing.

It is not only long but has also very wide range of limits. It is 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.

Technical Rotation: Rotation under which a species yield the maximum material of a specified size or suitability for economic conversion or for special use. The harvest depends upon the form in which he market demands the forest product to suit specific purposes, e.g. transmission poles, railway sleepers, match wood, paper pulpwood, saw logs etc. It is adopted, particularly, by industrial firms which own forests and plantations for the purpose of supplying raw materials for their plants.

Rotation of Maximum Volume Production: The rotation that yield the greatest annual quantity of material or that which produces the greatest mean annual increment of wood.

This is the widely used rotation throughout the world. It embodies the principles of sustained yield. Besides it aims profitable extraction and sale of wood. Maximum volume production is achieved when the mean annual increment (MAI) of a crop reaches the culmination point. This rotation yields largest volume per unit area, per annum, and is an important rotation which is adopted frequently.

It is suitable where the total quantity of woody material is important and not the size and specification, like firewood, raw material for paper pulp, fibre and particle board industries based on disintegration processes of wood.

Rotation of Highest Income: It is the rotation that yields highest average annual gross or net revenue irrespective of the capital value of the forests; also known as rotation of highest revenue or forest rental.

It is calculated without interest and irrespective of the times when the items of income or expenditure occur. Land value is also not considered in this case. This rotation is fixed under the assumption that the wood has same value whatever its size, and annual expenses do not vary with alterations in the rotation. In the case of present day industrial plantations

formed though borrowed money, this kind of rotation will not be of any use.

This rotation is important from the over all national point of view, as 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.

Private owners are interested in maximum net revenue by keeping the rotation period as short as possible.

Financial Rotation: It is the rotation which yields the highest net return on the invested capital. It is a rotation determined on financial considerations, i.e., that yielding the highest rate of interest. It is also known as "Economic Rotation". In this rotation all items of revenue and expenditure are calculated with compound interest at an assumed rate, usually the rate at which the Government is able to borrow money. It may be defined as,

- The rotation which gives the highest discount profit, usually at its commencement.
- The rotation which is most profitable.
- The rotation which gives the highest net return on capital value, i.e., under which the soil expectation value calculated with a given rate of interest is the maximum.

This rotation is not applicable to natural forests because of lack of data regarding age, growth rate, mortality, etc. of the forest crop, the actual costs of various operations and the price range of end products.

This is easily fitted to the management of man-made forests especially industrial plantations. The economic principles are applied in this case and this rotation gives the highest net profit over and above a certain fixed percent, after allowing compound interest on all expenditure and income.

CHOICE OF ROTATION

For commercial forestry, the rotation shall be "a combination of technical and silvicultural rotation tempered by market demands and essential economic considerations".

INCREMENT

Forest is a capital in the economic sense, which should produce interest. Trees are the capital and growth (increment) is interest; both are indistinguishable. Increment is the increase in growth of a tree or crop with age. It may be in term of wood content, or any of the factors which increase with age-diameter, height, basal area, volume, quality price or value. It is determined for any given period, by measuring it at the beginning and at the end of the period.

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

In Forest Management, the term increment refers usually to only volume increment, and that too of crops rather than of individual trees. It is intimately connected with the volume and age of the crops.

KINDS OF INCREMENT

Current Annual Increment (C.A.I.): The increase in growth that takes place in a particular year is called the C.A.I. for that year. Usually taken as the periodic annual increment over a short preceding period.

It may be expressed as [$V_{(n+1)} - V_n$) where $V_{(n+1)}$ is the volume of wood produced in (n+1) year and V_n the volume in n years.

Periodic Annual Increment (P.A.I.): The average increase in growth which takes place in any short period (5 or 10 years); sometimes referred to as periodic mean annual increment.

Since annual measurements are very difficult in forest and impossible in practice, only P.A.I. is taken as C.A.I. and all the yield tables consider P.A.I. as C.A.I.

If the period is short, P.A.I. and C.A.I. will be very close to each other.

Mean Annual Increment (M.A.I.): It is the average annual rate of growth up to any given date i.e., it is an average rate of growth representing the total growth or yield at a given age distributed or spread over the period. The total increment upto a given age divided by that age is M.A.I.

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 a chapter in the history of the tree. The mean 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.

M.A.I. = (Vx – Vo)/x, when Vx is volume at the end of x years;
Vo is the volume at the beginning.

Final Mean Annual Increment (F.M.A.I.): It is the M.A.I. at rotation age. This is calculated by dividing the total of volumes (final yield at the end of rotation + intermediate yields from thinnings, etc.) by the rotation period.

