


SUSTAINABLE FOREST MANAGEMENT MEASURES REALIZED WITHIN THE STREAM PROJECT

Václav Pecina et al.

Mendel University in Brno

Mendel University in Brno

Václav Pecina et al.

SUSTAINABLE FOREST MANAGEMENT

MEASURES REALIZED WITHIN THE STREAM PROJECT

May 2024

Mendel University in Brno

Authors

Václav Pecina[1]

Forest ecology and management

vaclav.pecina@mendelu.cz

Aleš Škoda[1,2]

Silviculture

skoda@clatrutnov.cz

Martin Smola[1]

Forest inventory

martin.smola@mendelu.cz

Antonín Kusbach[1]

Forest typology

antonin.kusbach@mendelu.cz

David Juřička[1]

Hydropedology

david.juricka@mendelu.cz

Jan Šebesta[1]

Botany

jan.sebesta@mendelu.cz

[1] *Mendel University in Brno, Zemědělská 1, 613 00, Brno, Czech Republic*

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

Revision

Dan Altrell[1]

Forestry expert

dan.altrell@giz.de

[1] *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Office Ulaanbaatar, Seoul Street 21, Sukhbaatar District, 1st Khoroo,14251 Ulaanbaatar, Mongolia*

Project

This report was prepared by experts from Mendel University in Brno as part of the Sustainable Resilient Ecosystem and Agriculture Management in Mongolia (STREAM) project. The STREAM project, co-financed by the European Union and the German Federal Ministry for Economic Cooperation and Development, is being implemented by the Mongolian Ministry of Environment and Tourism with the support of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the Food and Agriculture Organization of the United Nations (FAO).

GOVERNMENT OF MONGOLIA MINISTRY OF ENVIRONMENT AND TOURISM

Co-funded by the European Union

германы хамтын ажиллагаа DEUTSCHE ZUSAMMENARBEIT

Implemented by giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Food and Agriculture Organization of the United Nations

Mendel University in Brno heads a consortium of twelve educational and research institutions that collaborate on the forestry component of the project led by the GIZ.

More information about the project: https://www.giz.de/en/worldwide/128246.html

Mendel University in Brno

Abbreviations and acronyms

Age_{avg} = Average stand age

Am = Mongolian almond (*Amygdalus mongolica* (Maxim.) Ricker) or *Prunus mongolica* Maxim.

B = Birch (*Betula* sp.)

BA = Basal area

Bp = Asian silver birch (*Betula platyphylla* Sukaczev)

Cs = Siberian hawthorn (*Crataegus sanguinea* Pall.)

DBH = Diameter at breast height

DBH_{avgBA} = Average breast height

FAO = Food and Agriculture Organization of the United Nations

FMP = Forest management plan

FUG = Forest User Group

GIZ = Deutsche Gesellschaft für Internationale Zusammenarbeit

GMIT = German-Mongolian Institute for Resource and Technology

Hr = Sea-buckthorn (*Hippophae rhamnoides* L.)

H_{SUP} = Upper stand height

Lsi = Siberian larch (*Larix sibirica* Ledeb.)

MENDELU = Mendel University in Brno

MULS = Mongolian University of Life Sciences

NUM = National University of Mongolia

P = Poplar (*Populus* sp.)

Psy = Scots pine (*Pinus sylvestris* L.)

Pt = Aspen (*Populus tremula* L.)

S = Willow (*Salix* sp.)

SFM = Sustainable forest management

STREAM = Sustainable Resilient Ecosystem and Agriculture Management in Mongolia

Up = Siberian elm (*Ulmus pumila* L.)

Vol = Volume

CONTENTS

1. INTRODUCTION

This report was compiled by the forestry experts from MENDELU as a summary of SFM measures implemented within the STREAM project, which are to serve as bases for continuous knowledge sharing, inspiration and training of Mongolian foresters. The report serves as a guide with supporting explanations for their further education.

The STREAM project aims at increasing the capacity of Mongolian communities to implement innovative and sustainable long-term landscape management to address food system challenges and climate stresses. The project has two fields of action: agricultural led by the FAO and forestry led by the GIZ. During the implementation of the project (2022–2024), GIZ was supposed to focus, among other things, on support on improving capacity for sustainable landscape management of forest resources and conservation of biodiversity.

The implementation of practical demonstrations of SFM was realized mainly by the consortium led by MENDELU with support of the GIZ. This implementation also included related environmental research, monitoring and evaluation as well as related education and training in forests in the selected aimags and soums of Mongolia.

Based on the experience gained during the implementation of the project and the long-term previous work of the Czech forestry experts in Mongolia, the report was supplemented with recommendations for SFM in local conditions. The expertise in these recommendations is based not only on a forestry approach that considers socio-economic conditions or strict forest protection, as has been common in Mongolia until now, but tries to propose a concept of SFM that takes into account local environmental conditions, climate change and all theoretical aspects and principles of SFM.

2. BACKGROUND OF THE NECESSITY TO IMPLEMENT SUSTAINABLE FOREST MANAGEMENT IN MONGOLIA

Mongolian forests are changing. Although forest loss is not as dramatic as in the past, critical years without care and serious regulation of logging still resonate in the forests. The situation is made even worse by the fact that Mongolian forests are being degraded by several other factors. They react to extreme influences that negatively affect them.

More frequent fires limit the time for forests to recover and develop. The rise in temperatures associated with climate change is causing permafrost melting and lowering of groundwater levels. Trees suffering from stress caused by high temperatures and drought are weakened. This makes them an easy target for insect pests; pest outbreaks cause degradation of large complexes of both mature commercial and protected forests. Irresponsible logging focused on the selective plundering of commercial tree species in many places has led to the reduction of tree species diversity in forests; *Lsi* and *Psy* have been depleted, and the forests are often formed only of *Bp*. A unique gene pool of high-quality tree individuals adapted to the extreme climatic conditions of Mongolia is being lost. Tree solitaires are also disappearing from the landscape – individuals with extreme resistance representing the unique richness of the forest-steppe landscape as shelters from the scorching sun. Whether they be *Lsi*, *Psy*, or *U*. The last remnants of floodplain forests and riparian vegetation are rapidly disappearing around Mongolian rivers. What nature tries to restore naturally, or man artificially, is destroyed by livestock grazing and browsing. The situation is critical.

However, it is not hopeless. To counteract climate change related impacts and to ensure ecosystem stability, the president of Mongolia Ukhnaagiin Khurelsukh launched the "Billion Trees" national movement with the goal of restoring Mongolian forests. The forestry administration has recently changed with the establishment of the National Forest Agency, and a revision of the Mongolian Law on Forest is also ongoing. The country is heading towards improved forest management and increased tree planting.

It should be noted that as the effects of climate change progress, forests, steppes and water resources are degraded. This also has fatal consequences for the traditional livelihood in the countryside – pastoralism – which is becoming unsustainable in many places. On the other hand, working in forests can represent an alternative way of livelihood and at the same time a direction towards improving their condition. Therefore, the implementation of SFM in selected locations with inevitable human-forest interaction can be mutually beneficial.

In addition to commonly considered fields and activities such as forest protection, two forestry fields – forest tending and forest inventory – are essential for SFM. Since their application is not common in Mongolia, it is appropriate to present them in more detail.

Mongolian forests receive little or no treatment between the time of establishment and the time of harvest. However, the benefits of such ignored care in terms of improved species composition, growth rate and wood quality can be great. Silvicultural treatments applied in that time of forest development are called forest tending. Objectives of tending may include favouring certain species over others, regulating spacing and stand density, removing poorly formed or unhealthy trees, improving the wood quality of the remaining trees by pruning branches, salvaging dead or dying trees and fertilizing soils to increase growth rates.

Several types of intermediate treatments are practiced to regulate species composition and tree growth rates. Cleanings are performed in young sapling and pole stands of desired species and remove larger trees of competing species that suppress the priority trees or are likely to do. Stand density is regulated primarily by precommercial and commercial thinning. The purpose of thinning is to reduce stand density so that the growth of the remaining trees is accelerated. These regulations do not usually increase the total amount of wood produced by a forest. But since fewer trees are using the available light, water and nutrients, the remaining trees become larger, stronger and more vital.

Forest inventory is the basic method of finding out information about forests and its results are a basic indicator of the sustainability of forest management. Forest inventory is defined as the independent examination of forest lands and their development. Depending on the purpose of the inventory, the national forest inventory and an operational forest inventory are distinguished.

The main objectives of the operational forest inventory are:

- To provide complete information on the state of the forest and its development for the needs of the forest management measures.
- To verify development of growing stock in relation to growth or decrease in felling.
- To evaluate the fulfilment of basic forest management criteria (the preservation of health and vitality of forest stands, forest production functions and the biological diversity of forest ecosystems), as well as to reach strategic targets of forest management (the preservation of forests as sustainable and renewable natural resources, to apply principles of sustainable forest management).

3. MATERIALS AND METHODS

3.1 STREAM pilot sites

At local level, the implementation of the STREAM project was proposed in the Khentii and Selenge aimags, where are forest-steppes transitioning into extensive continuous forest complexes of boreal forests. As part of the assignment, six soums from the mentioned aimags were proposed:

- Selenge aimag:
  - Tunkhel
  - Javkhlant
  - Bugant
- Khentii aimag:
  - Umnudelger
  - Binder
  - Bayan-Adarga

Based on this pre-selection, an administrative and field investigation was carried out, followed by the final selection of suitable locations for the implementation of SFM measures. Firstly, GIZ presented the selection criteria for STREAM pilot sites containing the basic information about the potential pilot sites (forest composition, ownership, etc.). Local stakeholders (Forest User Groups) were involved, and they offered potential locations for the implementation of SFM measures at each pilot site. Subsequently, the potential for different types of illustrative demonstrations of SFM at each location was tentatively discussed between GIZ and MENDELU. In addition to the variety of possible SFM measures related to the variety of forests, one of the factors in the selection was also accessibility from the nearest settlement, in order to ensure the continuity and impact associated with education, for which these areas are primarily intended to serve.

Based on the potential of the given locations and local conditions for the realization of SFM measures, MENDELU prepared a final summary of locations (pilot sites) with specific proposals for SFM measures on each of them so that their scope was as varied as possible. This scope was intended to include mainly the weaknesses of forest management in Mongolia – forest restoration (reforestation and afforestation), forest protection and forest tending. The final positions of the sites (Figure 1) and the scope of activities were accepted by the GIZ and local stakeholders.

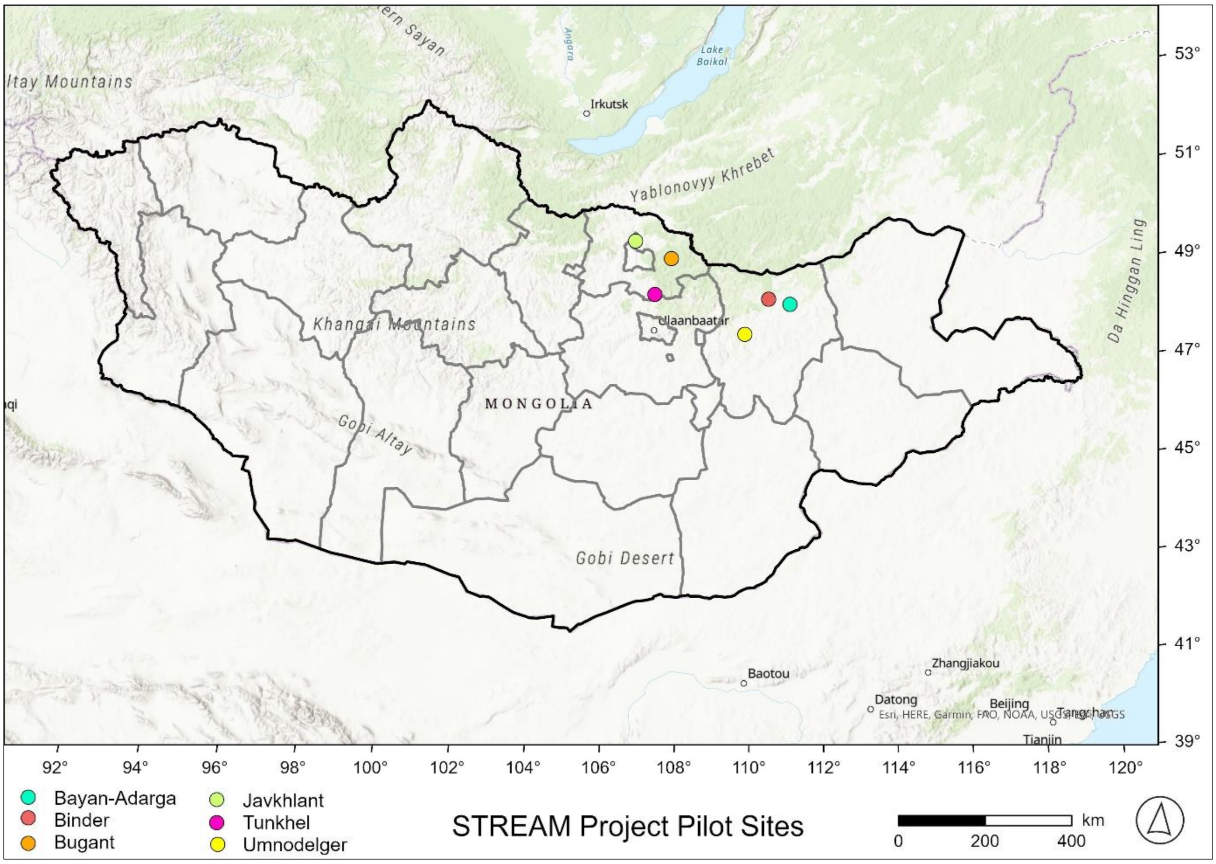

Figure 1. Position of the sites within Mongolia.

3.2 Designing of management measures

MENDELU generally defined SFM measures design suitable for each pilot site in first quartal of 2022. The defined activities at the pilot sites were discussed and confirmed by the GIZ. The landscape was stratified into basic ecosystems (matrix, patches, corridors) and the urgent issues regarding forest and landscape management were identified. Consequently, the main criteria were the representativeness of biotope and environment (no extremes), homogeneity of selected ecosystem, size of the selected site, accessibility, safety and perspectivity for other future activities, especially education.

The design of SFM measures was subsequently updated within the field trip of MENDELU in June-July 2022 considering local conditions during the implementation/realization phase. In general, SFM measures should include demonstrations of underplanting, planting, soil scarification, seedling protection, pruning and thinning. Based on the updates, MENDELU prepared a list of seedling species and numbers as well as a design for their planting for planting events in autumn 2022.

The measures aimed to improve the situation on multiple levels. The main target was to establish a network of variable SFM demonstrations. These should serve as a practical manual for studying proper forest management and contribute to strengthening the ecological, economic and social functions of forests. The dominant management goal was conditioned by the situation at the site; these goals are elaborated in more detail in sub-chapters dedicated to specific sites.

3.3 Realization of management measures

Demonstration plots with SFM measures were established by the consortium with the contribution of the GIZ following MENDELU design during 2022–2023.

The measures/interventions were primarily implemented by experts from MENDELU in cooperation with experts and students from Mongolian universities (Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, Figure 7). Specifically, these were MULS, NUM and GMIT. For the students, it was forestry practice i.e. direct education in the field. In this way, as future foresters and forest managers, they could best learn about the implementation of SFM from the basic position of a forest worker. Local foresters as well as the GIZ were also part of the implementation (Figure 8).

In addition to the construction of exclosures and small fencings, the implementation also included soil scarification, thinning (cutting), pruning, seedling planting, repellent application and forest cleaning. As part of the interventions and management, weeding was also carried out around the seedlings with high weed competition.

Figure 2. Establishing an exclosure for underplanting, Tunkhel.

Figure 3. Establishing an exclosure for planting in the forest-steppe ecotone, Umnudelger.

Figure 4. Planting – re-establishment of riparian forests near Javkhlant.

Figure 5. Marking of thinning intervention in a Bp forest, Bugant.

Figure 6. Marking of thinning intervention in a Lsi forest and related lecturing, Umnudelger.

Figure 7. Realization of pruning and related lecturing, Bugant.

Figure 8. Realization of precommercial thinning, Umnudelger.

In 2022, a total of 98 forest/landscape management plots were established. These included 16 exclosures with planting or underplanting, 10 plots with soil scarification, partially in combination with planting and individual tree protection (repellent), 12 training thinning plots, 28 thinning and pruning plots, 15 plots with planting, underplanting or natural regeneration with individual protection of seedling (repellent, individual fencing) and 17 reference plots for all types of the management interventions. Composition of management measures is unique for each pilot site. Six new plots (two exclosures, pruning, control to thinning, training thinning and thinning) beyond the original design were realized in the summer of 2023.

Thinning demonstration plots were selected according to the management objective. Three types of thinning demonstration plots were established:

- where the thinning intervention was implemented,
- with target trees, candidate trees and trees to be harvested marked,
- for training of thinning tree selection marking.

The demonstration plots for thinning were marked with coloured markers, wooden stakes and iron anchors to make them traceable for the future. All trees for training of thinning were measured and marked with unique numbers. Related information on species, such as DBH, height, basal area, was recorded for each tree, to provide immediate feedback to trainees.

In total, MENDELU and the consortium with partners designed and implemented 104 forest/landscape management measure plots.

During the implementation, there were problems especially regarding the machines for soil scarification and the quality of the seedlings for planting. Despite the availability of a high-quality machine for soil scarification, a suitable tractor was not available in the locations at that time, despite the agreement. Soil scarification was therefore implemented with a less suitable plough. Furthermore, in some locations (all sites in Khentii aimag), suitable planting material of local origin was not available in 2022. The seedlings were too old, overgrown and with a very poorly developed root system. Considering the absence of other seedlings, however, these low-quality seedlings had to be used for planting. The situation was used for an experiment to evaluate the success of plantings while maintaining the correct principles in the manipulation, handling, transportation and plating of seedlings, but low-quality seedlings. On the basis of the results, it will be possible to evaluate the importance of the quality of seedlings and thus the role of forest nurseries.

Tree species for planting were selected specifically for each site and plots with regard to their potential for the given habitat and natural occurrence in the area. The design of planting and seedling numbers were updated after the planting based on the real situation in the field. In 2022, a total of 2,161 seedlings were planted of which there were 538 *Lsi*, 844 *Psy*, 242 *S*, 212 *P*, 113 *Hr*, 68 *Cs* and 144 *Up* (Table 1). In the fall of 2023, repair planting of seedlings (instead of those that died) took place in exclosures, where the seedlings were sufficiently protected from browsing. In addition, two more plots in Javkhlant were established with extensive planting. Related details are presented later in the text along with survival rate results.

Table 1. Numbers of seedlings of different woody species planted at the sites in 2022.

Site	*Lsi*	*Psy*	*S.*	*P*	*Hr*	*Cs*	*Up*	Total
Tunkhel	122	203	0	0	0	0	0	325
Javkhlant	0	5	242	212	113	0	144	716
Bugant	32	50	0	0	0	0	0	82
Umnudelger	241	0	0	0	0	0	0	241
Binder	143	147	0	0	0	55	0	345
Bayan-Adarga	0	439	0	0	0	13	0	452
Total	538	844	242	212	113	68	144	2,161

3.4 Research and monitoring activities

An essential part of implementing SFM is respecting the natural conditions of the habitat. For that reason, experts from the consortium conducted a thorough investigation of environmental conditions at all sites, including an assessment of climatic conditions, soil and vegetation (2022–2023). Research activities at the sites can be divided into (I) short-term data collection and (II) long-term monitoring.

I. Short-term data collection included a one-time soil survey with the determination of soil types (Figure 9) with accompanying laboratory analyses of soil characteristics. It also included pedoanthracological mapping, botanical assessment of herb layer (Figure 10) and dendrological assessment of forest stands.
II. The state of the soil and climatic conditions are continuously monitored with a focus on temperature and moisture (Figure 11) and on precipitation (rainfall) (Figure 12) and air temperature, respectively.

These data are essential for understanding the natural extent of forests, their functioning, potential, limits, threats and for the preservation of biodiversity. Without such data, it is not possible to responsibly design SFM.

Figure 9. Describing the soil profile, soil characteristics and determining the resulting soil type. These characteristics are key for determining the water regime of soils and their nutrient enrichment. This affects the functioning and growth of the forest, as well as its species composition.

Figure 10. Botanical survey and identification of herb species. Important as a basis for determining the impact of SFM on biodiversity.

Figure 11. Downloading soil temperature and moisture data.

Figure 12. Downloading precipitation (rainfall) data.

3.5 Forest inventory

As part of the forest inventory, there was a detailed description of the state of forest stands. In each demonstration plot, DBH (1.3 m) of all trees was measured and exemplary individuals were selected for which height was measured and stem bore cores were taken to determine their age.

