


SUSTAINABLE FOREST MANAGEMENT SILVICULTURE BASICS

FOREST REGENERATION, PROTECTION AND TENDING IN MONGOLIAN LIGHT TAIGA FORESTS

Aleš Škoda & Václav Pecina

Mendel University in Brno

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PROJECT

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Reviewers

Oyunsanaa Byambasuren[1,2,3]

Tadeáš Štěrba[4]

[1] The National Forest Agency of Mongolia, Government Building 2, Chingunjav Street, 16050, Ulaanbaatar, Mongolia

[2] Fire Management Resource Center - Central Asia Region, National University of Mongolia, Building 3, 14201 Ulaanbaatar, Mongolia

[3] Department of Environment and Forest Engineering, National University of Mongolia, Building 3, 14201, Ulaanbaatar, Mongolia

[4] The Forest Management Institute, Branch Brno, Vrázova 1, 616 00, Brno, Czech Republic

Authors

Aleš Škoda[1,2]

Václav Pecina[3]

[1] Department of Forest Botany, Dendrology and Geobiocoenology, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 3, 613 00 Brno, Czech Republic

[2] Czech Forestry Academy Trutnov, Lesnická 9, 541 01 Trutnov, Czech Republic

[3] Department of Agrochemistry, Soil Science, Microbiology and Plant Nutrition, Faculty of AgriSciences, Mendel University in Brno, Zemědělská 1, 613 00, Brno, Czech Republic

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ABSTRACT

Forests are life. This handbook is intended for forest managers – foresters – who are looking for inspiration on how to manage forests better. The goal is to present topics related to forest cultivation (silviculture) adapted to Mongolian conditions in a simple and illustrative form. This is not a textbook that would comprehensively explain the issue of silviculture together with theory. It is a tool with which a forester can learn directly in the forest what to do there – how to make the forest stronger, healthier and more productive, and how to become more efficient at work and reduce costs and increase revenues. In particular, the handbook describes activities related to sustainable forest management, about which foresters need to know more. Silviculture is presented here in a broader context starting from seed collection, cultivation of seedlings in nurseries, reforestation, taking care of plants in forests until they are mature enough to be tended and harvested. Emphasis is placed on increasing the quality and efficiency of the processes in particular on forest protection and related activities. The content was prepared on the basis of the experience of Czech foresters with Mongolian forests in cooperation with Mongolian foresters.

Keywords: sustainability; forestry; thinning; planting; machinery; seedling; accessibility

INTRODUCTION

Well-managed **forests** provide society with many products and services. By managing a forest, every forester can influence large areas with global impacts. The forester's main goal is **sustainable forest management**, whose principle is to balance the ecological, economic and socio-cultural functions of forests. Its important aspect is **continuity** to ensure the continuous provision of forest functions to maintain both ecological, social and economic **stability**.

This handbook presents how to properly perform some of the forester's **silviculture** tasks and how to get closer to cultivating a healthy, strong and valuable forest providing multiple functions.

Simply put, a forester can work with two types of forest: **even-aged** and **uneven-aged**.

UNEVEN-AGED FOREST MANAGEMENT

Uneven-aged forest management is forest management using mainly a **selective cutting system**. The characteristic of such forest is a **continuous canopy cover** including trees of **several age classes**. Harvesting of target log dimensions takes place at an interval of about 7–10 years. This management supports **diverse and stable forests** that continuously provide all required functions without the need for artificial regeneration. This system **excludes** selective **removal of only the most economically profitable tree species** in a stand – it does not threaten tree species diversity of a forest.

HIGHLIGHTS:

- A complex method which requires **expert guidance**.
- More **suitable** for **dark taiga**.
- It is important to keep a certain number of **mother trees**.
- **Making forest accessible** is an important but a challenging requirement.
- Requires very **careful harvesting and wood extraction** respecting young trees.

Selection system is better for **shade tolerant species** such as *Abies*, *Picea*, and possibly *Pinus sibirica*.

Types of selection for harvesting:

Single-tree selection – scattered individuals of diverse age classes whose canopies are not touching (to limit gaps), are harvested.

Group selection – several adjacent trees are harvested across a stand (groups) – this creates a system of small openings suitable for natural regeneration.

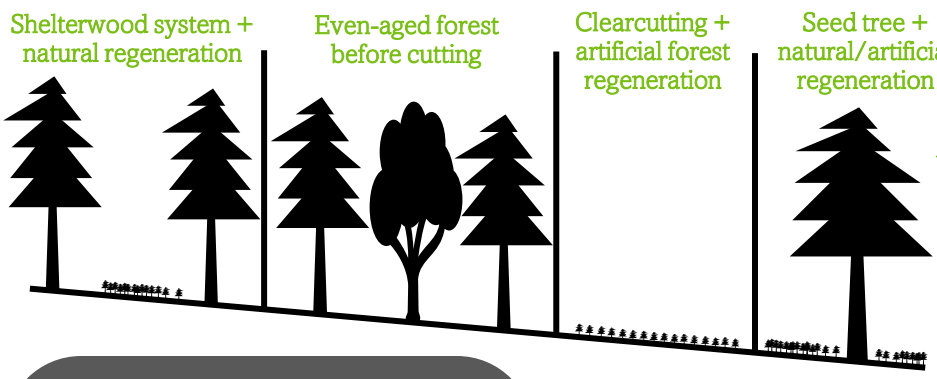
Forest development after **group selection**.

EVEN-AGED FOREST MANAGEMENT

It is management of forest with **one dominating age class** using mostly a **clearcutting** approach of final harvesting. This system follows the natural large-scale disturbances inherent to boreal forests and **light-demanding light taiga species** are well adapted to it. Under control, the entire forest stand is **replaced at once** by a new one in regular rotation periods. Regarding the development of the new forest stand, the **ecosystem services** provided by it **may be limited** for a period of several years. However, they are compensated by the surrounding forest stands.

HIGHLIGHTS:

- A relatively **simple and very cost-effective** method.
- More **suitable** for **light taiga**.
- **Operational complications** associated with remaining trees **are mostly eliminated.**
- The **size of the clearcut** (unstocked forest) significantly affects the success of the reforestation – **the smaller, the better**.
- Reforestation of cleared forest areas is made through **both natural regeneration** from seed trees left, and **artificial regeneration** (planting and/or sowing).



Even-aged forest management has different types of **silvicultural regeneration methods**.

One forest canopy layer of the: (I) original stand of mother trees and (II) new natural regeneration.

The most common reasons for the formation of an even-aged forest:

- fire
- clearcutting
- mining activities
- pest outbreak
- destructive livestock grazing eliminating natural regeneration

WHAT FOREST CARE IS NEEDED
ACCORDING TO ITS STAGE OF DEVELOPMENT

Determining forest management based on **stand age** can be confusing given the different growth characteristics of tree species and specific habitat conditions. For simple orientation, the stage of forest development characterized by **stand height** (in m) and **trunk diameter at breast height** (DBH; in cm) can be helpful. The following activities may be necessary (typical for even-aged forest management):

1. Open forest area (clear cut/burnt area)

- reforestation planning
- controlled grazing/browsing of livestock
- soil scarification (support of natural regeneration)
- seedling planting or sowing/natural regeneration
- protection of planted trees

2. Established forest regeneration (height <2 m)

- seedling and fence control
- repair planting
- fertilisation on poor soils
- weeding
- application of repellents against browsing
- watering if needed

3. Young forest stand (height 2–7 m, DBH 5–15 cm)

- thinning planning
- establishment of timber extraction and transportation infrastructure
- precommercial thinning for stand stability
- non-commercial use of produced wood at local level

WHAT FOREST CARE IS NEEDED

ACCORDING TO ITS STAGE OF DEVELOPMENT

One year progress.

