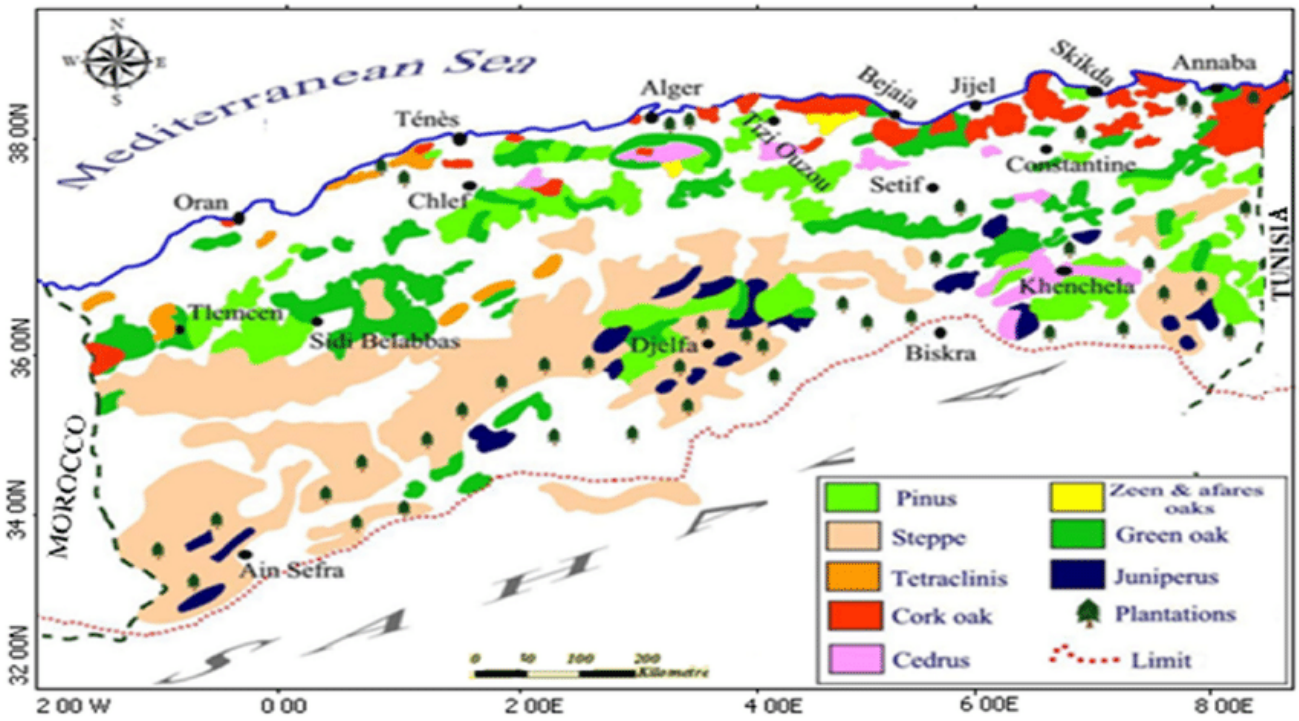
Distribution and ecology: In general, Algerian forests follow a rainfall gradient: humid north-east (Atlas cedar and cork oak), drier west and central (Aleppo pine and holm oak), and high mountains (cedar, fir, junipers). Many of these species form mixed forests: e.g. cedar often grows with Aleppo pine and Algerian oak; cork oak co-occurs with Turkish oak (*Q. canariensis*).

Each species has specific uses: timber, resin, cork, fuelwood, or non-timber products (acorns, oils). For example, cork oak bark is harvested sustainably for wine corks, Atlas cedar wood is used in furniture, and Aleppo pine resin is distilled. Understanding their biology and status is crucial: *Cedrus atlantica* and *Abies numidica* are conservation priorities due to their limited range and declining populations, whereas *Pinus halepensis* and *Quercus ilex* remain widespread and key to Algeria's forestry efforts.



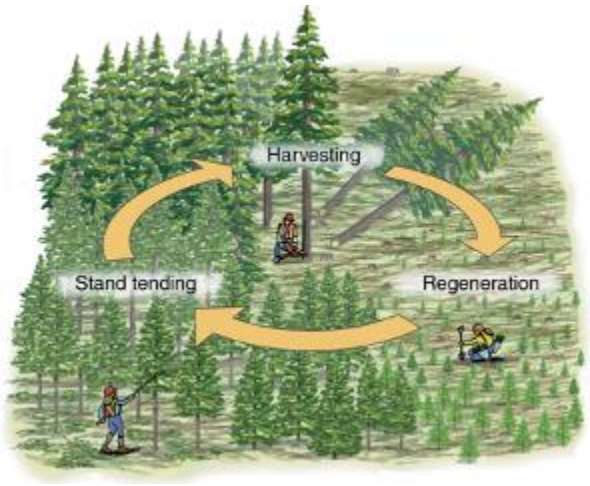
4. Silviculture in Natural Forests

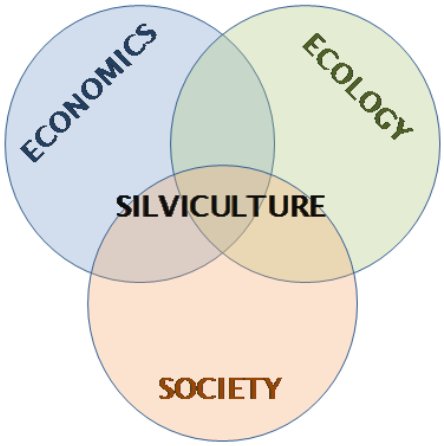
4.1 Silviculture

4.1.1 Definition

Silviculture is the **art and science** of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet society's diverse needs on a sustainable basis. In practice, silviculture involves selecting and applying treatments (such as planting, thinning, or controlled burns) that shape stand development toward specific goals. It is a fundamental component of forest management, providing the tools to align forest conditions with landowner and societal objectives. Silvicultural decisions must balance **ecological**, **economic**, and **social** considerations. For example, thinning or regeneration methods are chosen not only for timber yield, but also to maintain wildlife

habitat, watershed protection, and scenic values. Silviculture sits at the intersection of these themes: an action must be ecologically feasible, economically justifiable, and socially acceptable.





