Stand Prediction in Crops of Mixed Species and Age

2. **Forecast of future yields...**

1. Stand structure

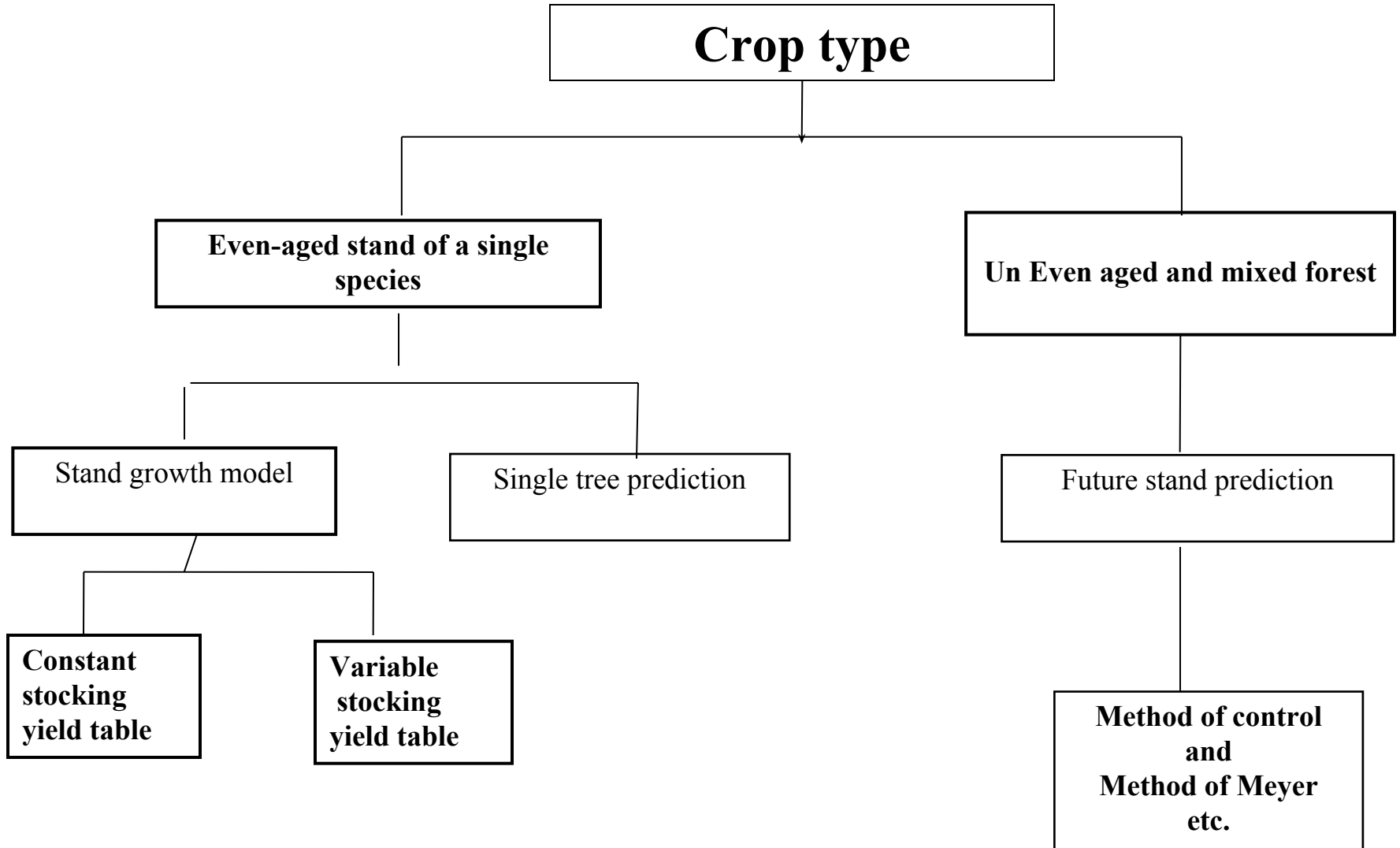2. ***Stand growth***

3. Stand density

4. Productive capacity of site, "site quality"

2. **Stand Growth**

- *Development of tree crops as they increase in age*

- 'Design of growth model' depends on :

