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Silvicultural Systems (in Tropics)

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Silviculture is the science and art of growing and tending forest crops.

Silviculture is the theory and practice of controlling the establishment, growth, composition, constitution, health, and quality of forests to meet diverse needs and values.

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Silvicultural Systems for management of tropical forests

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Key notes of the presentation

- What is so special on tropical and subtropical forest management?
- Silvicultural systems used in the world
- Silvicultural systems used in TS with emphasis on natural regeneration
- The case of secondary forest
- Practical examples
- What about artificial regeneration
- Conclusion

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Management of natural tropical forests

- In the past several cultures have been able to use the forest in sustainable manner = without compromising future generations to meet their own needs (settlement in the Amazon before European colonization) = human dominated ecosystems with conservation of the basic forest structure and function (inspiration for present tropical forest management)
- NFM less intensive than plantations, relatively lower short term yields, with lower capital inputs

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Management of TF should take into consideration:

- The **maintenance of biodiversity**, including the mutualisms that are essential for forest reproduction = natural regeneration
- The **maintenance of viable populations of wildlife**
- The **maintenance of nutrient retention and recycling mechanisms** of the forest
- The **maintenance of soil organic matter**

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Definition of natural forest management

„Controlled and regulated harvesting, combined with silvicultural and protective measures, to sustain increase the commercial value of future stands, all relying on natural regeneration of native species“

Basic principle: mimicking nature, reducing risks and costs

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Ecological and Economic Feasibility according to Management of NTF

- Are there enough seedlings, saplings, and advanced growth of commercial species at time of explotation to provide adequate stocking for the next harvest?
- What are the silvicultural characteristics of these species?
- What treatments will be necessary?
- What are probable growth rates and merchantable volume expectations of different species?
- What are the costs of the treatments?

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Obstacles to Sustainable FM

- Is SFM effective tool for conservation of primary forests?
- One-time harvest of ancient trees is more profitable than managing for future harvests
- Tropical countries are feeding ground for foreign logging corporations
- Weak environmental and social laws
- Forest resources are often controlled by a few powerful individuals
- Absence of responsibility for the future of that resource by the authorities

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Criticism of modern natural forest management

- Based on few valuable species (*Swietenia sp., Khaya, Cedrela, Teca etc.*)
- Selective logging reduces local populations of these species
- Damage to the forest is highly dependent on the logging intensity
  management techniques should imply restriction according to amount of timber harvested
- Lack of natural regeneration due to damage caused by logging
- Opening areas for local people (shifting cultivation)
- Roads increase access to wildlife hunting
- Risk of damage by fire

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Silvicultural systems used in management of forest worldwide

Uniform system – Age-class forestry (*trees in even aged blocks, each age class is of equal area or productivity – management unit: forest stand; in Europe –* ***shelterwood, clear-cut, border-cut***)

and

Selection system (*all aged forest, trees removed one by one by the total forest area, regeneration occur on the whole area, each age class is supported by the grater numbers in the class below it – arose in Europe, in tropics many limitations*).

The two ends of the range of silvicultural systems (in tropics not so clear boundaries between these particular management systems originating from Europe).

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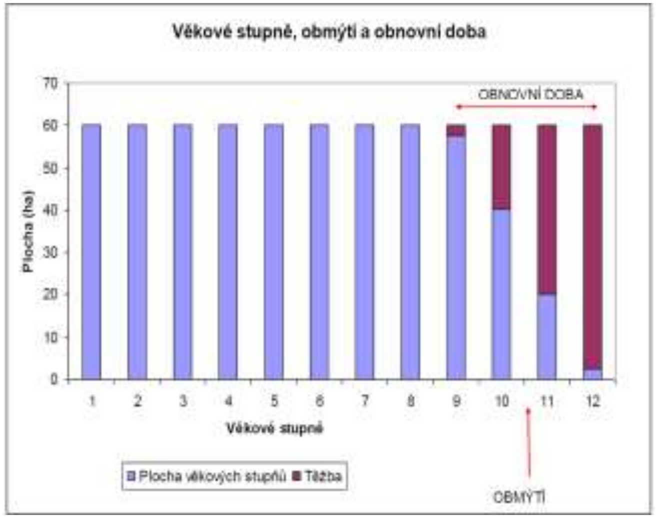
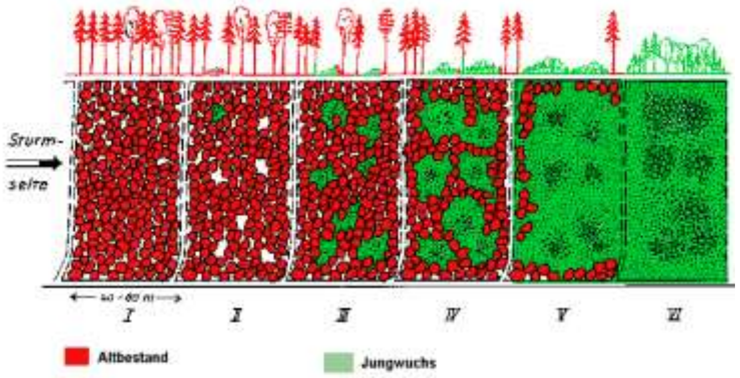
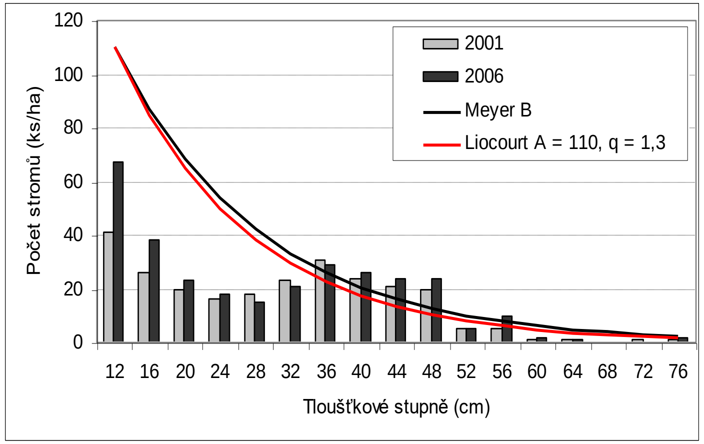
Development of Silviculture Concepts