In modern forestry, silviculture is explicitly linked to **sustainable forest management (SFM)**. SFM aims to "improve the economic, social, and environmental value of forests for present and future generations". By guiding stands through planned cycles of harvest and regeneration, silviculture ensures forests continue to provide timber and non-timber products while retaining biodiversity, clean water, and cultural values over the long term. For instance, in regions like Algeria – where forests cover only about 1% of land area – effective silviculture and SFM can help reduce wildfire risk and sustain limited forest resources. In this global and Algerian context, the purpose of silviculture is to tailor forest structure and species composition to meet **ecological goals** (e.g. maintaining wildlife habitat and ecosystem health), **economic goals** (timber, fuelwood, non-timber products), and **social goals** (recreation, cultural values) simultaneously.

4.1.2 Objectives

Economic:

- To obtain optimal timber production (saw timber, construction wood).
- To maximize production of non-wood forest products (e.g., edible mushrooms, cork, bark).
- To ensure profitable harvesting opportunities.
- To promote growth of stems over time and space.

Social:

- To maintain a forested environment.
- To provide spaces for leisure and recreation.

Environmental:

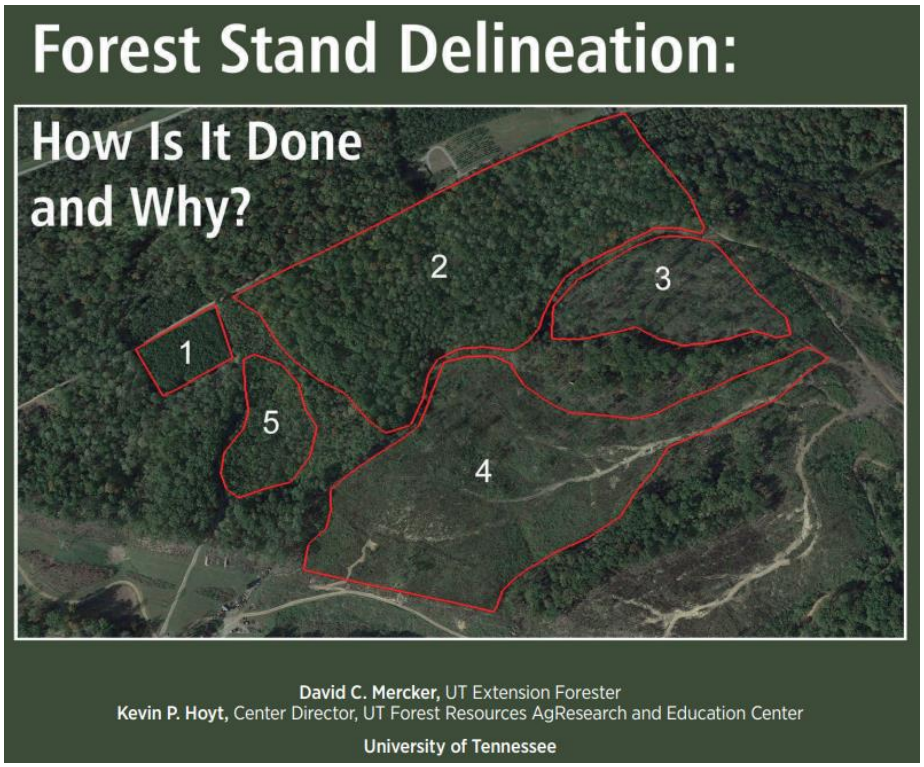
- To establish forest stands well adapted to the site.
- To protect the natural forest ecosystem and its productivity (e.g., conserving biodiversity, soil and water protection).

4.2 Forest Stands

Definition: A stand is a group of trees of similar species growing in the same area, with homogeneous structure and composition.

Key features:

- **Form:** Determined by regime, structure, and developmental stage.
- **Structure:**
    - *Elementary structure:* Regular (same age), irregular (different ages), or selection (multi-aged).
    - *Global structure:* Vertical (stratification) and horizontal (spatial distribution).
- **Development stages:** High forest or coppice growth phases.
- **Consistency:** Density and compactness of the stand.
- **Composition:** Pure (single species) or mixed (multiple species).
- **Vegetation state:** Healthy vs. declining stands.



4.3 Qualitative Study of Forest Stands

Qualitative assessment of a forest stand involves **descriptive attributes** that characterize its condition and potential beyond mere numbers. Key qualitative attributes include:

a) **Species composition** (which tree and plant species are present and in what proportions).
b) **Stand structure** (vertical layers and size diversity of trees, such as canopy, understory, and regeneration layers)
c) **Age distribution** (e.g. even-aged vs. uneven-aged structure).
d) **Regeneration status** (the presence and health of seedlings and saplings).