  – Resource available

  – Uses to which it will be put

  – Structure of tree crops

    Even or Uneven aged

    - Changes from year to year

- **Even aged stand**

  – Simplest models

- **Un Even aged or mixed species stand**

  – Very complex

A classification of growth models

Crop type

Even-aged stand of a single species

- Stand growth model
  - Constant stocking yield table
  - Variable stocking yield table
- Single tree prediction

Un Even aged and mixed forest

- Future stand prediction
  - Method of control and Method of Meyer etc.

Stand prediction
in
Un-Even aged or mixed species stand

Factors affecting stand structure

- Growth

- Death

- Cutting of trees

- **Definitions:**

  ❑ **Ingrowth:**

   ❑   volume of new trees growing into the

   minimum measurable size class during the

   measurement period.

❑ Mortality:

❑ the **#** or **vol.** of trees periodically dying from

natural causes as:

- Old age, Disease, Insects etc.

❑ Cut:

❑ the # or vol. of trees periodically felled or

salvaged

- **Types of Stand Growth (in terms of vol.)**

$$Gg = V_2 + M + C - I - V_1$$

Gg= Gross growth of initial vol.

V_2= Stand Vol. at end of growth period

V_1= Stand Vol. at beginning of growth period

M = Mortality Volume

C = Cut volume

I = Ingrowth Vol.

⟶ Gn = Net growth of initial volume

$$Gn = (Gg - M) = V_2 + C - I - V_1$$

⟶ G_d = Net increase in standing vol.

$$G_d = V_2 - V_1$$

Stand prediction in Un-Even aged crops

- Method of measuring growth of un-even aged crops
  - evolved from those developed in France & Switzerland in last century
  - Swiss forester , M Henri Biolley introduced " **Methode du Controle**"
    - Established the increment of forest over successive 100 % inventories by 3 categories
      - Large , Medium & small sized trees
    - This data then used to predict or plan future felling

Method of Control ...

- Depends on the following factors:

1. 100% inventories

2. Well defined procedure of measuring and re-measuring the diameter of standing trees

3. Measuring and determining the volume of felled trees and mortality trees

4. A simple method of determining ingrowth

5. Use of permanent local volume tables

- Initial inventory

  – Entire area is enumerated

  – Trees are classified by Dia- class

  – Record all trees removed till the next inventory

    (dia class as well as volume)