Measurement of tree (trunk) diameter

Tree diameters were measured with either an electronic or mechanical callipers. Digitech Professional (DP) II Haglöf electronic calliper with Tims software was used (Figure 13). The measurement of tree DBH with the calliper followed the basic procedures and rules for this measurement. Specific example of measurement of tree trunks diameter using DP II calliper Haglöf can be as follow:

1. **Settings - Default list**
    a. **SPECIES PARAMS** – select or overwrite the trees occurring on the area (YES/NO) ***(choose or overwrite code of trees)***
    b. ***Always in menu***: DEAD, STUMP, OST
2. ***Creating measure file***
    a. REGISTRATION – NEW LIST – DEFINED VALUES: YES
    b. ***Name of list***: ID Cluster – ID Plot (example: 381-1, 2-1)
    c. ***Confirm***: DATE, TYPE OF MEASURING: STANDING, TYPE OF INVENTORY: SAMPLE PLOTS, PLOT COORDINATE: NO, AREA: 0.05 ha, VOLUME CALCULATION: FORM FACTOR, MEASURE HEIGHT FOR EVERY TREE: NO, OPTIONS: Nothing
3. ***Measuring DBH***
    a. MEASURE
    b. Plot Nr: 1, area: 400 m^2
    c. ***Choose species – left or right button***
    d. ***Measure DBH (1. strongest, 2. 90° rotate)***
    e. ***Edit - Change species*** – **Back (left + down) – Option edit**
4. ***Edit height of tree individual***
    a. Option ***Height*** ~ ***(Back (left + down)***
    b. ***Choose tree – edit height***
5. ***Data result and send***

a. Option ***(Exit)*** ~ ***(Back (left + down)***
c. RESULT
d. SEND DATA – TO FILE – EXCEL – TREE BY TREE
e. EXIT

Figure 13. Determining tree diameter using a digital electronic calliper within lecturing.

Measurement of tree (trunk) height

Vertex Laser Geo hypsometer was used to measure tree heights (Figure 14). Total stem height is defined as the vertical distance between the horizontal plane intersecting the uppermost vegetative organ of the stem and the horizontal plane intersecting the base of the stem. The heights ware measured using Vertex Laser Geo. This instrument provides several ways in which height can be measured.

Using the HEIGT 3P function, the height can be measured using a laser rangefinder. The prerequisite is a clear view of the tree trunk to determine the distance from the trunk and the base and top of the tree visible from one location to determine the angle of intent.

If undergrowth and other obstructions do not allow a clear view of the tree trunk and it is not possible to ensure that the base and top of the trunk are visible from one location, it is advisable to use the HEIGHT DME function to measure the trunk height. This function uses ultrasonic wave reflection to determine the distance to the tree. The condition is that the ultrasonic reflector is correctly positioned on the trunk at its elevation or other height, which must match the TRP setting. HGT. At the same time, the meter should see the reflector to ensure the correct angle of aim.

The height of the trunk must be measured from a suitable point in the stand; the condition is that the base of the trunk or the reflector and the top of the trunk should be clearly visible from this point. The height will be measured from at least the distance of the approximate height of the trunk. The principle that measurements against the slope should only be used in exceptional cases (significant distortion of heights may occur) should be followed. When measuring heights, the basic procedure is to measure the height along the contour, while maintaining sufficient spacing.

For trunks where the projection of the top of the crown is offset from the base of the trunk, a special procedure is used to measure the height. However, care should be taken when measuring a leaning trunk on a slope. It must be ensured that the reflector is at the height of the trunk. Therefore, if possible, the height of leaning trunks should be measured along the contour or perpendicular to the direction of deflection.

Figure 14. Determining tree heights using a Vertex Laser within lecturing.

Determination of tree age

Pressler increment borer was used to determine age of trees (Figure 15). It was used only for trees for which diameter and height were also measured. Using the tool, the dendrochronological bore core (sample) is taken. The bore core is made at the point of DBH.

The first few turns of the drill bit before the outer thread of the orbiter takes hold are crucial for the quality of the bore core. The drill bit should be pushed into the wood and the spindle turned so that sideways movement is minimal. If too much crimping is done, the marginal tree rings will tear and make it difficult to extract the sample. The moment the outer thread of the drill bit is cut, it is necessary to stop pushing on the drill bit and just turn the spindle smoothly. The drill bit only needs to be drilled into the center (core) of the trunk. Once this is reached (the depth of the bore can be estimated by the length of the spoon), the spoon is inserted into the drill cavity. The bore core is "undercut" without using force and the spoon is gently pushed into the drill bit. To gently pry out the sample away from the center of the trunk, rotate the drill bit one and a half turns backwards and half a turn forwards. Only then is the bore core pulled out with the spoon. The entire drill bit is then drilled out of the tree. The sample on the spoon must be moved over the prepared plates, where the sample is gently removed with a knife and placed in the plates. It is advisable to carry out this operation above the bore core folder, as the bore core is usually broken, and it is necessary to add the parts one by one. It is very important to maintain the correct order of the individual parts of the bore core. Subsequently, tree rings are counted and thus the age of the tree is determined.

Figure 15. Determining tree age using an increment borer.

4. SUSTAINABLE FOREST MANAGEMENT MEASURES

4.1 Khentii province

4.1.1 Tunkhel

4.1.1.1 Site introduction

Tunkhel forest-steppe site (48°40'07.8"N 106°52'37.5"E; Table 2) is characterised by an intensive pastureland utilization and large-scale complexes of mixed forests. The area is affected by the presence of permafrost. The forests are managed by the GIZ and therefore have great potential for promoting SFM and environmental education under continuous and long-term supervision. There is a railway in the nearby town Tunkhel, which is an important advantage for timber transport. There are also forest nurseries (small household productions) and a sawmill in the town.

Table 2. Basic site characteristics of Tunkhel area.

Elevation (m a.s.l.)	Parent rock	Soil type	Dominating ecosystem	Forest composition
1,150	Gray-green shale	Cambic Phaeozem Loamic	Forest-steppe	*Bp-Psy* forest

The forests are composed mainly of *Lsi* and *Bp*. According to available sources, *Psy* also grew in the area before, but it disappeared from the forest stands due to irresponsible selective logging. Forest stands are sparse with frequent canopy openings. The height structure of forest stands is probably affected by fire and grazing; natural regeneration is limited and usually regularly damaged by browsing. Artificial planting was implemented to a limited extent in one experiment with non-functional protection and management.

The area was damaged by a fire several years ago, after which part of the forest failed to fully recover. A thick layer of weeds prevents the natural regeneration of the unstocked forest in the fire-degraded area. Another problem is forest grazing, which limits success of natural forest regeneration, especially in the edge zones. Although there are many good forestry projects in the area, there is a lack of I) sustainability and/in commercialization and II) management and tending of the young and premature forest stands.

The high production potential of forest stands is unfulfilled; on the contrary, with regard to their condition, the provision of other ecosystem services may also be threatened. The continuous threat of forest retreat and loss caused by intensive grazing at the forest-steppe transition and fires is accompanied by consequences such as temperature growth, permafrost degradation, aridization and loss of wood resources. For this reason, forestry intervention is appropriate with an important application of SFM.

4.1.1.2 Objectives of SFM measures

Local forestry measures should serve as a practical manual for studying proper forest management and contribute to the forest restoration in the post-fire unstocked forest area. Partial measures should represent ways of I) supporting and protecting natural forest regeneration, II) artificial forest regeneration and protection, III) improving forest stability, health, and heterogeneity and IV) increasing economic value of timber and the forest in general. This should also include the reintroduction of the economically valued *Psy*. With regard to the possibility of simplified rail transport of wood to Ulaanbaatar and the perspective for production management thanks to favourable environmental conditions, production function should be preferred to meet the national demand for wood and protect more vulnerable forest ecosystems from logging.

The planned activities will help to maintain the forest in its natural range and enable its simultaneous sustainable utilization in a way that could support local community and national wood market. Higher profits from better quality timber can provide financial resources for the forest protection and healthy and resilient forest will reliably provide ecosystem functions for current and future generations. In addition, long-term research and monitoring of natural conditions will support the local management and enable the evaluation of the situation on a wider scale.

The aim of the measures should be:

- To improve stability, health, vitality and heterogeneity of the forest.
- To increase economical value of the forest.
- To protect permafrost.
- To restore forest on the unstocked forest areas with unsuccessful natural regeneration.
- To support natural forest regeneration.
- To support local forest production and community.
- Awareness raising & knowledge sharing.

4.1.1.3 Forest management measures

With regard to the character and state of the forest, the implemented SFM measures (Figure 16, Table 3) can be divided into three main categories:

1. Forest regeneration (reforestation)
2. Forest protection
3. Forest tending

The measures are located in three different types of forest:

a) Sparse mixed forest (*Bp*, *Lsi*)
b) Fire-affected unstocked forest
c) Young *Lsi* stand

In total, 15 demonstration plots were established at Tunkhel site (Figure 16, Table 3).

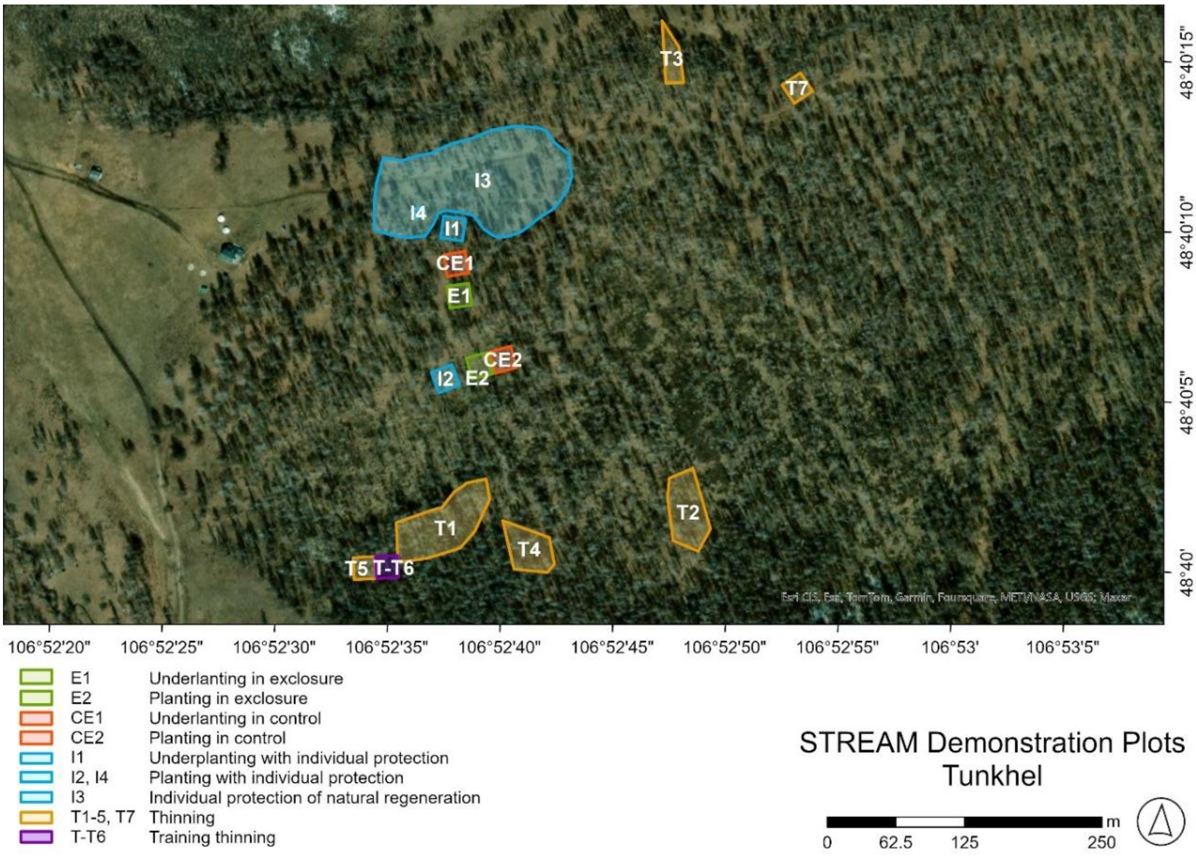

Figure 16. The distribution of forest management measures at the Tunkhel site.

Table 3. A summary of interventions at Tunkhel site.

ID	Intervention	Ecosystem	General category	Main goal	What do we want to show	Description	Size (m)	Area (ha)
E1	Underplanting in exclosure	*Bp*-Lsi forest	Reforestation	Reforestation under the protection of the shelterwood/current stand and protection of planted seedlings from browsing	How to do artificial reforestation with a high level of seedling protection in sparse forests	Fully fence-protected seedlings (*Lsi* domination, *Psy* admixture) planted into gaps in the sparse stand	20×20	0.04
CE1	Underplanting in control	*Bp-Lsi* forest	Reforestation control		How to do artificial reforestation with no seedling protection in sparse forests: Is it possible to do it successfully?	Unprotected seedlings (*Lsi* domination, *Psy* admixture) planted into gaps in the sparse stand	20×20	0.04
I1	Underplanting + individual protection	*Bp-Lsi* forest	Forest protection		How to do artificial reforestation with a low level of seedling protection in sparse forests	Seedlings (*Lsi* domination, *Psy* admixture) with terminals protected by repellent planted into gaps in the sparse stand	20×20	0.04
E2	Planting in exclosure	Unstocked forest	Reforestation	Reforestation in the burned forest area and protection of planted seedlings from browsing	How to do artificial reforestation with a high level of seedling protection in unstocked forests	Fully fence-protected seedlings (*Psy* domination, *Lsi* admixture) in the unstocked forest	20×20	0.04
CE2	Planting in control	Unstocked forest	Reforestation control		How to do artificial reforestation with no seedling protection in unstocked forests: Is it possible to do it successfully?	Unprotected seedlings (*Psy* domination, *Lsi* admixture) planted in the unstocked forest	20×20	0.04
I2	Planting + individual protection	Unstocked forest	Forest protection		How to do artificial reforestation with a low level of seedling protection in unstocked forests	Seedlings (*Psy* domination, *Lsi* admixture) with terminals protected by repellent planted in the unstocked forest	20×20	0.04
I3	Individual protection of natural regeneration	*Bp-Lsi* forest	Forest protection	Protection of naturally-occurring seedlings	How to increase the success (successful growth) of natural forest regeneration with a low to medium level of seedling protection	Naturally-occurring seedlings with terminals protected by repellent or individually fenced	-	1.31

Table 3. (Continued).

I4	Planting + individual protection	Forest gap	Forest protection	Reforestation in the forest gap and protection of planted seedlings from browsing	How to do reforestation in forest gaps with a low level of seedling protection	Seedlings (*Lsi*) with terminals protected by repellent planted in the forest gap with unsuccessful natural regeneration	-	0.01
T1	Thinning	*Bp-Lsi* forest	Forest tending	Light availability management of the forest (modification of the spatial structure)	How to stimulate natural forest regeneration and mature tree volume growth	Thinning, release of young *Lsi*, support of natural forest regeneration	-	0.40
T2	Thinning	*Bp-Lsi* forest	Forest tending		How to stimulate growth of existing naturally-occurring seedlings and mature tree volume growth	Thinning, release of young *Lsi*, support of natural forest regeneration	-	0.25
T3	Thinning	*Bp-Lsi* forest	Forest tending	Support of target trees (modification of the spatial structure)	How to increase target trees volume growth, quality and health	Release of promising target tree individuals	20×35	0.07
T4	Thinning	*Bp-Lsi* forest	Forest tending	Light availability management of the forest (modification of the spatial structure)	How to stimulate growth of existing naturally-occurring seedlings and mature tree volume growth	Thinning, release of young *Lsi*, support of natural forest regeneration	-	0.15
T5	Thinning	*Lsi* forest	Forest tending	Support of target trees (modification of the spatial structure)	How to increase target trees volume growth, quality and health	Release of promising target tree individuals	20×20	0.04
T-T6	Training thinning	*Lsi* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to propose a thinning intervention	Stand with full numbering of trees for thinning training (comparation to T5 - realized)		
T7	Thinning	*Bp-Lsi* forest	Forest tending	Light availability management of the forest (modification of the spatial structure)	How to stimulate natural forest regeneration and mature tree volume growth	Thinning, release of young *Lsi*, support of natural forest regeneration	20×20	

E1 Underplanting in exclosure

The demonstration of forest regeneration by underplanting of *Lsi* and *Psy* seedlings in the sparse forest. At the same time, commercial tree species are introduced into the stand with *Bp* domination. The goal is to show an artificial reforestation with a high level of seedling protection from browsing (by fencing) and climatic extremes (provided by the surrounding trees) in sparse forests (Figure 17). The intention is to (I) increase the productivity of the forest with the support of commercial tree species and (II) ensure a continuous soil cover by trees to regulate the microclimate and protect permafrost.

CE1 Underplanting in control

The description is the same as in the case of the E1 plot, the difference is that there is no protection against browsing (Figure 18). The plot is also used to find out the necessity of protecting of seedlings against browsing.

I1 Underplanting + individual protection

The description is the same as in the case of the E1 plot, the difference is that there is low protection against browsing by repellent applied to terminal shoots (Figure 19). The plot is also used to compare the effectiveness of seedling protection by repellent and fencing.

Figure 17. Fencing protecting planted seedlings from browsing in the sparse forest (E1). Once the seedlings outgrow the risk of the browsing terminal, the fence can be removed and used elsewhere.

Figure 18. Underplanted Lsi without any protection at the control plot in sparse mixed forest (CE1).

Figure 19. Underplanted Lsi (detail in the bottom right corner) with individual protection of seedlings by repellent at the plot in sparse mixed forest (I1).

E2 Planting in exclosure

The demonstration of necessary artificial reforestation in the burned forest area with extreme conditions (without the shade of trees and high weed competition) where natural regeneration has failed and without artificial intervention or another fire is unlikely in the horizon of several decades. Intervention is therefore necessary to provide continued provision of forest functions. The goal is to show the artificial reforestation with an emphasis on the introduction of commercial tree species (*Psy* and *Lsi*) with a high level of seedlings protection from browsing by fencing (Figure 20).

CE2 Planting in control

The description is the same as in the case of the E2 plot, the difference is that there is no protection against browsing (Figure 21). The plot is also used to find out the necessity of protecting of seedlings against browsing.

I2 Planting + individual protection

The description is the same as in the case of the E2 plot, the difference is that there is low protection against browsing by repellent applied to terminal shoots (Figure 22). The plot is also used to compare the effectiveness of seedling protection by repellent and fencing.

Figure 20. Fencing protecting planted seedlings from browsing in the burned forest area (E2). Regular weeding is necessary (approximately 1–2 times a year) in this open-space area with soils rich in nutrients and high soil moisture level to ensure successful seedling growth.

Figure 21. Planted seedlings without any protection at the control plot in the burned forest area (CE2).

Figure 22. Planted seedlings with individual protection by repellent at the plot in the burned forest area (I2).

I3 Individual protection of natural regeneration

The demonstration of protection of naturally occurring seedlings. The goal is to show how to increase the success (successful growth) of natural forest regeneration with a low to medium level of seedling protection from browsing by repellent or individual fencing, respectively (Figure 23). The protection of seedlings originating from natural regeneration focuses on all tree species in the stand in order to preserve and promote biodiversity. New shoots will easily grow through the repellent if it is applied correctly (Figure 24).

I4 Planting + individual protection

The demonstration of forest regeneration by planting of *Lsi* seedlings at the forest gap. This area was conceived as an experiment, where weaker and less vital seedlings were planted in two pieces per hole (Figure 25). There is low protection against browsing provided by repellent applied to terminal shoots.

Figure 23. Various methods of individual protection of seedlings – protective coating of the terminal shoot with repellent and individual fencing of entire seedlings (I3). The protective coating must be repeated according to the situation (weather conditions) every few months, individual fencing must be removed at the right time to avoid damaging the tree.

Figure 24. An example of new shoots that have grown through a protective repellent applied in the autumn of the previous year.

Figure 25. Planted seedlings (two per hole) before application of repellent at the plot on the forest gap (I4).

T1 Thinning

The demonstration of light availability management through the modification of the spatial structure in the mixed forest. The goal is to stimulate and support natural forest regeneration and mature tree volume growth. In this thinning intervention, young *Lsi* individuals are released, especially by removing low-quality *Bp* individuals and by improving light conditions, the natural regeneration of the forest stand will be stimulated and supported. Furthermore, promising *Lsi* individuals (target trees) are supported by removing competing trees (Figure 26).

T2 Thinning

The description is the same as in the case of the T1 plot (Figure 27).

T3 Thinning

The description is the same as in the case of the T1 plot; support for target trees is a priority (Figure 28).

Figure 26. Marked support of high-quality target trees (orange stripe) with high economic value through removal of competing trees (orange dot) in the mixed forest (T1). Unmarked healthy trees are left in the stand. A blue dot indicates that the trees have been inventoried.

Figure 27. Marked support of high-quality target trees (orange stripe) with high economic value through removal of competing trees (orange dot) in the mixed forest (T2).

Figure 28. An example of choosing the best quality target tree that deserves future support at the expense of other quality individuals in the vicinity (T3).

T4 Thinning

The description is the same as in the case of the T1 plot. Support of naturally regenerated *Lsi* seedlings presented in the forest stand is a priority. High-quality *Bp* can also be supported as a target tree (Figure 29).

T5 Thinning

The demonstration of the modification of the spatial structure with the support of promising target trees in the *Lsi* forest stand. The main goal is to stimulate and support growth of the remaining trees (Figure 30). In this thinning intervention, promising *Lsi* individuals (target trees) are supported by removing competing trees.

T-T6 Training thinning

The description is the same as in the case of the T5 plot, however, the intervention is not realized, and the plot is dedicated for training of thinning marking (Figure 31). This plot without the implementation of the intervention can be compared with the adjacent plot after the implementation of the intervention.