It also considers **tree health** (signs of stress, disease, or pest damage) and **site conditions** (soils, moisture, and light regimes). Importantly, qualitative assessment extends to **ecological values**: habitat

quality (biodiversity, presence of habitat features), and **aesthetic or landscape value** (scenic beauty, cultural significance). For example, a stand with mixed species and multi-layered canopy often supports higher wildlife diversity and is valued in protected areas, while a uniform plantation might be viewed as less natural or scenic.

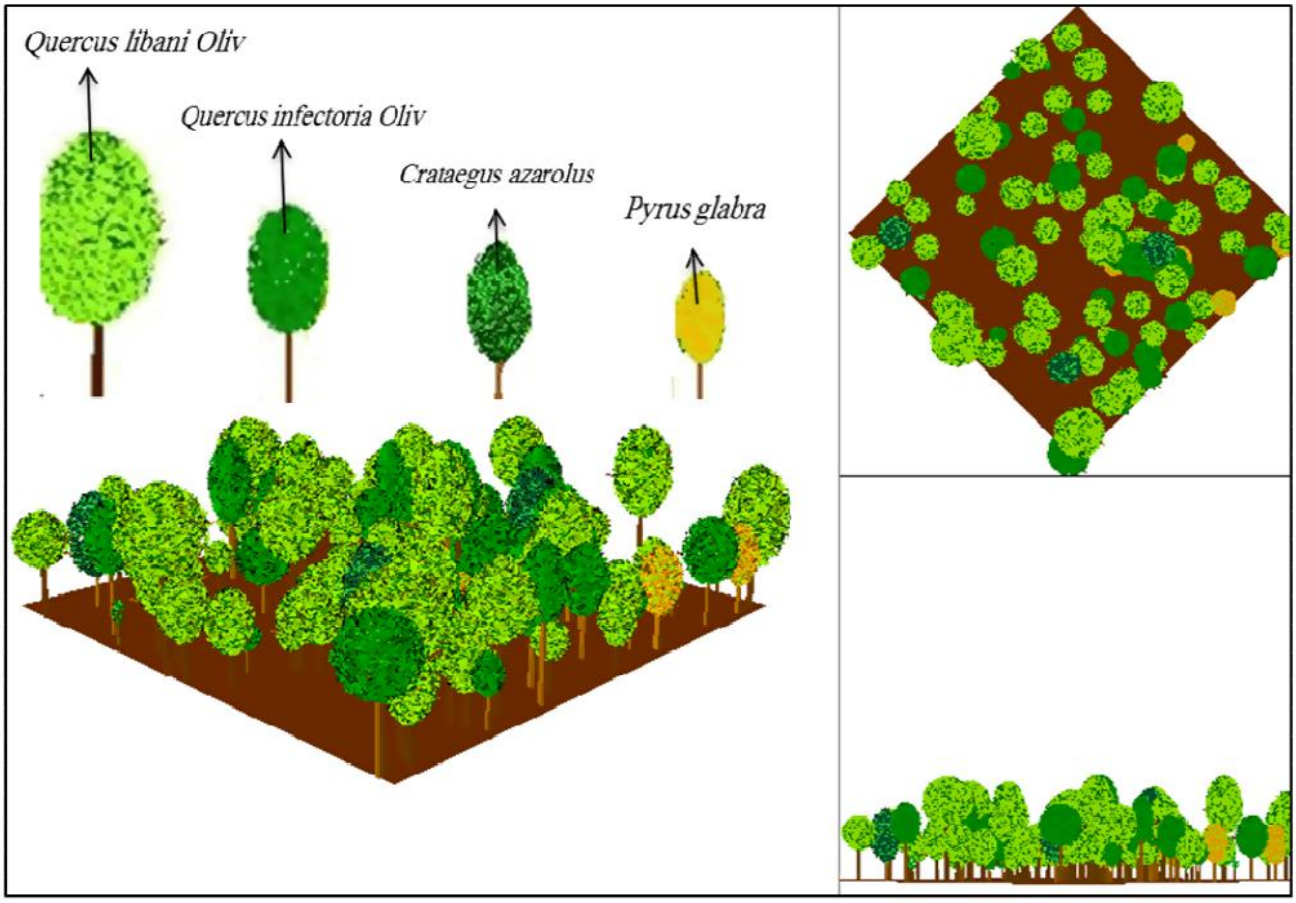


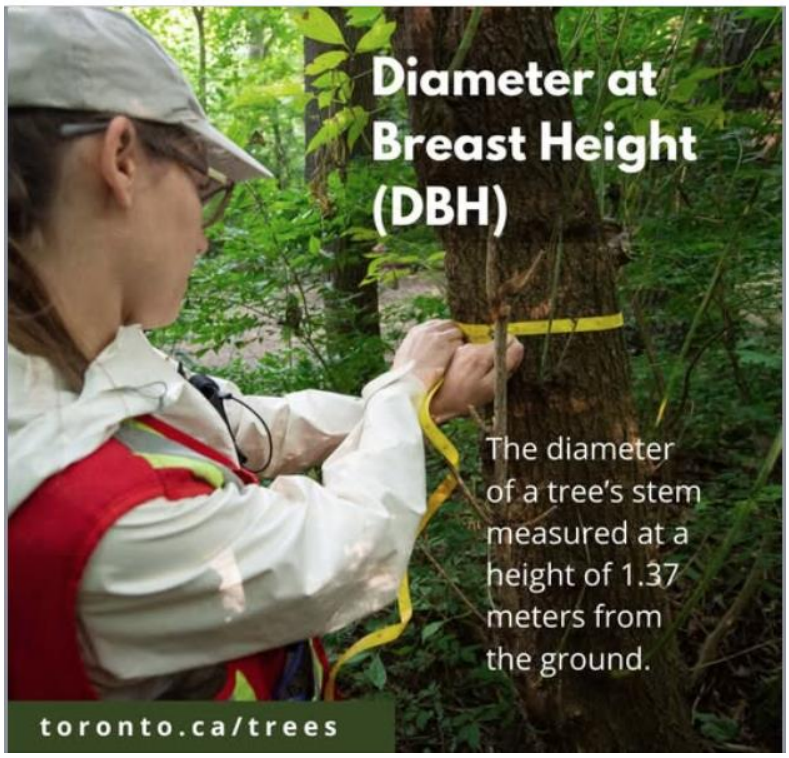
Figure 10. Stand visualization simulation of Blake forest (vertical and horizontal structure)
Figure 10 showed Blake forest have two story layers.