- Next Inventory

  – Entire area is again enumerated

- Volume calculation

  - Using LVT

  - For each dia –class

  - Add volume of each dia class to obtain volume of each inventory

- Cut and mortality together constitute trees removed

a) Vol at time t $\quad = V_1$

b) Vol at time (t + 5) yrs $\quad = V_2$

c) Account total vol.
   removed during the
   period $\qquad = C$

Then, net growth, including ingrowth, of initial volume

$$\textbf{Gn+i} = \textbf{V}_2 + \textbf{C} - \textbf{V}_1$$

The Calculation of increment in the Methode du Controle

Dbh (1)	Vol./tree (2)	2010 No./ha (3)	2010 Vol./ha (4)	2015 No./ha (5)	2015 Vol./ha (6)	Felled No./ha (7)	Felled Vol./ha (8)	Recruits No./ha (9)	Recruits Vol./ha (10)	Revised total 2015 No./ha (11)	Revised total 2015 Vol./ha (12)	Volume inc./ha in 5 yr (13)	Annual volume increment per ha (14)	% (15)
75	5.56	–	–	1	5.56	–	–			1	5.56			Large trees
70	4.93	1	4.93	–	–	–	–			–				
65	4.32	–	–	–	–	–	–			–				
60	3.72	2	7.44	5	18.60	–	–			5	18.60			
55	3.20	5	16.00	6	19.20	2	6.40			2	6.40			
Total large trees		8	28.37	12	43.36	2	6.40	6	19.20	8*	30.56	2.19	0.44	1.6
								Recruits	6	19.20				Medium trees
50	2.70	11	29.70	7	18.90	1	2.70			8	21.60			
45	2.22	13	28.86	17	37.74	5	11.10			22	48.84			
40	1.66	27	44.82	27	44.82	1	1.66			28	46.48			
35	1.14	32	36.48	41	46.74	4	4.56			19	21.66			
Total medium trees		83	139.86	92	148.20	11	20.02	26	29.64	83*	157.78	17.92	3.58	2.6
								Recruits	26	29.64				Small trees
30	0.12	66	47.52	52	37.44	5	3.60			57	41.04			
25	0.37	69	25.53	83	30.71	13	4.81			96	35.52			
20	0.16	117	18.72	94	15.04	19	3.04			73	11.68			
Total small trees		252	91.77	229	83.19	37	11.45	40	6.4	252	117.88	26.11	5.22	5.7
Total		343	260.00	333	273.75	50	37.87			343	306.22	46.22	9.24	3.6

Methode du Controle
(volume increment by dia. class)

1. the classes of diameter at breast height were grouped into three major categories of large, medium and small trees. A separate increment % was calculated for each.

2. data derived from a one parameter volume table.

3. from an inventory of the compartment made in 2010

4. col. 2 X col. 3

5. From an inventory of the compartment made in 2015

6. col. 2 X col. 5

7. From the compartment records of outturn for the period 2010-2015

8. col. 2 X col. 7

9. only to be completed in the line of the totals for the large and medium trees = total of col. 5 + total of col. 7 – total of col. 3, i.e. $V_2 + F - V_1$ or the number of trees of medium size in 2010 recruited to the large tree category, etc.

10. col. 2 X col. 9 for totals only.

11. has to be completed for the total line of the large trees first and must <u>equal the corresponding total in col. 3</u>.

- Then starting with the largest diameter class of the large trees, col. 11 = col. 5 + col. 7 until the sum of these totals equals the figure previously entered in the total line.

- The balance of trees in the large tree diameter classes has been recruited from the medium category and this balance is entered in the blank line at the head of the medium tree category in col. 11 and labelled **'recruits'** in the adjoining space in col. 10

12. col. 2 X col. 11

13. completed for the total line of the large, medium and small tree category only = col. 12 – col. 4

14. col. 13 divided by the period of years between the inventories

15. column 14 expressed as a % of col. 4

- **Meyer (1953)** reviewed the Stand Prediction Method
  - Developed new system was similar to Methode du Controle but
    - Predicted the future structure of a stand either from increment measured from successive inventories or in sample plots

Methodology

1. Current diameter increment by diameter classes

    – Use of data collected

2. Predict future structure of stand and growth in volume

1.   **<u>Diameter increment by diameter classes</u>**

- Takes in to account

  - no. of trees rising into a diameter class,

  - Trees remaining stationary in the class

  - Trees going out of the class

    in successive inventories

- Increment in each dia class,

$$I = (DR/DE) * C$$

where,

DR = double rising (sum of trees rising out

and rising into a class)

DE = double effective (sum of trees in the

first and second inventories   after

correction for trees removed)

C = width of dia class

Table
Calculation of Periodic Annual Diameter Increment by Diameter Classes by the Method of Control