T7 Thinning

The description is the same as in the case of the T1 plot (Figure 32).

Figure 29. An example with marked trees for cutting to support natural regeneration of the forest and high-quality target trees (orange stripe) in the mixed forest with a predominance of Bp (T4).

Figure 30. Forest hygiene with marked thinning intervention with the support of target trees (yellow stripe) in the Lsi stand (T5).

Figure 31. Marked and numbered thinning intervention with the support of target trees (yellow stripe) in the Lsi stand before thinning intervention (T5) and Lsi stand dedicated to training in the background (T-T6).

Figure 32. Marked thinning intervention in the mixed forest (T7).

4.1.1.4 Tree planting

In autumn 2022, 325 seedlings from the local production (small household productions in Tunkhel town) were planted in Tunkhel (Table 4). Of this number, 122 were *Lsi* seedlings and 203 were *Psy* seedlings. *Psy* planting prevailed in the open area where the forest was destroyed by fire. *Lsi*, on the other hand, was mainly used in underplanting and in the forest gap area with regulated light conditions. Other tree species were not used due to their natural absence in the locality or natural regeneration (*Bp*).

Table 4. Numbers of seedlings planted in Tunkhel in 2022.

ID	Intervention	Main goal	*Lsi*	*Psy*	Total
E1	Underplanting in exclosure	Reforestation under the protection of the shelterwood/current stand and protection of planted seedlings from browsing	20	3	**23**
CE1	Underplanting in control		20	3	**23**
I1	Underplanting + individual protection		20	3	**23**
E2	Planting in exclosure	Reforestation in the burned forest area and protection of planted seedlings from browsing	10	66	**76**
CE2	Planting in control		10	62	**72**
I2	Planting + individual protection		10	66	**76**
I4	Planting + individual protection	Reforestation in the forest gap area and protection of planted seedlings from browsing	32	0	**32**
Total planted seedlings in Tunkhel			122	203	**325**

Spacing for plantings was designed 2.6×2.6 m for underplanting and 2.2×2.2 m for plantings in the open area. In the case of underplanting, the distribution of seedlings followed forest stand gaps with the absence of trees and better light conditions.

The success rate of plantings was medium to low (Table 5) although the results cannot be considered final. In the case of *Psy* (Figure 33), one of the factors for the high mortality (around 50%) may be the young age of the seedlings used; it would be better to plant seedlings one year older, but they were not available in the nurseries. The shock associated with transplantation may have been critical at such a young age.

Table 5. Mortality of seedlings planted in Tunkhel (evaluated in September 2023).

ID	Intervention	Mortality (%)		
		Lsi	*Psy*	Total
E1	Underplanting in exclosure	70	0	61
CE1	Underplanting in control	95	100	96
I1	Underplanting + individual protection	90	0	78
E2	Planting in exclosure	0	36	32
CE2	Planting in control	20	69	63
I2	Planting + individual protection	30	53	50
I4	Planting + individual protection	100	-	100

In the case of *Lsi*, the numbers of mortality can be considered indicative as only needle damage was visible in September (Figure 34), which may look like seedling death (they look like withered). The first detailed inventory after the winter (in June 2023) showed a survival rate of *Lsi* 97–100%. The summer period was therefore critical for the development of the damage. The damage to the assimilation apparatus was probably caused by a combination of extremely humid weather (compared to the normal semi-arid conditions of Mongolia) and a biotic agent. The results of the monitoring of climate and soil conditions at the site indicated extreme rainfall events and increased soil moisture during the summer season. The accompanying growth of weeds and the creation of extreme microclimatic conditions could contribute to the development of fungal diseases causing the damage. The damage could also have been caused by an insect pest. However, it is probable that the damaged *Lsi* seedlings will resprout next spring and survive the damage.

Seedling damage by browsing was only around 10%. Size of the seedlings (so far very small) probably contributed to such low damage.

Figure 33. Some Psy individuals showed significant annual growth. Such young and developed seedlings are more suitable for planting than the originally used ones.

Figure 34. Damage to Lsi needles at the end of the growing season.

Repair planting was carried out in September 2023. It was realized only at the fenced plots to maintain protection against browsing. As the damaged *Lsi* seedlings were expected to regenerate, they were left at the plots and only the dead *Psy* individuals were replaced. Therefore, repair planting only concerned the E2 plot (Table 5). Only *Lsi* was planted due to the good quality of the available seedlings and the results from June 2023. The root system of the newly planted seedlings was treated with hydrogel in local forest nursery. A total of 25 seedlings were planted within the repair planting.

Highly needed weeding was carried out in June (Figure 35) and September 2023 in all planted plots (only in the immediate vicinity of the seedlings).

Figure 35. Plot CE2 after weeding around the seedlings.

4.1.1.5 Forest inventory

The results of the forest inventory on thinning plots are summarized in Table 6. The results summarize the basic descriptive characteristics of forest stands and their development in the case of thinning intervention. Inventory details, including species composition, are part of a separate document.

The T-T6 plot was intended for training purposes only. Therefore, the inventory was not necessary, and it is only marked. The key to determine/mark the thinning intervention in the stand with full tree numbering is presented in Table 7.

Table 6. Forest inventory at thinning plots in Tunkhel.

Plot	H_{sup} (m)	Age_{avg} (years)	Thinning intervention				
			Characteristic (unit)	Pre-thinning	Post-thinning	Thinning	
T1	9.6		BA (m^2/ha)	21.5	4.9	16.6	Intensity = 77%
			DBH_{avgBA}/DBH_{avg} (cm)	20.5	21.4	20.3	
			Density (stems/ha)	653	138	515	
			Vol (m^3/ha)	103	23.7	53.1	
T2	15	42	BA (m^2/ha)	34.3			Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)	19.1			
			Density (stems/ha)	1,200			
			Vol (m^3/ha)	257			
T3			BA (m^2/ha)	5.1			Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)	17.5			
			Density (stems/ha)	214			
			Vol (m^3/ha)				
T4	16.3	42	BA (m^2/ha)	16.8	4.4	12.4	Intensity = 74%
			DBH_{avgBA}/DBH_{avg} (cm)	19.4	15.9	21.3	
			Density (stems/ha)	567	220	347	
			Vol (m^3/ha)	136	35.5	39.7	
T5	18.9	66	BA (m^2/ha)	27.1	24.0	3.1	Intensity = 11%
			DBH_{avgBA}/DBH_{avg} (cm)	16.0	16.7	12.5	
			Density (stems/ha)	1,350	1,100	250	
			Vol (m^3/ha)	257	228	9.8	
T-T6			BA (m^2/ha)				Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)				
			Density (stems/ha)				
			Vol (m^3/ha)				
T7	13.6	47	BA (m^2/ha)	31.5	21.5	10.0	Intensity = 32%
			DBH_{avgBA}/DBH_{avg} (cm)	18.9	18.5	19.8	
			Density (stems/ha)	1,125	800	325	
			Vol (m^3/ha)	214	146	32.2	

Table 7. Numbers of trees at the plot T-T6 intended for thinning intervention.

Tree species	Thinning intervention	
	Target trees	Trees for cutting
Larix sibirica	4, 6, 11, 17, 21, 25, 28, 35, 36, 44, 46, 49, 51, 52, 56	26, 34, 35, 37, 39, 40, 47, 48
Betula platyphylla	5, 15, 20, 29, 31, 32	12, 13, 24, 33, 60

4.1.1.6 Recommendations for forest management

Based on experience after the first year since establishment, it is possible to recommend the following forest management for plots with the measures and surrounding forest stands:

- Due to interruption of maintenance and inspections of the SFM plots (before the STREAM project), these have lost much of their value in demonstrating SFM best practices. The wood prepared for the production of charcoal remained unused in the forest and degraded wood. The fence built to protect the seedlings was full of holes and did not fulfil its protective function. Trees with individual protection overgrew the protective fencing and were limited in growth by it. The situation resulted in significant financial losses and degradation of the forest. The main recommendation for forest management is therefore to assign it to a responsible person (forester/forest manager) who will take care of the forest.
- The aim of the forest manager should be primarily to support the production functions of the forest together with their stability and vitality.
- It is necessary to reduce forest grazing.
- Regular inspection of the forest (approximately once a month). In the case of natural disasters or a higher risk of the occurrence and impact of negative factors (e.g. long periods of drought, season with high risk of pest outbreaks), it is necessary to carry out inspections more often.
- The results of the plantings indicate that it is advisable to continue the reintroduction of *Psy* into the local forest stands where it naturally belongs. Since a large part of the forest edge is too sparse and commercial tree species have disappeared from it (as a result of long-term selective logging and grazing), it is advisable to continue underplanting *Lsi* and its responsible protection.
- Regular inspection of the condition of the fencing (at least once a month). It is also advisable to check the situation after extreme events such as storms and strong winds. Branches or whole trees can fall on fences and seriously damage them. If even one goat gets into the exclosure, all the seedlings can be damaged within a few hours.
- Regular inspection of the condition of the seedlings in the exclosures (approximately once every two weeks). Accordingly, it is possible to plan further necessary interventions (e.g. weeding, special action for seedling protection against game, livestock, insect pests and pathogens). In this case, it was certainly appropriate to use

a chemical spray (probably insecticide) on *Lsi* seedlings that were attacked and damaged by a biotic pest probably during August.

- Regular weeding 1–2x per year depending on the rains and the situation in the exclosures. The expected suitable month with the necessary first weeding intervention is July. It is sufficient to implement weeding only in the immediate vicinity of the seedlings (50 × 50 cm). The weeded biomass is left spread around the seedling as a mulch to improve soil moisture conditions and prevent further rapid weed growth. Protecting seedlings from damage is a priority, so weeding must be done carefully by a responsible worker.
- As soon as the seedlings outgrow weeds and the risk of terminal browsing (1.5–2 m), it is possible to remove the fences and use the mesh to build new exclosures where necessary. This may take approximately 7–10 years.
- The application of the repellent must be done carefully to avoid damaging tree (seedling) buds. This damage can also be caused by a too thick layer of repellent, which prevents needles or leaves from sprouting in the spring. Damage of a similar nature was rarely recorded on both *Lsi* and *Bp*.
- Implementation of marked thinning interventions and transport of wood from the forest. With regard to the missing permit and the complicated provision of skidding, it was not possible to implement thinning interventions at most of the thinning plots. However, their implementation is essential in the forest. The forest manager's task this year will therefore be to implement the marked interventions dedicated to realization and to apply their principle to other parts of the forest.
- After felling mature trees in the thinning interventions with the main goal targeted on light availability management of the forest (modification of the spatial structure), undergrowth with seedlings from natural forest regeneration will already be safe from browsing and weeds. Further care for them is therefore not necessary, it is only necessary to ensure that they are not damaged during logging operations and skidding.
- Reasonable selective cutting in forests may continue, but a balance needs to be found with the simultaneous reintroduction of commercial tree species. That should be one of the fundamental principles of sustainability.
- To develop the vitality, stability and economic value of the forest, it is necessary to practice forest regeneration, protection and tending and not only the final selective

cutting. The layout of these activities must be based on a responsible SFM and forest management plan. Therefore, updating and following the existing plan is essential.

4.1.2 Javkhlant

4.1.2.1 Site introduction

Javkhlant steppe site (49°45'06.2"N 106°10'14.7"E; Table 8) is characterised by an intensive pastureland utilization with signs of aridization and desertification and a moving sand dune. Long-term herding and grazing in the area resulted in the pastureland degradation together with loss of riparian forest composed mostly of willows along the Shariin Gol River approximately twenty years ago. The presence of the river and the interest of the locals in restoring the landscape represents a great opportunity for development and implementation of demonstrations of sustainable landscape management. Plantations and a forest nursery were established in a nearby village Javkhlant. In addition, there is a large exclosure with plantings established by the FAO. This exclosure is directly adjacent to the site with our measures.

The threat of continued aridization and desertification caused by the current too intensive utilization of the landscape is accompanied by consequences such as the loss of pasture production and deterioration of water quality up to the definitive loss of pastureland and water from the river.

Table 8. Basic site characteristics of Javkhlant area near the river.

Elevation (m a.s.l.)	Parent rock	Soil type	Dominating ecosystem	Forest composition
700	Fluvial and eolian sediments	Stagnic Fluvic Phaeozem Arenic Turbic	Steppe	-

The site represents a transect from a sand dune across a degraded steppe to the river. Due to intensive grazing and trampling, it is not possible for the dune to be covered by vegetation naturally, and therefore it moves due to the action of the wind. Climatic conditions in the region allow *S* to grow along rivers and *P* and *Up* also in the steppe or on sandy soils, respectively.

The main problem is overgrazing, which limits vegetation growth and accelerate soil erosion and landscape degradation. However, the landscape also lacks original natural ecosystems that can serve as centres of biodiversity and wind barriers, which have been destroyed by the joint action of humans (e.g, logging for firewood) and grazing. To limit landscape degradation, it is necessary to implement the principles of sustainability in landscape management, limit grazing and restore original ecosystems to provide ecosystem services.

4.1.2.2 Objectives of SFM measures

Local measures should serve as a practical manual for studying proper landscape management, restoration of valuable small fragments of forest-like habitats (woody features; hedgerows) in steppe landscape and contribute to the restoration of riparian forest. Partial measures should represent ways of I) sand dune stabilization, II) providing shelter from the wind and protecting soil from erosion, III) riverbank and water protection, IV) supporting biodiversity and V) presenting the possibilities of accompanying landscape production as a possible additional source of income for local communities.

The main target is the establishment of tree shelterbelt following the sand dune-steppe-river bank gradient. The shelterbelt must be composed of the tree species adapted to specific site conditions to promote sustainability. In addition to stabilizing the soil, reducing wind speed and supporting pasture production, their contribution should also be in the production of plant biomass. Produced fruits and sprouts can be used by local communities in the future and contribute to their development.

Furthermore, restoring part of the riparian forest will help water in the river and local livestock: it will reduce soil erosion, water pollution and evaporation, and provide shade. In addition, long-term research and monitoring of natural conditions will support the local management and enable the evaluation of the situation on a wider scale.

The aim of the measures should be:

- To improve quality of the pastureland.
- Reintroduce native tree species to the landscape.
- To decrease wind speed.
- To provide a source of shade in an open landscape.
- To mitigate sand transport into nearby settlements.
- To mitigate soil erosion.
- To restore part of the original riparian forest and its ecological functions.
- To support biodiversity.
- To support local agricultural production and community.
- Awareness raising & knowledge sharing.

4.1.2.3 Landscape management measures

With regard to the character and state of the landscape, the implemented forestry measures (Figure 36, Table 9) can be divided into three main categories:

1. Afforestation
2. Reforestation
3. Forest protection

The measures are located in three different ecosystems:

a) Sand dune area
b) Steppe area
c) Riverbank area

In total, 11 demonstration plots were established at Javkhlant site (Figure 36, Table 9).

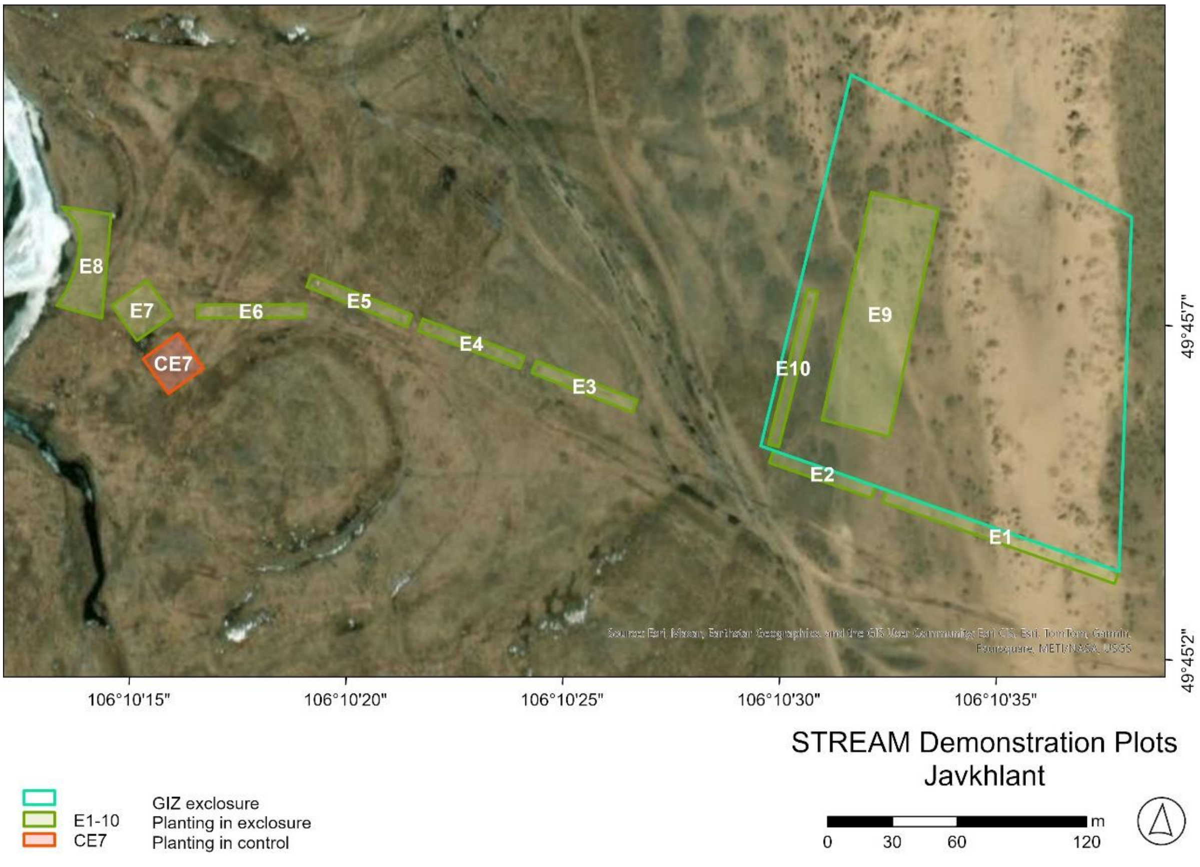

Figure 36. The distribution of landscape management measures at the Javkhlant site.

Table 9. A summary of interventions at Javkhlant site.

ID	Intervention	Ecosystem	General category	Main goal	What do we want to show	Description	Size (m)	Area (ha)
E1	Planting in exclosure	Sand dune and steppe	Afforestation	Establishment of a shelterbelt in open steppe (connecting the agriculture unit's shelterbelt with the river via several hedgerow segments on the gradient of the sand dune-degraded steppe-river bank) and protection of planted seedlings from browsing	How to establish multi-purpose shelterbelts with a high level of seedling protection	Fully fence-protected seedlings (*Up* domination, *P* admixture) in the sand dune with degraded steppe fragment	6×114	0.07
E2	Planting in exclosure	Steppe	Afforestation			Fully fence-protected seedlings (*Up* domination, *P* admixture) in the degraded steppe	6×48	0.03
E3	Planting in exclosure	Steppe	Afforestation			Fully fence-protected seedlings (mixed hedgerow with *P* predominance) in the degraded steppe	6×48	0.03
E4	Planting in exclosure	Steppe	Afforestation			Fully fence-protected seedlings (mixed hedgerow with *P* predominance) in the degraded steppe	6×48	0.03
E5	Planting in exclosure	Steppe	Afforestation			Fully fence-protected seedlings (mixed hedgerow with *P* predominance) in the degraded steppe	6×48	0.03
E6	Planting in exclosure	Steppe	Afforestation			Fully fence-protected seedlings (mixed hedgerow) in the degraded steppe	6×48	0.03
E7	Planting in exclosure	Riverbank	Reforestation	Establishment of riparian forest fragment and protection of planted seedlings from browsing	How to restore riparian forests with a high level of seedling protection	Fully fence-protected seedlings (*S* domination, *P* admixture) at the riverbank	20×20	0.04

Table 9. (Continued).

CE7	Planting in control	Riverbank	Reforestation control	Establishment of riparian forest fragment and protection of planted seedlings from browsing	How to restore riparian forests with a low level of seedling protection: Is it possible to do it successfully?	Seedlings (*S* domination, *P* admixture) with terminals protected by repellent planted at the riverbank (control to Ja_E7)	20×20	0.04
E8	Planting in exclosure	Riverbank	Reforestation		How to restore riparian forests with a high level of seedling protection	Fully fence-protected seedlings (mixed forest) at the riverbank	20×48	0.10
E9	Planting in exclosure	Sand dune and steppe	Afforestation	Sand dune stabilization using various soil additives and protection of planted seedlings from browsing	How to stabilize sand dunes with a high level of seedling protection and support	Experiment - fully fence-protected *Up* seedlings in the sand dune with degraded steppe fragment supported by various soil additives	108×32	0.35
E10	Planting in exclosure	Steppe	Afforestation	Establishment of a shelterbelt in open steppe and protection of planted seedlings from browsing	How to establish multi-purpose shelterbelts with a high level of seedling protection	Fully fence-protected *Am* seedlings in the degraded steppe	74×5	0.04

E1 Planting in exclosure

The demonstration of afforestation at the transition from sand dune to degraded steppe. Intervention is planned to provide mainly soil stabilization and windbreak functions. The goal is to establish a multi-purpose shelterbelt with a high level of seedling protection from browsing by fencing (Figure 37, Figure 38). With regard to the extreme sandy conditions, *Up*, which is naturally adapted to sandy soils, was chosen as a dominant tree species for planting in this exclosure. An admixture of *P* is also present. A key aspect is to limit livestock movement and grazing; the shrubs, grasses and herbs naturally growing in the area will get the chance to grow undisturbed, expand, colonize and stabilize the sand. The presence of trees is mainly supplementary in the first phase.