WHAT FOREST CARE IS NEEDED

ACCORDING TO ITS STAGE OF DEVELOPMENT

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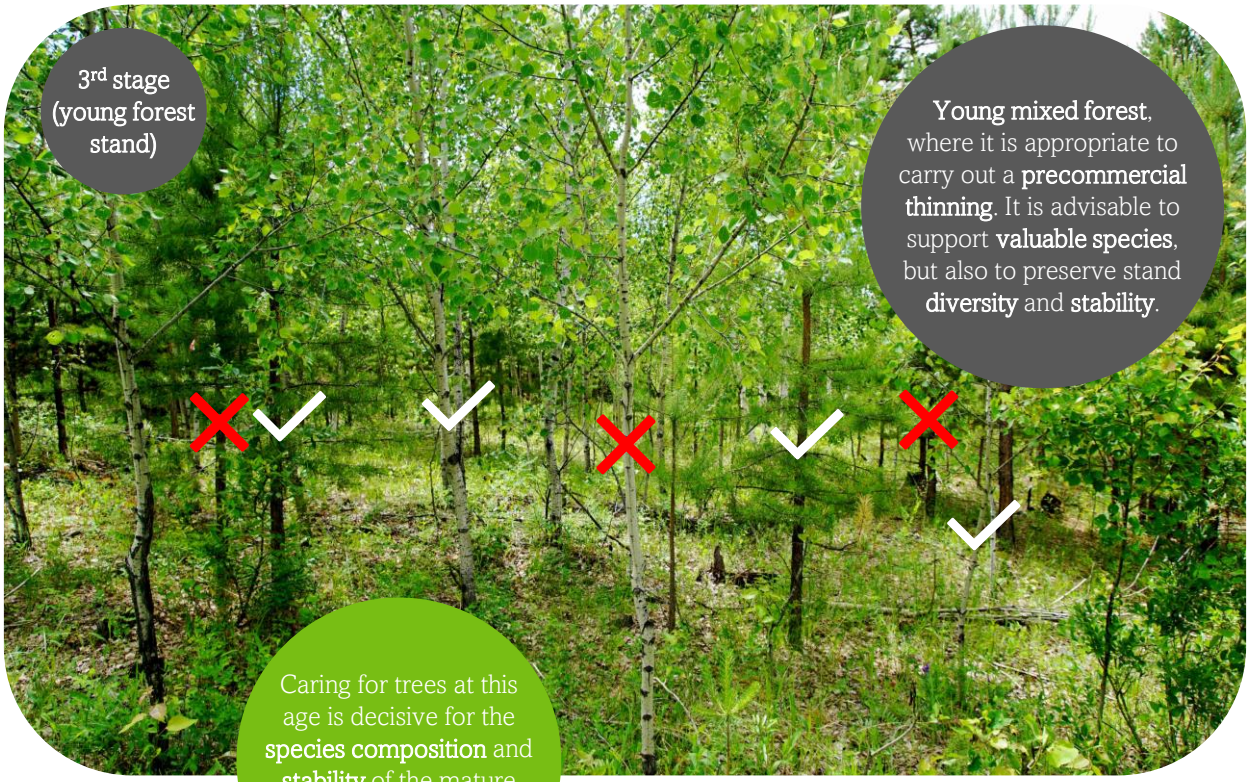
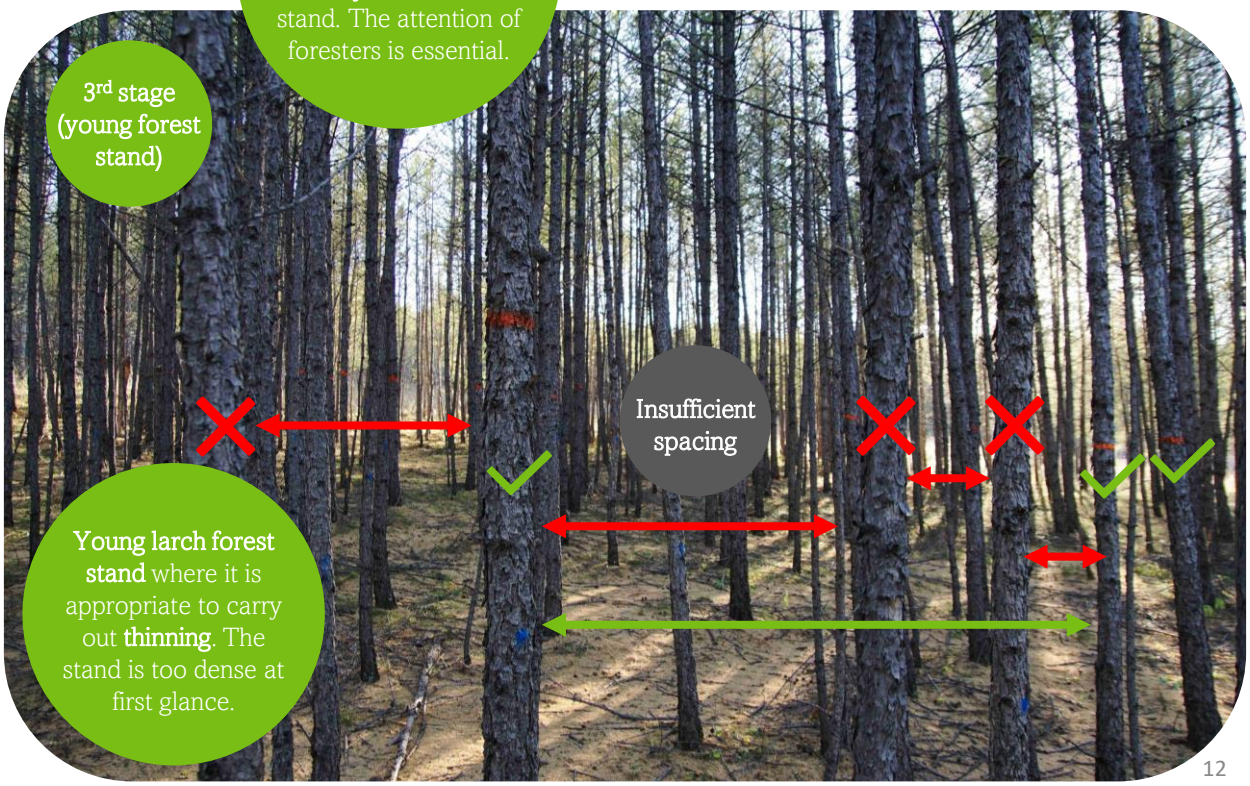




WHAT FOREST CARE IS NEEDED
ACCORDING TO ITS STAGE OF DEVELOPMENT

4. Medium-old forest stand (height 7–20 m, DBH 15–40 cm)

- thinning planning
- commercial thinning
- positive promotion of the best quality individuals
- transport of harvested wood for commercial use

5. Final harvesting of mature trees (DBH >40 cm; preferred DBH 40–60 cm)

- forest regeneration cutting
- the width of the harvested area should be no more than twice the height of the adjacent remaining trees (forest) to ensure lateral protection and a favourable microclimate
- gradual harvesting of mature trees in 2–3 phases, interval 10–20 years
- preparation of areas for natural regeneration (e.g. soil scarification)
- on extreme sites, it is possible to let pioneer species (birch and aspen) regenerate and develop naturally in the first phase; in the second phase, target tree species (larch and pine) are introduced and artificially supported while naturally protected by pioneer species
- the best quality trees are harvested in the last phase – use of high-quality genetics in new stands via their natural regeneration
- harvesting of the last mother trees after the establishment of new seedlings
- to support ecosystem biodiversity, it is advisable to leave suitable marked biotope (habitat) trees with tree-related microhabitats
- sustainable harvesting of trees, transport and use of wood for commercial purposes

WHAT FOREST CARE IS NEEDED

ACCORDING TO ITS STAGE OF DEVELOPMENT

A MONGOLIAN FORESTER'S CALENDAR

A simplified calendar presenting the timing of the **main silviculture activities**:

ACTIVITY	WINTER		SPRING			SUMMER			AUTUMN		WINTER	
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Forest management planning	■	■	■								■	■
Seed collection	■	■	■	■	■	■					■	■
Fire control			■	■	■	■	■	■	■	■		
Forest cleaning for planting			■	■	■	■	■	■	■	■	■	
Soil scarification				■	■	■	■	■	■	■		
Chemical preparation of soil				■	■							
Sowing				■	■	■						
Seedling planting				■	■			■	■			
Seedling fencing				■	■	■	■	■	■			
Weeding						■	■	■	■			
Pest control				■	■	■	■	■	■			
Repellent application									■	■		
Forest grazing control	■	■	■	■	■	■	■	■	■	■	■	■
Pruning		■	■	■	■			■	■			
Thinning marking					■	■	■	■	■	■		
Cutting/logging/thinning	■	■				■	■	■			■	■
Skidding (timber extraction)	■	■				■	■	■			■	■
Illegal logging control	■	■	■	■	■	■	■	■	■	■	■	■
Forest management control	■	■	■	■	■	■	■	■	■	■	■	■

- The timing proposal mainly follows an ecological and practical approach, but it is necessary to **respect the superior** (I) **forest law**[1] and (II) the **specific requirements** of different tree species (indicated in light green).
- It is always necessary to **respect the weather** and the related **condition of natural ecosystems** or **infrastructure** (e.g. when a long period without rain is forecast, it is inappropriate to plant seedlings; if it rains and the roads are muddy, it is inappropriate to transport heavy wood, etc.).

The activities are further explained on the following pages.

SOURCES OF DETAILED INFORMATION ON THE TOPICS

The information in this handbook is presented in a simplified form suitable for the practical work of a forester. However, in some cases, the texts contain professional terms from forestry practice, which may be unfamiliar to beginning foresters. For their explanation, it is possible to refer to the following materials in Mongolian that have been published recently[2,3,4,5]:

- Forester's Handbook (Ойн ажилтны гарын авлага) (2016) summarizing the basics of forestry operations and current forest-related legal acts and regulations.
- Development of Forests and the Gene Pool of Local Forest Tree Ecotypes in Mongolia (Монгол орны ойн болон орон нутгийн ой модны генийн сангийн хөгжил) (2017) summarizing forestry basics within three separate book parts. Several topics simply presented in this handbook are elaborated in detail in the textbook.
- The Forestry Professional: A Handbook (Ойн мэргэжлийн ажилтан: Гарын авлага) (2018) summarizing forestry basics. Several topics simply presented in this handbook are elaborated in detail in the textbook.
- About planting and growing forests (for enthusiasts) (ой тарьж, ургуулах тухай (сонирхогчдод зориулав)) (2022) summarizing principles and basics of forest regeneration, seed collection and work in forest nurseries.

FOREST REGENERATION

To preserve a forest, it is necessary to **replace** the harvested or degraded trees with new ones. In case of favourable environmental conditions **with a seed source** and **without intensive grazing/browsing**, a forest will regenerate naturally. Where possible, **tree species mixing** is preferred. Forests should only be planted where they grow or have recently **grown naturally** – natural conditions must always be respected.

Natural forest regeneration

The preferred **cost-efficient** method with benefits such as (I) greater **genetic, species** and **spatial diversity** of the new forest, (II) **natural adaptation** of individuals to environmental conditions and related (III) **higher resilience** and **resistance.**

Artificial regeneration

Necessary in **degraded areas without fruiting mother trees** and **big open areas** or in the case of (I) **introduction of new species,** (II) **repair planting** and **improving forest regeneration** or (III) **non-seed years.**

FOREST GENETICS

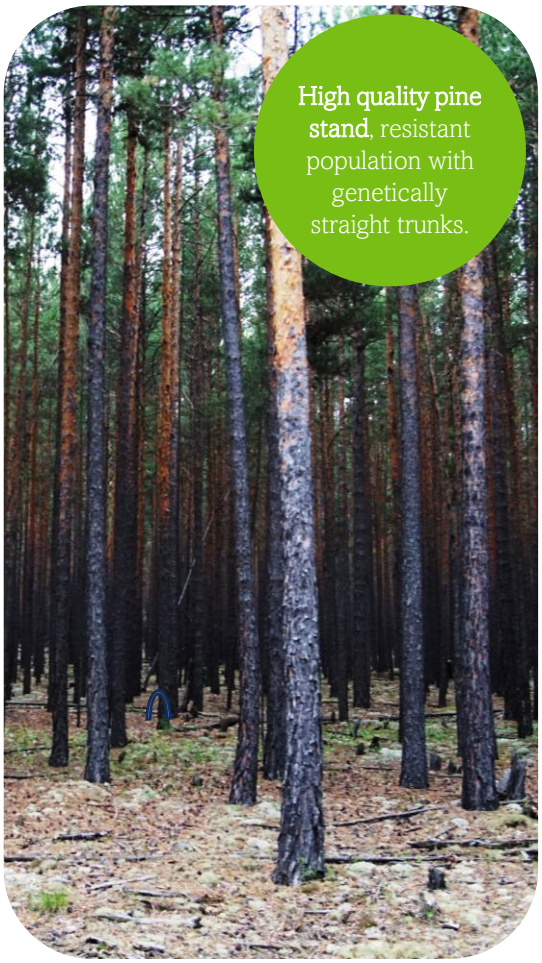
The **genetic quality** of future stands depends on **mother trees** – the seed sources. The selection of high-quality tree populations is the basis for future prospective forest management. A high diversity of the trees is preferred. An important part of forest genetics is the respect for provenance – seeds from **local stands** are highly preferred for **local nurseries** and future **local planting**.

Main criteria for the genetic quality of new stands:

1. **stand stability and resilience**
2. **quality** of stems, wood and crown
3. rapid biomass growth

Resources for seed collection:

1. selected elite trees
2. selected high-quality forest stands
3. seed orchards



High quality pine stand, resistant population with genetically straight trunks.

Larch seed orchard

Along with **elite trees or stands** as seed sources, it is possible to establish special **seed orchards**. These can be used **to save the gene pool** of exceptional individuals and to **easily obtain seeds**.

SEED COLLECTION

Seed collection is an important forestry activity to ensure sufficient **high quality seed material** for **forest nurseries**. Collected seed should be properly **labelled and stored**. This is important for further utilization and **preservation of seed quality parameters** such as germination percentage, seed moisture content, etc. Proper seed storage will then ensure a sufficient supply of seed even in years without seed production.

Methods of seed collection:

1. **From standing trees using rope-climbing techniques.**
2. From standing trees using climbing irons.
3. From felled trees.
4. **From standing trees by shaking down the seeds onto a tarp.**
5. From standing trees using ladders, etc.

Important:

- **Tree species is largely decisive** for the choice of seed collection method.
- Collect only **ripe cones** from conifers.
- Always be **secured** with a rope around the tree when collecting on standing trees.
- **The cones must not be damaged** during transport and storage.
- Seeds must not be damaged during **cone processing** and **seed extraction**.
- **Seed stratification** (pre-treatment) is essential for seed germination of most tree species (especially conifers).
- Adhering to the **proper labelling and storage** process increases the chances of **producing high-quality seedlings in large numbers.**

Rope-climbing technique

SOWING AND CARE
IN FOREST NURSERIES

The process of sowing seeds into substrates or directly into beds. The sowing is preceded by **perfect soil and seed (stratification, maceration, pickling, pelletizing, etc.) preparation**. The method of growing seedlings and cuttings varies according to the tree species and the silvicultural goal. Specific information on the cultivation of **container seedlings** is not given due to their very limited use in Mongolia.

Sowing seeds in rows.

Root pruning (undercutting) of seedlings is made in the middle of the growing period.

Full-area sowing.

Seedlings are **transplanted** after two–three years of growing.