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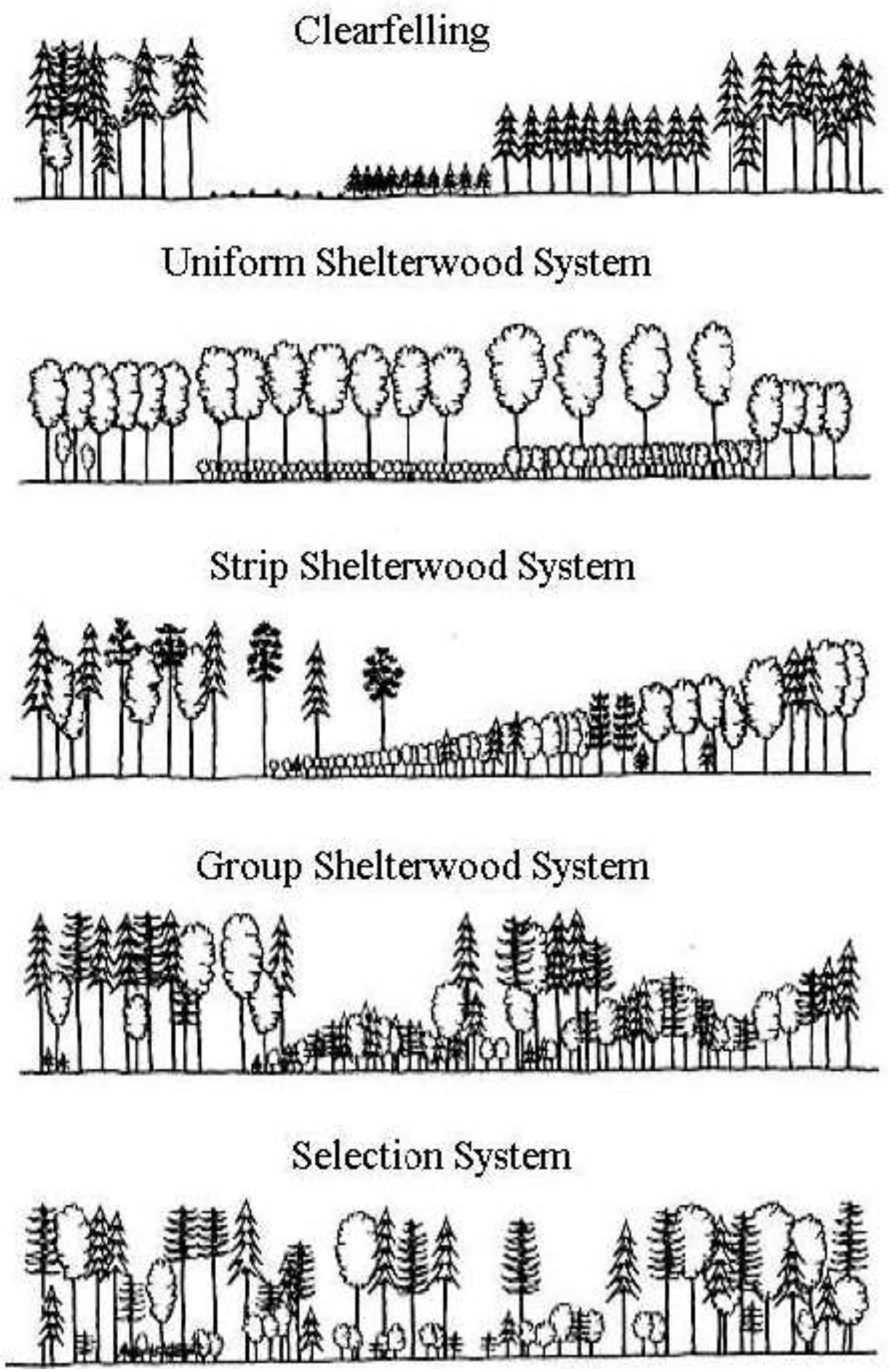

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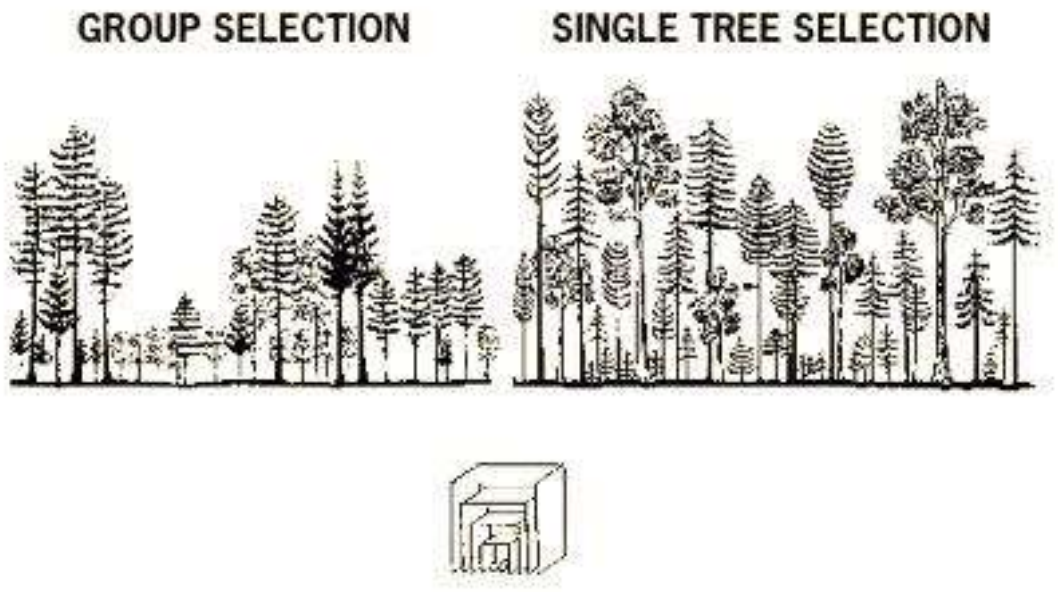
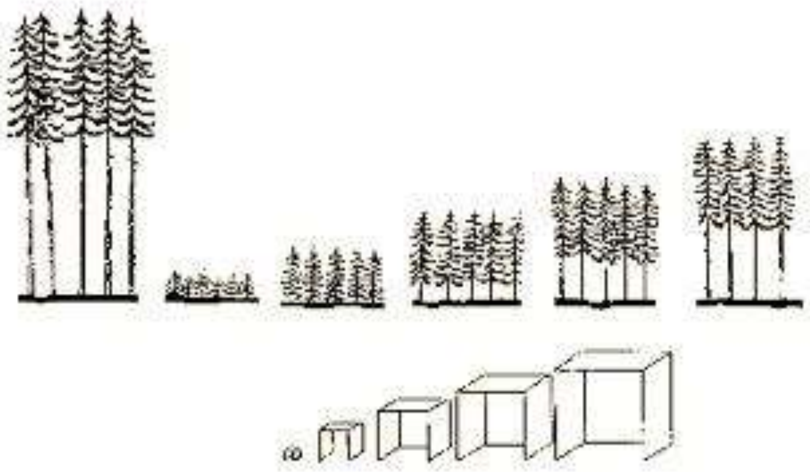


Continuous cover forestry systems – Vertically arranged growing stock



Plantation clearcut system – Horizontally arranged growing stock

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Normal Forest

Aim - to secure sustainable and equal harvest

Hundeshagen (1826), Heyer (1841)

- Requirements
  - Normal number and area of age classes (10 or 20 years)
  - Normal spatial arrangement
  - Normal increment (full stocked forest stand)

- Results
  - Normal volume
  - Normal harvest

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Normal Forest – Age classes

Number of age classes (m)

- Range of age class (n = 10 or 20 years)
- Rotation age (r)

$$m = \frac{r}{n}$$

Area of age class (A_i)