F.M.A.I. = (Vr + Vi)/r, when Vr is the volume at the end of rotation;
Vi is the intermediate yield, and
r is the rotation in years.

C.A.I. Curves: The study of C.A.I. curves is interesting. The C.A.I. is small in the seedling stage, gradually rises, reaches its maximum and falls till it approaches zero when death occurs.

In case of light demanders and moderate shade bearers, the maximum is reached when the height growth culminates.

In case of shade bearers, maximum is attained several years after the culmination of height growth, and after attaining maximum, C.A.I. falls rapidly at first and then more slowly.

C.A.I. and M.A.I. Curves, Their Relationship and Significance

There is a definite relationship between C.A.I. and M.A.I. The curves drawn for different species conform to the same pattern as show in Fig. 11.1, is another specialty.

```
1000 ┤
 900 ┤
 800 ┤
 700 ┤
 600 ┤
 500 ┤
 400 ┤
 300 ┤
 200 ┤
 100 ┤
     └───────────────────────────
```

0   5   10   20   30   40   50   60

Fig. 1: Relationship between C.A.I. and M.A.I. Curves.

The C.A.I. and M.A.I. curves allow to draw following conclusions:

- At first M.A.I. Keeps below C.A.I.
- C.A.I. attains its maximum before M.A.I. and will be falling while M.A.I. will be still rising.
- While C.A.I. is greater that M.A.I., the latter is rising.
- When C.A.I. is less than M.A.I., the latter is falling.
- When C.A.I. = M.A.I., the latter is stationary.
- When C.A.I. and M.A.I. curves meet, the latter has attained its maximum.
- The meeting points of C.A.I. and M.A.I. curves determine the rotation of maximum volume production.

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.

It is an expression of the relation between increment and volume. It is the ratio of increment and volume expressed percentage.

Increment % (I.P.) = Increment/Average volume x 100

TYPES OF INCREMENT PERCENT (I.P.)

Current annual increment percent: It is the relation between the annual increase of increment during a given year and the volume at the beginning of the year expressed as percentage.

Period increment percent: This is the percentage ratio between the increment during a given period to a basic volume i.e., mean volume for that period or the volume at the beginning of the period.

Mean annual increment percent: It is the percent ratio which the M.A.I. for a given age bears to the total volume at that age.

UTILITY OF I.P.

(i) It is the indicator of maturity of individual trees or crops and used for fixing the rotation or the yield. The decrease in I.P. indicates the increase in age/maturity of the stand (Fig. 2).
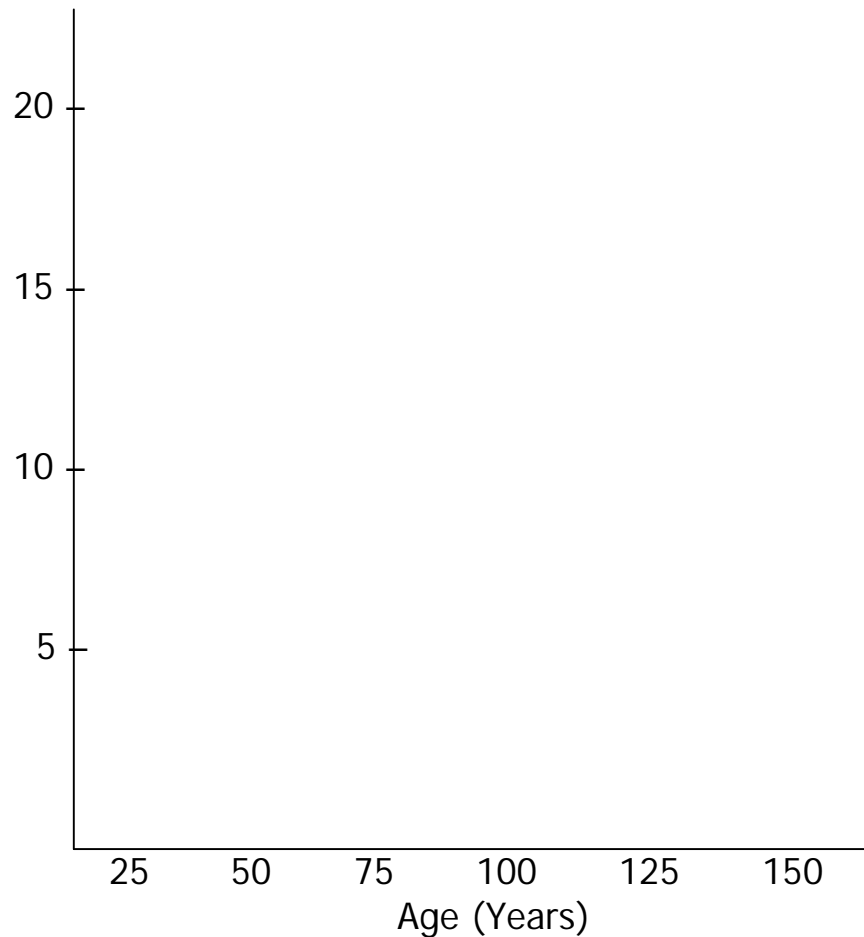

Fig. 2 : Age and C.A.I. percent curve.