Main activities in forest nurseries:

- **regular irrigation**
- fertilisation of seedlings
- **undercutting of root system, transplanting**
- treatment of seedlings with fungicides and herbicides (or manual weeding)
- **shading of seedlings**
- overwintering of seedlings

Growing in rows.

Too dense hand sowing.

A seed drill carried behind a tractor.

CONTAINER SEEDLINGS

In comparison with **bare-root seedlings**, a **container seedling** has its **roots in contact with substrate** during cultivation, handling and planting. Container seedlings have therefore several advantages, but also a few important disadvantages that can be limiting in Mongolia.

Advantages:

1. **Do not dry out during handling as fast as bare-root seedlings.**
2. Can be planted in moist soil throughout the growing season.
3. **Faster growth** in the first years after planting.
4. Possibility of **inoculating mycorrhizae** and other growth enhancers into the substrate in the nursery.
5. **Lower mortality.**

Disadvantages:

1. **Expensive to produce.**
2. **Complex and expensive nursery technology.**
3. Requires constant availability of electricity, water, good quality substrate.
4. Technology requires daily supervision and management.

Type of packaging (containers):

1. **Degradable**: peat cups, degradable fabrics.

2. **Plastic**: pots, planters, bags, tarpaulins.

Container seedlings

Packing of seedlings initially grown in bare soil.

Packed seedling

FOREST MACHINERY
IN FOREST NURSERIES

Work in a forest nursery can be easier, more efficient and improved by various machines. This can contribute to the production of **higher quality seedlings** in **larger numbers**. In addition to the conventional machines, it is advisable to use **a rotavator, a seed drill, a root pruning machine** (undercutter) and **a backpack sprayer** in local nurseries. Every professional nursery should also have a **sprinkler irrigation system**.


A rotavator

A rotavator:

- **Improves and refines soil structure.**
- Incorporates fertilisers.
- Shapes seedbeds.
- Must be used **before sowing** for fine seedbed preparation.
- Suitable for use before transplanting seedlings.


A root pruning machine

A root pruning machine:

- **Improves the root system** of seedlings (fine root growth support).
- Used for cut at a depth of about **10 cm** in the second year of seedling life.
- Used during **vegetative growth**.

A backpack sprayer:

- A simple device for **chemical weeding** of seed beds and other areas in a nursery.
- Young seedlings should be protected by spraying **fungicides** – using backpack sprayer.
- It is necessary to use **prescribed concentrations** of chemicals for spraying.
- An alternative is a **tractor-mounted sprayer**.


A backpack sprayer

SEEDLING HARVESTING, HANDLING AND TRANSPORT

Final harvesting, handling and transport of seedlings are very important tasks in the forest establishment process. All these steps must be done **correctly and quickly** without damaging the seedlings. Seedling damage may not be apparent immediately; it can be manifested even weeks after planting by the death of the seedlings due to the **drying out of the root system** in the period **between harvesting and planting**.

Manual harvesting of seedlings.

A seedling lifting machine

Basic post-harvest operations:

1. **quick pickup**
2. sorting seedlings by size
3. **soaking roots (optionally in hydrogels or mycorrhiza)**
4. counting and packing
5. temporary storage
6. **transport in covered moist containers**
7. transport in closed vehicles

The exposed root system will be severely damaged already after **20 minutes** exposed to the sun and wind. **Quick handling** is necessary to preserve the life and vigour of the seedlings.

An earth pit for storing seedlings using snow.

Soaking seedlings in **hydrogel**.

SEEDLING PLANTING

One of the basic prerequisites for successful planting is the **selection of seedlings**: **high-quality** seedlings of **suitable species**. The selection of seedlings starts with the selection of a forest nursery. Respect natural regionality – seedlings from local nurseries **adapted to the specific natural conditions** of the region are highly preferred. The selection continues in the forest nursery – **poor quality seedlings must be eliminated**. By selecting only high-quality seedlings, the chance of successful reforestation is increased and the risk of additional costs is reduced.

Time for planting:

- **Spring:** From soil thawing to seedling sprouting (April–June)
- **Autumn: Conifers**: termination of terminal growth (August–September)
- **Autumn**: **Deciduous trees**: after leaf fall (September–October)

The ratio of below- to above-ground biomass is about 1:6 => **the root system is insufficiently developed** to supply the seedling with water.

Smaller seedlings have the ratio of about 1:2 => the seedlings are better **adapted to survive extreme conditions**.

Valid for any type of planting:

The roots of the planted seedlings must be tightly held in the soil.

Seedlings must have their roots covered to prevent drying out during transportation.

Watering of newly planted seedlings is recommended.

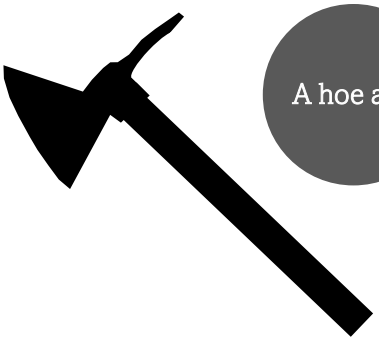
SEEDLING PLANTING
IN A PIT (HOLE) USING A HOE AXE

This method is suitable for:

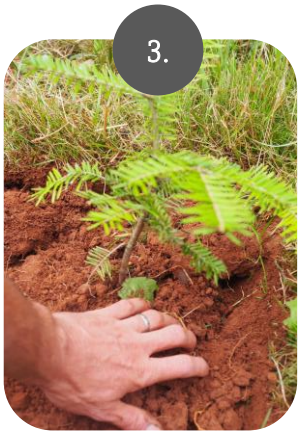
- mature seedlings of larger sizes
- large container seedlings
- sites with nutrient-rich and moist soils
- rocky and heavily rooted soils
- habitats with high herbaceous vegetation

Workflow

1. Remove a sod in an area of 30 × 30 cm with a hoe axe.
2. Dig a hole with the hoe axe.
3. Place the seedling in the middle of the hole and cover the seedling with soil.
4. Press down firmly to compact the soil.



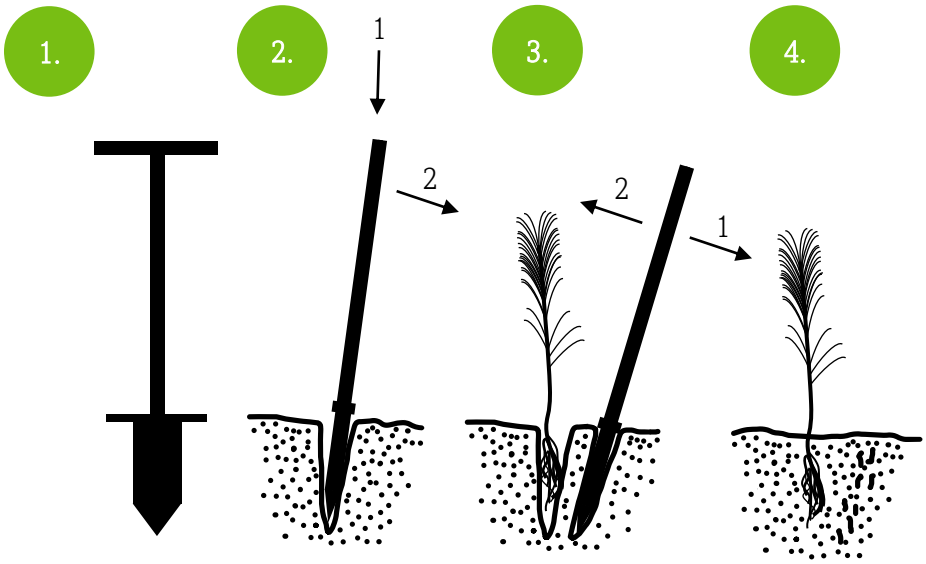
A hoe axe



SEEDLING PLANTING
IN A SLIT USING A PLANTING SPADE

This method is suitable for:

- ploughed/scarified areas
- small seedlings with a narrow root system
- sites with fine, sandy soil
- habitats with very little herbaceous vegetation



Workflow

1. **The planting spade.**
2. **Create a slit in the ground with a planting spade.**
3. **Place the seedling in the slit with the root collar slightly under the ground level. Approximately 5 to 8 cm from the first slit, a second puncture is made, and the root system of the seedling is closed and compacted by moving the planter towards you.**
4. **Finally compact the soil around the seedling.**

The work can be mechanized with a **furrow planting machine**.