- Total area of the forest (A)
- Number of age classes

$$A_i = \frac{A}{m} = \frac{A}{r} * n$$

$$A_1 = A_2 = ... = A_m$$

$$A = \sum_{i=1}^{m} A_i$$

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Normal Forest – Age classes

A = 1.200 ha, n = 10 years, r = 120 years

$$m = \frac{120}{10} = 12$$

$$A_i = \frac{1200}{12} = \frac{1200}{120} * 10 = 100$$

$$A_1 = A_2 = ... = A_m$$

$$A = \sum_{i=1}^{m} A_i$$

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Normal Forest – Age classes

Theoretical clearing (C)

- Reforestation period (b) – 1 or 2 years

$$C = \frac{A}{r+b} * b$$

$$A_i = \frac{A}{r+b} * n \qquad A_1 = A_2 = \dots = A_m \qquad A = \sum_{i=1}^{m} A_i + C$$

$$A_i = \frac{1200}{120+1} * 10 = 99.17 \qquad C = \frac{1200}{120+1} * 1 = 9.92$$

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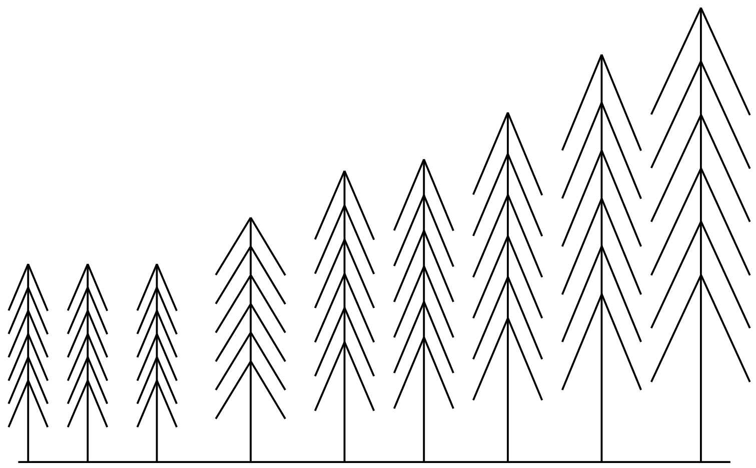
Normal Forest – Spatial arrangement



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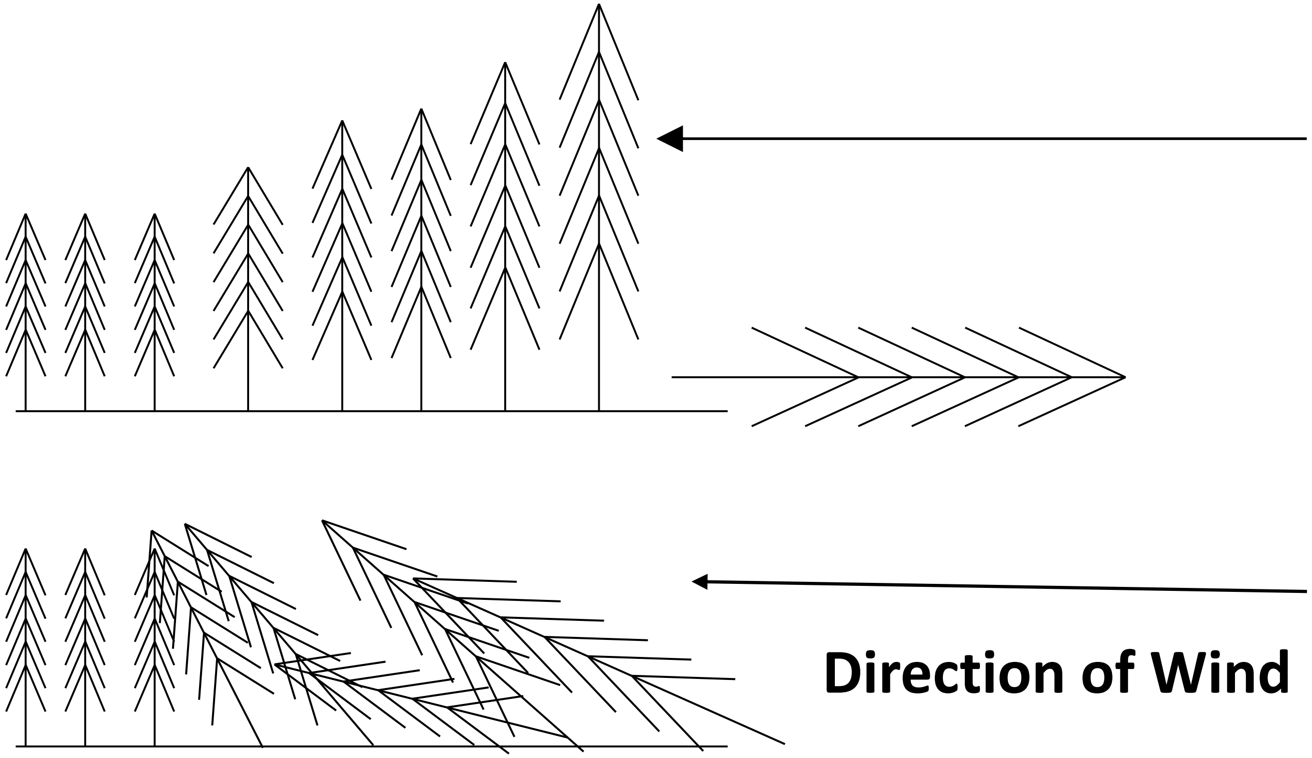
Normal Forest – Spatial arrangement