(ii) The trees/crops showing lowest I.P. should be selected for felling. This allows the removal of greatest possible volume of wood capital with reduction of smallest possible amount of increment. In effect it transforms the forest capital from low to increased I.P. as a whole.

Increment percent (I.P.) is the C.A.I.%, which is usually computed from Yield Tables by Pressler's Formula as under:

$$\text{Increment percent (I.P.)} = [[(V\text{-}v)/n]/(V + v)/2] \times 100$$
$$= (V - v)/(V + v) \times 200/n$$

Where   V = Present volume of the crop,
         V = Volume of the crop n years ago,
   C.A.I. = (V – v)/n, and
Average Volume = (V + v)/2.

19

Pressler also discovered that the increment percent (I.P.) for the year r, in which the M.A.I. culminates, can be expressed by the formula:

$$I.P. = 100/r$$

RECORDS

The importance of Rs in all forestry operations cannot be over emphasized.
1.   It affords in an inexperience officer the opportunity to know the work done, the procedure and the relative cost.
2.   It is particularly useful as a guide for planning future schemes for projects.
3.   It also brings into view the financial commitments involved.

TYPES OF RECORDS

1.   **COMPARTMENT REGISTER**
       A compartment in the smallest permanent territorial units in a forest reserve. Occasionally a compartment may be sub divided into sub-compartment temporarily.

A compartment register is precisely a book for recording the time, cost and different type of operations carried out in the compartment. The costs of operation are expressed in mandays. However the cost of a manday at the time of operation is also stated so that the cost can be evaluated in cash.

The silvicultural system in operation time and cost of thinning, climber cutting, Reasoning are clearly stated. These are some examples of operations to be recorded in a compartment register.

2.   **NURSERY REGISTER:-** This shows the details of seeds received and used and plant or seedlings raised and dispatched i.e. the centrum in a nursery or output of a nursery.

3.   **NURSERY CALENDAR:-** This shows the details procedure of operation carried out in the nursery. For example the ratio of different component of the Rotting mixture e.t.c.

4.   **COSTINGS:-** This shows the details and analysis of cost of operation.

5. **CASH FLOW:-** This shows the annual expenditure and revenue realized during the year. It shows the net profit or loss of the nursery.

6. **WORK CALENDAR:-** This gives the time and the number of mandays involved in all operations carried out during the year Example of a work calendar:

Months	January	February	.... December
Operations	Weeks	Weeks	Weeks
Collection of seeds			
Site preparation			
Filling of pots			
Sowing pricking out			
Watering			

7. **PIE CHART:-** The cost of different operations are expressed on % ages of the total cost of a project or scheme. These percentages are indicated in a circular design drawn to scale. Both % and operations are expressed in the various sections.
    Example:- Raising a nursery to produce 10,000 seedling

	Total cost	⟶ ₦100	=	100%
1.	Seed collection	⟶ ₦5	=	5%
2.	Potting	⟶ ₦10	=	10%
3.	Site preparation	⟶ ₦50	=	50%
4.	Potting Mixture	⟶ ₦20	=	20%
5.	Watering	⟶ ₦10	=	10%
6.	Stumping	⟶ ₦5	=	5%
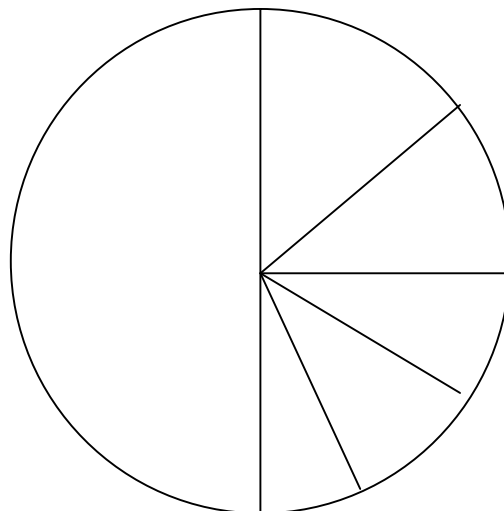
8. **CONTROL FORM:-**

Supposing you planned to be producing 100,000 seedlings yearly in your state so as to meet up with a forestation programme, the form below is used. Control form is a form of completion report, stating the amount of work expected to be done, work done and reasons for excess or deficit. Control form is not used for nursery alone; it is also applied to plantation programme. For example a state may decide to plant up 1,000 acres of land yearly but it may happen that in a particular year they planted only 950 acres and so having a deficit of 50 acres. It may also happen that they plant say 10.5 acres in another area hence having an excess of 915 acres that year. In this programme the control form is used as a sort of guidance.