SEEDLING PLANTING
IN A HOLE USING AN EARTH AUGER

This method is suitable for:

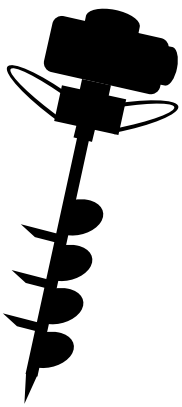
- areas with **soils without stones**
- all types of seedlings

An earth auger

- **Drill diameter 15–20 cm.**
- Petrol must be mixed with lubricating oil.
- Drill cutting edge must be ground.

Workflow

1. **Drill a hole to a depth of about 25 cm.**
2. **Insert the seeding into the hole.**
3. **Cover the roots of the seedling with the drilled soil**
4. **Compact the soil around the seedling with your hands and feet.**



Advantage: Very fast to make plantation holes.
Disadvantage: In places with high vegetation, it is necessary to remove the sod first.

An alternative to manual operation is a **tractor-mounted earth auger**.

SOIL SCARIFICATION

Mechanical disturbance of the soil surface **increases the chance** for new seedlings **to germinate** and young plants **to survive in the competition** from surrounding weeds. Most tree species require exposed mineral soil and sufficient light for establishment and initial growth. Soil scarification can promote successful natural regeneration of forest without the need for artificial planting. In addition, it can be **supported by manual or mechanized sowing** if naturally available sources of seed are insufficient or unsuitable.

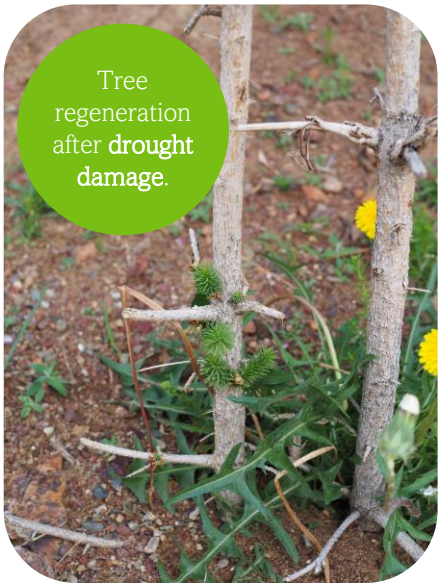
Conditions for successful implementation:

1. **Suitable equipment** (e.g. a tractor, a rotary tiller preferred).
2. Suitable soil and terrain conditions.
3. Suitable **timing** (seed year).
4. Proximity to **mature fruiting trees**.

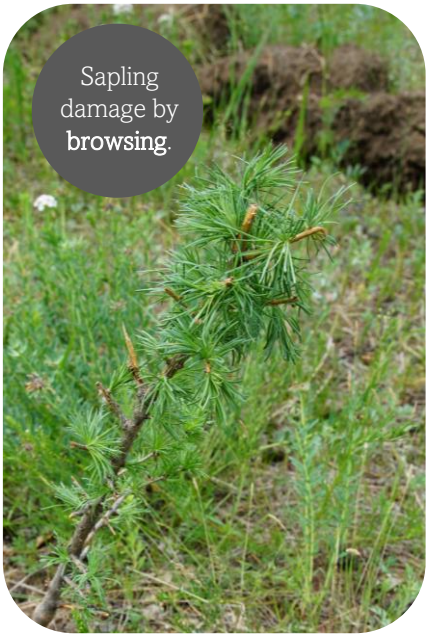
SEEDLING PROTECTION IN FOREST REGENERATION

New and young seedlings must be **managed until successful growth is ensured**. Seedlings may be damaged by:

- **extreme weather** (e.g. drought or flooding)
- **weeds**
- **wildlife** or **livestock** (e.g. **browsing**)
- harmful **insects** or **fungi**


Tree regeneration after **drought damage**.


Tall **weeds** threatening seedlings inside the fence.


Sapling damage by **browsing**.

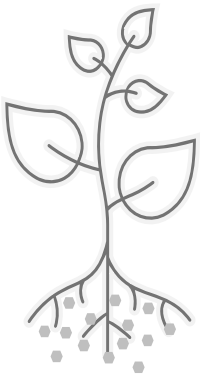

Sapling damage by roe deer **fraying**.


Frost heaving: seedlings are pushed out of the ground.

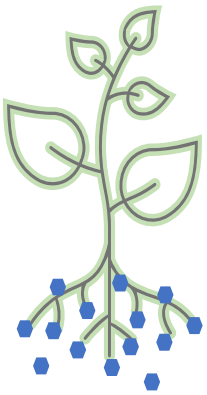
SPECIAL DROUGHT PROTECTION FOR SEEDLINGS

Hydrogel is a powder, but as soon as it encounters water, it begins to swell and adopts a gel-like consistency. This substance can absorb a significant amount of water and nutrients, increasing its volume up to 250 times. In the long term, it helps to supply plant roots with the necessary **moisture and nutrients**.

How hydrogels work



One gram of **hydrogel** retains up to 400 g of water.



Hydrogel powder

Use in the forest nursery:

1. Mix fine powdered hydrogel with water as instructed by the manufacturer.
2. **Soak the roots of seedlings** in the hydrogel after harvesting (protection against drying out of the root system during transport).

Hydrogel-protected roots.

Use in planting:

1. Add approximately **3–5 g of hydrogel to the plantation hole** and mix it thoroughly with the soil.
2. After planting, the seedling must be watered.

INDIVIDUAL SEEDLING PROTECTION FROM BROWSING

Individual protection against browsing is used in areas with **low-moderate game** or **livestock pressure** on vegetation. This kind of protection is suitable to use in places with a small number of young trees (e.g. trees outside forests) or in the protection of vulnerable **tree species rare for the site**.

Applying **repellent** to the terminal shoot.

Repellent application

Repellents are gentle chemical agents that **repel animals with their smell, taste and abrasives**. They are harmless to nature. Their effectiveness is time-limited. The coating needs to be **renewed regularly** (every three weeks in summer, every six months in winter).

The repellent coating is **applied only to the terminal shoot** (8–15 cm).

New shoots will **easily grow through** the paint in spring.

Individual fencing

Mechanical fencing is carried out up to a **height of approximately 160 cm** and the mesh size defines the level of protection. It is necessary to stabilize the fence by 2–3 poles hammered into the ground. The fence must be removed from the forest later, however, it **can also be used repeatedly**.

GROUP SEEDLING PROTECTION
FROM BROWSING

Full protection of the planted area against grazing, browsing, gnawing, scratching and fraying.

Workflow for the construction of an exclosure:

1. Exclosure measurement and designing (**spacing of poles 3–4 m**).
2. Drilling holes for the poles with an earth auger.
3. Distribution of poles and their stabilization in soil.
4. Installation of supporting stakes.
5. Stretching the **wire mesh** and nailing it to the poles.
6. Applying a barbed wire on the top of the fence (to avoid cattle pushing the fence – only at extreme risk).
7. **Gate/ladder/crossing** construction.
8. Other minor modifications.

Advantage: 100% protection against livestock and game.

Hammering: poles must be **well fixed** in the ground.

An alternative to manual operation is a tractor-carried **fence construction machine**.

Disadvantages: (I) expensive, (II) one breach of the fence jeopardises the whole plantation, and (III) necessary to remove later.