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
dbh Class (inches)	Inventory Spring 1999 (number)	Trees Removed (number)	Inventory Spring 1999 Minus Trees Removed (number)	Inventory Spring 2009 (number)	Trees Rising (number)	Double Rising (number)	Double Effective (number)	DR/DE	Periodic Diameter Increment (inches)	Periodic Annual Diameter Increment (inches)
32	0		0	1	0 / 1	1	1	1.000	2.00	0.200
30	2		2	4	3	4	6	0.667	1.33	0.133
28	3		3	0	0	3	3	1.000	2.00	0.200
26	3	2	1	9	8	8	10	0.800	1.60	0.160
24	10	1	9	7	6	14	16	0.875	1.75	0.175
22	10	4	6	21	21	27	27	1.000	2.00	0.200
20	23	4	19	39	41	62	58	1.069	2.14	0.214
18	37	7	30	72	83	124	102	1.216	2.43	0.243
16	73	5	68	169	184	267	237	1.127	2.25	0.225
14	194	17	177	234	241	425	411	1.034	2.07	0.207
12	249	9	240	379	380	621	619	1.003	2.01	0.201
10	418	15	403	507	484	864	910	0.949	1.90	0.190
Total	1022	64	958	1442		2420	2400			

$$\frac{\Sigma DR}{\Sigma DE} = 1.008$$

Average = 2.02   0.202

Number of trees ingrowth = 1442 − 958 = 484 (checks with last figure in Column 6). Trees were removed (Column 3) immediately following the 1999 inventory. Data from 143 permanent sample plots of ⅕ acre located on Morgan-Monroe State Forest, Indiana. Sample area: 28.6 acres. Growth period: 10 years.

- No. of trees rising in to class =

(# of trees in 2nd Inv)

- (# of trees in 1st Inv)

+ (# of trees rising out of the class)

$$C6_{i+1} = C5i - C4i + C6_{i-1}$$

$$C7i = C6_{i+1} + C6_{i-1}$$

$$C8i = C4i + C5i$$

2. Predict future structure of stand and growth in volume

   □   STAND PREDICTION METHOD

Dbh Cm	Vol. per tree (Cum)	Inventory - No. of Stems Per Ha	Diameter increment in 5 years Cm (i)	Ratio i/c*	Station ary	1dia. Class	2 dia. Class	Future stand No. of stems per Ha	Present Volume (Cum per ha)	Volume prediction (Cum per ha)
1	2	3	4	5	6	7	8	9	10	11
42	1.80	-	-					1.10	-	1.98
40	1.58	2	1.1	0.55	0.90	1.10	-	2.70	3.16	4.27
38	1.38	3	1.2	0.60	1.20	1.80	-	5.45	4.14	7.52
36	1.19	5	1.7	0.85	0.75	4.25	-	10.55	5.95	12.55
34	1.02	8	2.0	1.00	-	8.00		8.50	8.16	8.67
32	0.88	9	2.4	1.20	-	7.20	1.80	11.70	7.92	10.30
30	0.76	13	2.2	1.10	-	11.70	1.30	17.10	9.88	13.00
28	0.65	18	1.9	0.95	0.90	17.10	-	13.70	11.70	8.90

Dbh Cm	Vol. per tree (Cum)	Inventory - No. of Stems Per Ha	Diameter increment in 5 years Cm (i)	Ratio i/c*	Stationary	1dia. Class	2 dia. Class	Future stand No. of stems per Ha	Present Volume (Cum per ha)	Volume prediction (Cum per ha)
1	2	3	4	5	6	7	8	9	10	11
26	0.55	16	1.6	0.80	3.20	12.80	-	22.80	8.80	12.54
24	0.46	28	1.4	0.70	8.40	19.60	-	28.90	12.88	13.29
22	0.38	41	1.0	0.50	20.50	20.50		58.20	15.58	22.12
20	0.31	58	1.3	0.65	20.30	37.70		70.90	17.98	21.98
18	0.25	92	1.1	0.55	41.40	50.60		99.45	23.00	24.86
16	0.18	129	0.9	0.45	70.95	58.05		70.95	23.22	12.77
	Total	**422**						**422.00**	**152.37**	**174.75**

c = class interval = 2 cm

5 years' total increment   = (174.75 – 152.37) = 22.38 ;

current annual increment 4.48 per year or 2.9%

Notes on calculation in Example of the
STAND PREDICTION METHOD

COLUMN

1   Classes of diameter at breast height

2   From a one parameter volume table

3   From an inventory

4   From repeated measurements on sample trees

5   Col.4 divided by the diameter class interval

COLUMN

6,7,8   If the increment is 1/n of the class interval, then on average 1/n of the trees will move out   of   the class in to the next larger dia class;