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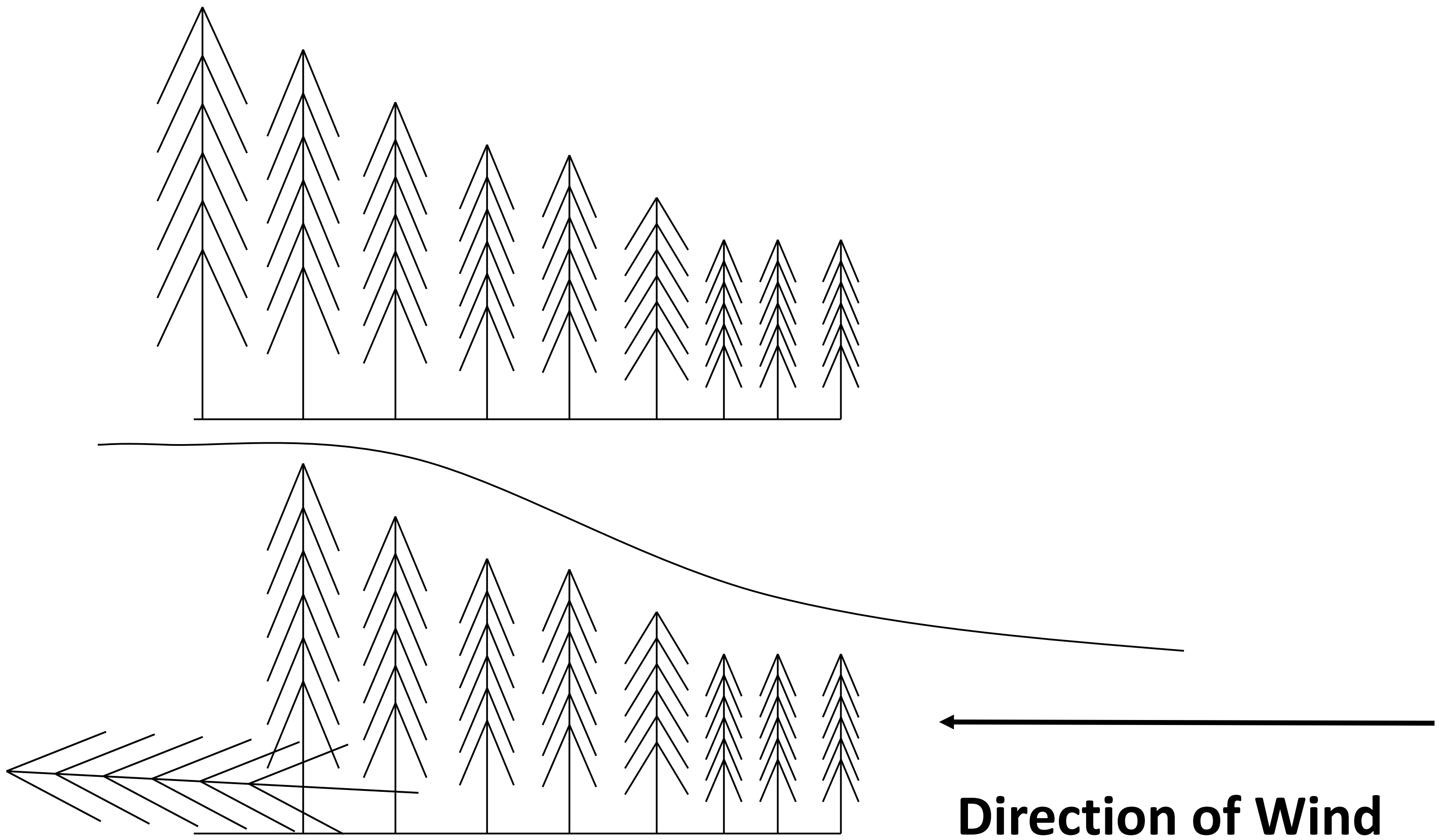
Normal Forest – Spatial arrangement



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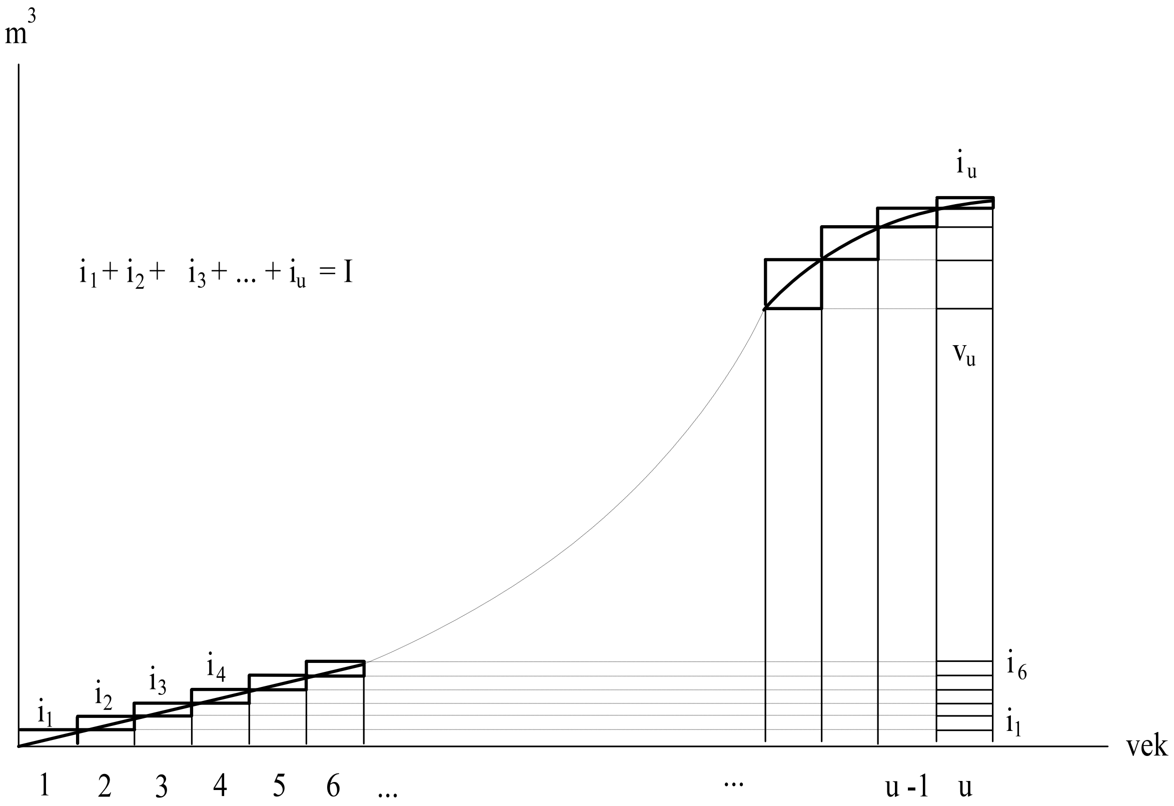
Normal Forest – Increment

Equal to max. increment (I)



$$I = i_1 + i_2 + \ldots + i_j = \sum_{j=1}^{r} i_j$$

$$I = V_r$$

$$I = FMI$$

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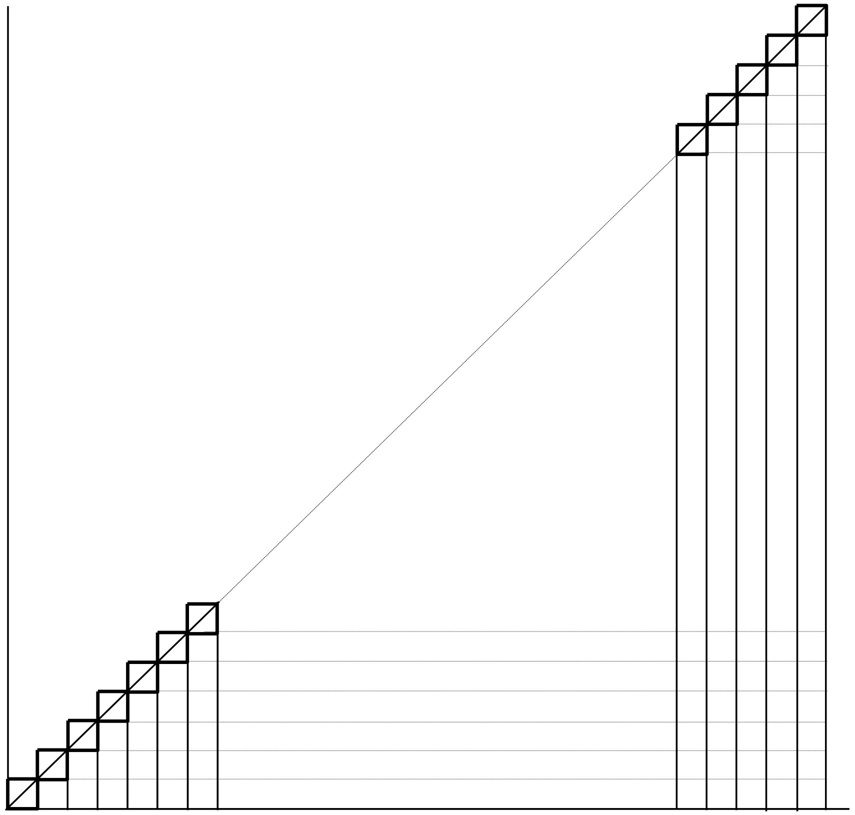
Normal Forest – Volume