E2 Planting in exclosure

The demonstration of afforestation in the degraded steppe. Intervention is planned to provide mainly windbreak and shading functions. The goal is to establish a multi-purpose shelterbelt with a high level of seedling protection from browsing by fencing (Figure 39). Extreme-tolerant *Up* dominates, an admixture of *P* is also present.

Figure 37. A moving sand dune with fencing and planted seedlings (E1). The sand is gradually being colonized by small herbs. This is possible by preventing the movement and grazing of livestock.

Figure 38. The second part of plot E1 – degraded steppe with planted Up and P seedlings.

Figure 39. A shelterbelt in an open degraded steppe – inside the fenced area (E2), a higher vegetation cover is already visible compared to the surrounding grazed steppe.

E3 Planting in exclosure

The description is the same as in the case of the E2 plot, the difference is that there is a predominance of *P* (Figure 40) followed by *Up, Hr* is presented to provide fruit production.

E4 Planting in exclosure

The description is the same as in the case of the E3 plot (Figure 41).

E5 Planting in exclosure

The description is the same as in the case of the E3 plot; the share of *P* increases at the expense of *Up*. The reason for this is that the plot is located closer to the river and therefore better moisture conditions in the soil can be expected. The change in moisture conditions is also evident from the change in the character and height of the herb layer. The difference between grazed and ungrazed steppe is also more visible (Figure 42) compared to the drier segments of the shelterbelt (Figure 39).

Figure 40. Successful growth of P in the exclosure E3. The exclusion of grazing enabled the surrounding vegetation to grow to such an extent and height that it was necessary to implement weeding. Plant biomass from weeding can be left to enrich soils and improve moisture conditions as mulch. In the future, it can also be used to feed livestock.

Figure 41. The exclusion of grazing allowed the surrounding vegetation to grow up to the height of the protective fencing (E4). This shows the potential of the steppe to regenerate with regulated grazing. This is an important indicator for setting up sustainable landscape management.

Figure 42. Thanks to the fencing (E5), the shelterbelt already serves as an effective barrier for catching wind-borne waste. The difference in vegetation between grazed and ungrazed steppe is clearly visible.

E6 Planting in exclosure

The description is the same as in the case of the E5 plot. Considering the proximity to the river, *S* was also used in planting (Figure 43).

E7 Planting in exclosure

The demonstration of reforestation in the area of the assumed original riparian forest. Intervention is planned to provide both ecological and production functions. The goal is to establish a riparian forest fragment with a high level of seedling protection from browsing by fencing (Figure 44). Considering the proximity of the river and the assumed easily accessible groundwater level, mainly *S* were planted. Another main tree species is *P*.

CE7 Planting in control

The description is the same as in the case of the E7 plot, the difference is that there is low protection against browsing by repellent applied to terminal shoots (Figure 45).

Figure 43. As the shelterbelt approaches the river, S was also used for planting. S seedlings were left unpruned when planted by the GIZ and are therefore very tall.

Figure 44. Seedlings at the plot E7 were pruned before planting. They are thus smaller than the seedlings in the surrounding plots but should have a better developed root system. Thanks to it, they will be able to grow faster in the future.

Figure 45. Plot CE7 immediately after establishment: The seedlings have their terminals coated with a protective repellent.

E8 Planting in exclosure

The description is the same as in the case of the E7 plot, the difference is that there is a significant presence of *Hr* to provide fruit production in the future. The exclosure is located right on the riverbank (Figure 46). Soil stabilization and reduction of water erosion will be key functions of planted vegetation.

Figure 46. S planted on the riverbank have ideal conditions for growth. Their early production and provision of ecological and production functions can therefore be expected.

E9 Planting in exclosure

The demonstration of afforestation with *Up* at the transition from sand dune to degraded steppe (Figure 47). Intervention is planned to provide mainly soil stabilization and windbreak functions. The goal is to establish a shelterbelt with a high level of seedling protection from browsing by fencing and to find out how it is possible to improve the survival rate and growth of seedlings in these extreme conditions using various soil additives.

E10 Planting in exclosure

The description is the same as for the E2 plot, however, only *Am* was planted (Figure 48).

Figure 47. Planting of Up using various supporting additives. The additives were poured into the holes and mixed with the soil before planting the seedlings.

Figure 48. Planting Am in the degraded steppe.

4.1.2.4 Tree planting

In autumn 2022, 716 seedlings from the regional production (Darkhan and Shaamar forest nurseries) were planted in Javkhlant (Table 10). Later, in 2023, two more plots were established, on which 620 seedlings were primarily planted. The plantings were dominated by *Up* followed by *S* and *P*. *Hr* and *Am* were mainly planted experimentally to support biodiversity with possible added production. These bushy species are also adapted to extreme conditions. For variety, several *Psy* seedlings were experimentally planted on the sand dune. All species grow naturally in the region. The seedlings were watered after planting.

The planned design of species composition in exclosures E1, E3 and E4 was not followed in the plantings organized by the GIZ, and therefore more *P* and less *Up* were planted. The planned planting of *Hr* in exclosures E7 and CE7 was not possible because it was not available at the time of planting. In these plots, during the plantings organized by MENDELU, the plan was also not followed; during public plantings, the planned planting scheme and numbers of seedlings were not correctly followed.

Table 10. Numbers of seedlings planted in Javkhlant in 2022.

ID	Intervention	Main goal	*Psy*	*S*	*P*	*Hr*	*Am*	*Up*	Total
E1	Planting in exclosure	Establishment of a shelterbelt in open steppe (connecting the agriculture unit's shelterbelt with the river via several hedgerow segments on the gradient of the sand dune-degraded steppe-river bank) and protection of planted seedlings from browsing	5		31			81	**117**
E2	Planting in exclosure				13			32	**45**
E3	Planting in exclosure				29	8		8	**45**
E4	Planting in exclosure				31	7		7	**45**
E5	Planting in exclosure				31	8		8	**47**
E6	Planting in exclosure			8	23	8		8	**47**
E7	Planting in exclosure	Establishment of riparian forest fragment and protection of planted seedlings from browsing		58	26				**84**
CE7	Planting in control			66	12				**78**
E8	Planting in exclosure			110	16	82			**208**
E9*	Planting in exclosure	Sand dune stabilization using various soil additives and protection of planted seedlings from browsing						525	**525**
E10*	Planting in exclosure	Establishment of a shelterbelt in open steppe and protection of planted seedlings from browsing					95		**95**
Total planted seedlings in Javkhlant			5	242	212	113	95	669	1,336

* Seedlings were planted later (in autumn 2023) during the establishment of plots E9 and E10.

Prevailing designed spacing for plantings was 3.0×3.0 m, slight deviations were mainly in the case of experiments. In some cases, the seedlings were planted closer together to make the future vegetation denser to better fulfil the function of a windbreak.

Planting success was high with a survival rate mostly between 80 and 90% (Table 11). Slightly increased mortality was especially in the central part of the shelterbelt on the degraded steppe (E4, E5, E6). This mortality can be linked to the extreme environmental conditions on open flat steppe, where these tree species do not grow naturally. Their growth in the given space is assumed to be at the limit of their ecological niche. Therefore, further long-term monitoring is necessary to evaluate sustainability of planting there.

Table 11. Mortality of seedlings planted in Javkhlant (evaluated in September 2023).

ID	Intervention	Mortality (%)						
		Psy	S	P	Hr	Am	Up	Total
E1	Planting in exclosure	60		19			5	**11**
E2	Planting in exclosure			8			13	**11**
E3	Planting in exclosure			17	0		13	**13**
E4	Planting in exclosure			13	29		14	**16**
E5	Planting in exclosure			10	25		63	**21**
E6	Planting in exclosure		38	26	13		13	**23**
E7	Planting in exclosure		10	19				**13**
CE7	Planting in control		100	100				**100**
E8	Planting in exclosure		11	19	34			**21**
E9*	Planting in exclosure						-	**-**
E10*	Planting in exclosure					-		**-**

* Seedlings were planted later (in autumn 2023) during the establishment of plots E9 and E10, therefore, it was not possible to evaluate their mortality.

Near the river, the increased mortality can be explained by insufficient management during the summer season. The moderately high mortality of *Hr* (E8) can be associated with the absence of weeding in the summer period. Planted *Hr* seedlings were relatively small and planted deep (Figure 49). Tall weeds visibly oppressed and "suffocated" the seedlings in many places. Competition for light was probably a critical factor. Similar problem was also reported at the E7 plot (Figure 50). Mortality could be reduced by timely weeding implemented based on monitoring local conditions – the situation may differ even at small distances (Figure 51).

Figure 49. Comparison of the size of the Hr seedling and the surrounding weeds – the seedling was deep under the weed cover (before release) but survived. Many others failed (E8).

Figure 50. A released P seedling visibly damaged by surrounding weeds (E7).

Figure 51. Properly timed weeding led to the release of the seedling from the competitive pressure of surrounding weeds (E7).

In the case of the CE7 plot, grazing combined with browsing was the critical factor (Figure 52). The protective coating of repellent (Figure 45) was not a sufficient protection from large herds passing through the degraded steppe. This result was expected and indicates the need for solid fencing. Although the seedlings were browsed to ground level or even below it, some seedlings still produced new shoots (Figure 53) that were observable even during the evaluation period one year after the first fatal browsing-related damage was recorded. Seedling mortality in this case is therefore not an absolutely accurate indication. Some seedlings have a potential to grow even after a year of intensive browsing. However, with current grazing pressure, their death is only a matter of time with a survival perspective of 2–3 years.

Figure 52. Plot E7, where P and S seedlings were planted a year ago. At first glance, there are none left.

Figure 53. A small living S shoot growing from a seedling that is regularly browsed to the ground level.

Damage to seedlings directly in the fenced areas was also a frequent phenomenon. Some were broken, probably by the action of a strong wind; this particularly concerned *P. Up* often had a partially dead crown (Figure 54a). This was mainly caused by the planting of large older seedlings that were not sufficiently adapted to extreme conditions and the root system was not able to supply water and nutrients to the entire above-ground part. For future plantings, it is therefore more appropriate to use smaller seedlings with a well-developed root system. In addition, damage by browsing was also observed (Figure 54b). There were small holes in the fence in the sand dune area (E1). An animal probably got in this way and caused damage by browsing on several seedlings. Such a damage can be prevented by regular inspection and repairs of fences. However, in summary, most of the seedlings will survive the damage mentioned.

Figure 54. a) Dead crown of Up seedling and new shoots (marked in a circle) from the base. A common phenomenon at many plots. b) Damage to the terminal shoot of Up seedling by browsing. Seedlings survive these types of damage.

Repair planting was carried out in September 2023. It was realized only at the fenced plots (except E8 due to the high density of plantings) to maintain protection against browsing. Repair planting also included planting seedlings to empty places according to the original planting design, which were omitted during the first planting in 2022. On the contrary, dead seedlings in places where they should not have been, according to the design, were not replaced. In exclosure E1 on the sand dune, several seedlings were planted beyond the original design in critical places with unstable sand to make the vegetation cover denser and stabilize the sand more quickly.

Only *Up* and *Am* seedlings were planted due to the good quality of the available seedlings and the results from June 2023. The root system of the newly planted seedlings was treated with hydrogel in local forest nursery. A total of 96 seedlings of *Up* and 10 of *Am* were planted within the repair planting and additional planting. The seedlings were watered after planting.

Weeding was carried out in September 2023 in all exclosures (only in the immediate vicinity of the seedlings).

4.1.2.5 Recommendations for landscape management

Based on experience after the first year since establishment, it is possible to recommend the following management measures for the plots:

- It is necessary to reduce grazing.
- The aim of the landscape manager should be primarily to support the ecological functions of the forest and its stability and vitality.
- Regular inspection of the condition of the fencing (at least once a week). If even one goat gets into the exclosure, all the seedlings can be damaged within a few hours.
- Regular inspection of the condition of the seedlings in the exclosures. Accordingly, it is possible to plan further necessary interventions (e.g. weeding, special action for seedling protection against livestock or rodents). In the case of some areas, rodent damage was recorded. It is possible to defend against them mechanically (traps) or by supporting their natural predators. Since the fences attracted birds, including predators, there was a partial biological prevention. Weeding can also be helpful.
- Regular weeding at least once a year depending on the rains and the situation in the exclosures. The expected suitable month with the necessary intervention is July. It is sufficient to implement weeding only in the immediate vicinity of the seedlings (50 × 50 cm). The weeded biomass is left spread around the seedling as a mulch to improve soil moisture conditions and prevent further rapid weed growth. To support biodiversity, mowing the whole exclosure area at the beginning of the growing season may also be suitable. This mowing should not concern the area of the sand dune, on the contrary, it

is necessary near the river due to the high level of groundwater. This biomass can be used for other purposes. Protecting seedlings from damage is a priority, so mowing must be done carefully by a responsible worker. Considering that steppe ecosystems are naturally adapted to grazing, mowing is suitable for keeping the ecosystem healthy.

- To increase windbreaking and protection functions, the aim of tending trees is to increase the vegetation density of the stand/shelterbelt. For that reason, it is advisable to apply pruning to trees. The goal is not to grow tall trees with straight trunks as in commercial forests, but to create dense and resistant vegetation adapted to extreme conditions that will fulfil the required functions. It is therefore desirable to encourage tree pruning. Pruning intervention in this case is aimed at reducing top growth (opposite to commercial forest, where we reduce lateral growth). This will support the development of a strong root system and subsequent rapid growth of new shoots. Some of the seedlings planted were too tall with insufficiently strong trunks, therefore more prone to breaking in the wind. This is especially true for *P*; *S* are naturally more flexible and therefore bend in the wind.
- After securing the growth of trees, i.e. the terminal shoot will not be threatened by damage by browsing (in approximately 5 to 10 years depending on the situation), it is possible to experimentally try regulated sheep grazing instead of manual weeding. Only sheep can be used for these purposes, no other livestock.
- After stabilization of the plots, it is possible to use the shelterbelt production (e.g. plant biomass from weeding, *Hr* fruits, *S* shoots) to support the local community. In addition to these productive functions, the shelterbelt, if well maintained, will also provide the desired ecological functions that are prioritized here.

4.1.3 Bugant

4.1.3.1 Site introduction

Bugant site is divided into two separate sites with different conditions. The first site (49°25'51.7"N 107°20'43.6"E) is in a hard to access continuous forest near the river (Table 12) in the gold mining area and is covered by a mixed forest composed mainly of *Bp* and *Psy*. The second site (49°32'46.584"N 107°4'29.073"E) is dominated by a forest-steppe ecosystem characterised by an intensive pastureland utilization and extensive complexes of forests with similar composition as the first site. At the transition of steppe and forest, there is a *Psy* ecotone transitioning to mixed forest.

The region is affected by the presence of permafrost which supplies the forests with water. Higher precipitation compared to other regions of Mongolia, accompanied by water from permafrost, enabled the formation of extensive forest complexes of light taiga, which transition to dark taiga at higher altitudes. In addition to the mentioned species, Siberian pine (*Pinus sibirica* Du Tour), Siberian spruce (*Picea obovata* Ledeb.) and Siberian fir (*Abies sibirica* Ledeb.) also grow in the area. *Lsi* occurs rather rarely.

Table 12. Basic site characteristics of Bugant area (first site near the river).

Elevation (m a.s.l.)	Parent rock	Soil type	Dominating ecosystem	Forest composition
815	Fluvial sediments	Fluvic Phaeozem Loamic	Forest	*Bp-Psy* forest

Bugant area has well-stabilized forests with great potential and only minor damage by forest grazing. However, the issue is the decline of commercial tree species and their insufficient quality as there is a lack of management and tending of the young and premature forest stands. Artificial planting has only taken place to a limited extent. Although there are many good forestry projects in the area, there is a lack of SFM and tending of the young and premature forest stands.

The forestry tradition and the wood processing industry in Bugant is a great opportunity for the development of forests and forestry in the area. There are two semi-professional to professional forest nurseries and a sawmill in the town (soum). One of the forest nurseries experienced significant production development in recent years. The sawmill operation processes wood from local forests (mostly *Psy*) and produces, for example, ger constructions and furniture. Transport of wood products from the town can be a complication with regard to the quality of the road network. Water transport and a nearby railway may represent an opportunity.

The high production potential of local forests is unfulfilled Therefore, continuation of forestry development and SFM implementation can be beneficial at all levels. Higher incomes from forestry can help protect and restore local commercial forests, combat frequent forest fires, protect the endangered dark taiga ecosystems and develop local communities, including improving the quality of life.

4.1.3.2 Objectives of SFM measures

Local measures should serve as a practical manual for studying proper forest management contributing to higher wood production of forest ecosystems and growth of their economic value. Partial measures should represent ways of I) supporting and protecting natural forest regeneration, II) artificial forest regeneration and protection, III) improving forest stability, health, and heterogeneity and IV) increasing economic value of timber and the forest in general. With regard to the perspective for production management thanks to favourable environmental conditions, production function should be preferred to meet the national demand for wood and protect more vulnerable forest ecosystems from logging.

The planned activities will help to maintain the forest in its natural range and enable its simultaneous sustainable utilization in a way that could support local community and national wood market. Higher profits from better quality timber can provide financial resources for the forest protection and healthy and resilient forest will reliably provide ecosystem functions for current and future generations. In addition, long-term research and monitoring of natural conditions will support the local management and enable the evaluation of the situation on a wider scale.

The aim of the measures should be:

- To improve stability, health, vitality, and spatial heterogeneity of the forests.
- To increase economical value of the forest.
- To protect permafrost.
- To restore forest on the unstocked forest areas with unsuccessful natural regeneration.
- To support natural forest regeneration.
- To support local forest production and community.
- Awareness raising & knowledge sharing.

•

4.1.3.3 Forest management measures

With regard to the character and state of the forest, the implemented SFM measures (Figure 55, Table 13, Figure 56) can be divided into three main categories:

1. Forest protection
2. Forest tending

The measures are located in three different types of forest:

a) *Bp* forest
b) Mixed forest (*Bp*, *Psy*)
c) *Psy* forest (*Psy* corridor)

In total, 12 demonstration plots were established at Bugant sites (Figure 55, Table 13, Figure 56).

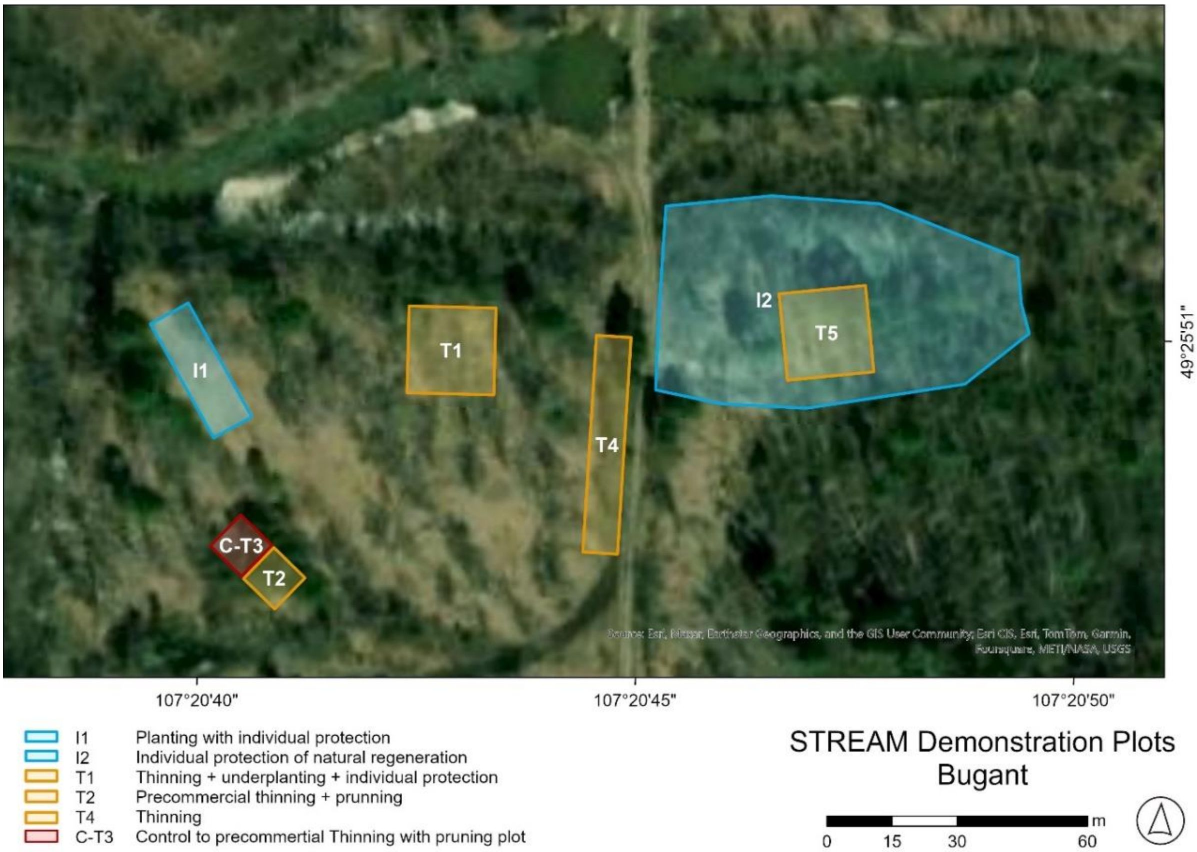

Figure 55. The distribution of forest management measures at the Bugant site (first site near the river).