These qualitative factors critically inform silvicultural decisions. For instance, if a stand has little natural regeneration under a dense overstory, managers may choose a release or shelterwood cut to create light conditions for seedlings. If certain tree species are over-represented (e.g. fast-growing exotics), a manager might clean or thin to favor more desirable species. Likewise, stands with high aesthetic or habitat value (mature old-growth or riparian forests) may be managed more gently or even reserved from harvest. In short, qualitative attributes help answer **"what and why"**: *what* are the forest's ecological and social values, and *why* should certain interventions (or protections) be applied. These insights complement quantitative metrics to produce a holistic forest plan.

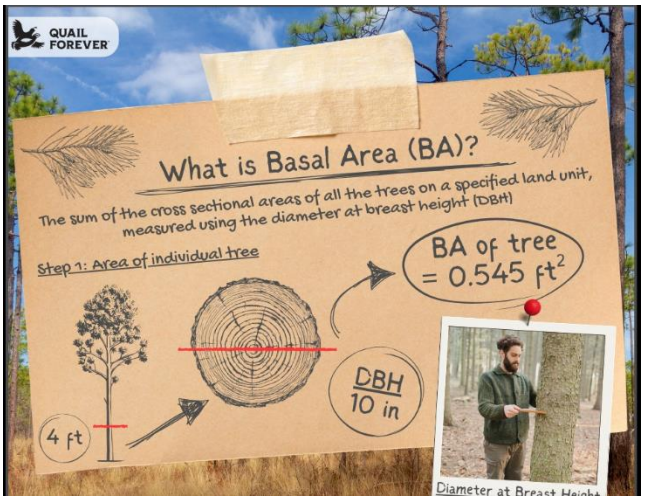
4.4 Quantitative Study of Forest Stands

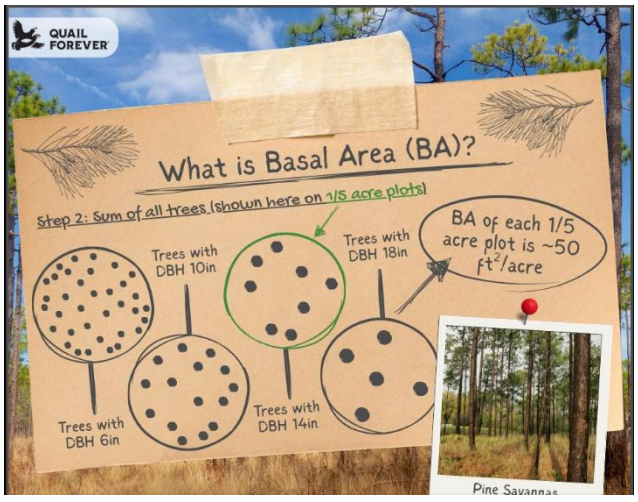
Quantitative study involves measuring **numerical metrics** that describe a stand's size and stocking. Common metrics include:

1. **DBH (Diameter at Breast Height)** – the diameter of a tree measured at about 1.3 m above ground;