- According to FMI

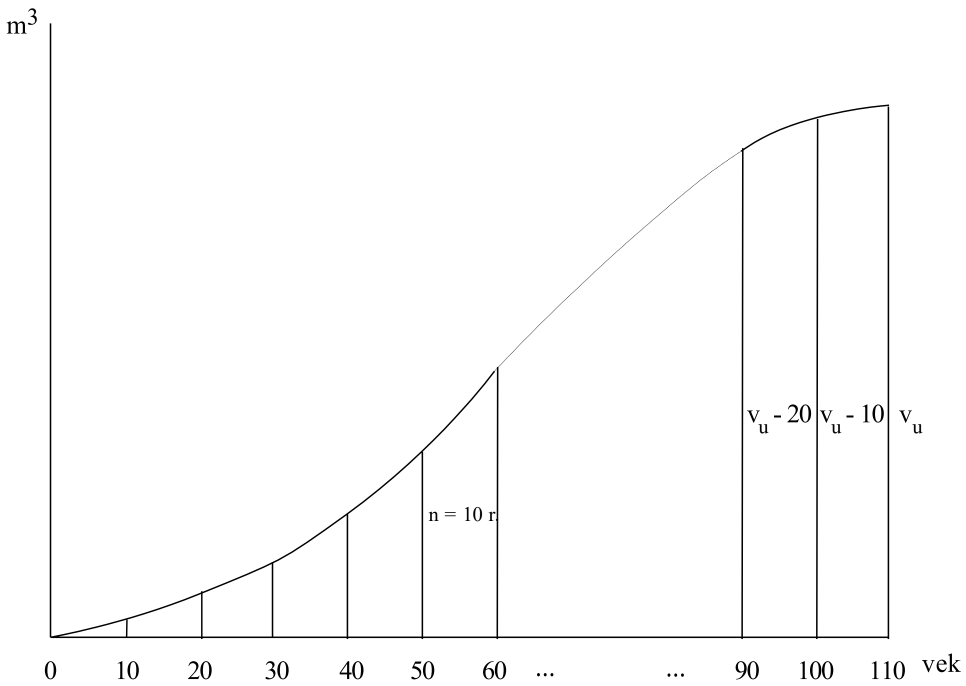
$$V = \frac{a*b}{2} = \frac{r*V_r}{2} = \frac{r*I}{2} = \frac{r*FMI}{2}$$



Normal Forest – Volume

- Pressler's formula

$$V = n * \left(v_n + v_{2n} + \ldots + v_{r-n} + \frac{v_r}{2} \right)$$



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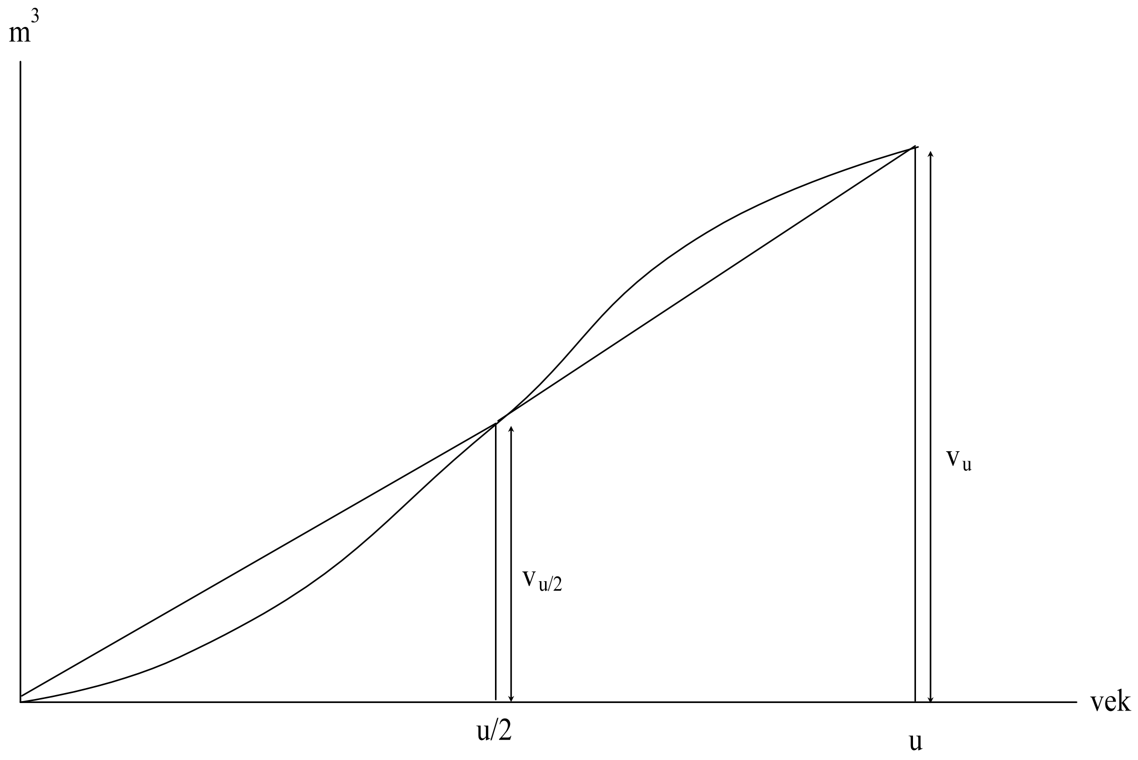
Normal Forest – Volume

- Singer's formula



$$V = \frac{r}{4} * \left(v_r + 2v_{r/2}\right)$$

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Normal Forest – Volume

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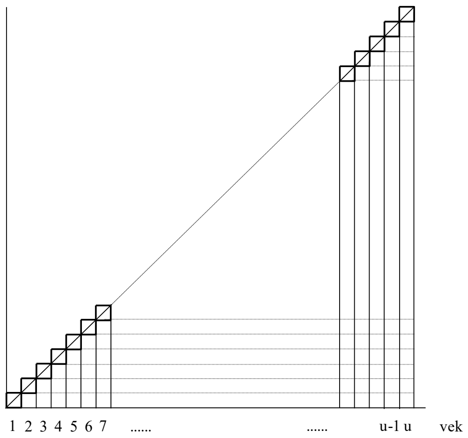
- According to reduction coefficients