Table 13. A summary of interventions at Bugant site.

ID	Intervention	Ecosystem	General category	Main goal	What do we want to show	Description	Size (m)	Area (ha)
I1	Planting + individual protection	Forest gap	Forest protection	Reforestation in the forest gap and protection of planted seedlings from browsing	How to do reforestation in forest gaps with a low level of seedling protection	Seedlings (*Lsi* + *Psy*) with terminals protected by repellent planted in the forest gap	10×30	0.03
I2	Individual protection of natural regeneration	*Bp-Psy* forest	Forest protection	Protection of naturally-occurring seedlings	How to increase the success (successful growth) of natural forest regeneration with a low level of seedling protection	Naturally-occurring seedlings with terminals protected by repellent	-	0.35
T1	Thinning + underplanting + individual protection	*Bp* forest	Forest tending	Light availability management of the forest (modification of the spatial structure) + reforestation under the protection of the shelterwood/current stand and protection of planted seedlings from browsing	How to stimulate natural forest regeneration and mature tree volume growth + how to do artificial reforestation with a low level of seedling protection in sparse forests	Thinning in the *Bp* stand + seedlings (*Psy*) with terminals protected by repellent planted	20×20	0.04
T2	Precommercial thinning + pruning	*Bp-Psy* forest	Forest tending	Creation of the stand structure and its support + support of knot-free wood production	How to increase the stability, vitality and economic value of forest and value of future timber/lumber	Thinning (intensity 26%), release of target *Psy* individuals, health and shape selection + pruning; demonstration of strip road	10×10	0.01
C-T3	Control to precommercial thinning with pruning	*Bp-Psy* forest	Tending control	Monitoring of the development of unmanaged forest	How an unmanaged forest develops	Unmanaged control for the realized interventions (marked) with demonstration of strip road	10×10	0.01
T4	Precommercial thinning + pruning	*Bp-Psy* forest	Forest tending	Creation of the stand structure and its support + support of knot-free wood production	How to increase the stability, vitality and economic value of forest and value of future timber/lumber	Thinning, release of target individuals in the dense stand along the road, health and shape selection + pruning	8×50	0.04
T5	Thinning	*Bp-Psy* forest	Forest tending	Light availability management of the forest (modification of the spatial structure)	How to stimulate natural forest regeneration and support growth of existing naturally-occurring seedlings	Maked target individuals, health and shape selection	20×20	0.04

Table 13. (Continued).

T6	Precommercial thinning + pruning	*Psy* forest	Forest tending	Creation of the stand structure and its support + support of knot-free wood production	How to increase the stability, vitality and economic value of forest and value of future timber/lumber	High intensity (50%) precommercial thinning + pruning	20×20	0.04
T7	Precommercial thinning	*Psy* forest	Forest tending	Creation of the stand structure and its support	How to increase the stability, vitality and economic value of forest	Medium intensity (30%) precommercial thinning	20×20	0.04
C-T8	Control to precommercial thinning	*Psy* forest	Tending control	Monitoring of the development of unmanaged forest	How an unmanaged forest develops	Unmanaged control for the realized interventions in the young dense *Psy* stand	20×20	0.04
T9	Thinning	*Bp* forest	Forest tending	Support of target trees (modification of the spatial structure)	How to increase target trees volume growth, quality and health + how to increase stability of the forest	High intensity (60%) thinning, release of target individuals, health and shape selection, support of *Psy* natural regeneration	20×20	0.04
C-T10	Control to thinning	*Bp* forest	Tending control	Monitoring of the development of unmanaged forest	How an unmanaged forest develops	Unmanaged control for the realized interventions in the *Bp* stand	20×20	0.04

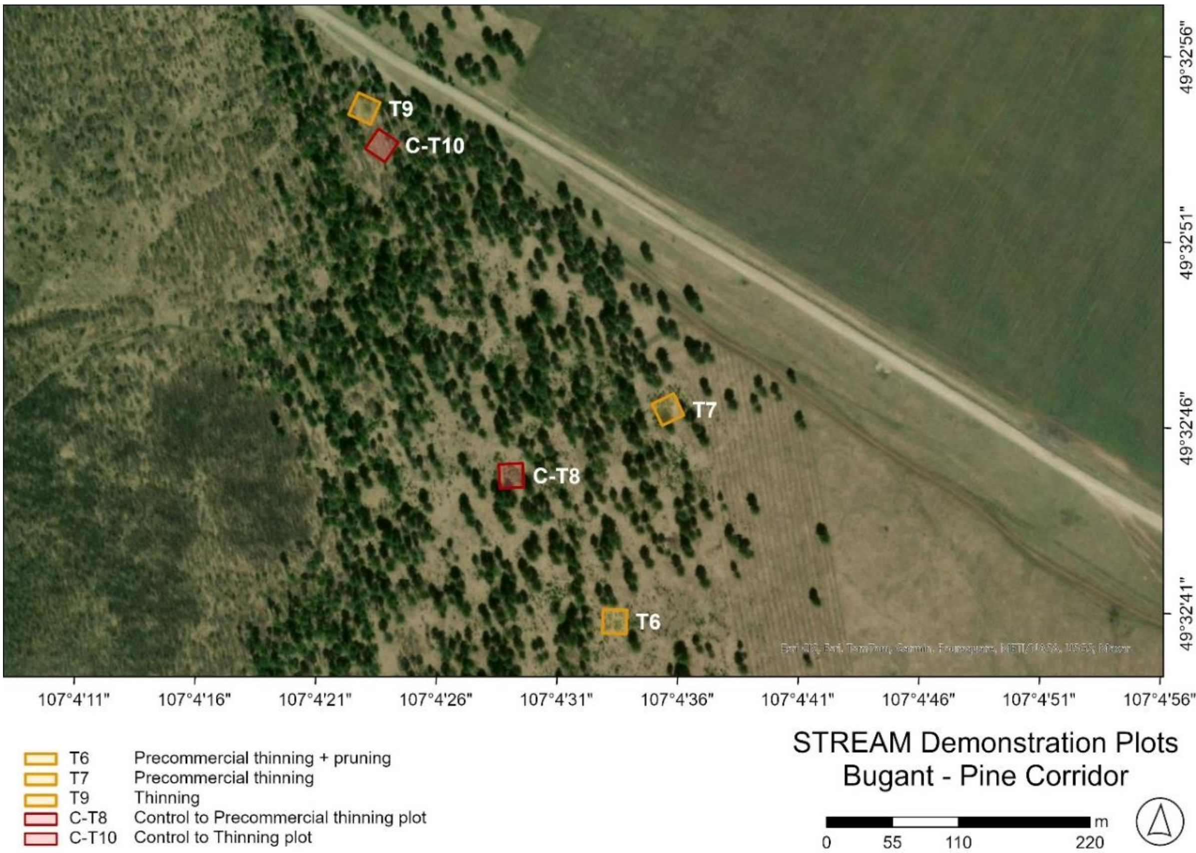

Figure 56. The distribution of forest management measures at the Bugant site (second site near the Psy corridor).

I1 Planting + individual protection

The demonstration of forest regeneration by planting of *Psy* and *Lsi* seedlings at the forest gap (Figure 57). Although *Lsi* is rarely found in the area, one individual was found in the stand within natural regeneration. Therefore, *Lsi* was introduced here as well, although mature trees were not recorded. The goal is to show the artificial reforestation with an emphasis on the introduction of commercial tree species (*Psy* and *Lsi*). There is low protection against browsing provided by repellent applied to terminal shoots (Figure 58).

I2 Individual protection of natural regeneration

The demonstration of protection of naturally occurring seedlings. The goal is to show how to increase the success (successful growth) of natural forest regeneration with a low level of seedling protection from browsing by repellent (Figure 59).

Figure 57. Planted seedlings at the forest gap (I1). The positions of the seedlings are marked with sticks so that they can be easily found during weeding in case of high weeds.

Figure 58. A seedling treated with repellent to be protected from browsing (I1). In this case, the terminal shoot is not treated in order not to damage it – it is too small.

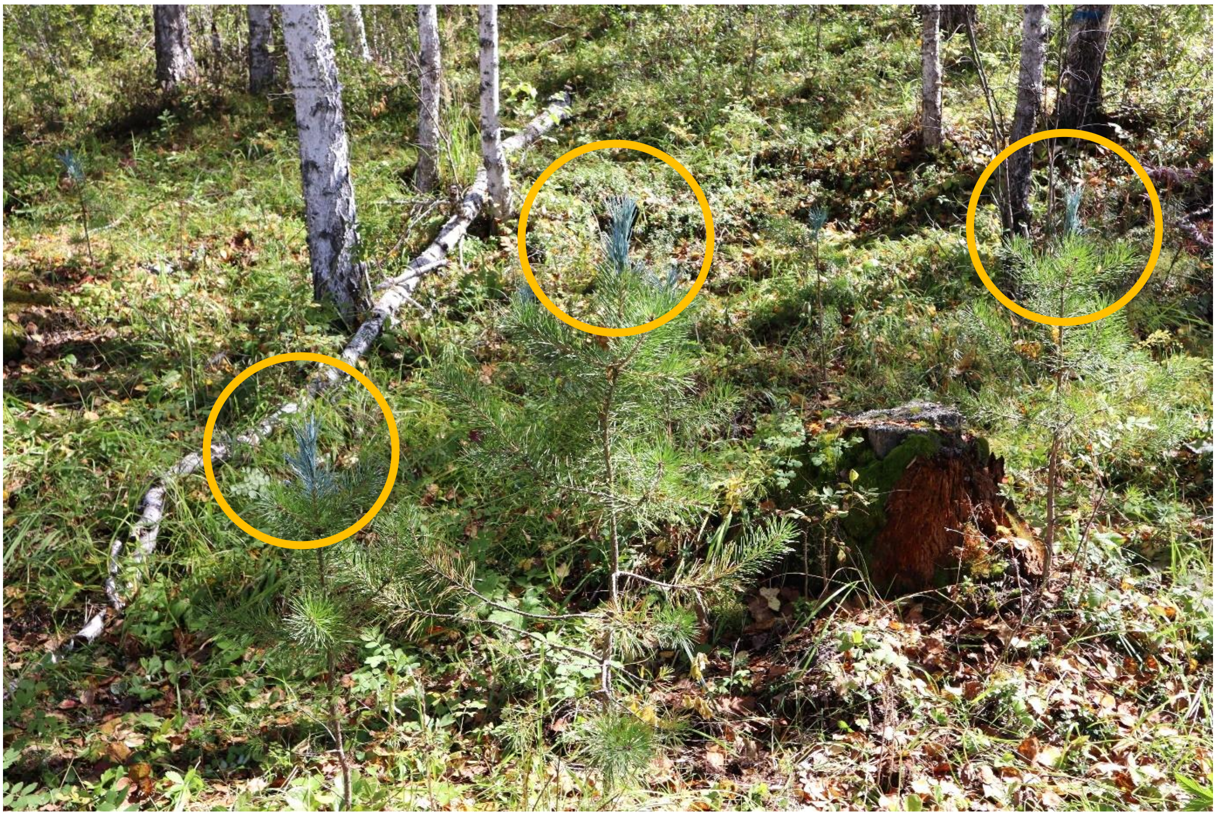

Figure 59. A demonstration of terminal shoots of Psy seedlings coated with a protective repellent (I2).

T1 Thinning + underplanting + individual protection

The demonstration of light availability management through the modification of the spatial structure in the *Bp* forest (Figure 60). The goal is to stimulate and support natural forest regeneration and mature tree volume growth. In this thinning intervention, high-quality *Bp* individuals (target trees) were released and supported in growth by removing low-quality *Bp* individuals. With the improved light conditions, the natural regeneration of the forest stand will be soon stimulated and supported. In addition, the plot is a demonstration of forest regeneration by underplanting of *Psy* seedlings in the forest canopy openings (Figure 61). In this way, commercial tree species are introduced into the stand with *Bp* domination. The intention is to (I) increase the productivity and economic value of the forest with the support of commercial tree species and (II) ensure a continuous soil cover by trees to regulate the microclimate and protect permafrost. Planted seedlings are protected from browsing by repellent applied to terminal shoots. Near the designed plot, more trees were marked for thinning intervention in the *Bp* stand to demonstrate the decision-making process of tree selection without implementation (Figure 62).

Figure 60. Locally too dense Bp stand with empty canopy openings (imbalance) before the implementation of the intervention (T1).

Figure 61. Bp stand after the intervention implementation (T1). Seedlings are planted in canopy openings and marked with sticks for future weeding (to prevent damage).

Figure 62. Bp forest with trees marked for logging (orange dot) and for support – target trees (orange stripe).

T2 Precommercial thinning + pruning

The demonstration of creation of the stand structure and its support together with support of knot-free wood production of target trees in young dense mixed stand (Figure 63). The goal is to show how to increase the stability, vitality and economic value of forest and value of future timber/lumber. In this thinning intervention, older high-quality *Psy* individuals (target trees) were released and supported by removing low-quality competitive individuals and pruned. In addition, a strip road was designed to make the forest stand more accessible and wood transport easier (Figure 64).

C-T3 Control to precommercial thinning with pruning

Monitoring of the development of unmanaged mixed forest stand (Figure 65). The goal is to show how an unmanaged forest develops compared to the neighbouring managed one. Thinning intervention was planned.

Figure 63. Mixed stand with marked target (yellow stripe) trees after precommercial to commercial thinning intervention and pruning of target trees (T2).

Figure 64. Realized strip road serving for future timber transport (T2–T3).

Figure 65. Mixed stand with marked target trees (yellow stripe) without implemented thinning intervention (T3).

T4 Precommercial thinning + pruning

The demonstration of creation of the stand structure and its support together with support of knot-free wood production of target trees (Figure 66) in young dense mixed stand. The goal is to show how to increase the stability, vitality and economic value of forest and value of future timber/lumber. In this thinning intervention, target trees were supported by removing low-quality competitive individuals and pruned.

T5 Thinning

The demonstration of light availability management through the modification of the spatial structure in the mixed forest (Figure 67). The goal is to stimulate and support natural forest regeneration and mature tree volume growth. In this thinning intervention, young *Psy* individuals are released, especially by removing low-quality *Bp* individuals and by improving light conditions, the natural regeneration of the forest stand will be stimulated and supported. Furthermore, promising *Psy* individuals (target trees) are supported by removing low-quality competing trees.

Figure 66. Realization of pruning of target trees (marked with yellow stripe) in a mixed stand (T4).

Figure 67. Presentation of the planned intervention at the T5 plot to local foresters. Trees marked for logging have an orange dot and trees for support – target trees – have an orange stripe.

T6 Precommercial thinning + pruning

The demonstration of creation of the stand structure and its support together with support of knot-free wood production in young dense *Psy* stand. The original *Psy* stand had not fully closed canopy. As a result, many individuals in this area showed too extensive branching. During this intervention with high intensity (50%), the best individuals were released and pruned (Figure 68). Later, their crowns will develop intensively and after 15 years it will be necessary to prune them again up to 5 meters. Significantly lower *Psy* individuals were left to form lower storey. The goal is to show how to stimulate tree growth and increase the stability, vitality and economic value of forest and value of future timber/lumber.

T7 Precommercial thinning

The demonstration of creation of the stand structure and its support. Intervention intensity was 30% (Central European standard). Low-quality and excessive individuals were removed within the intervention, and the remaining individuals were left in a spacing of 1.2–1.5 m. Growth in a dense canopy is expected (Figure 69), ensuring self-pruning. The lower intensity compared to the T6 plot will mean slightly slower growth, but due to the absence of pruning intervention, tending will be less expensive. The goal is the same.

Figure 68. Psy stand after the intervention implementation (T6). Older trees are pruned, smaller ones are left without pruning for vital growth.

Figure 69. Psy stand after the intervention implementation (T7). Compared to T6, a higher stand density is visible.

C-T8 Control to precommercial thinning

Monitoring of the development of unmanaged *Psy* forest stand (Figure 70). The goal is to show how an unmanaged forest develops compared to the neighbouring managed one.

Figure 70. Dense control plot in Psy stand (C-T8) without any intervention.

T9 Thinning

The demonstration of the modification of the spatial structure with the support of promising target trees in the *Psy* forest stand. Intervention intensity was high (60%). The main goals were to stimulate and support growth of the remaining trees (Figure 71) and to increase stability of the forest. In this thinning intervention, promising (health and shape selection) *Bp* individuals (target trees) were supported by removing competing trees and natural regeneration of the more economically valuable *Psy* was supported.

C-T10 Control to thinning

Monitoring of the development of unmanaged *Bp* forest stand (Figure 72). The goal is to show how an unmanaged forest develops compared to the neighbouring managed one.

Figure 71. Realized thinning intervention with remaining marked Bp target trees (blue stripe) and preferred Psy in the Bp stand (T9). The high-quality mature Psy individual will serve as a seed source for natural regeneration. Existing and future natural regeneration (preferably Psy seedlings) will be supported by the improved light conditions in the stand. Compared to the adjacent control area in the same Bp stand without intervention, there is a visible difference in the stand density.

Figure 72. Dense control plot in Bp stand (C-T10) without any intervention.

4.1.3.4 Tree planting

In autumn 2022, 82 seedlings from the local production (Bugant FUG forest nursery) were planted in Bugant (Table 14). Other tree species were not used due to their natural absence in the locality or natural regeneration (*Bp*, *Pt*). Due to the overall good natural regeneration, it was not necessary to reforest more.

Table 14. Numbers of seedlings planted in Bugant in 2022.

ID	Intervention	Main goal	*Lsi*	*Psy*	Total
T1	Thinning + underplanting + individual protection	Light availability management of the forest (modification of the spatial structure) + reforestation under the protection of the shelterwood/current stand and protection of planted seedlings from browsing	-	30	**30**
I1	Planting + individual protection	Reforestation in the forest gap and protection of planted seedlings from browsing	32	20	**52**
Total planted seedlings in Bugant			32	50	82

Spacing for plantings was designed 2.6×2.6 m for plantings in the open area. In the case of underplanting, the distribution of seedlings followed forest stand gaps with the absence of trees and better light conditions.

The success rate of plantings was high (Table 15). High-quality seedlings were used for planting, which contributed to a high success rate. Good soil moisture conditions also ensured successful growth in 2023.

Table 15. Mortality of seedlings planted in Bugant (evaluated in September 2023).

ID	Intervention	Mortality (%)		
		Lsi	*Psy*	Total
T1	Thinning + underplanting + individual protection	-	10	61
I1	Planting + individual protection	0	15	96

In the case of *Lsi*, seedlings showed similar damage of needles as in Tunkhel. The damage to the assimilation apparatus was probably caused by a combination of extremely humid weather (compared to the normal semi-arid conditions of Mongolia) and a biotic agent. The results of the monitoring of climate and soil conditions at the site indicated extreme rainfall events and increased soil moisture during the summer season. The accompanying growth of weeds and the creation of extreme microclimatic conditions could contribute to the development of fungal diseases causing the damage. The damage could also have been caused by an insect pest. However, it is probable that the damaged *Lsi* seedlings will resprout next spring and survive the damage. There was no damage by browsing.

Considering the high success rate of planting (in total ≥90% per plot), it was not necessary to do repair planting.

Weeding was carried out in June and September 2023 in both planted plots (only in the immediate vicinity of the seedlings).

4.1.3.5 Forest inventory

The results of the forest inventory on thinning plots are summarized in Table 16. The results summarize the basic descriptive characteristics of forest stands and their development in the case of thinning intervention. Inventory details, including species composition, are part of a separate document. Thinning at plots T1, T2 and T4 was implemented.

Table 16. Forest inventory at thinning plots in Bugant.

Plot	H_{sup} (m)	Age_{avg} (years)	Thinning intervention				
			Characteristic (unit)	Pre-thinning	Post-thinning	Thinning	
T1	13.5		BA (m^2/ha)				Intensity = 11%
			DBH_{avgBA}/DBH_{avg} (cm)	16.2			
			Density (stems/ha)				
			Vol (m^3/plot)	5.1		0.6	
T2	10		BA (m^2/ha)				Intensity = 27 %
			DBH_{avgBA}/DBH_{avg} (cm)	12.0			
			Density (stems/ha)				
			Vol (m^3/plot)	3.3		0.9	
C-T3	9.3		BA (m^2/ha)				Intensity = 24%
			DBH_{avgBA}/DBH_{avg} (cm)	11.3			
			Density (stems/ha)				
			Vol (m^3/plot)	1.2		0.3	
T4	9.2		BA (m^2/ha)				Intensity = 23%
			DBH_{avgBA}/DBH_{avg} (cm)	11.4			
			Density (stems/ha)				
			Vol (m^3/plot)	5.2		1.2	
T5	13.6		BA (m^2/ha)				Intensity = 12%
			DBH_{avgBA}/DBH_{avg} (cm)	17.5			
			Density (stems/ha)				
			Vol (m^3/plot)	6.0		0.7	

4.1.3.6 Recommendations for forest management

Based on experience after the first year since establishment, it is possible to recommend the following forest management for plots with the measures and surrounding forest stands:

- The aim of the forest manager should be primarily to support the production functions of the forest together with their stability and vitality.
- For easier forest management, the repair of the road network and the bridge leading to the site is necessary.
- Regular inspection of the forest (approximately once a month). In the case of natural disasters or a higher risk of the occurrence and impact of negative factors (e.g. long periods of drought, season with high risk of pest outbreaks), it is necessary to carry out inspections more often.
- The results of the plantings indicate that it is advisable to continue the introduction of both *Lsi* and *Psy* into the local forest stands where it naturally belongs. Most of the forests in the area show signs of former selective logging of *Psy*, which has not returned

to the stands, or is returning there very slowly. Its reintroduction needs to be continued and artificially supported, taking into account the demand for *Psy* wood. It is advisable to return *Lsi* to places of its original and natural occurrence.