However, if the increment is more than the class interval, then all the trees will move up

If the increment is 1 ¼ times the class interval, all the trees will move up and   ¼   will   move beyond into the next but   one diameter class

Co.6= 0,   if Col.5 is greater than 1, or else = (1- col.5) (Col.3)

Col.7 = Col.3 - (col.6+ col.8)

Col.8 = 0, if col.5 is less than 1, or else = (col.5 - 1) (col.3)

Column 9   Col6 + (the entry in Col.8 of 2 diameter classes lower) +

(the entry in col.7of 1 diameter class lower), e.g.

Dbh 42   col.9 = 0+1.10 =1.10

Dbh 40   col.9 = 0.90+1.80 = 2.70

10   col.2 X col.3

11   col.2 X col.9

 The total of column 3 must equal that of column 8 .

Q: Following inventory data has been collected in two different years in the same forest area:

Dia class (in cm)	Volume per tree	Initial inventory in 2001 (number)	Second inventory in 2011 (number)
1	2	3	4
42	1.8	0	1
40	1.58	2	3
38	1.38	4	5
36	1.19	6	11
34	1.02	12	20
32	0.88	18	26
30	0.76	22	30
28	0.65	26	33
Total		90	129

Calculate annual diameter increment in each dia class, overall annual diameter increment and also future volume in year 2016 using Method of Control.

Basic Types of Forest Growth Models

- **Process Models**: simulate the biological process that convert CO_2, nutrients & moisture into biomass through photosynthesis

- **Empirical Models:** based on periodic tree measurements and make no attempt to measure every factor related to tree growth

Classification of Growth Models of Forest Crops

- Simplest Models: even-aged stands of a single species

- Most Complex Models: uneven-aged stands with mixed species

- Stand Growth Model: predicts stands through general parameters- total basal area/ha, mean volume/tree

- Single tree Growth Model: predicts the growth of individual trees and stand growth from the sum of individual samples