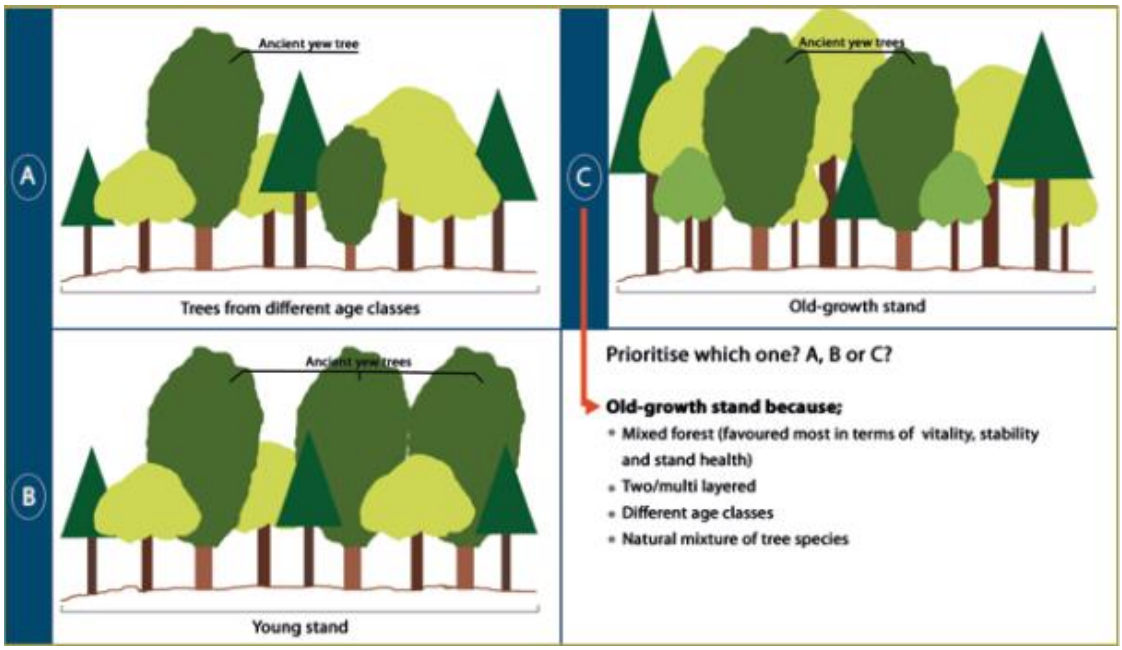


2. **tree height** (often total height in meters, or merchantable height to a specified top);
3. **basal area (BA)** – the cross-sectional area of a tree's stem at breast height (summed for all trees per hectare or acre);





4. **wood volume** – often in cubic meters or board-feet per tree or stand;
5. **stand density** – typically number of trees per hectare (or per acre) or a density index combining tree count and size; and
6. **age class** – the mean or range of tree ages in the stand.



Forest inventory methods are used to estimate these metrics. Two fundamental approaches are *fixed-area plots* (e.g. circular or rectangular sample plots of known size, where all trees above a minimum DBH are measured) and *variable-radius (point-sampling) plots* (using tools like an angle gauge or prism to sample trees at a point, which effectively counts only trees above a certain basal-area factor). Additional methods include **line transects**, **strip plots**, and specialized plot designs (e.g. for seedling counts). In practice, foresters walk planned plots or transects, measuring each selected tree's DBH, height, crown class, etc. These field measurements are then scaled up to per-hectare values using expansion factors.

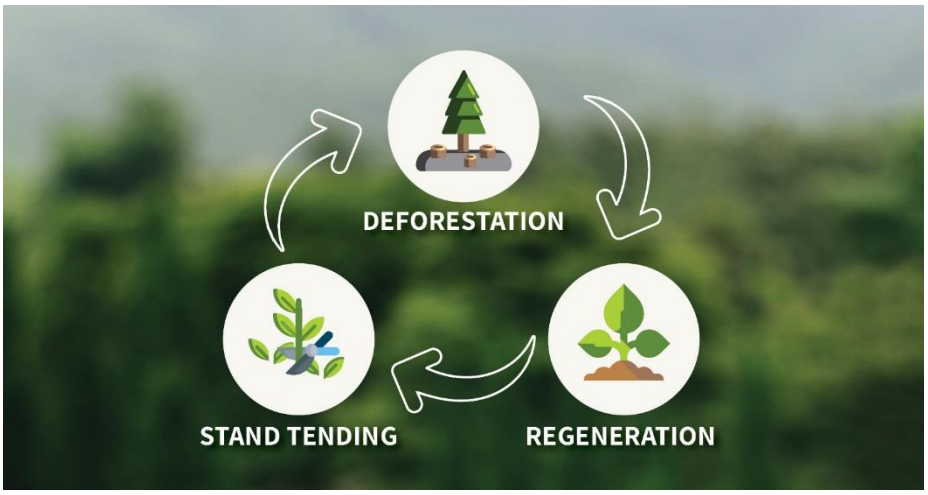
These quantitative data feed directly into planning. For example, **basal area per hectare** is an index of stand stocking: a high BA (dense stand) may indicate the need for thinning, whereas low BA may prompt light planting to increase stocking. Similarly, DBH and height distributions are used in yield tables or growth models to predict timber volume and growth rates. **Stand density** (trees/ha or a derived index) informs competition assessments – heavily stocked stands may have slowed individual tree growth, guiding when to thin. Age-class data help determine rotation length and suitability for certain silvicultural systems (e.g. even-aged vs. uneven-aged management). In modern practice, statistical sampling ensures accuracy: inventories are designed to meet planning needs (e.g. sampling 5–10% of area for management plans). The resulting data (site index, BA, TPA, species composition, etc.) provide the quantitative basis for estimating yields and scheduling treatments.

4.5 Silvicultural system

A silvicultural system is a planned program of treatments for managing a forest stand, including tending, harvesting, and regeneration, to achieve specific long-term structural and yield objectives. These systems are classified based on the harvesting method and desired age structure (even-aged or uneven-aged), with common examples including clearcutting, shelterwood systems, and selection systems.

Key components and objectives

1. **Tending**: A planned program of activities, such as thinning, that are performed during the life of the forest stand to improve timber quality, growth, and stand structure.
2. **Harvesting**: The removal of mature trees, which is done in a way that depends on the specific system and the desired outcome.
3. **Regeneration**: The process of re-establishing a new forest crop, which can be done through natural or artificial methods.



- **Stand structure**: Silvicultural systems aim to create a specific forest structure, such as even-aged stands (all trees are the same age) or uneven-aged stands (multiple age classes are present).
- **Yield**: Systems are designed to produce a predictable yield of benefits, such as timber, over a specific period.

Historically, the value of a silvicultural system was measured mainly by the commercial timber it produced. Today, integrated resource management also considers:

- Soil stabilization and erosion prevention,
- Maintenance of native populations of living organisms,
- Improvement of wildlife habitats,
- Water quality protection,
- Production of animal forage,
- Landscape aesthetics and recreational opportunities.