$$V = \frac{r * FMI}{2} = r * \frac{FMI}{2} = r * 0.5FMI$$

- Korf’ coefficient for spruce: c = 0.43

$$V = r * c * FMI = r * 0.43 * FMI$$

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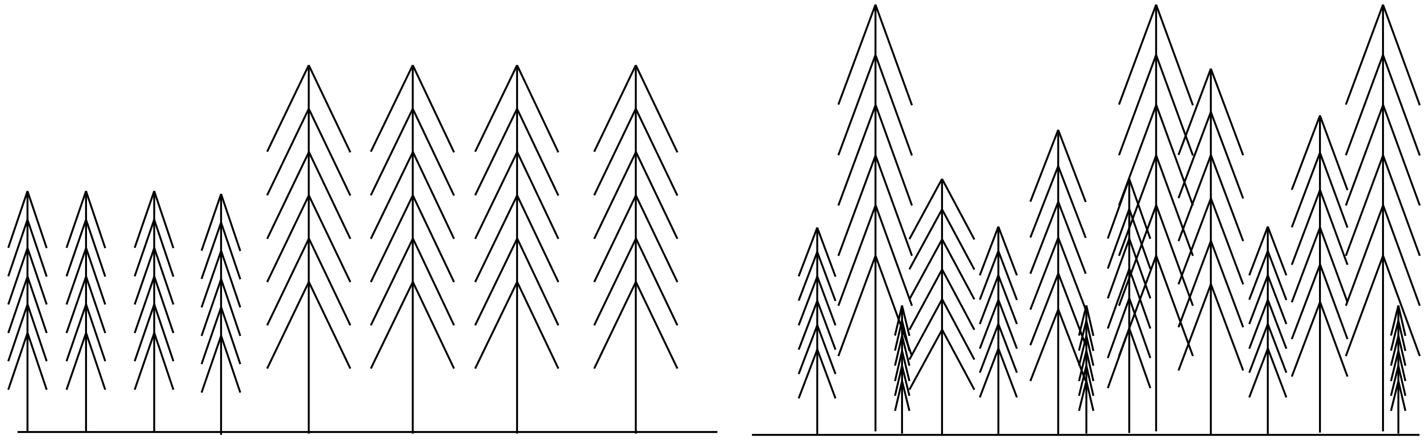
Ideal Selection Forest



Normal	Selection
age	diameter
rotation age	target diameter
age structure	diameter structure

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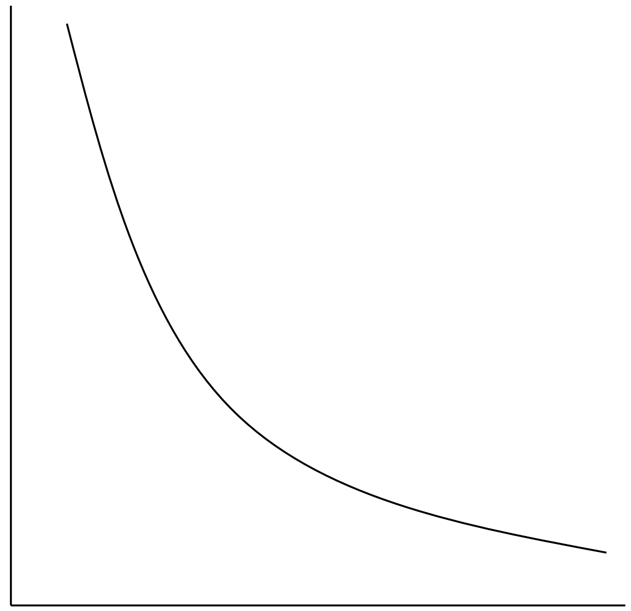
Ideal Selection Forest

- Liocourt's formula

$$N_i = N_1 * q^{-(i-1)}$$



N – number of trees

i – diameter class

q – quotient of decreasing geometric series

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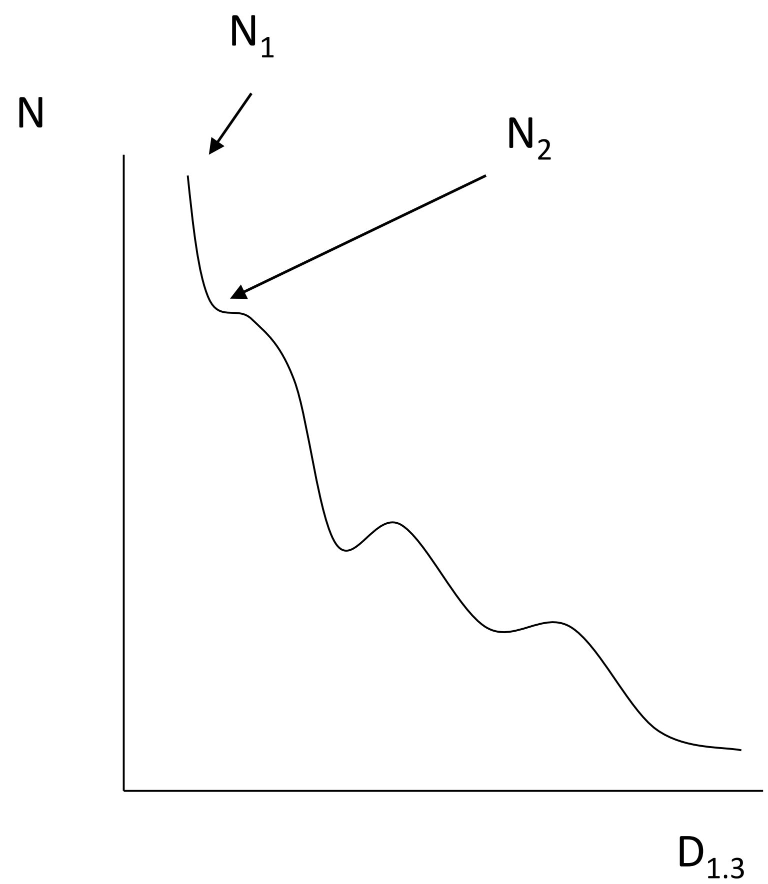
Ideal Selection Forest

$$q_1 = \frac{N_1}{N_2}$$

$$\Downarrow$$

$$\bar{q} = \frac{\sum q}{n}$$

(1.25 – 1.35)



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Ideal Selection Forest

- Volume

$$V_i = n_i * v_i \quad \Longrightarrow \quad V = \sum_{i=1}^{n} V_i$$

- Current Total Increment (CTI)

$$CTI_i = n_i * i_{v,i} * i_d \quad \Longrightarrow \quad CTI = \sum_{i=1}^{n} CTI_i$$

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Ideal Selection Forest

FRAME

Meyer

$$y = k * e^{-\alpha x}$$

y – number of trees

x – diameter class

k, α – constant factors repreenting curve type

e – natural logarithm

N/ha	224	300	350	381	398	405
V/ha	225	316	343	347	343	323
Type	-	A	B	C	D	E
k	26.2	41.4	56.5	71.7	86.9	102.1
α	0.050	0.055	0.060	0.065	0.070	0.075