Year	Expected Production	Actual Production	Difference		Total Difference up to date		Remarks
			Excess	Deficit	Excess	Deficit	
1972	100,000	99,000	-	1000	-	1000	Lack of seeds
1973	100,000	100,050	50	-	-	950	Higher gn %
1974	100,000	100,100	100	-	-	850	Higher gn %
1975	100,000	99,940	-	60	-	910	Lack of Seeds
1976	100,000	101,500	1500	-	590	-	High Gn %

YIELD REGULATION

Once the structure of a normal or ideal forest has been decided upon, it is necessary to plan the management of the given working cycle so as to develop it towards this standard.
The management procedure leading to this result is called yield regulation. Y.R. consists of:

(a)   Estimating productive capacity of the area in its present condition i.e. production possibility.
(b)   Deciding how much of this should be retained to built up the grows stock or how much of the excess growth stock should be removed to minimize loss and balance the yield.
(c)   Deciding in what localities, time, proportion and total volume of timer to cut (i.e. where, when and how much to cut).
(d)   Deciding on the kind of timber species and size that should compose the volume cut.

The very essence of Y.R. is in determining the cut. There is no single formula for the solution of cut-determination. This depends on state and

trends of market, intensity of management and silvicultural systems adopted.

Thus Y.R. necessarily involves a compromise between economic and silvicultural consideration in management.

Generally the main objectives why timber production and telling of trees should be regulated can be broadly discussed under 4 headings namely:

1. Silvicultural
2. Labour
3. Industries   Object of Yield Regulation
4. Economic Reasons.

1. **SILVICULTURE**
(a) **Over Cutting** (i.e. Cutting more than required or cutting more than can be replaced).
    This may cause determination of the soil, introduction of unwanted species. (example <u>Musanga cescropioides)</u> and dieing out of wanted species due to lack of regeneration.
(b) **Under-Cutting:** May lead to over matured trees which deteriorate in wood quality and the seeds and fruits of which loose viability rapidly.
    The dense shade of an over-matured tree will make it difficult for young plant on forest floor to survive due to lack of light.

2. **LABOUR**
    The employer needs skilled labour to carry out his work and this can only be got by regular employment intermittent employment leads to forced employment of casual labour with consequent lack of skill and responsibility.

    Similarly an employee will not stay in a job or trade hthat offers only intermittent employment. It means then that both parties employer and employee suffer when the work is intermittent.

3. **TIMBER INDUSTRY**
    Both the industries themselves and the workmen they employed cannot continue to operate it the out turn of wood raw material is only intermittent.

They must have a continuous and steady supply of timber to function adequately and profitably.

4. **ECONOMIC REASONS**
   We can liken forestry to a business operating within biological limits. These capital investments is made up of two things – the trees themselves and the money expended in operations in that forest.

   Although the owner of the forest may make a profit by waiting 60 years or more for the trees to mature before selling them, yet he has nothing to line on in the meantime. Whereas he can get better returns on this money by merely putting it in a saving bank.
   We must consider the capital tied up in the forest to be an investment upon it every sensible petran expects a return or profit. Not as a final profit but as a steady interest on the money invested. This can only be got by regular periodic (Preferably Annual) yield from the forest.

METHOD OF YIELD REGULATION

The objects of management are firstly to obtain sustained yield and secondly to aim at a normal forest.
Several methods have been tried particularly in Europe to regulate yield and attain those objectives. Some methods have been move successful than others.

The type of method to be adapted depends on the type of forest and the degree of accuracy required.
The methods used so far can be divided into 4 major groups:
   1. Methods based on area only.
   2. Methods based on area and volume control.
   3. Methods based on volume or volume and increment of growing stock
   4. Methods based on number and size of trees.

A. **AREA ONLY**
i. Annual Coupe Method.

B. **AREA AND VOLUME CONTROL**
(i) Control by rotation and age classes or periodic blocks methods.

C. **VOLUME OF VOLUME AND INCREMENT OF G. S.**
(i)   Von Mantel's method and Smythies modification.
(ii)   The Austrians formula and Heyers modification.
(iii)   Methods of successive enumeration or continuous inventory base on Biolleys method of control.