Crossing variant: Height of the fence is 160 cm.

Regular inspection of fence damage and **immediate repairs** are necessary.

WEEDING

The purpose of weeding is **to remove high-competing vegetation around the planted seedlings**, ensuring sufficient light for photosynthesis, access to water and successful growth. On the other hand, low vegetation maintains a suitable microclimate and removal is not necessary.

Where to apply weeding:

- Sites with **fertile soils** and sufficient soil moisture.
- Sites with planted **light-demanding tree species** such as Scots pines, larches, etc.

Tools for weeding:

- sickles
- scythes
- machetes
- brush cutters

When working with the brushcutter, the **operator must be very careful** not to damage the planted trees.

Depending on the **type and size of the weed**, different **trimmer heads and blades** are chosen.

Planted trees **must receive sunlight**.

Terminal buds must be above dense vegetation.

CONTROL OF PLANTING SUCCESS AND REPAIR PLANTING

It is necessary to **regularly evaluate** previous planting and maintenance activities. From the results of the inspection, a forester should determine a further course of action.

Spring frost damage.

Main reasons for reforestation failure:

- **poor seedling quality (small root system)**
- poor manipulation of seedlings in a nursery
- **poor seedling transport conditions**
- poor quality planting (technology)
- too high competition from surrounding vegetation
- planted seedlings being cut down during weeding
- **harsh climatic/weather conditions**
- pest damage
- **browsing**

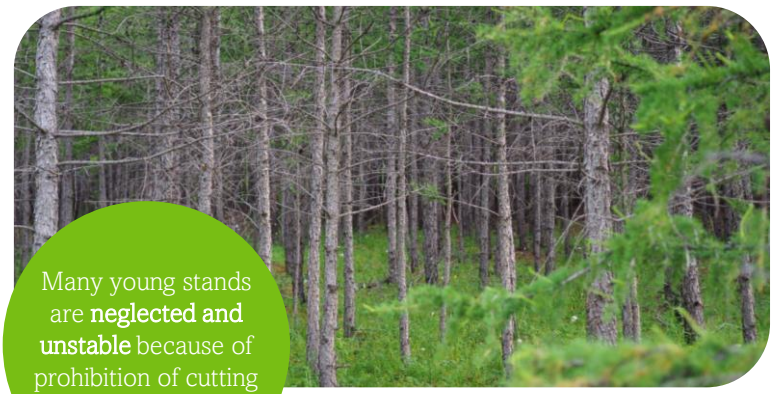
Drought damage.

Repair planting:

- Losses of up to 20% can be tolerated.
- Repair plantings are carried out with high quality and adequate planting material.

FOREST TENDING

Forest tending is an important management measure bringing both **ecological and economic benefits**. Tending is carried out by interventions that **remove or support individuals based on their perspective** for further development of the forest. It involves removing unsuitable trees (e.g. damaged, weak, overtopping) or supporting suitable (e.g. high-quality) trees. An experienced forester marks the trees to be felled, on the basis of inventory.



Many young stands are **neglected and unstable** because of prohibition of cutting down living trees.

Stands without thinning are often **too thin and weak** and therefore damaged by strong wind.

Forest tending has several purposes:

- **To increase stability and resilience of current and future forest.**
- To accelerate stem diameter growth and value development of remaining trees.
- To facilitate forest regeneration and better genetic quality of future forest generation.
- **To lower risk of significant damage caused by fire.**
- To increase clarity and accessibility of forests.
- To increase attractivity of forest for recreation.

Properly maintained stand with **suitable space for high-quality trees growth.**

Thinning in middle-aged stands already **yields timber** for utilization.

BASIC FOREST MACHINERY AND HAND TOOLS FOR TENDING

Forest tending tools are chosen depending on the size of the **area and age of the trees**. For an effective intervention on a larger area or in an older stand, mechanization is necessary. In interventions limited to small areas and a few young individuals such as saplings, it may be easier to use manual hand tools. These can be used especially during **cleanings**.

Basic tools used according to the age of the tree or stand:

- machetes (<15 years)
- **loppers (<15 years)**
- **axes (<20 years)**
- bow/folding saws (<20 years)
- brush cutters (<15 years)
- **chainsaws (>15 years)**

Basic personal protective equipment mandatory for a chainsaw worker:

- a protective helmet equipped with hearing protection and a visor
- chainsaw gloves
- chainsaw trousers
- cut-resistant chainsaw boots

Regular maintenance is necessary to extend the life of tools as well as for work efficiency and worker safety! Maintenance can be performed daily, weekly or monthly depending on the operation being performed. **Basic maintenance** should be done **daily** after the end of the work process.

PRECOMMERCIAL THINNING
IN BIRCH STANDS

Asian white birch (*Betula platyphylla*) is a highly light-demanding species adapted to **pioneer colonization of extreme sites**. Birch wood grows quickly and has a wide range of uses in good dimensions. It often **sprout-regenerates from stumps**; however, too dense stands are easily bent down by heavy snow.

Unstable slender birch forest.

Sprout-regeneration from stumps.

Rules for thinning:

1. The **first thinning** is carried out at a **stand height of 5–8 m**.
2. **Spacing of 2–3 m** (800–1500 trees/ha).
3. Stands are **not pruned**.

Support birch trees with:

- **Good quality** and good trunk shapes (straight).
- Trunks **free of visible damage**.
- Sufficiently **developed crowns**.

Thinned birch forest with remaining high-quality trees (1200 per ha).

General use of birch wood:

- veneer and plywood
- furniture
- **paper**
- **firewood**
- **charcoal**

PRECOMMERCIAL THINNING
IN PINE STANDS

Scots pine (*Pinus sylvestris*) has **high requirements for sunlight** and tolerates dry periods as well as **sandy soils**. It regenerates very well after fires or on disturbed soils. Pine has a space-spreading crown; to grow good quality trunks, young pine stands should be kept **relatively closed**.

Unstable pine stand without care.

Rules for the first thinning:

1. It is carried out at a **stand height of 3–5 m**.
2. Spacing of 1.5–2 m (2000–4000 trees/ha).
3. **Overtopping** and **wolf trees are removed.**
4. Healthy, stable and good shape trees shall be left standing.

Rules for the second thinning:

1. It is carried out at a **stand height of 7–10 m.**
2. Approximately **50% of individuals are removed.**
3. After thinning, about 800–1500 trees per ha remain.
4. **High-quality individuals can be pruned**, especially in areas with free canopies.

Pine stand after the **first thinning**.

General use of pine wood:

- all types of **wooden buildings**
- good quality timber for **furniture industry**
- assortments for the paper industry
- **wood fuel (logs, chips, pellets)**
- poles, posts
- fibreboard

PRECOMMERCIAL THINNING
IN LARCH STANDS

Siberian larch (*Larix sibirica*) has high **requirements for sunlight** and **grows poorly in dense stands**. It requires open space for the canopy to grow well, however, it easily self-prunes. Larch forest fragments are extremely vulnerable (pests, climate change), any introduction of other tree species is welcome.

Unstable larch stand without proper care.

Rules for thinning:

1. The **first thinning** is carried out at a **stand height of 5–7 m**.
2. Choose **good quality trees** with good trunk shapes.
3. Trunks must be free of visible damage.
4. Sufficiently developed open crowns.
5. **Spacing of 1.5–3 m** (1000–3000 trees/ha).
6. **Target trees should be pruned.**
7. Potentially 500–800 trees/ha can be strongly released in the canopy space; weak and short trees can remain.