- In suitable locations, it is possible to try to introduce dark taiga species into forest stands. They can contribute to increasing biodiversity and production of forest stands.
- Regular inspection of the condition of the seedlings (approximately once every two weeks). Accordingly, it is possible to plan further necessary interventions (e.g. weeding, special action for seedling protection against game, livestock, insect pests and pathogens). In this case, it was certainly appropriate to use a chemical spray (probably insecticide) on *Lsi* seedlings that were attacked and damaged by a biotic pest probably during August.
- Regular weeding 1–2x per year depending on the rains and the situation in the exclosures. The expected suitable month with the necessary first weeding intervention is July. It is sufficient to implement weeding only in the immediate vicinity of the seedlings (50 × 50 cm). The weeded biomass is left spread around the seedling as a mulch to improve soil moisture conditions and prevent further rapid weed growth. Protecting seedlings from damage is a priority, so weeding must be done carefully by a responsible worker.
- After felling mature trees in the thinning interventions with the main goal targeted on light availability management of the forest (modification of the spatial structure), undergrowth with seedlings from natural forest regeneration will already be safe from browsing and weeds. Further care for them is therefore not necessary, it is only necessary to ensure that they are not damaged during logging operations and skidding.
- In the area of the second part of the site with the *Psy* corridor, it will be appropriate to implement precommercial thinning and pruning in the following years.
- The *Psy* forest belt, which is very sparse locally, can be improved by underplanting or preferably by supporting the natural regeneration by soil scarification.
- Reasonable selective cutting in forests may continue, but a balance needs to be found with the simultaneous reintroduction of commercial tree species. That should be one of the fundamental principles of sustainability.
- For the development of forestry in the area and the protection of local forests, it is necessary to stop neglecting pioneer tree species (*Bp*, *Pt*). Despite their lower economic potential compared to *Psy*, it is possible to increase their economic value by appropriate

forest tending. Management of these common species and their promotion for the wood processing industry as well as for use in households (e.g. as firewood) is the way to sustainability.

- To develop the vitality, stability and economic value of the forest, it is necessary to practice forest regeneration, protection and tending and not only the final selective cutting. The layout of these activities must be based on a responsible SFM and forest management plan. Therefore, updating and following the existing plan is essential.

4.2 Selenge province

4.2.1 Umnudelger

4.2.1.1 Site introduction

Umnudelger forest-steppe site (47°54'21.7"N 109°43'30.3"E; Table 17) is characterised by an intensive pastureland utilization and small scattered fragments of forests. These forest fragments are mainly composed of *Lsi*, rarely accompanied by *Bp*. Such landscapes are characterized by a very fragile balance, the forests are highly adapted to extreme natural conditions, but highly vulnerable to human-induced influences and changes.

These fragments are common shelters for livestock during extreme weather periods. However, the comfort for livestock comes at a high price – the whole forest faces the risk of being damaged by browsing. In the case of overgrazing, successful regeneration of forests is impossible without proper protection, as is also evident in a few places in this area, especially in the forest edge zones. In addition, more frequent fires and improper logging reduce the heterogeneity of forests in the region, which are then weaker and more prone to large-scale dieback and pest outbreaks.

Table 17. Basic site characteristics of Umnudelger area.

Elevation (m a.s.l.)	Parent rock	Soil type	Dominating ecosystem	Forest composition
1,500	Granite	Cambic Skeletic Phaeozem Loamic	Forest-steppe	Lsi forest

The site is dominated by a dense Lsi forest that has been established by natural regeneration within a few years after a wildfire. Therefore, the forest structure is mainly made up of even-aged stands with limited diversity. The continuity of the forest is disturbed by several forest gaps, where successful regeneration of the forest did not take place. The ecotone parts of the forest at the transition to the steppe are mostly formed by a gradual transition with sparsely scattered Lsi individuals. Natural regeneration is limited and usually regularly damaged by browsing.

Thinning interventions were implemented by the FAO in the forest several years ago, serving as small demonstration areas of forest tending. As part of this, a strip road was also implemented. However, there is a lack of continuity of forestry interventions and expansion into the surrounding area, as well as demonstrations of artificial forest regeneration and forest protection.

Without human help, these forest fragments can easily disappear and cease to provide irreplaceable functions for the entire landscape, such as a shelter, soil stabilization, protection of water sources and a source of wood. For this reason, forestry intervention is appropriate with an important application of SFM.

4.2.1.2 Objectives of SFM measures

Local forestry measures should serve as a practical manual for studying proper forest management and contribute to the stabilization of the forest in its natural range in the area. Partial measures should represent ways of I) supporting and protecting natural forest regeneration, II) artificial forest regeneration and protection, III) improving forest stability, health, and heterogeneity and IV) increasing economic value of timber and the forest in general. Considering the rarity and vulnerability of forests in the region and their irreplaceable ecological importance, the priority should be their stabilization and support of ecosystem functions accompanied by small local wood production.

The planned activities will help to maintain the forest in its natural range and enable its simultaneous sustainable utilization in a way that could support local community. Higher profits from better quality timber can provide financial resources for the forest protection and healthy and resilient forest will reliably provide ecosystem functions for current and future generations. In addition, long-term research and monitoring of natural conditions will support the local management and enable the evaluation of the situation on a wider scale.

The aim of the measures should be:

- To improve stability, health, vitality and spatial heterogeneity of the forest.
- To increase economical value of the forest.
- To restore forest on the unstocked forest areas with unsuccessful natural regeneration.
- To expand forest to the forest-steppe transitional zone.
- To support natural forest regeneration.
- To support local forest production and community.
- Awareness raising & knowledge sharing.

4.2.1.3 Forest management measures

With regard to the character and state of the forest, the implemented SFM measures (Figure 73, Table 18) can be divided into three main categories:

1. Forest regeneration (reforestation and afforestation)
2. Forest protection
3. Forest tending

The measures are located in three different types of forest:

a) Forest-steppe transition (ecotone) area
b) Dense Lsi forest stands developed after a wildfire
c) Sparse Lsi forest stands partially developed or undeveloped after a wildfire

In total, 20 demonstration plots were established at Umnudelger site (Figure 73, Table 18).

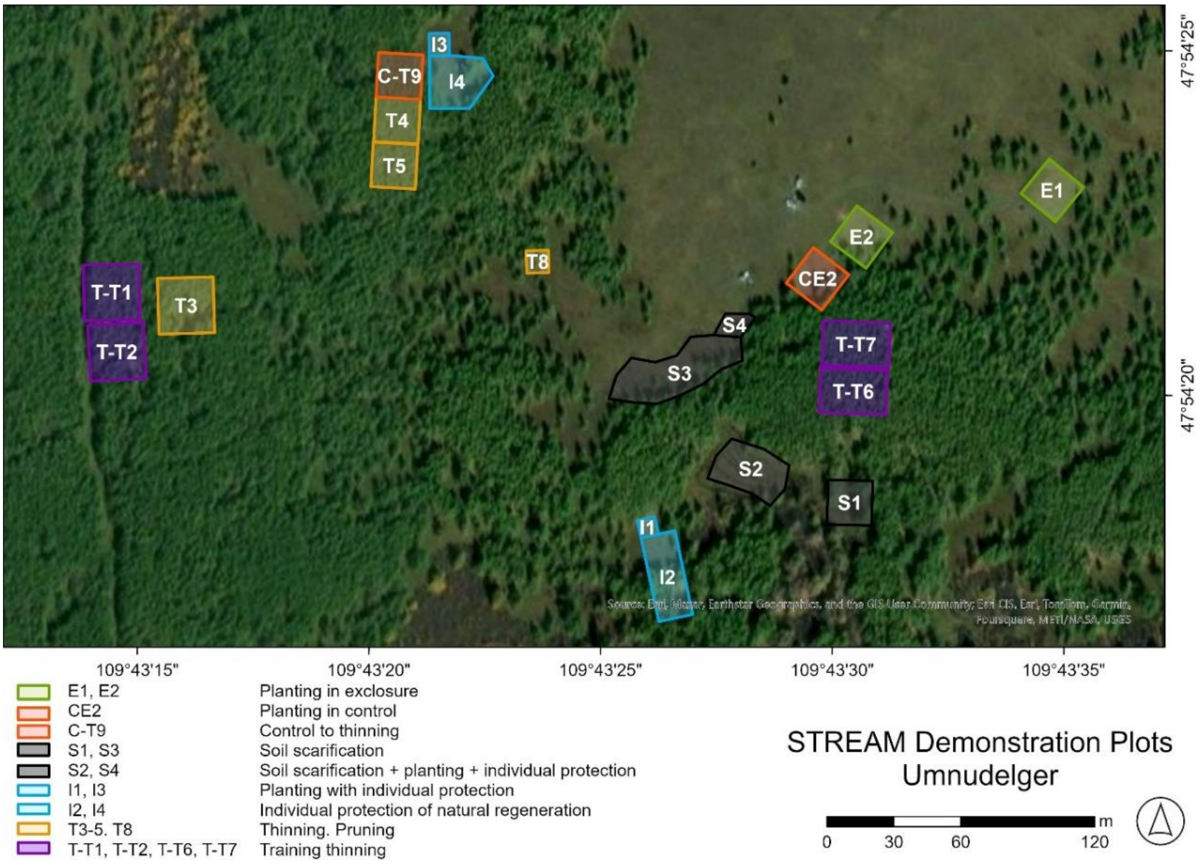

Figure 73. The distribution of forest management measures at the Umnudelger site.

Table 18. A summary of interventions at Umnudelger site.

ID	Intervention	Ecosystem	General category	Main goal	What do we want to show	Description	Size (m)	Area (ha)
E1	Planting in exclosure	*Lsi* forest-steppe transition	Reforestation	Expansion of the forest by artificial regeneration at the forest-steppe transition and protection of planted seedlings from browsing	How to do artificial reforestation with a high level of seedling protection in sparse forests	Fully fence-protected seedlings (*Lsi*) planted into the gap of the sparse ecotone	20×20	0.04
E2	Planting in exclosure	*Lsi* forest-steppe transition	Afforestation		How to do afforestation with a high level of seedling protection: Is it possible to do it successfully?	Fully fence-protected seedlings (*Lsi*) planted at the forest-steppe transition	20×20	0.04
CE2	Planting in control	*Lsi* forest-steppe transition	Afforestation control		How to do afforestation with a low level of seedling protection: Is it possible to do it successfully?	Seedlings (*Lsi*) with terminals protected by repellent planted at the forest-steppe transition (control to Umn_E2)	20×20	0.04
S1	Soil scarification	Forest gap	Reforestation	Improvement of conditions for natural forest regeneration in the forest gap and protection of future seedlings from browsing	How to increase the success (successful germination) of natural forest regeneration in forest gaps with a high level of future seedlings protection	Fully fence-protected soil scarification under the seed trees (2 quarters scarified, 2 unmanaged) in the forest gap	20×20	0.04
S2	Soil scarification + planting + individual protection	Forest gap	Reforestation	Improvement of conditions for natural forest regeneration in the forest gap + reforestation and protection of planted seedlings from browsing	How to increase the success (successful germination) of natural forest regeneration in forest gaps + artificial reforestation with a low level of seedling protection	Soil scarification in the forest gap + few seedlings (*Lsi*) with terminals protected by repellent planted	~25×12	0.06
S3	Soil scarification	Steppe	Afforestation	Expansion of the forest by improvement of conditions for natural forest regeneration at the forest-steppe transition	How to do afforestation based on natural forest regeneration: Is it possible to do it successfully?	Soil scarification at the forest edge with the seed trees	~10×40	0.10

Table 18. (Continued).

S4	Soil scarification + planting + individual protection	Steppe	Afforestation	Expansion of the forest by improvement of conditions for natural forest regeneration at the forest-steppe transition + reforestation and protection of planted seedlings from browsing	How to do afforestation based on natural forest regeneration and planting with a low level of seedling protection: Is it possible to do it successfully?	Soil scarification at the forest edge with the seed trees + seedlings (*Lsi*) with terminals protected by repellent sparsely planted	~10×18	0.01
I1	Planting + individual protection	Forest gap	Forest protection	Reforestation in the forest gap and protection of planted seedlings from browsing	How to do reforestation in forest gaps with a low level of seedling protection	Seedlings (*Lsi*) with terminals protected by repellent planted in the forest gap with unsuccessful natural regeneration	6×6	0.00
I2	Individual protection of natural regeneration	Forest gap	Forest protection	Protection of naturally-occurring seedlings	How to increase the success (successful growth) of natural forest regeneration with a low level of seedling protection	Naturally-occurring seedlings with terminals protected by repellent	-	0.06
I3	Planting + individual protection	Forest gap	Forest protection	Reforestation in the forest gap and protection of planted seedlings from browsing	How to do reforestation in forest gaps with a low level of seedling protection	Seedlings (*Lsi*) with terminals protected by repellent planted in the forest gap with unsuccessful natural regeneration	4×4	0.00
I4	Individual protection of natural regeneration	Forest gap	Forest protection	Protection of naturally-occurring seedlings	How to increase the success (successful growth) of natural forest regeneration with a low to medium level of seedling protection	Naturally-occurring seedlings with terminals protected by repellent or individually fenced	-	0.06
T-T1	Training thinning	*Lsi* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to propose a thinning intervention	Stand with full numbering of trees (183 trees) for thinning training	25×25	0.06

Table 18. (Continued).

T-T2	Training thinning	*Lsi* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to study the proposed thinning intervention	Stand with full numbering of trees for thinning training/studying with target trees marked and planned intervention (intensity 15%)	25×25	0.06
T3	Thinning	*Lsi* forest	Forest tending	Support of target trees (modification of the spatial structure)	How to increase target trees volume growth, quality and health	Low intensity (20%) thinning with the support of target trees	25×25	0.06
T4	Thinning	*Lsi* forest	Forest tending			Medium intensity (40%) thinning with the support of target trees + pruning	20×20	0.04
T5	Thinning	*Lsi* forest	Forest tending			High intensity (60%) thinning with the support of target trees + pruning	20×20	0.04
T-T6	Training thinning	*Lsi* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to propose a thinning intervention	Former control FAO plot (X-765-II) with pruning: stand with full numbering of trees for thinning training	30×20	0.06
T-T7	Training thinning	*Lsi* forest	Tending training		How to do forest tending in practice: the opportunity to study the proposed thinning intervention	Thinning training/studying with marked target trees and planned second intervention in the original FAO site (X-765-II)	30×20	0.06
T8	Pruning	*Lsi* forest	Forest tending	Support of knot-free wood production	To increase the economic value of future timber/lumber	Pruning in the sparse *Lsi* stand	10×10	0.01
C-T9	Control to thinning	*Lsi* forest	Tending control	Monitoring of the development of unmanaged forest	How an unmanaged forest develops	Unmanaged control for the realized interventions in the *Lsi* stand (control to Umn_T4 and Umn_T5)	20×20	0.06

E1 Planting in exclosure

The demonstration of artificial reforestation in the sparse forest area with extreme conditions (ecotone at the transition from the forest to the steppe) which, nevertheless, still allow the natural growth of the trees (Figure 74). The goal is to show the expansion of the forest by artificial regeneration at the forest-steppe transition while respecting the natural conditions with a high level of *Lsi* seedlings protection from browsing by fencing.

E2 Planting in exclosure

The demonstration of artificial afforestation in extreme conditions (ecotone at the transition from the forest to the steppe) on the natural border of forest and steppe. The goal is to show the expansion of the forest by artificial regeneration at the forest-steppe transition while testing the sustainability of the expansion into the steppe with a high level of *Lsi* seedlings protection from browsing by fencing (Figure 75).

CE2 Planting in control

The description is the same as in the case of the E2 plot, the difference is that there is low protection against browsing by repellent applied to terminal shoots (Figure 76). The plot is also used to compare the effectiveness of seedling protection by repellent and fencing.

Figure 74. Placement of the plot (E1) in a sparse forest gap, where there can be natural conditions for the growth of a dense forest. Considering the high level of grazing pressure, the seedlings are well protected by a fence.

Figure 75. Placement of the plot (E2) at the forest edge, where there can be natural conditions for forest growth.

Figure 76. Control plot (CE2) to E2 used to compare the importance and level of seedling protection. In this case, seedling terminals were coated with repellent, representing a low level of protection.

S1 Soil scarification

The experimental demonstration of support of natural forest regeneration under seed trees through improvement of conditions for seed germination by soil scarification at the forest gap (Figure 77). The area was divided as part of the experiment into four equal parts, two with soil scarification and two without. By comparing them, it is possible to evaluate the meaning of scarification. Due to the unplanned closure of the exclosure before scarification and the absence of the possibility to use a rotary tiller, it was necessary to perform the intervention manually. The timing of scarification for the seed year is essential. Sufficient opening of the bare soil is also important to limit the impact of weeds (Figure 78, Figure 79). The goal is to contribute to reforestation by support of natural processes and improving conditions for natural forest regeneration. There is high protection against trampling and browsing of future seedlings provided by fencing.

Figure 77. Soil scarification under the seed trees (Lsi) in the exclosure at the forest gap (S1). The new generation of the forest will grow under the protection of the seed trees.

Figure 78. Part of the S1 plot immediately after soil scarification.

Figure 79. The same area as in Figure 78, one year after the implementation of the intervention. The insufficient opening of the soil and favourable natural conditions allowed a critical expansion of weeds.

S2 Soil scarification + planting + individual protection

The experimental demonstration of support of natural forest regeneration through improvement of conditions for seed germination by soil scarification accompanied by sparse planting at the forest gap (Figure 80). Soil scarification was implemented with an unsuitable but available plough. The goal is to contribute to reforestation by support of natural processes and improving conditions for natural forest regeneration and by sparse planting. Planted seedlings were protected against browsing by repellent applied to terminal shoots.

Figure 80. Planted Lsi seedlings coated with a protective repellent in the furrows after soil scarification (S2).

S3 Soil scarification

The demonstration of support of natural forest regeneration through improvement of conditions for seed germination by soil scarification at the forest-steppe transition (Figure 81). Soil scarification was implemented with an unsuitable but available plough. The goal is to contribute to expansion of the forest by support of natural processes and improving conditions for natural forest regeneration.

S4 Soil scarification + planting + individual protection

The description is the same as in the case of the S3 plot, the difference is that there were planted *Lsi* seedlings with low protection against browsing by repellent applied to terminal shoots

(Figure 82). It is therefore a combination of supporting natural regeneration and artificial regeneration.

Figure 81. The furrows after soil scarification (S3) are still open for seeding and seed germination on the steppe a year after the intervention implementation due to more extreme natural conditions (compared to S1 plot).

Figure 82. Soil scarification furrows with planted Lsi seedlings protected by repellent (S4).

I1 Planting + individual protection

The demonstration of forest regeneration by planting of *Lsi* seedlings at the forest gap (Figure 83). The goal is to show the artificial reforestation. There is low protection against browsing provided by repellent applied to terminal shoots.

I2 Individual protection of natural regeneration

The demonstration of protection of naturally occurring seedlings. The goal is to show how to increase the success (successful growth) of natural forest regeneration with a low level of seedling protection from browsing by repellent (Figure 84).

I3 Planting + individual protection

The description is the same as in the case of the I1 plot (Figure 85).

I4 Individual protection of natural regeneration

The demonstration of protection of naturally occurring seedlings. The goal is to show how to increase the success (successful growth) of natural forest regeneration with a low to medium level of seedling protection from browsing by repellent or individual fencing, respectively (Figure 85, Figure 86).

Figure 83. Planted Lsi seedlings with terminals coated with a protective repellent (I1).

Figure 84. Naturally occurring seedlings one year after the application of a protective repellent coating (I2).

Figure 85. Planted Lsi seedlings with terminals coated with a protective repellent (I3). Seedlings from natural regeneration treated with repellent can also be seen in the background (I4).

Figure 86. Naturally occurring seedlings one year after the application of a protective repellent coating and an example of an individual fencing made from the remains of mesh from the construction of local exclosures(I4).

T-T1 Training thinning

The training plot for a training of thinning with the opportunity to propose a thinning intervention in young *Lsi* stand. The stand is fully inventoried and, based on the selection of numbers with which all the trees in the stand are marked (Figure 87), it is possible to calculate the intensity of the intervention proposed by a trained person. The goal is to enable practical education of forest users and students.