D. **NUMBER AND SIZES OF TREES**
(i)   Brandis or Indian methods.
(ii)   Melands or French methods of 1883

A.   **AREA ONLY (DIRECT METHOD)**
      ANNUAL COUPE METHOD:-
This is the oldest method of regulating the cut (14th – 16th) century ago-based on an area and rotation methods. The methods consist of dividing the whole forest into equal areas, equal in number to the rotation. Each part is cut and regenerated sequentially every year.

$$\therefore \text{ Size of annual coupe } = \frac{\text{area of forest}}{\text{Rotation}}$$

It should be noted that only one rotation is used throughout. The annual coupe then consist of a series of "R" stands differing in age by one year (R = Rotation)

Assumptions:-
   1.   Since there will be site difference or micro site variation; each area will produce at different yield. It follows therefore that the longer the Rotation the greater the differences will be. Hence this method is assumed to be best suited for short rotation crops.
   2.   The method also assumes an evenness in ages of crop.
In general this method is best suited for plantations grown on short rotation e.g. fuel wood, poles, pulpwood plantation e.t.c.

ADVANTAGES:
The method is direct and simple and aims directly at establishing a normal series of age gradation in the first Rotation.

It is this the quickest way of attaining a sustain yield from the forest.

DISADVANTAGES

This method is rigid and tend to ignore economic and silvicultural conditions for example it may entail some heavy sacrifices of immature stands. The method tries to decide ahead the allowable cut and its location for the whole rotation.

Due to the fact that the tropical high forest is compared of many different species, it means that the yield from each annual coupe is likely to be vastly different in the first rotation. This difference is further aggravated by the facts that some species are economic while some are not. And it is only the economic ones that are exploited several attempts have been made to overcome these vast difference in annual yield. This include:

1.   Reservation of some rotation of the forest. A part of the forest is set aside as a reserved area and is not considered as part o the yield. This reserve is intended to be used as a BUFFER against large fluctuations in yield and will be used to replace or supplement any areas of very low yield. In this case area of annual coupe is equal to the area of the whole forest misuse area of reserve divided by the rotation.

i.e. Area of Annual Coupe = Area of whole far
$$\frac{- \text{Area of Res.}}{\text{Rotation}}$$

2.   Free choice of coupe by contractors

In this case, the contractor is allowed to choose the order in which he takes the annual coupes. Normally the contractor enumerates the forest and from his data he can nominate which coupe he wants to take next. He can then select his yield to sait the market demand.

For instance if the contractor wants obese, he will nominate or choose the coupe with a large proportion of obeche while on the other hand if he wants mahogany, he will opt for a coupe with a large proportion of mahogany. By so doing it is hoped that by the time he eventually gets to the coupe with a lower yield, it is likely the number of economic species taken to the market should have increased considerably so that they are which was thought to be of low yield earlier on will now be considered as high yielding area.

3.   Fixing of minium felling girth.

The third method for adjusting the yield of a coupe is also practiced in high forest. By this method a mnim fell girth is set for each species below which the contractor is not allowed to fell.

This method acts as a guide against over cutting and also ensures that there is something left behind for the next rotation (this method however prevents the quick achivert of uneven aged forest).

B. METHOD BASE ON AREA AND VOLUME CONTROLS PERMANENT OR FIXED PERIODIC BLOCK METHOD.

The method of annual coupe is more suitable for the crop that is clear felled at rotation age and for system of direct planfix or artificial regeneration. In this method however it can be applied suitably to a high forest system i.e. shelter wood system.

The shelter wood system demands a gradual removal of the trees in the area to encourage natural regeneration. i.e. fellings are made on the same area over a period of time until the whole area is felled and completely regenerated.

The periodic block is therefore that part of the forest allocated fir regeneration or other treatment during a specific period.
When all the periodic blocks are allocated and maintain their territorial identity or a working plan they are termed fixed or permanent periodic blocks.

To avoid the vigidity and reduce the sacrifices of the permanent periodic block method, the obvious remedy is to abandon fixed periodic blocks and realot then according to circumstances at each revision of the work plan namely at the end of each period. Such blocks that di bit retain their territorial identities at a W. P. is termed a Revocable periodic block.