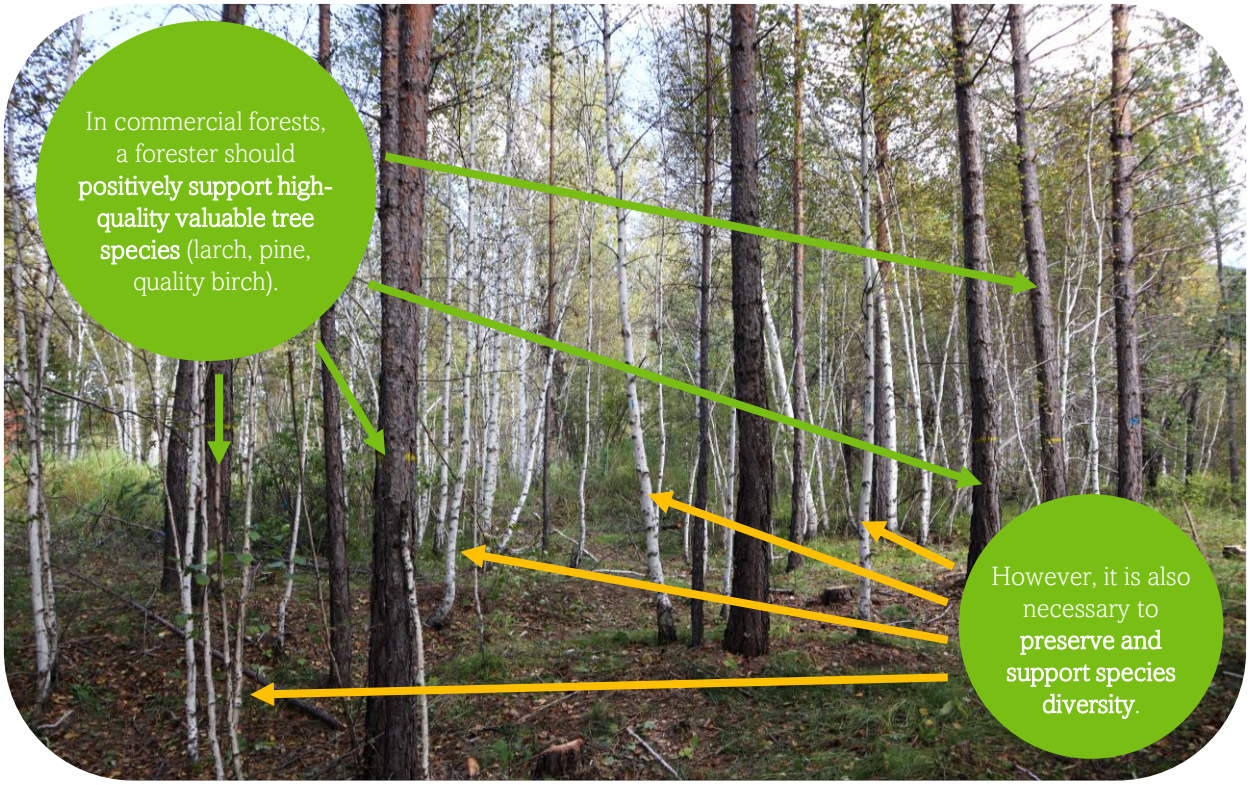
After thinning and pruning, **about 1200 high-quality trees remain**.

General use of larch wood:

- timber log buildings
- terraces, poles, columns
- wooden panels
- construction timber
- firewood

PRECOMMERCIAL THINNING
IN MIXED STANDS

Mixed stands are always **more stable and resilient**, therefore preferred. Boreal coniferous forests are species-poor, but often with an important **mixture of deciduous pioneer tree species** (birches, poplars, willows, etc.). When thinning, the **ecological requirements** of the species must always be respected.

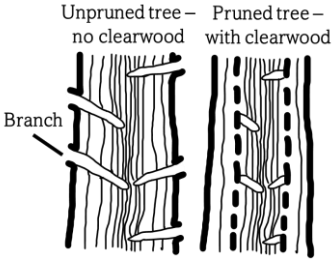


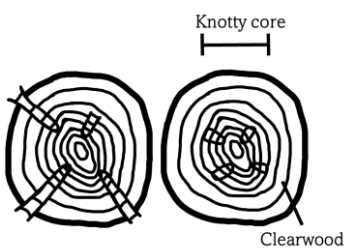
PRUNING

The main purpose of pruning is to cultivate **wood without knots** for **higher wood quality** and **commercial value**. It may be particularly suitable for promising individuals in open-canopy forests. In addition, it makes young forest more transparent and accessible. Another benefit is **lowering the risk** of significant damage caused by **crown fire**; in this case, tree quality is ignored.

Rules:

- To prune trees **before they reach 15 cm in DBH**.
- Only **target high-quality trees** are pruned.
- At least **1/3 of the green crown** remains.





COMMERCIAL THINNING

Thinning in stands **of over 30 years old**, with DBH of harvested trunks **over 10 cm**. The harvested trees can already be processed into various products: sawn timber, milled poles, stakes, fuel, wood chips, charcoal, paper pulp. Besides production, the aim of commercial thinning is also to **support prospective individuals**, increase stem diameter growth and improve **stand stability** and **resistance**.

Trees marked for educational **thinning intervention.**

Rules:

1. **Positive promotion of the best quality individuals.**
2. Health selection.
3. **Intervention intensity of 30–50%.**
4. **Intervention interval of 15–30 years.**
5. Maintaining long tree crowns, min. 1/3 of the tree height.

Future?

A small **thinning harvester.**

Future?

Potential **timber from commercial thinning.**

Suitable technology is needed for **transport**, ideally with the use of a **loading crane**.

FOREST HYGIENE:
DEADWOOD AND SLASH

The main purpose is to care for **forest health**. In addition to tending interventions focused mainly on living trees, a forester must also focus on **deadwood**. **Dying or recently dead standing trees** serve as potential hosts for pests – and must be removed by **sanitation cutting**. Although deadwood harvesting is allowed with a license, the removal of all dead trees from the stand impact forest health and can rarely contribute to the permanent retreat of the forest from the given site. The forester's task is to find a **compromise**.

Benefits of deadwood:

1. **Habitat for many organisms and related biodiversity.**
2. Carbon storage.
3. **Microclimate regulation.**
4. Substrate for natural regeneration.
5. **Nutrient and water reservoir.**

Risks with deadwood:

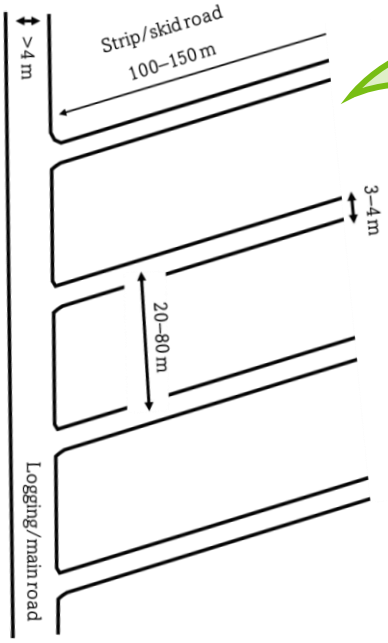
1. **Contribution to fire intensity.**
2. **Contribution to pest outbreaks.**
3. Obstacles for the movement of forest machines.
4. **Falling may cause personal injury and damage to property.**
5. Economic losses (higher value before dying).

Slash (logging debris) may increase **fire hazard**. Therefore, its management is important. It can be profit-making as a raw material for **wood chips** or **firewood**. But it can also be used directly in the forest as a material to **stabilize soft soil** during logging, to avoid damage of soil and roads. Leaving the slash in the forest is beneficial, but it is advisable to **concentrate it**.

FOREST ACCESSIBILITY

Forest accessibility refers to how to get to the forest with human resources and machines and how to extract wood and other forest products. As part of **silviculture**, the forester should create a **transportation network inside the forest**. The main purpose of **forest roads** is to lower the cost of accessing forest areas for silviculture and logging operations. In addition to making forestry operations more efficient:

- Side trees along the roads have a **stabilizing function.**
- The roads **improve access for the public and tourists**.
- The roads partly serve as **firebreaks** and provide fast access to combat wildfires.
- The roads **limit damage to the surrounding forest** during logging operations.