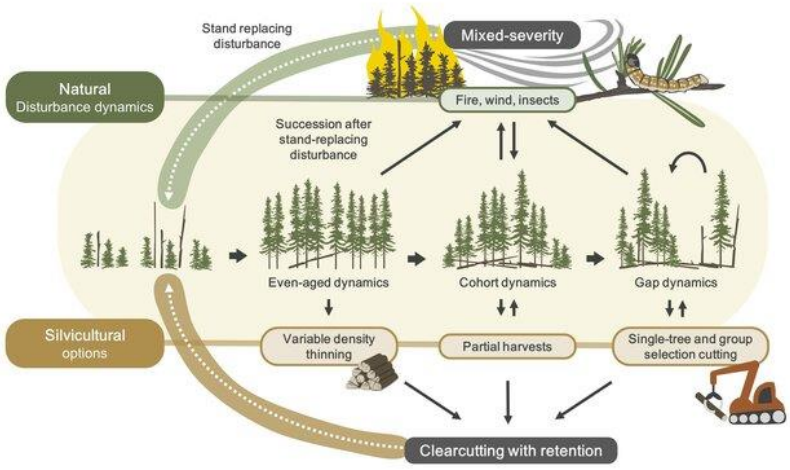


Fig. This model represents silvicultural options for maintaining landscape-level forest structures and age distributions similar to those that would exist under a natural disturbance regime. Structural cohorts (green bubbles) correspond to the various postfire stand successional stages, and silvicultural options (brown bubbles) are presented along a gradient of harvest intensity. This illustration is inspired and adapted from the principle of the multicohort model and the ASIO model (Angelstam, 1998; Bergeron et al., 2002)

4.6 Silvicultural Regimes

Silvicultural regimes are long-term forest management methods that define how a forest is established, tended, harvested, and regenerated, leading to distinct stand structures. They involve a series of interventions (cuttings, silvicultural operations) applied throughout the entire production cycle, from the birth of the stand until its final harvest and renewal.

The three main types of silvicultural regimes are:

4.6.1 High Forest (Futaie):

This regime aims to produce high-quality timber over long production cycles (several decades, even a century or more). The trees originate from seeds or plantings and have relatively uniform ages, heights, and diameters in the case of **even-aged high forest**, or conversely, are very mixed in the case of **uneven-aged high forest** (also called the selection system). Regeneration is achieved by natural seeding or planting after harvest, sometimes under the progressive cover of the remaining trees (shelterwood system).

☞ **Structure:**
- **Regular:** Stands of the same species and age, usually from plantations or uniform natural regeneration.
  - *Cluster High Forest (futaie par bouquet):* Same as regular high forest but applied to small patches (<0.5 ha).
  - *Compartment High Forest (futaie par parquet):* Similar, but for larger areas (>0.5 ha).
- **Irregular:** Stands with trees of different ages, with some age classes missing.
- **Selection (Jardinée):** Uneven-aged stands, with a complex dynamic and continuous regeneration.

☞ **Advantages:**
- High-quality timber with significant economic value.
- Production of wood across all age classes and sizes.
- Climate regulation (micro- and mesoclimate).
- Soil stability and fertility through humus formation.

☞ **Disadvantages:**
- Regeneration is slow and difficult.
- Older trees may be prone to pest infestations, serving as reservoirs for insects.
- Higher erosion risk during regeneration cuts.
- External factors (climate, predation) affect seed regeneration.

4.6.2 Coppice (Taillis):

This regime is based on the ability of certain broadleaf species to regenerate vegetatively by sprouts from stumps (coppice shoots). The production cycle is short (generally less than 30 years), and the production is mainly intended for firewood, industrial wood (pulp, panels), or biomass. Conifers are generally not suited to this regime.

☞ **Structure:**

- *Simple coppice:* Vegetative regeneration after clear-cutting, mainly for charcoal and fuelwood.
- *Coppice with standards (taillis fureté):* Only selected shoots of commercial size are harvested each cycle, leaving smaller ones to grow.

☞ **Advantages:**

- Rapid, reliable regeneration largely independent of climatic variability.
- Soil stability through live root systems.
- Conservation of the species' genetic heritage.

☞ **Disadvantages:**

- Low-quality products, mostly fuelwood.
- Soil nutrient depletion due to frequent harvesting.

4.6.3 Mixed regime, Coppice with Standards (Taillis sous Futaie):

This is a mixed regime, combining the previous two. It consists of two distinct layers:

- *Coppice with Standards (taillis sous futaie):* Lower layer of coppice combined with an upper layer of scattered high forest trees (standards). Produces both fuelwood and small timber.
- *High Forest from Coppice (futaie sur souche):* Aging coppice stands with a high proportion of stump-shoot trees, converted into a high forest through **standards selection (balivage)**.
- *Standards (baliveaux):* Vigorous, straight young trees chosen for future timber. Typically 1.5–2 m tall, ≤4 years old.

Balivage (standards selection): Silvicultural practice to convert coppice into high forest by selecting the best young stems (standards) and encouraging their growth for future quality timber.

4.6.4 Determinate factors for regime choice

The choice of silvicultural regime depends on several factors, including management objectives (wood production, biodiversity conservation, soil protection, recreation), site characteristics (forest species, soil, climate), and economic and social constraints. The silvicultural treatments applied within these regimes (release, cleaning, thinning, pruning, etc.) aim to guide the stand towards the desired structure and promote tree growth and health.