Generally we call the period over which the fellings are completed as the regeneration period (P). The whole forest has to be divided ino a number of equal areas known as periodic blocks equal in number to rotation over regeneration period. i.e.

$$\text{Number of periodic block} = \frac{\text{Rotation}}{\text{Regeneration Period}} = \frac{r}{p}$$

For example if r = 100 and p = 20
Then number of periodic block $= \frac{100}{20} = 5$

If the total area of the forest is equal to 2,000 hectares, then area of periodic block $= \dfrac{2,000}{5} = 400$ hectares.

These periodic blocks are then marked on the ground and hene the system is known as the Permanent Periodic block method. Within each P.b., fellings are done over a wide area accord to silvicultural regts. Hence it is impossible to calculate yield by area but it has to be calculated by volume. If the trees were not growing, then the yearly volume yield would be their present volume (v) divided by the period (P). But they do grow. Now the trees cut at the beginning of the period have no time to grow but those cut at the end of the period can grow for the whole period. So on average the trees put on half the increment (I) they would have put on if they have been left untouched. So the volume available for cutting annually in the regeneration block is the present volume (v) plus half the increment (I) that the untouched stands would have put on in the period. This can be expressed in symbols known as COTTA's formula.

Total volume available for few during the period $= V + \frac{1}{2}I$

$\therefore$ Annual yield $= \dfrac{V + \frac{1}{2}I}{P}$ or $\dfrac{v}{p} + \dfrac{\frac{1}{2}I}{p}$ .... (n

Annual increment (i) $\dfrac{I}{P}$

Substituting i for I in equation i we have A.Y $= \dfrac{V}{P} + \frac{1}{2}i$ (cotta's formula)

Generally the convenience of this method is its flexibility since felling can be varied in intensity and position to suit progress of regeneration.

C. METHODS BASED ON VOLUME OR VOLUME AND INCREMENT OF GROWING STOCK

All methods of Y.A. own at determine how much timber should be cut from a working cycle.

The volume of cut can be determined <u>indirectly</u> through area control methods or <u>directly</u> through volume control method. The mgority of methods of Y.R. had been based on direct approach which is the only one available for irregular forest where age-class cannot be recognized by area.

There are a number of methods based on this direct approach which have been derived on the basis of relationship between growing stock and increment under certain assumed conditions and expressed in formulae. It is always necessary to check up whether the presumed conditions have been fulfilled otherwise these formulae would be misleading.

Advantages:
1. Applicable to all types of silvicultural system.
2. Useful as an overall guide to appropriate cut.
3. Useful in bringing an unmanaged forest under some degree regulation.
4. Being derived from a mathematical model of the grow stock, it allows for the quick estimation of the allowable cut often from a limited amount of data.

Disadvantages:

1. Even though more accurate than area method, it could be more expensive in the sence that regular or constant enumeration will be required and this is time and money consuming and labour demanding.
2. Increment which is regard in most volume formulae tend to be a weak figure. If volume or increment data are incurrect, there is no assurance that the forest is constituted as desired. Therefore for safe application of V.C.M. a reasonably high degree of accuracy of volume and increment data are regard.

VON MANTEL'S FORMULA
Some volume methods are certainly more successful than the others. The simplest method is von Mantel's formula.

Von Mantel assumed the concept of a normal forest i.e. that the N.G.S is equal to the annual yield multiplied by R^n all upon 2.

i.e. $N.G.S = \dfrac{I \times r}{2}$ where I = Annual Yield

r = Rotation

$I = \dfrac{2\ NGS}{r}$

$A.Y = \dfrac{2\ NGS}{r}$ (Von Mantel's Formula)

1. If the G.S. is completely measured include the small and big trees then the annual yield can be calculated quite simply.

2.   However in practice, trees are not enumerated or mmed below a certain girth limit.

3.   Another disadvantage is that the formula is wrongly applied to all forest irrespective of their normality. If there is no normal distribution of trees of all age classes then the annual yield will be very wrong. Therefore there is a modification to this called SMYTHIES MTD OR MODIFICATION.

In many countries especially in the tropics, it is usual to measure the volume over a certain minimum girth. Let us call the volume 'V' and the age at which the trees reach the minimum girth as 'X' and rn as "r" Smithies submission is that:

$$A. \; Y. \; = \; \frac{2V}{r-x}$$

The disadvantage of these methods (i.e. Von Mantel & Smithies) is that the forest is assumed to be normal. Anything contrary to this assumption (i.e. that the forest in normal will lead to great errors in calculation.