T-T2 Training thinning

The training plot for a training of thinning with the opportunity to study the proposed thinning intervention and design your own in young *Lsi* stand. The stand is fully inventoried and, based on the selection of numbers with which all the trees in the stand are marked (Figure 88), it is possible to calculate the intensity of the intervention proposed by a trained person. This can be compared with the proposed intervention, in which target trees and trees to be felled are marked with thinning intensity 15%. Compared to the T-T1 plot, a trained person can be affected by the proposed intervention, therefore it is particularly suitable for education and understanding of principles. The goal is to enable practical education of forest users and students.

Figure 87. Corner of plot T-T1. Trees for thinning intervention training are marked with blue numbers.

Figure 88. Corner of plot T-T2. Trees for thinning intervention training are marked with blue numbers. Target trees with the best quality for targeted care are marked with an orange stripe, trees unsuitable for cultivation (bad shape, unhealthy etc.) intended for felling with an orange dot.

T3 Thinning

The demonstration of the modification of the spatial structure with the support of promising target trees in the *Lsi* forest stand. In this thinning intervention with low intensity (20%), promising *Lsi* individuals (target trees) were supported by removing competing trees (Figure 89Figure 30). The main goal is to stimulate and support growth of the remaining trees. The intervention will help to create living space for the remaining trees and thereby improve their growth and vitality, contributing to the stabilization of the forest stand.

Figure 89. Lsi stand after a low intensity thinning (T3) with marked target trees (orange stripe). White dots indicate that the trees were inventoried.

T4 Thinning

The description is the same as in the case of the T3 plot, the difference is that the thinning intensity was moderate (40%), and the intervention included basic pruning (Figure 90).

T5 Thinning

The description is the same as in the case of the T3 plot, the difference is that the thinning intensity was high (60%), and the intervention included basic pruning (Figure 91, Figure 92).

Figure 90. Lsi stand after a moderate intensity thinning (T4) with marked target trees (orange stripe). Blue dots indicate that the trees were inventoried.

Figure 91. Lsi stand after a high intensity thinning (T5) with marked target trees (orange stripe). Blue dots indicate that the trees were inventoried.

Figure 92. Lsi stand on the border between the plots T4 and T5 before the implementation of thinning interventions.

T-T6 Training thinning

The training plot for a training of thinning with the opportunity to propose a thinning intervention in young *Lsi* stand. The stand is fully inventoried and, based on the selection of numbers with which all the trees in the stand are marked (Figure 93), it is possible to calculate the intensity of the intervention proposed by a trained person. The goal is to enable practical education of forest users and students.

T-T7 Training thinning

The training plot for a training of thinning with the opportunity to study the proposed thinning intervention and design your own in young *Lsi* stand. The stand is fully inventoried and, based on the selection of numbers with which all the trees in the stand are marked, it is possible to calculate the intensity of the intervention proposed by a trained person. This can be compared with the proposed intervention, in which target trees (Figure 94) and trees to be felled are marked. Compared to the T-T6 plot, a trained person can be affected by the proposed intervention, therefore it is particularly suitable for education and understanding of principles. The goal is to enable practical education of forest users and students.

Figure 93. Training thinning plot (T-T6) with trees intended for thinning intervention marked with blue or white numbers. Only trees with DBH > 7 cm were marked.

Figure 94. Training thinning plot (T-T7) with trees intended for thinning intervention marked with blue numbers and with marked target trees (orange stripe). Blue dots indicate that the trees were inventoried. Only trees with DBH > 7 cm were marked.

T8 Pruning

The demonstration of support of knot-free wood production in the sparse *Lsi* stand (Figure 95). The goal is to show how to increase the economic value of future timber/lumber. Considering the time and financial demands, it is better to prune only high-quality individuals.

Figure 95. Pruned high-quality Lsi individuals in the sparse Lsi forest stand (T8).

C-T9 Control to thinning

Monitoring of the development of unmanaged *Lsi* forest stand (Figure 96). The goal is to show how an unmanaged forest develops compared to the neighbouring managed ones – plots T4 and T5. Such dense stands are very often unstable and face the threat of more serious impacts during wildfires. Their management is therefore important not only from the point of view of wood production, but also from an ecological point of view.

Figure 96. Common too dense Lsi stand at the site without any intervention left as a control plot (C-T9) for the implemented thinning interventions. White dots indicate that the trees were inventoried.

4.2.1.4 Tree planting

In autumn 2022, 241 *Lsi* seedlings from local production were planted in Umnudelger (Table 19). Other tree species were not used due to their natural absence in the locality or absence in the forest-steppe transition at the site.

Table 19. Numbers of seedlings planted in Umnudelger in 2022.

ID	Intervention	Main goal	*Lsi*	Total
E1	Planting in exclosure	Expansion of the forest by artificial regeneration at the forest-steppe transition and protection of planted seedlings from browsing	65	**65**
E2	Planting in exclosure		56	**56**
CE2	Planting in control		61	**61**
S2	Soil scarification + planting + individual protection	Improvement of conditions for natural forest regeneration in the forest gap + reforestation and protection of planted seedlings from browsing	9	**9**
S4	Soil scarification + planting + individual protection	Expansion of the forest by improvement of conditions for natural forest regeneration at the forest-steppe transition + reforestation and protection of planted seedlings from browsing	37	**37**
I1 + I3	Planting + individual protection	Reforestation in the forest gap and protection of planted seedlings from browsing	13	**13**
Total planted seedlings in Umnudelger			241	241

Spacing for plantings was designed 2.6×2.6 m for plantings in the open area with regard to the naturally sparser forest stands in forest-steppe areas.

The success rate of plantings was medium to low (Table 20). The decisive factor for seedling mortality was mainly their quality. Overgrown seedlings with a very poorly developed root system were delivered for planting from local nursery (Figure 97). Seedlings of this quality are completely unsuitable for planting in the extreme conditions of the forest-steppe. The shock associated with transplantation was probably critical.

Table 20. Mortality of seedlings planted in Umnudelger (evaluated in September 2023).

ID	Intervention	Mortality (%)	
		Lsi	Total
E1	Planting in exclosure	45	45
E2	Planting in exclosure	54	54
CE2	Planting in control	61	61
S2	Soil scarification + planting + individual protection	56	56
S4	Soil scarification + planting + individual protection	86	86
I1 + I3	Planting + individual protection	77	77

Figure 97. Poor quality seedlings delivered for planting at the site. All of them are overgrown and most of them do not have a developed root system at all. Using such seedlings for planting is a waste of money.

Besides seedling quality, the influence of all other environmental factors on seedling mortality was rather minor. Browsing damage to seedlings was recorded (Figure 98) but had no significant effect on seedling mortality. Regarding the height of the seedlings, the damage caused by weeds was also not significant.

Figure 98. A seedling on the control plot CE2 damaged by browsing.

Repair planting was carried out in September 2023. It was realized only at the fenced plots to maintain protection against browsing. Therefore, repair planting only concerned the E1 and E2 plots (Table 20). Higher quality seedlings were used based on the selection of MENDELU experts directly in the local forest nursery. The root system of the newly planted seedlings was treated with hydrogel in the nursery. A total of 58 seedlings were planted within the repair planting.

4.2.1.5 Forest inventory

The results of the forest inventory on thinning plots are summarized in Table 21. The results summarize the basic descriptive characteristics of forest stands and their development in the case of thinning intervention. Inventory details, including species composition, are part of a separate document. Thinning at plots T3, T4 and T5 was implemented.

Table 21. Forest inventory at thinning plots in Umnudelger.

Plot	H_{sup} (m)	Age_{avg} (years)	Thinning intervention				
			Characteristic (unit)	Pre-thinning	Post-thinning	Thinning	
T-T1	9.7	29	BA (m^2/ha)	20.5			Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)	9.5			
			Density (stems/ha)	2,928			
			Vol (m^3/ha)	99			
T-T2	9.8	30	BA (m^2/ha)	14.0	11.9	2.1	Intensity = 15%
			DBH_{avgBA}/DBH_{avg} (cm)	10.4	11.2	7.9	
			Density (stems/ha)	1,648	1,216	432	
			Vol (m^3/ha)	69	58.8	6.7	
T3	9.5	29	BA (m^2/ha)	16.9	13.5	3.4	Intensity = 20%
			DBH_{avgBA}/DBH_{avg} (cm)	9.3	9.6	8.3	
			Density (stems/ha)	2,480	1,856	624	
			Vol (m^3/ha)	80.5	64.3	10.9	
T4	8.5	35	BA (m^2/ha)	21.2	9.2	12.0	Intensity = 57%
			DBH_{avgBA}/DBH_{avg} (cm)	8.3	9.7	7.6	
			Density (stems/ha)	3,925	1,250	2,675	
			Vol (m^3/ha)	90	39.1	38.3	
T5	7.7	32	BA (m^2/ha)	31.8	16.5	15.3	Intensity = 48%
			DBH_{avgBA}/DBH_{avg} (cm)	8.7	10.4	7.6	
			Density (stems/ha)	5,300	1,950	3,350	
			Vol (m^3/ha)	122	63	49.0	
T-T6	9.7	30	BA (m^2/ha)	24.6			Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)	10.2			
			Density (stems/ha)	3,038			
			Vol (m^3/ha)	119.0			
T-T7	9.6		BA (m^2/ha)	14.7			Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)	11.7			
			Density (stems/ha)	1,363			
			Vol (m^3/ha)	71			
T8			BA (m^2/ha)				Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)				
			Density (stems/ha)				
			Vol (m^3/ha)				
C-T9	9.2		BA (m^2/ha)	20.9			Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)	9.2			
			Density (stems/ha)	3,125			
			Vol (m^3/ha)	95.8			

4.2.1.6 Recommendations for forest management

Based on experience after the first year since establishment, it is possible to recommend the following management measures for the plots:

- It is necessary to reduce forest grazing.
- The aim of the forest manager should be primarily to support the ecological functions of the forest and its stability and vitality.
- One of the priorities of forest management should be to increase the heterogeneity of forests. Forest fragments in the forest-steppe landscape are extremely vulnerable ecosystems that can quickly degrade and disappear under current environmental and human-induced pressures. At the confluence of various factors, the forest can quickly degrade and disappear from the landscape. Manifestations are increasingly frequent pest outbreaks or wildfires in conjunction with overgrazing. The goal of the forest manager should therefore be to grow heterogeneous and varied stands with a balance of different age classes.
- Recommendations for increasing biodiversity are also associated with heterogeneity. Part of that approach should be the support and introduction of less common tree species, such as in this case especially *Bp* and potentially *Pt*. Pioneer species must be part of the forest and should be supported.
- Regular inspection of the forest (approximately once a month). In the case of natural disasters or a higher risk of the occurrence and impact of negative factors (e.g. long periods of drought, season with high risk of pest outbreaks), it is necessary to carry out inspections more often.
- A plough is sufficient for soil scarification on the steppe, but in the case of gales it is necessary to use a rotary tiller, because the competition from weeds is too strong. Soil scarification must be timed to the seed year.
- For successful reforestation, it is necessary to use quality seedlings with a well-developed root system in such extreme conditions.
- Regular inspection of the condition of the fencing (at least once a month). It is also advisable to check the situation after extreme events such as storms and strong winds. Branches or whole trees can fall on fences and seriously damage them. If even one goat gets into the exclosure, all the seedlings can be damaged within a few hours.

- Regular inspection of the condition of the seedlings in the exclosures (approximately once every two weeks). Accordingly, it is possible to plan further necessary interventions (e.g. weeding, special action for seedling protection against game, livestock, insect pests and pathogens).
- Regular weeding approximately once per year depending on the rains and the situation in the exclosures. The expected suitable month with the necessary first weeding intervention is July. It is sufficient to implement weeding only in the immediate vicinity of the seedlings (50 × 50 cm). The weeded biomass is left spread around the seedling as a mulch to improve soil moisture conditions and prevent further rapid weed growth. Protecting seedlings from damage is a priority, so weeding must be done carefully by a responsible worker.
- As soon as the seedlings outgrow weeds and the risk of terminal browsing (1.5–2 m), it is possible to remove the fences and use the mesh to build new exclosures where necessary. This may take approximately 7–10 years.
- The application of the repellent must be done carefully to avoid damaging tree (seedling) buds. This damage can also be caused by a too thick layer of repellent, which prevents needles or leaves from sprouting in the spring. Damage of a similar nature was rarely recorded on *Lsi* terminal shoots.
- Utilization of wood from precommercial and commercial thinning. Despite the implementation of thinning and the preparation of wood for transport from the forest, the wood remained on the site. This led to its unnecessary deterioration. Wood biomass from these tending interventions has the potential to be used, for example, for fences, heating, etc.
- To develop the vitality, stability and economic value of the forest, it is necessary to practice forest regeneration, protection and tending. The layout of these activities must be based on a responsible SFM and forest management plan. Therefore, updating and following the existing plan is essential.

4.2.2 Binder

4.2.2.1 Site introduction

Binder site is divided into two separate sites with slightly different conditions. The first site (48°38'48.3"N 110°26'45.7"E) is at the base of a hill (Table 22) at the transition of forest and steppe and it is covered by a post-fire unstocked forest area and mixed forest composed mainly of *Lsi*, *Psy* and *Bp*. The adjacent steppe is intensively used for grazing. The second site (48°38'36.425"N 110°30'28.901"E) is dominated by a *Psy* forest ecosystems on the sandy plain characterised by a recreational utilization and extensive structuralized and accessible complexes of *Psy* forest stands.

There are several good demonstrations of forest management in Binder site (e.g. seed stand, forest nursery, forest road network, demonstrations of thinning and forest regeneration methods) and multipurpose utilization of the forests. The state of some parts of the forests indicates past forestry management and thus the forestry tradition in the area. This represents a good opportunity for the development of forestry, application of SFM, education about it and the development of the recreational function of forests. The area has potential for both the development of productive and non-productive forest functions.

Table 22. Basic site characteristics of Binder area.

Elevation (m a.s.l.)	Parent rock	Soil type	Dominating ecosystem	Forest composition
1,095	Eolian sediments (sand)	Eutric Cambisol Loamic Ochric	Forest-steppe	Mixed forest

The area of the first site was damaged by a fire several years ago, after which the edge part of the forest failed to fully recover. This part is therefore made up of sparsely scattered mature *Lsi* individuals without artificial forest regeneration. A thick layer of weeds prevents the natural regeneration of the unstocked forest in the fire-degraded area. Therefore, natural regeneration is limited and usually regularly damaged by browsing. Towards the slope, a successful natural regeneration of the forest took place with the establishment of mixed stands of *Lsi*, *Psy*, *Bp* and P, in which it is appropriate to carry out a thinning intervention.

The area of the second site as covered by a *Psy* corridor with recreational use and it is characterized by extensive complexes of even-aged *Psy* forest stands with a high risk of instability and vulnerability to climate change and pest outbreaks.

Although there are many good forestry projects in the area, there is a lack of I) sustainability (especially in the edge zones) and II) management and tending of the young and premature forest stands. The high production potential of forest stands is unfulfilled; on the contrary, with regard to their condition, the provision of other ecosystem services may also be threatened. The continuous threat of forest retreat and loss caused by intensive grazing at the forest-steppe transition and fires is accompanied by consequences such as soil erosion, sand movement, temperature growth, aridization and loss of wood resources. For this reason, forestry intervention is appropriate with an important application of SFM.

4.2.2.2 Objectives of SFM measures

Local forestry measures should serve as a practical manual for studying proper forest management and contribute to the forest restoration in the post-fire unstocked forest area. Partial demonstrations represent ways of I) supporting and protecting natural forest regeneration, II) artificial forest regeneration and protection, III) improving forest stability and health and IV) increasing economic value of timber and the forest in general. On the site, it is necessary to find a balance between the productive, ecological and recreational functions of forests.

The planned activities will help to maintain the forest in its natural range and enable its simultaneous sustainable utilization in a way that could support local community and national wood market. Higher profits from better quality timber can provide financial resources for the forest protection and healthy and resilient forest will reliably provide ecosystem functions for current and future generations. In addition, long-term research and monitoring of natural conditions will support the local management and enable the evaluation of the situation on a wider scale.

The aim of the measures should be:

- To improve stability, health, and vitality of the forests.
- To increase economical value of the forests.
- To restore forest on the unstocked forest areas with unsuccessful natural regeneration.
- To support natural forest regeneration.
- To support local forest production and community.
- To support the development of forestry in the area.
- Awareness raising & knowledge sharing.

4.2.2.3 Forest management measures

With regard to the character and state of the forest, the implemented SFM measures (Figure 99, Figure 100, Table 23, Table 24) can be divided into three main categories:

1. Forest regeneration (reforestation)
2. Forest protection
3. Forest tending

The measures are located in three different types of forest:

a) Mixed forest (*Lsi*, *Psy*, *Bp*, *Pt*)
b) Fire-destroyed unstocked forest area
c) Premature *Psy* forest (*Psy* corridor)

In total, 29 demonstration plots were established at Binder sites (Figure 99, Figure 100, Table 23, Table 24).

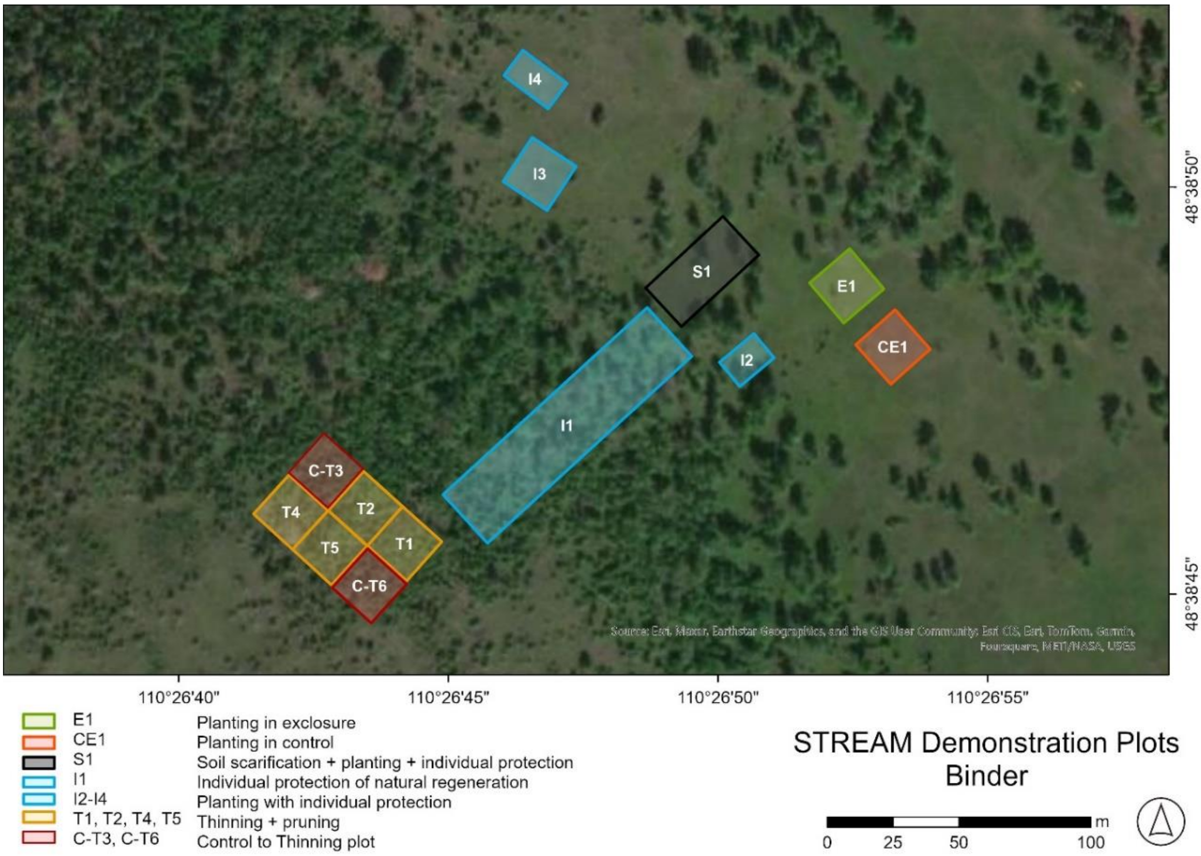

Figure 99. The distribution of forest management measures at the Binder site.

Table 23. A summary of interventions at Binder site.

ID	Intervention	Ecosystem	General category	Main goal	What do we want to show	Description	Size (m)	Area (ha)
E1	Planting in exclosure	Unstocked forest	Reforestation	Reforestation in the burned forest area and protection of planted seedlings from browsing	How to do artificial reforestation with a high level of seedling protection in unstocked forests	Fully fence-protected seedlings (*Lsi* + *Psy*) in the unstocked forest	20×20	0.04
CE1	Planting in control	Unstocked forest	Reforestation control		How to do artificial reforestation with low level of seedling protection in unstocked forests: Is it possible to do it successfully?	Seedlings (*Lsi* + *Psy*) with terminals protected by repellent planted in the unstocked forest (control to Bi_E1)	20×20	0.04
S1	Soil scarification + planting + individual protection	Forest gap	Reforestation	Improvement of conditions for natural forest regeneration in the forest gap + reforestation and protection of planted seedlings from browsing	How to increase the success (successful germination) of natural forest regeneration in forest gaps + artificial reforestation with a low level of seedling protection	Soil scarification under the seed trees in the forest gap + seedlings (*Psy* + *Lsi* + *Cs*) with terminals protected by repellent sparsely planted	20×40	0.08
I1	Individual protection of natural regeneration	*Lsi*-*Psy* forest	Forest protection	Protection of naturally-occurring seedlings	How to increase the success (successful growth) of natural forest regeneration with a low level of seedling protection	Naturally-occurring seedlings with terminals protected by repellent	-	0.26
I2	Planting + individual protection	Forest gap	Forest protection	Reforestation in the burned forest area and protection of planted seedlings from browsing	How to do artificial reforestation with a low level of seedling protection in unstocked forests	Seedlings (*Psy*) with terminals protected by repellent planted in the forest gap	8×6	0.00
I3	Planting + individual protection	Unstocked forest	Forest protection			Seedlings (*Lsi* + *Psy* + *Cs*) with terminals protected by repellent planted in the unstocked forest	18×12	0.02
I4	Planting + individual protection	Unstocked forest	Forest protection			Seedlings (*Psy* + *Lsi*) with terminals protected by repellent planted in the unstocked forest	14×6	0.01

Table 23. (Continued).