4.6.5 Transitional Treatments

These practices aim to convert a stand from one regime to another:

- **Conversion:** Transition from coppice (or coppice-with-standards) to high forest through natural regeneration. Example: converting an oak coppice-with-standards to a regular high forest of oak.
- **Transformation:** Replacement of an existing stand by new species through planting or natural regeneration from a few seed trees. Example: replacing low-productivity black pine stands with beech.

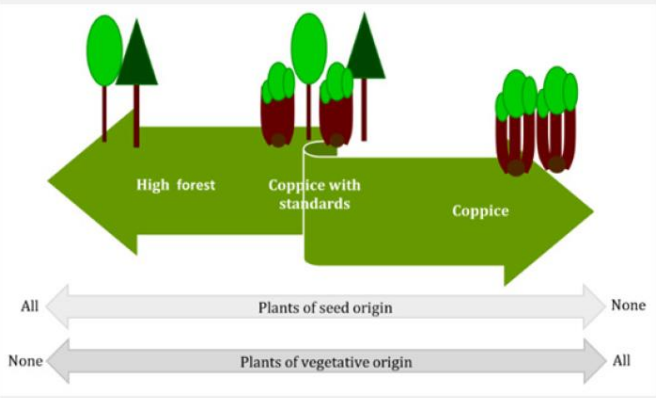


Figure 1: Representation of regime variability.

4.7 Improvement Operations

Improvement operations (sometimes called *intermediate treatments* or *timber stand improvement – TSI*) are silvicultural treatments applied after a stand is established (past the seedling stage) to enhance its health, composition, or quality.

Their goals are:

1. To boost growth of desirable trees,
2. Improve timber quality,
3. Maintain stand health.

Common improvement operations include **thinning**, **pruning**, **cleaning**, **liberation**, and **sanitation/salvage** cutting. These treatments are typically applied before final harvest to steer stand development.

4.7.1 Thinning:

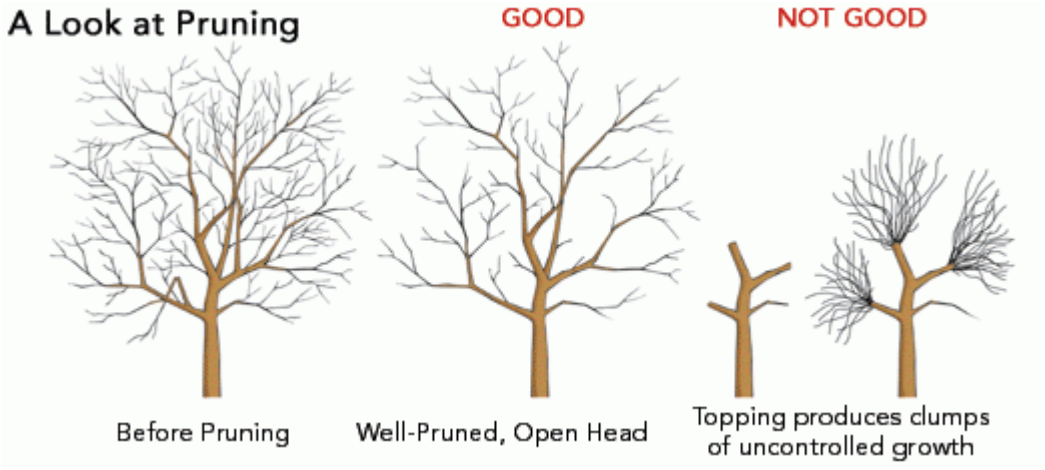
A density-reduction cut that removes some trees to accelerate growth of the remaining trees. Thinning concentrates resources (light, water, nutrients) on the most vigorous or valuable trees. It can be *commercial* (where cut trees are merchantable) or *pre-commercial/cleaning* (where small or poor trees are cut at a loss to improve others). Thinning aims to enhance diameter growth, reduce mortality, and sometimes harvest mature wood earlier. For example, a stand approaching 100–120 ft²/acre basal area should be evaluated for thinning to avoid stagnation. Objectives of thinning include improving stand health and vigor, releasing timber yield from anticipated mortality, and producing larger, higher-value trees. Timing depends on species and site; many conifers are first thinned when crowns begin to close in 15–30 years.

4.7.2 Cleaning and Liberation:

Both are types of *release* treatments applied to young stands. **Cleaning** removes undesirable trees of the same cohort that overtop or compete with crop trees (usually when stand is still relatively young). It frees good seedlings or saplings from competition by weedy or poorly formed neighbors, thereby regulating species composition and improving growth of the favored crop trees. **Liberation** cuts are applied when a promising young cohort is overtopped by an older, undesired overstory. Liberation removes those overtopping trees to "liberate" the young trees underneath. For example, if a mixed-age stand has some advanced oak seedlings under a dense pine canopy, a liberation cut might remove the pines to allow oaks to thrive.

4.7.3 Pruning:

Cutting live lower branches on crop trees to improve timber quality. Lateral branches form knots in logs, reducing lumber value. By removing branches flush to the stem early (while small), pruning accelerates the development of clear wood. For instance, pine or cedar plantations are often pruned up to a certain height to produce knot-free logs. Pruning is labor-intensive and thus applied to high-quality trees only, and usually in several lifts as trees grow.