AUSTRIAN METHOD

The Austrian method is a means of calculate the yield by comparison of actual growing stock and normal growing stock. (AGs & NGs).
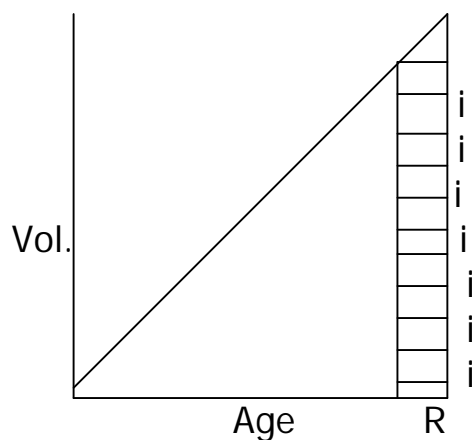
The AGs is mmed and it is assumed that the stock on R^n age plot is equal to the annual yield and is equal to (I) sum of increment of all the age classes of the growing stock.

That is:

$$AY \; = \; I \; = \; Ri$$

Where AY = Annual Yield ; R = Rotation

i = annual increment; $I \; = \; \varepsilon_i \; = \; R$ = sum of increment of all the age class of the G.S.

i earlier assumption on the NGs it was found that NGs $= \frac{I \times r}{2}$ (Von Mantel formula)

However when the AGs was mmed it was found out that the total volume is either greater than or less than the volume of the normal growth stock.

The Austrian tax collector mmed the Volume of the AGs and the volume of the R^n age stand. This was assumed to be equal to $I = AY$.

He postulated that AY ought to be the volume of R^n (I) age plus the AGs minus the NGS all upon R^n.

$$AY \; = \; I + \frac{(AGs \; - \; NGs)}{R}$$

And if the AGs is greater than NGs the little excess will be positive and if the AGs is less than the NGs, the little deficit will be negative.

(A)	(B)
AGs > NGs	AGs < NGs
AY = I + x	AY = I – x
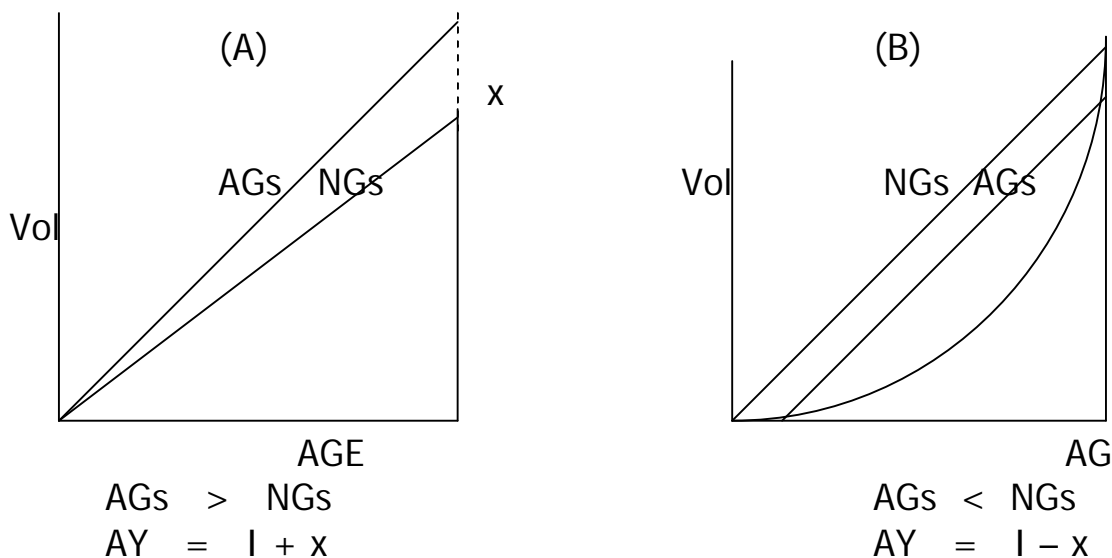
It means that AY will be greater than I if AGs is greater than NGs see sketch 'A', But AY would be less than I if AGs is less than NGs.

HEYER'S MODIFICATION

The disadvantage of Austrian's method is that too much emphasis have been placed on the stand of the R^n age. However he thought that it would be better to measure the actual increment of each stand after a certain period says 10 years i.e.

$$AY \; = \; PMAI \; + \; \frac{(AGs \; - \; NGs)}{R}$$

METHODS OF SUCCESSIVE ENUMERATION OR CONTINUOUS INVENTORY BASED ON BIOLLEYS METHOD OF CONTROL

This is infact the most detailed and probably accurate method but it depends on successive enumeration or short interval so that it is practicable where forestry is intensive.