Stand Prediction

- Development of models for even-aged plantations of single species- rapid

- Knowledge on inter-specific and inter-size growth relationships is inadequate in uneven aged forests of mixed species arising from natural regeneration
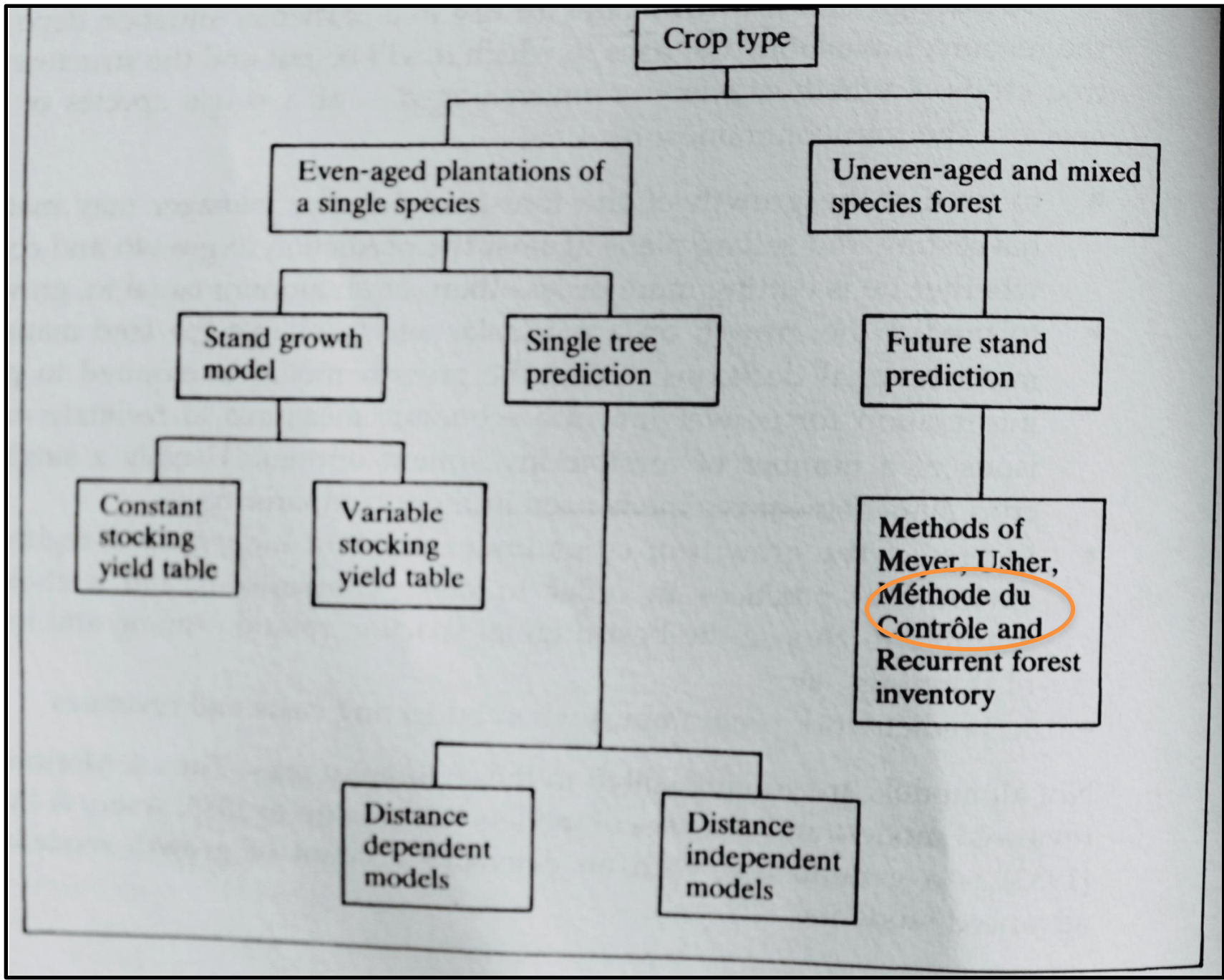
```
                              ┌──────────────┐
                              │  Crop type   │
                              └──────┬───────┘
               ┌─────────────────────┴────────────────────┐
    ┌──────────────────────┐                  ┌──────────────────────┐
    │ Even-aged plantations│                  │ Uneven-aged and mixed│
    │ of a single species  │                  │ species forest       │
    └──────────┬───────────┘                  └───────────┬──────────┘
        ┌──────┴────────┐                                 │
┌──────────────┐  ┌──────────────┐            ┌──────────────────────┐
│ Stand growth │  │ Single tree  │            │ Future stand         │
│ model        │  │ prediction   │            │ prediction           │
└──────┬───────┘  └──────┬───────┘            └───────────┬──────────┘
   ┌───┴────┐            │                                │
```

Constant stocking yield table	**Variable stocking yield table**	**Methods of Meyer, Usher, Méthode du Contrôle and Recurrent forest inventory**

```
              ┌──────────────┴──────────────┐
      ┌──────────────┐              ┌──────────────┐
      │ Distance     │              │ Distance     │
      │ dependent    │              │ independent  │
      │ models       │              │ models       │
      └──────────────┘              └──────────────┘
```

- M. Henri Boilley, a famous Swiss Forester introduced a method **Methode du Controle (Control or Check Method).**

- Established increment of the forest by sucessive 100% inventories by 3 categories- the large, the medium, the small sized trees.