4.7.4 Sanitation and Salvage Cutting:

These operations address pest, disease, or disturbance-related mortality. **Sanitation cutting** removes infected or pest-infested trees to prevent spread of insects or pathogens. It is a precautionary measure to protect stand health (e.g. cutting out bark-beetle–infested pines before beetles spread). **Salvage cutting** removes trees that are already dead, dying, or badly damaged (e.g. by fire or wind) to recover economic value and reduce hazards. For example, after a severe storm, a salvage cut would remove blown-down and broken trees to salvage usable timber.

These improvement cuts are carefully timed: early in a stand's development for release and cleaning, middle rotations for pruning or thinning, and as needed for sanitation after outbreaks. The effects of these treatments include increased growth of retained trees, improved wood quality, reduced future mortality, and maintenance of stand vigor. In summary, improvement operations manipulate stand density and composition between regeneration and final harvest to keep forests productive and healthy.

4.8 Regeneration Methods

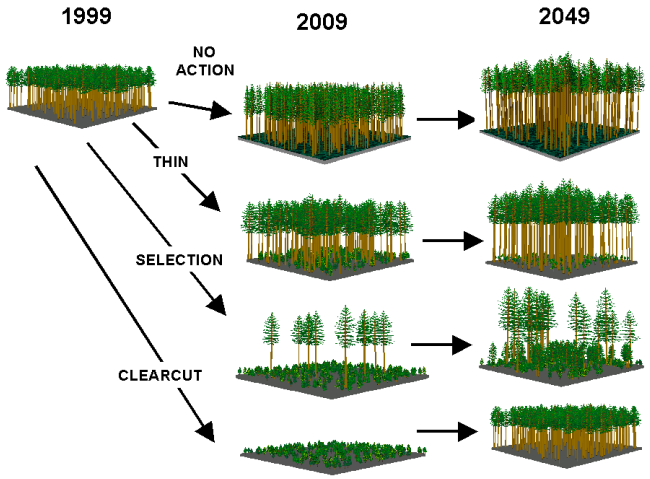
Regeneration is the re-establishment of a forest stand after harvest or disturbance. It is critical because it starts a new rotation of forest growth. Regeneration methods must be chosen to match species requirements, site conditions, and management goals. Broadly, regeneration can be **natural** or **artificial**. *Natural regeneration* relies on the site's existing seed source or vegetative sprouts. For example, trees may regenerate from wind-dispersed seeds of remaining trees, from seed caches (by animals), or from the sprouting of stumps and roots (*coppicing*). *Artificial regeneration* involves human planting or seeding to establish a new stand, giving foresters control over species mix and genetics.

Common **artificial techniques** include **direct seeding** (broadcasting or drilling seeds) and **planting seedlings** grown in nurseries. Direct seeding is less expensive but less predictable than planting; its success depends on good seedbed preparation and seed viability. Plantation (seedling) establishment allows precise spacing and species choice, often used when natural regeneration is unlikely (e.g. to introduce a non-native species or improved stock). In Algeria, for instance, pine seedlings are often planted to restore degraded watersheds. **Coppice** regeneration is another natural approach: many broadleaf species (e.g. chestnut or poplar) can sprout vigorously from stumps after cutting. Coppicing enables very rapid stand renewal in these species, though it produces even-aged, multi-stem stands.

There are also **silvicultural systems** that define how harvests are arranged to regenerate stands:

- **Clearcut:** Removal of essentially all trees in one cut, exposing the site fully. Regeneration follows from windblown seed, seeding from adjacent stands, or planting/seedling if needed. This is an even-aged method (one cohort). It is simple and works well for light-demanding species. For example, even-aged pine plantations in Algeria are often regenerated via clearcut and planting.
- **Shelterwood:** A series of cuts that gradually open the canopy. An initial cut (or cuts) creates openings and stimulates advance regeneration under a "shelter" of residual trees. Later, a final cut removes the remaining overstory once the young cohort is established. Shelterwood favors intermediate-tolerance species and heavy-seeded trees (e.g. oak), and provides a more controlled microclimate for seedlings.
- **Seed-tree:** Similar to shelterwood, but fewer trees are left – usually a small number of well-spaced "seed trees" that are good seed producers. These scatter seed over the cut area. After natural regeneration is established, the seed trees are removed. Seed-tree is often used for shade-intolerant conifers (e.g. Scots pine) or fast-growing hardwoods.
- **Two-aged or group methods:** In uneven-aged or irregular regimes, small patches (gaps) are cut, allowing adjacent trees to seed or regrow new age classes within gaps. This maintains multiple cohorts.

When selecting a regeneration method, one must consider ecological and economic factors. **Species silvics** are paramount: shade-intolerant trees (e.g. many pines) often require full sunlight (clearcut or seed-tree), whereas shade-tolerant species (e.g. beech, cedar) can regenerate under partial shade (shelterwood or selective). Seed ecology matters: serotinous cones (as in Aleppo pine) open after fire, so natural regeneration may follow wildfires. Seed dispersal ability is key: heavy-seeded trees (oaks) regenerate poorly under seed-tree or clearcut unless many trees or advanced regeneration exist, so shelterwood is preferred.



Silvicultural and economic considerations also drive the choice. Natural regeneration maintains local genetics and is cheapest if conditions allow. Planting is used when natural seeding is too slow, sporadic, or if improved genotypes are required. For example, planting fast-growing alder or pine may be warranted on severely degraded sites or for afforestation programs. Site factors like slope and soil stability also matter: on steep slopes where erosion is a risk, slower, partial cuts (shelterwood) can protect soil while allowing regeneration. Finally, economic analysis may favor one method: if delaying harvest for natural regeneration costs more than planting now, then artificial regeneration may yield higher net returns.