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Ideal Shelterwood Forest

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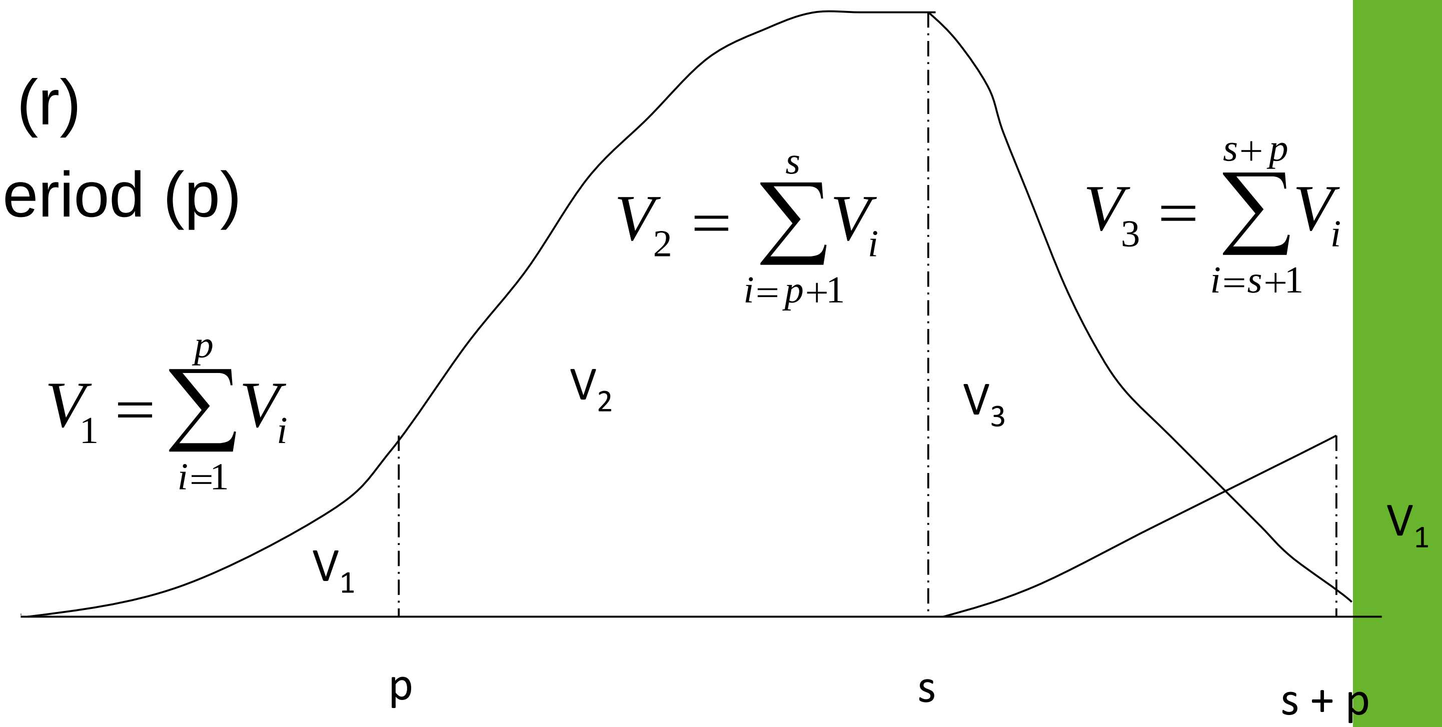
Korf (1963)

- Rotation period (r)
- Regeneration period (p)



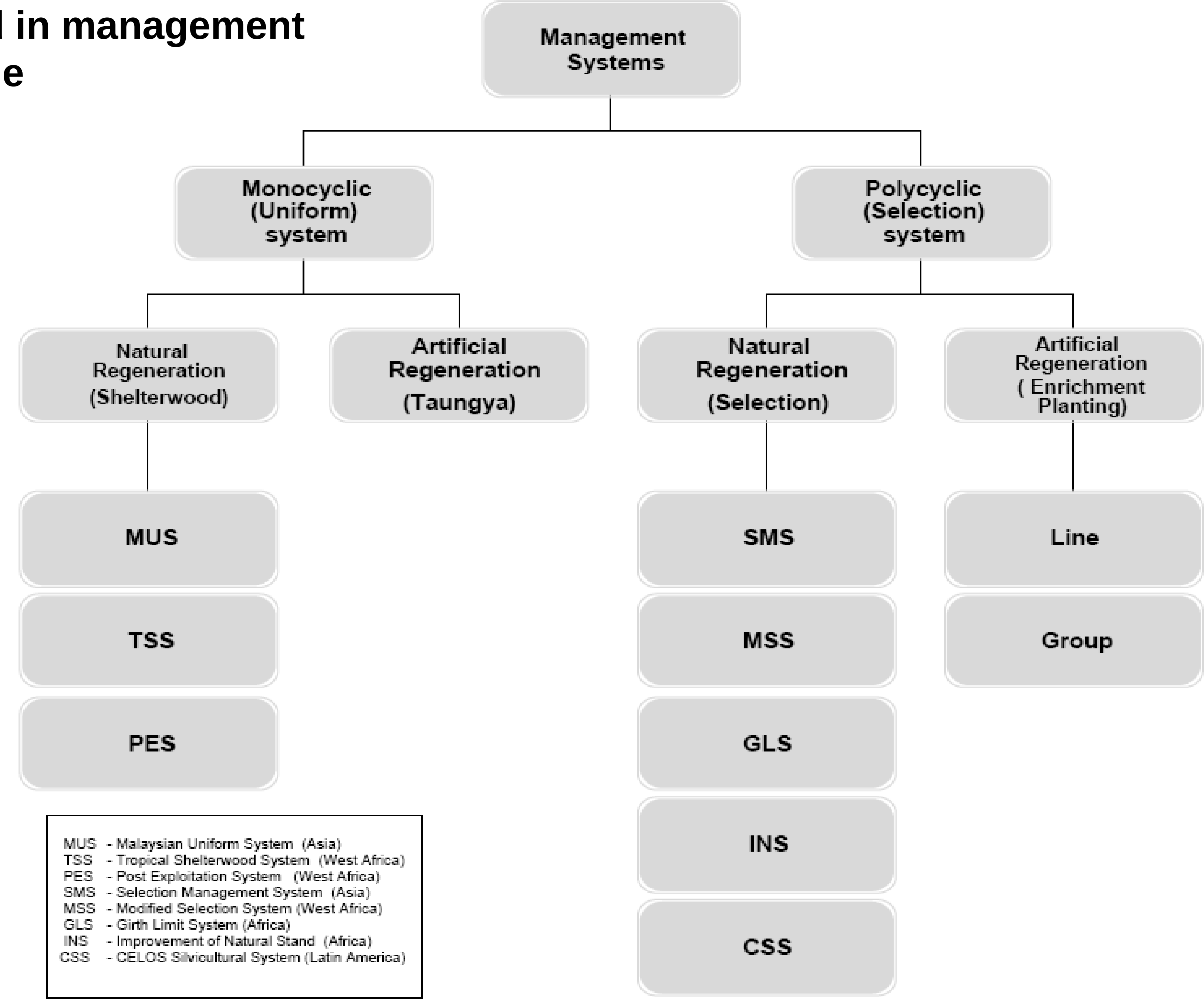
$$V_1 = \sum_{i=1}^{p} V_i$$

$$V_2 = \sum_{i=p+1}^{s} V_i$$

$$V_3 = \sum_{i=s+1}^{s+p} V_i$$

$$V = V_1 + V_2 + V_3$$

Silvicultural systems used in management of tropical forest worldwide



http://www.fao.org/forestry/docrep/wfcxi/publi/V6/T385E/1-3.HTM

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Silvicultural systems used in management of tropical forest worldwide

1) Natural Regeneration Systems

- Reduction of crown cover of undesired species
- Liberation treatments of economic species
- Eradication of unwanted vegetation (removing vines, lianas etc.)
- Species managed should have wide diameter distribution and good quality timber
- Should not eliminate food sources for wildlife
- Avoid too much refinement and liberation (= sterilize the forest by removing habitats and food sources)

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Note:

Refinement: eliminating the overstory of undesired species and individuals (promoting maximal use of forest site by high-value timber species)

Liberation: freeing of desirable species by removing vines, lianas, climbers etc.