Methode du Controle

1. the classes of diameter at breast height were grouped into three major categories of large, medium and small trees. A separate increment % was calculated for each.

2. data derived from a one parameter volume table.

3. from an inventory of the compartment made in 1970

4. col. 2 X col. 3

5. From an inventory of the compartment made in 1975

The Calculation of increment in the Methode du Controle

EXAMPLE 51 The calculation of increment in the Méthode du Contrôle

Dbh (1)	Vol./tree Silve (2)	No./ha (3)	Vol./ha Silve (4)	No./ha (5)	Vol./ha Silve (6)	No./ha (7)	Vol./ha Silve (8)	No./ha (9)	Vol./ha Silve (10)	No./ha (11)	Vol./ha Silve (12)	Volume inc./ha in 5 yr Silve (13)	Silve (14)	% (15)
		2010		2015		Felled		Recruits		Revised total 2015			Annual volume increment per ha	
75	5.56	–	–	1	5.56	–	–			1	5.56		Large trees	
70	4.93	1	4.93	–	–	–	–			–				
65	4.32	–	–	–	–	–	–			–				
60	3.72	2	7.44	5	18.60	–	–			5	18.60			
55	3.20	5	16.00	6	19.20	2	6.40			2	6.40			
Total large trees		8	28.37	12	43.36	2	6.40	6	19.20	8*	30.56	2.19	0.44	1.6
								Recruits	6		19.20		Medium trees	
50	2.70	11	29.70	7	18.90	1	2.70			8	21.60			
45	2.22	13	28.86	17	37.74	5	11.10			22	48.84			
40	1.66	27	44.82	27	44.82	1	1.66			28	46.48			
35	1.14	32	36.48	41	46.74	4	4.56			19	21.66			
Total medium trees		83	139.86	92	148.20	11	20.02	26	29.64	83*	157.78	17.92	3.58	2.6
								Recruits	26		29.64		Small trees	
30	0.12	66	47.52	52	37.44	5	3.60			57	41.04			
25	0.37	69	25.53	83	30.71	13	4.81			96	35.52			
20	0.16	117	18.72	94	15.04	19	3.04			73	11.68			
Total small trees		252	91.77	229	83.19	37	11.45	40		252	117.88	26.11	5.22	5.7
Total		343	260.00	333	273.75	50	37.87			343	306.22	46.22	9.24	3.6
													Excluding recruits	

*This total is made the same as that in the earlier inventory. If no fellings had taken place there would have been 12 + 2 = 14 trees in the large-size class in 1975. Therefore 14 − 8 = 6 trees had been recruited from the medium-size class. Similarly, if there had been no fellings or recruits there would have been 92 + 11 + 6 = 109. Medium-sized trees: 1975. Therefore 109 − 83 = 26 trees had been recruited from the small-size class.

6. col. 2 X col. 5

7. From the compartment records of outturn for the period 1970-1975

8. col. 2 X col. 7

9. only to be completed in the line of the totals for the large and medium trees = total of col. 5 + total of col. 7 − total of col. 3, i.e. $V_2 + F − V_1$ or the number of trees of medium size in 1970 recruited to the large tree category, etc.

10. col. 2 X col. 9 for totals only.

11.   has to be completed for the total line of the large trees first and must equal the corresponding total in col. 3.

- Then starting with the largest diameter class of the large trees, col. 11 = col. 5 + col. 7 until the sum of these totals equals the figure previously entered in the total line. The balance of trees in the large tree diameter classes has been recruited from the medium category and this balance is entered in the blank line at the head of the medium tree category in col. 11 and labelled 'recruits' in the adjoining space in col. 10

12. col. 2 X col. 11

13. completed for the total line of the large, medium and small tree category only = col. 12 – col. 4

14. col. 13 divided by the period of years between the inventories

15. column 14 expressed as a % of col. 4