It is also suitable for forest under selection system and clear fell into. Depends on complete enumeration at regular intervals and works as follows:

   P = Period between enumeration

   V1 = Volume enumerated in the 1st enumeration

   V2 = Volume enumerated in the 2nd enumeration

   N = Volume felled between enumerator

<u>Note</u>:- These Vols ("N") are got from things . The annual yield for the succeeding period is equal to PMA = $\dfrac{V_2 + N - V_1}{P}$

$$AY = PMAI = \dfrac{V_2 + N - V_1}{P}$$

Since the AY in the preceding period is $\dfrac{N}{P}$ the aim is to get the calculated

Yield exactly equal to this so that the volume remains constant.

<u>Other Methods of Volume Control</u>
1. Hundeshagen method
2. Hufuagels Method
3. Kuusela Nyyssonen method (finish formular)
4. Armorlization formula
5. Grosenhangl's allowable cur formula

i)   NUMBER AND SIZES OF TREES

   Up till now we've been discussing methods it take into consideration the age of the trees.

   This is possible where we are considering approximately over-aged forest as is obt'ed in clear felling, or in temperate countries.

   In the tropical high forest trees of different ages are all mixed together. It therefore becomes meaningless to use age class distribution as a yard stick or measure of yield regulation.

Hence we apply size class distribution to uneven-aged forests. Further more it is difficult to know ages of trees in tropical high forest since there are no clear-cut relationship between age and size classes.

Also growth rings are not equivalent to annual rings and so it is difficult to assess the ages of these trees.

Methods of yield regulation of un even-aged forest based on size classes includes:

1. French method of 1883 or Meland method
2. Brandis method or Indian Method
3. Meyers method
4. The Recruitment method
5. The chapmans Horizontal cut method.

FRENCH METHOD OF 1883 OR MELARD METHOD
In this method we divide the growth stock into three parts according to the sizes and these are equated to the rotation as follows:
Let size at R^n (r) be equal to x
i.e.

Rotation	Size girth in fees
R = 75	x = 6
1/3r = 25	1/3x = 2
2/3r = 50	2/3x = 4

The G.S is divided into three.
1. The large Trees (L.W) = 2/3x and above.
2. The Medium Trees (M.W.) 1/3x to 2/3x
3. The small trees (S.W) – below 1/3x

The vol. of the large tree is then measured and the annual yield is then calculated by Cotta's formular.

$$AY = \frac{V}{P} + \frac{1}{2}i$$

$$A.Y. \frac{\text{Vol of L.W}}{1/3r} + \frac{1}{2}\text{ annual increment of L.W.}$$

Above is of course the figure representing trees in the final yield.

During this period thinnings have been done especially among the medium trees and it is assumed that in a well stocked forest 1/3 of the annual increment of the medium trees can be removed as thinnings. In some cases however it is less than 1/3 of annual increment i.e. about ¼ only. The total AY therefore becomes Total AY = <u>Vol of LW</u> + 1/3 annual

$$\frac{1}{3r}$$

increment of L.W.

BRANDIS/INDIAN METHOD

This method was developed to regulate the cutting of teak in Burma.
The regulation is by size classes based on number of trees that can be removed with respect to rate of replacement or recruitment.

<u>Method</u>:-
i.   Classification of growth stock to three girth classes namely:
        I = > 6ft
        II = 4½ - 6ft
        III = 3 – 4½ feet
        Fixing of class I as the minimum felling girth.

ii.   Calculation of TIME it will take all trees in girth class II to go into girth class I.
<u>Note</u>:- This can be done by ring count or observation of trees of known ages.

iii.   Brandis determine the recruitment period to be 24 years.

iv.   Therefore allowable cut = 1/24 of the present number of class I trees.

REFERENCE/FURTHER READINGS

Adekunle, M.F, Momoh, S.and Agbaje, B.M .(2008). Valuing urban forests: The application of Contingent Valuation Methods. *Ethiopian Journal of Environmental Studies and Management (published by ;Department of Geography, Bahir Dar university ,Bahir Dar ,Ethiopia) 1 (2) 61-67. www.ajol.info/index.php*

Adeyoju, S. K. (1975), <u>Forestry and The Nigerian Economy</u>, Ibadan University Press.

Etukudo, I. G. et al (1994): <u>Elements of Forestry</u>

Gbile, Z. O. (1979): <u>Exploitation of Nigeria's economic non-timber plant species in the wild – progress and prospects</u>. An invited paper for the 9th Annual conference of the Forestry Association of Nigeria, November 1979.

Hill, Albert F. (1951): <u>Economic Botany</u>. McGraw – Hill Book Company, Inc.

M. B. Shrivastava 2004. Department of Forestry The Papua New Guinea University of Technology Lae. Vikas Publishing House PVT Ltd 576, Masjid Road, Jangpura, New Delhi – 110 014