The **skid roads** are established in dense young stands, preferably **during pre-commercial thinning**.

Spacing of strip/skid roads according to the machinery working in the forest:

1. **Cut-to-length** technology: **20–30 m.**
2. **Tractors, trucks**: **40–80 m** (transport and storage).

FOREST MACHINERY
FOR SKIDDING

Skidding is an activity of timber extraction in forest harvesting by which logs or whole trees are dragged over the ground over **short distances from forest stand to a loading area**, where they are loaded on trucks for further transport. When skidding, it is necessary to **minimize damage** to surrounding standing trees, natural regeneration and soil. This is important for the **health and quality of the remaining trees** of all ages.

Technology for thinning and skidding:

- **a chain saw – a farm tractor with a logging winch** (skidding accessories)
- **a chain saw – an iron horse**
- a chain saw – a draft horse
- **a chain saw – a truck with a logging winch**
- a harvester – a farm tractor with a forestry trailer (a combined logging winch for skidding and a hydraulic loading crane)

An iron horse

A farm tractor with **skidding accessories.**

Skidding principle is based on **power** and **a cable and a winch** or **a hydraulic grapple** (on the boom or on the back of the frame) accompanied by **movement**.

A farm tractor with a **logging winch** for skidding combined with a **draft horse** – a way to **minimize damage** in the forest.

Skidding with a **draft horse.**

FOREST MACHINERY
FOR TIMBER TRANSPORTATION

The **transportation of wood** from forest to customers (wood hauling) is limited by the quality of the **road network** in Mongolia as well as by **available machinery** and its loading capacity. These factors make it difficult to transport wood from forests and lead to **slash accumulation** and **economic losses**. A basic solution can be to make truck or trailer **loading more efficient**, especially through **winches** and **loading cranes**. Another solution may be to invest in suitable machines.

A farm tractor with **a logging winch** and **a hydraulic crane** on **a trailer**.

Farm tractors with forestry trailers

Farm tractors with forestry trailers can be used especially for transport **within the forest and the surrounding area** up to tens of kilometres in difficult road network conditions. Their advantage is the **loading crane**, which enables easy loading and unloading of the **trailer**.

A forwarder

ZIL truck

Future of wood extraction and transportation?

A terrain truck with a trailer.

ZIL trucks

ZIL trucks are traditionally used in Mongolia for timber transport. Their potential can be improved with a **winch** and a **loading ramp** allowing the transport of **longer cuts/logs**.

CONCLUSIONS

Silviculture is among the most important tasks in forest management. Forest regeneration, protection and tending are the key to **sustainable forest management**. The result of these activities is a healthy, strong and resistant forest that performs all the required **social, ecological and production functions**, and can thus benefit not only the forester, but the entire society. In conclusion, the following information should be highlighted:

1. **Seeds** are only collected **from diverse high-quality trees**.
2. Seeds from **local stands** are highly preferred for **local nurseries** for future **local planting**.
3. **Root undercutting** to improve the root system of seedlings is a necessary activity.
4. **Seedling care** principles during **handling and transport** must be strictly followed to ensure successful plantation.
5. Forests should only be (re)planted in places where they **grow/grew naturally**.
6. When **planting**, it is essential to use high-quality seedlings with a **well-developed root system**.
7. When **protecting seedlings**, wood from the **local forest can be used** for fencing.
8. **Weeding** is an important part of protecting seedlings.
9. It is necessary to **implement thinning** and **to make use of the thinned wood**.
10. During **logging**, it is necessary to pay attention to forest **hygiene**.
11. **New machines and technology** will make work easier and more efficient.
12. It is necessary to **support biodiversity**.
13. **Sustainable forest management** creates opportunities **for employment and prosperity**.

REFERENCES

[1] Mongolian Law on Forest. Ministry of Environment and Green Development of Mongolia. A revised version. Government Bulletin No 22. Published on May 17, 2012, Ulaanbaatar. Available at: https://legalinfo.mn/mn/detail/15624.

[2] Enkhtaivan, N. and Gelegjamts, Ch. eds., 2016. Forester's Handbook (Ойн ажилтны гарын авлага). Third edition. Admon LLC.

[3] Kusbach A., Štěrba T., Smola M., Novák J., Lukeš P., Strejček R., Škoda A., Bažant V. and Pondělíčková A., 2017. Development of Forests and the Gene Pool of Local Forest Tree Ecotypes in Mongolia. Proceedings of the seminar, Sharyn Gol/Darkhan, Mongolia, September 2017. ÚHÚL Brandýs nad Labem, Czech Republic.

[4] Bayartsetseg, B., Chuluuntsetseg, D., Ganzorig, B. and Gerelbaatar S., 2018. The Forestry Professional: A Handbook (Ойн мэргэжлийн ажилтан: Гарын авлага). UB BCI (УБ Би Си Ай).

[5] Baatarbileg, N. ed., 2022. About planting and growing forests (for enthusiasts) (ой тарьж, ургуулах тухай (сонирхогчдод зориулав)). Admon LLC.

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Václav Pecina

Aleš Škoda

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Václav Pecina

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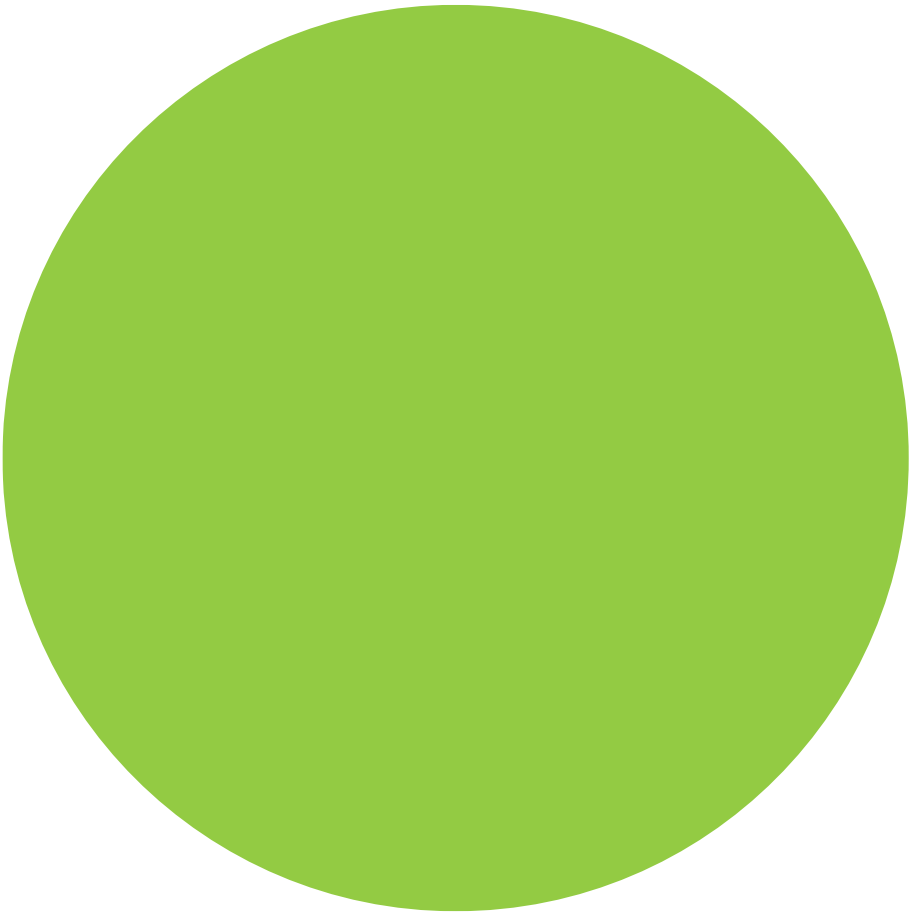

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