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Natural regeneration systems

A) Monocyclic method

- *One of the oldest management systems originating from SE Asia – designed for relatively uniform and rich in commercial species of Shorea genus*
- *Developed in lowland region of Malaysia*
- ***The Malayan Uniform System** (MUS), developed after the Second World War*
- *Converts virgin tropical lowland rain forest (a rich, complex, multispecies, multi-aged forest) to a more or less even-aged forest containing a greater proportion of commercial species.*

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MUS – Malayan Uniform System

- All trees of desired species and diameters are harvested in **single operation** *(Dipterocarpaceae)*
- All unwanted stems are **poison-girdled** (band made around the trunk of a tree by the removal of a strip of bark including fibre)
- After 3 – 5 years sampling of regeneration followed by treatments enhancing regeneration and growth of commercial species (each 10 to 20 years intervention promoting regrowth – rotation period 70 years)
- **Limitations:** occurrence of natural regeneration in hilly regions, increasing use of more wood species

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TSS - Tropical shelterwood system

- The TSS was designed in Nigeria in 1944
- In contrast to MUS the forest did not have enough regeneration potential – canopy openings created several years before harvest (“preparatory felling”)
- **5 years pre-harvest period**
- Its objective was to **enhance the natural regeneration of valuable species before exploitation** by, gradually opening up the canopy (poisoning undesirable trees, cutting climbers) to obtain at least 100 of 1-m high seedlings per ha over five years
- Large canopy opening (65 – 80 % of total basal area)
- **Every tree without economic value killed**
- In practice not effective – ground vegetation instead of regeneration
- **Good for light demanding tree species and locations with low occurrence of climbers and weeds**
- Two hundred thousand ha of forest were treated this way by the Nigerian Forestry Department between 1944 and 1966, after which the method was dropped.

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Palcazu Method (Strip Cutting)

- Eastern Peru in 1980
- Of experimental nature – funded by US Agency for International Development
- 50 000 ha in a region of low hills
- Based on observations of gap phase dynamics in tropical forests
- **Shade intolerant species regenerate in the center, shade tolerant near the borders of the gap**
- Cutting strips **30 – 40 m long**
- Harvested strip bordered by primary forest or advanced secondary forest
- Different products (**charcoal, poles, sawn timber – small local processors**).

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Natural regeneration systems

B) Polycyclic Methods

- less productive than the uniform system (plantations)
- less capital-intensive
- more acceptable to developping countries
- maintenance of biodiversity
- traditional use of the forest by the local communities for the extraction of non-timber forest products

- **Selective Management System** – SMS (World)
- **Celos Silvicultural System** – CSS (Surinam)

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SMS - Selective Management System

- Developed as reaction on changing situation in forest management **(more flexible than Monocyclic Methods, use of more species,** better reflection of natural conditions)
- **Pre-felling inventory** – further used as permanent plots
- **Determination of growth rates, species, mortality, regeneration, felling damage**
- **MDL – minimum diameter limits for each species**
- Expected yields 30 – 40 m^3/ha in 25 – 30 years cutting cycles
- Success strongly depends on the efficacy of the control of logging

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Celos Silvicultural System – CSS

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- Centre for agricultural research in Suriname **Several cycles of interventions**
- Initial extraction (10 m^3/ha) followed by subsequent interventions after 8 and 16 years
- Total harvest. – around 20 m^3/ha in 20 years (few trees per ha) – **(in CR annual main felling per year and ha - 6.67 m^3)**
- Liberation enforcing the regeneration and growth of desired species
- **Long term plots testing the state of forests**
- Used in natural and lightly used forests
- **State of the forest must be periodically tested**
- Developed in Surinam to replace the uniform system

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Note:

Most management systems for natural tropical forests today are modifications of the SMS and CSS geared to suit the local ecological of the forest as well as the management history and economic conditions of the region.

SMS – Selective Management System is not a true selection system according to standard silvicultural terminology where single stems or very small groups of trees are removed as they reach maturity on a more or less constant (polycyclic) basis.

Truly polycyclic systems have not functioned success- fully on a wide scale anywhere in the humid tropics ***(relatively low volumes of harvestable trees, long distances between these ind., unsufficient forest roads network)*.**

It is therefore perhaps more accurate to describe this as a system which leaves the manager with wide discretionary powers to determine where silvicultural treatment will be most advantageous from a cost/benefit standpoint.

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Management of Secondary Forest

- Forests that have recently regenerated following a natural or human-induced disturbance
- **Two types of secondary forests:**
  - Cut over in the past 60 – 80 years, not completely clearcutted, retaining former characteristics **– 55%**
  - Former clear-cut for agriculture, pasture, wood extraction **(“volunteer” forests) – 45%**

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Most secondary forest developed after selective forest extraction are located in:

Tropical Asia (47%)

Tropical America (32%)

Tropical Africa (21%)

Techniques generally similar to that of natural forest. Often used forest enrichment techniques.

1 – bosque pobre 1980

2 – clear cut

3 – 5 x 5 m Cordia sp.

4 – regeneration of commercially interesting species (until 1988 removed)

5 – 2002 plantation harvested

6 – Ongoing regeneration of desired species:

Laurel (pioner) – Coco (*Virola sp*.) – Sande (*Brosimumm utile*) – Copal (*Dacryodes copularis*) – Animé (*Protium columbianum*)

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Expectation: in 25 years 50 to 80 m^3, plantation 140 m^3/rotation, primary f. 20 – 30 m^3

Natural regeneration of *Brosimum utile*

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Systems used in management of tropical forest worldwide

2) Systems based on artificial regeneration

- **Taungya** (*sequential agroforestry system*)

  A Burmese word that is now widely used to describe the practice, in many tropical countries, of establishing tree plantations by planting and tending tree seedlings together with food crops. Food cropping is ended after 1–2 years as the trees grow up.

- **Enrichment planting**

- applied to increase regeneration in degraded forests
- alternative to natural regeneration
- In the past enrichment planting rather failed – lack of understanding of ecological requirements, poor supervision and follow-up maintenance

- **Plantation forestry**

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Conclusion:

Silvicultural systems, which were developed to improve the productivity of the forest, have all been based on the classic European experiences of **Uniform (Monocyclic)** and **Selection (Polycyclic) systems**

Selection system:

- less productive
- less capital-intensive
- requires appropriate management (regular inventories)
- closer to traditional use of forest
- affords protection of biodiversity

Uniform system (where natural regeneration should be obtained):

- shelterwood the main technology applied
- transforming the uneven aged and heterogeneous humid forest into a homogenous and even-aged forest
- in Africa and the neo-tropics the shelterwood has not been very successful (poor germination, low ratio of timber species in regeneration layer)