T1	Thinning + pruning	*Lsi-Psy* forest	Forest tending	Support of target trees (modification of the spatial structure) + support of knot-free wood production	How to increase target trees volume growth, quality and health and value of future timber/lumber	High intensity thinning with the support of target trees + pruning	20×20	0.04
T2	Thinning + pruning	*Lsi-Psy* forest	Forest tending			Medium intensity thinning with the support of target trees + pruning	20×20	0.04
C-T3	Control to thinning	*Lsi-Psy* forest	Tending control	Monitoring of the development of unmanaged forest	How an unmanaged forest develops	Unmanaged control for the realized interventions in the mixed stand	20×20	0.04
T4	Thinning + pruning	*Lsi-Psy* forest	Forest tending	Support of target trees (modification of the spatial structure) + support of knot-free wood production	How to increase target trees volume growth, quality and health and value of future timber/lumber	High intensity thinning with the support of target trees + pruning	20×20	0.04
T5	Thinning + pruning	*Lsi-Psy* forest	Forest tending			Medium intensity thinning with the support of target trees + pruning	20×20	0.04
C-T6	Control to thinning	*Lsi-Psy* forest	Tending control	Monitoring of the development of unmanaged forest	How an unmanaged forest develops	Unmanaged control for the realized interventions in the mixed stand	20×20	0.04

Table 24. A summary of interventions at Binder site (Psy corridor).

ID	Intervention	Ecosystem	General category	Main goal	What do we want to show	Description	Size (m)	Area (ha)
PC T1	Thinning	*Psy* forest	Forest tending	Light availability management of the forest (modification of the spatial structure)	How to stimulate natural forest regeneration and mature tree volume growth + how to increase stability and vitality of the forest	Premature stand (intermediate cutting) with target trees marked and planned thinning intervention	25×25	0.06
PC T-T2	Training thinning	*Psy* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to study the proposed thinning intervention	Premature stand (intermediate cutting) with full numbering of trees for thinning training/studying with target trees marked and planned intervention	25×25	0.06

Table 24. (Continued).

PC T-T3	Training thinning	*Psy* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to propose a thinning intervention	Premature stand (intermediate cutting) with full numbering of trees (95 trees) for thinning training	25×25	0.06
PC C-T4	Control to thinning	*Psy* forest	Tending control	Monitoring of the development of unmanaged forest	How an unmanaged forest develops	Unmanaged control for the realized interventions in the premature stand (intermediate cutting)	25×25	0.06
PC T-T5	Training thinning	*Psy* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to propose a thinning intervention	Premature stand (intermediate cutting) with full numbering of trees (175 trees) for thinning training	25×25	0.06
PC C-T6	Control to thinning	*Psy* forest	Tending control	Monitoring of the development of unmanaged forest	How an unmanaged forest develops	Unmanaged control for the realized interventions in the premature stand (intermediate cutting)	25×25	0.06
PC T-T7	Training thinning	*Psy* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to study the proposed thinning intervention	Premature stand (intermediate cutting) with full numbering of trees for thinning training/studying with target trees marked and planned intervention	25×25	0.06
PC T8	Thinning	*Psy* forest	Forest tending	Light availability management of the forest (modification of the spatial structure)	How to stimulate natural forest regeneration and mature tree volume growth + how to increase stability and vitality of the forest	Premature stand (intermediate cutting) with target trees marked and planned thinning intervention	25×25	0.06
PC T-T9	Training thinning	*Psy* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to study the proposed thinning intervention	Premature stand (intermediate cutting) with full numbering of trees for thinning training/studying with target trees marked and planned intervention	25×25	0.06
PC T10	Thinning	*Psy* forest	Forest tending	Light availability management of the forest (modification of the spatial structure)	How to stimulate natural forest regeneration and mature tree volume growth + how to increase stability and vitality of the forest	Premature stand (intermediate cutting) with target trees marked and planned thinning intervention	25×25	0.06
PC T-T11	Training thinning	*Psy* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to propose a thinning intervention	Premature stand (intermediate cutting) with full numbering of trees (107 trees) for thinning training	25×25	0.06

Table 24. (Continued).

PC C-T12	Control to thinning	*Psy* forest	Tending control	Monitoring of the development of unmanaged forest	How an unmanaged forest develops	Unmanaged control for the realized interventions in the premature stand (intermediate cutting)	25×25	0.06
PC T-T13	Training thinning	*Psy* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to propose a thinning intervention	Premature stand (intermediate cutting) with full numbering of trees (92 trees) for thinning training	25×25	0.06
PC C-T14	Control to thinning	*Psy* forest	Tending control	Monitoring of the development of unmanaged forest	How an unmanaged forest develops	Unmanaged control for the realized interventions in the premature stand (intermediate cutting)	25×25	0.06
PC T15	Thinning	*Psy* forest	Forest tending	Light availability management of the forest (modification of the spatial structure)	How to stimulate natural forest regeneration and mature tree volume growth + how to increase stability and vitality of the forest	Premature stand (intermediate cutting) with target trees marked and planned thinning intervention	25×25	0.06
PC T-T16	Training thinning	*Psy* forest	Tending training	Practical education of forest users and students	How to do forest tending in practice: the opportunity to study the proposed thinning intervention	Premature stand (intermediate cutting) with full numbering of trees for thinning training/studying with target trees marked and planned intervention	25×25	0.06

Figure 100. The distribution of forest management measures at the Binder site (Psy corridor).

E1 Planting in exclosure

The demonstration of necessary artificial reforestation in the burned forest area with extreme conditions (without the shade of trees and high weed competition) where natural regeneration has failed and without artificial intervention or another fire is unlikely in the horizon of several decades. Intervention is therefore necessary to provide continued provision of forest functions. The goal is to show the artificial reforestation with an emphasis on the introduction of commercial tree species (*Psy* and *Lsi*) with a high level of seedlings protection from browsing by fencing (Figure 101).

CE1 Planting in control

The description is the same as in the case of the E1 plot, the difference is that there is low protection against browsing by repellent applied to terminal shoots (Figure 102). The plot is also used to compare the effectiveness of seedling protection by repellent and fencing.

Figure 101. Fencing protecting planted seedlings from browsing in the burned forest area (E1). Regular weeding is necessary (approximately once a year).

Figure 102. Planted seedlings with individual protection by repellent at the plot in the burned forest area (CE1).

S1 Soil scarification + planting + individual protection

The experimental demonstration of support of natural forest regeneration through improvement of conditions for seed germination by soil scarification accompanied by sparse planting under the seed trees in a sparse forest/forest gap. (Figure 103). Soil scarification was implemented with an unsuitable but available plough. However, due to sandy soil conditions, even this method of scarification can be effective (Figure 104, Figure 105). The goal is to contribute to reforestation by support of natural processes and improving conditions for natural forest regeneration and by sparse planting. Planted seedlings were protected against browsing by repellent applied to terminal shoots. Experimentally, several individuals of *Cs* were planted as a hedge with a protective function due to the thorns.

Figure 103. Soil scarification was carried out under seed trees, where there is a high chance of natural regeneration. The depth of the furrows must be chosen responsibly – the roots of the seed trees must not be damaged; it is enough only to disturb (remove) the sod. Furrows are made along the contour to prevent soil erosion.

I1 Individual protection of natural regeneration

The demonstration of protection of naturally occurring seedlings. The goal is to show how to increase the success (successful growth) of natural forest regeneration with a low level of seedling protection from browsing by repellent (Figure 106).

Figure 104. Due to the nutrient-poor sandy soils, plough disturbance was sufficiently effective. Even a year after scarification, the furrows were not overgrown with weeds.

Figure 105. One year after soil scarification, the first seedlings from natural regeneration appear in the furrows.

Figure 106. An example of new shoots that have grown through a protective repellent applied in the autumn of the previous year. Repellent residues are still visible.

I2 Planting + individual protection

The description is the same as in the case of the E1 plot, the difference is that there is low protection against browsing by repellent applied to terminal shoots (Figure 107). In addition, the extremity of the environmental conditions was mitigated by situating the plot in the immediate vicinity of the forest to ensure partial protection by mature vegetation. The area is more like a forest gap. Only *Psy* was planted. The plot is also used to compare the effectiveness of seedling protection by repellent and fencing.

I3 Planting + individual protection

The description is the same as in the case of the I2 plot (Figure 108). However, both *Psy* and *Lsi* were planted in a post-fire unstocked forest area together with *Cs* as an experimental hedge with a protective function thanks to thorns.

I4 Planting + individual protection

The description is the same as in the case of the I2 plot. However, both *Psy* and *Lsi* were planted a post-fire unstocked forest area (Figure 109).

Figure 107. Planted Psy seedlings with terminals coated with a protective repellent (I2).

Figure 108. Planted Lsi seedlings (one year after planting) with terminals coated with a protective repellent (I3).

Figure 109. Planted Psy and Lsi seedlings with terminals coated with a protective repellent (I4).

T1 Thinning + pruning

The demonstration of the modification of the spatial structure with the support of promising target trees and knot-free wood production of target trees in the young dense mixed stand (Figure 110). In this high intensity thinning intervention, promising *Lsi* and *Psy* individuals (target trees) were supported by removing competing trees and basically pruned. The main goal is to stimulate and support growth of the remaining trees and value of future timber/lumber. The intervention will help to create living space for the remaining trees and thereby improve their growth and vitality, contributing to the stabilization of the forest stand.

T2 Thinning + pruning

The description is the same as in the case of the T1 plot, however, the intensity of the thinning intervention was only moderate (Figure 111).

C-T3 Control to thinning

Monitoring of the development of unmanaged mixed forest stand (Figure 112). The goal is to show how an unmanaged forest develops compared to the neighbouring managed one.

Figure 110. Plot T1 with implemented high intensity thinning. Target trees are marked with blue stripe.

Figure 111. Plot T2 with unimplemented medium intensity thinning. Target trees are marked with blue stripe. It is possible to implement the intervention or leave the plot to study the intervention.

Figure 112. Control plot C-T3 left to natural development. No markings or numbering.

T4 Thinning + pruning

The description is the same as in the case of the T1 plot (Figure 113). Due to the high proportion of stones in the soil, the forest is naturally sparser in this place. The order and structure of interventions in the rectangle is created in such a way that all three types of interventions can be easily compared with each other.

T5 Thinning + pruning

The description is the same as in the case of the T2 plot (Figure 114).

C-T6 Control to thinning

The description is the same as in the case of the C-T3 plot (Figure 115Figure 108).

Figure 113. Plot T4 with implemented high intensity thinning. Target trees are marked with blue stripe.

Figure 114. Plot T5 with unimplemented medium intensity thinning. Target trees are marked with blue stripe. It is possible to implement the intervention or leave the plot to study the intervention.

Figure 115. Control plot C-T6 left to natural development. No markings or numbering.

PC T1 Thinning

The demonstration of light availability management through the modification of the spatial structure in the premature *Psy* stand (Figure 116). The goal is to stimulate and support natural forest regeneration and mature tree volume growth together with the stability and vitality of the stand. In this thinning intervention, natural regeneration of the forest stand will be stimulated by improving light conditions. Furthermore, promising high-quality *Psy* individuals (target trees) are supported by removing competing trees.

PC T-T2 Training thinning

The training plot for a training of thinning with the opportunity to study the proposed thinning intervention and design your own in the premature *Psy* stand. The stand is fully inventoried and, based on the selection of numbers with which all the trees in the stand are marked (Figure 117), it is possible to calculate the intensity of the intervention proposed by a trained person. This can be compared with the proposed intervention, in which target trees and trees to be felled are marked. Compared to the T-T3 plot, a trained person can be affected by the proposed intervention, therefore it is particularly suitable for education and understanding of principles. The goal is to enable practical education of forest users and students.

Figure 116. Plot PC T1 designated for the implementation of thinning. The implementation of the intervention failed to be approved by the Binder FUG due to related permissions. Trees are numbered in purple.

Figure 117. Plot PC T-T2 with trees for thinning intervention training marked with white numbers. Target trees with the best quality for targeted care are marked with a purple stripe, trees unsuitable for cultivation (bad shape, unhealthy, competing with target trees etc.) intended for felling with a purple dot.

PC T-T3 Training thinning

The training plot for a training of thinning with the opportunity to propose a thinning intervention in the premature *Psy* stand. The stand is fully inventoried and, based on the selection of numbers with which all the trees in the stand are marked (Figure 118), it is possible to calculate the intensity of the intervention proposed by a trained person. The goal is to enable practical education of forest users and students. Inspiration for intervention can be drawn from PC T1 and PC T-T2 plots.

PC C-T4 Control to thinning

Monitoring of the development of unmanaged *Psy* forest stand (Figure 119). The goal is to show how an unmanaged forest develops compared to the neighbouring managed one.

PC T-T5 Training thinning

The description is the same as in the case of the PC T-T3 plot (Figure 120).

PC C-T6 Control to thinning

The description is the same as in the case of the PC C-T4 plot (Figure 121).

PC T-T7 Training thinning

The description is the same as in the case of the PC T-T2 plot (Figure 122).

PC T8 Thinning

The description is the same as in the case of the PC T1 plot (Figure 123).

PC T-T9 Training thinning

The description is the same as in the case of the PC T-T2 plot (Figure 124).

PC T10 Thinning

The description is the same as in the case of the PC T1 plot (Figure 125).

PC T-T11 Training thinning

The description is the same as in the case of the PC T-T3 plot (Figure 126).

Figure 118. Plot PC T-T3 with trees for thinning intervention training marked with white numbers.

Figure 119. Control plot PC C-T4 left to natural development. No markings or numbering.

Figure 120. Plot PC T-T5 with trees for thinning intervention training marked with white numbers.

Figure 121. Control plot PC C-T6 left to natural development. No markings or numbering.

Figure 122. Plot PC T-T7 with trees for thinning intervention training marked with white numbers. Target trees with the best quality for targeted care are marked with a purple stripe, trees unsuitable for cultivation (bad shape, unhealthy, competing with target trees etc.) intended for felling with a purple dot.

Figure 123. Plot PC T8 designated for the implementation of thinning. The implementation of the intervention failed to be approved by the Binder FUG due to related permissions. Trees are numbered in purple.

Figure 124. Plot PC T-T9 with trees for thinning intervention training marked with white numbers. Target trees with the best quality for targeted care are marked with a purple stripe, trees unsuitable for cultivation (bad shape, unhealthy, competing with target trees etc.) intended for felling with a purple dot.

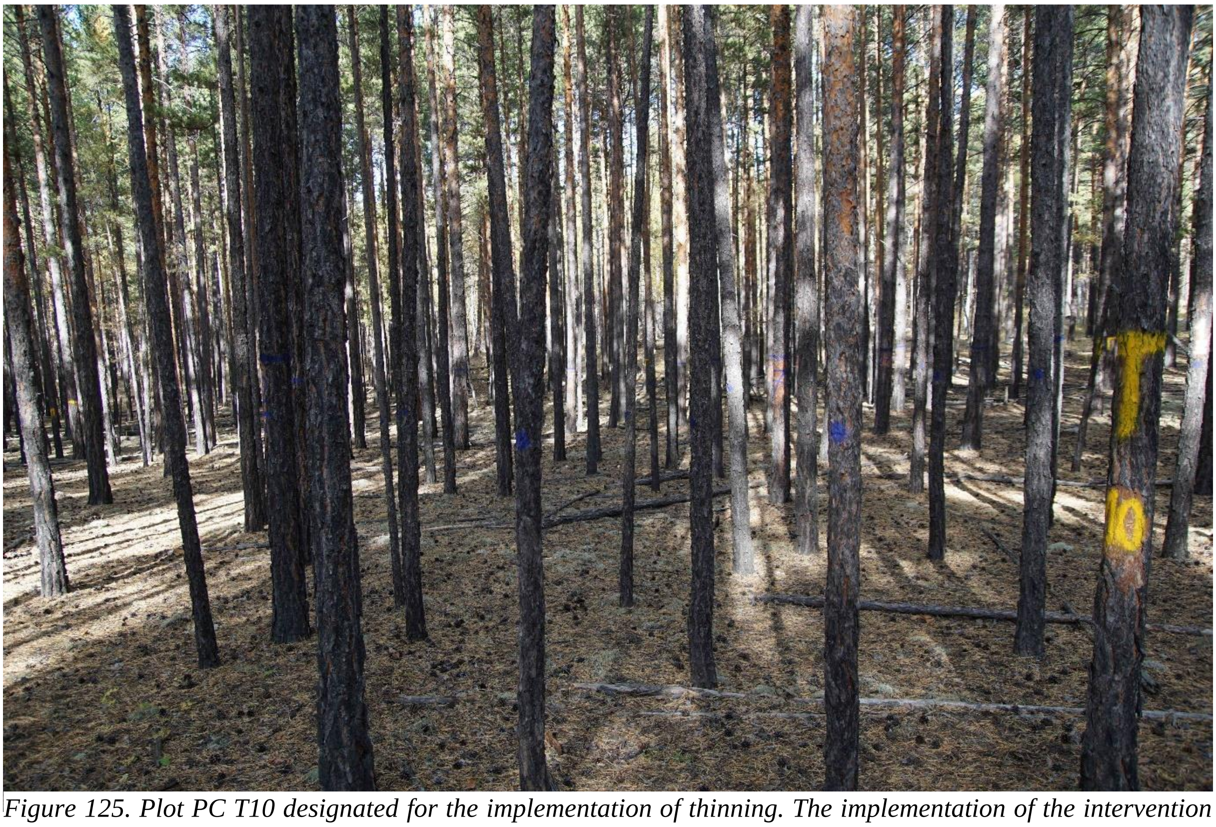

Figure 125. Plot PC T10 designated for the implementation of thinning. The implementation of the intervention failed to be approved by the Binder FUG due to related permissions.

Figure 126. Plot PC T-T11 with trees for thinning intervention training marked with white numbers.

PC C-T12 Control to thinning

The description is the same as in the case of the PC C-T4 plot (Figure 127).

PC T-T13 Training thinning

The description is the same as in the case of the PC T-T3 plot (Figure 128).

PC C-T14 Control to thinning

The description is the same as in the case of the PC C-T4 plot (Figure 129).

PC T15 Thinning

The description is the same as in the case of the PC T1 plot (Figure 130).

PC T-T16 Training thinning

The description is the same as in the case of the PC T-T2 plot (Figure 131).

Figure 127. Control plot PC C-T12 left to natural development. No markings or numbering.

Figure 128. Plot PC T-T13 with trees for thinning intervention training marked with white numbers.

Figure 129. Control plot PC C-T14 left to natural development. No markings or numbering.

Figure 130. Plot PC T15 designated for the implementation of thinning. The implementation of the intervention failed to be approved by the Binder FUG due to related permissions.

Figure 131. Plot PC T-T16 with trees for thinning intervention training marked with white numbers. Target trees with the best quality for targeted care are marked with a purple stripe, trees unsuitable for cultivation (bad shape, unhealthy, competing with target trees etc.) intended for felling with a purple dot.

4.2.2.4 Tree planting

In autumn 2022, 345 seedlings from local Binder forest nursery were planted in Binder (Table 25). Of this number, 143 were *Lsi* seedlings, 147 were *Psy* seedlings and 55 were *Cs* seedlings. The ratio of *Lsi* and *Psy* seedlings was distributed almost equally among the interventions. *Cs* seedlings were used rather experimentally and to a limited extent. Other tree species were not used due to their natural absence in the locality or potential for natural regeneration (*Bp*, *Pt*).

Spacing for plantings was designed 2.2×2.2 m for plantings in the open area with regard to the natural potential of local forest stands.

Table 25. Numbers of seedlings planted in Binder in 2022.

ID	Intervention	Main goal	*Lsi*	*Psy*	*Cs*	Total
E1	Planting in exclosure	Reforestation in the burned forest area and protection of planted seedlings from browsing	42	36		**78**
CE1	Planting in control		39	36		**75**
S1	Soil scarification + planting + individual protection	Improvement of conditions for natural forest regeneration in the forest gap + reforestation and protection of planted seedlings from browsing	19	31	13	**63**
I2 + I3 + I4	Planting + individual protection	Reforestation in the burned forest area and protection of planted seedlings from browsing	43	44	42	**129**

Total planted seedlings in Binder	143	147	55	345

The success rate of plantings was medium to low (Table 26). This was caused by two decisive factors – the quality of the seedlings and the grazing of livestock. Overgrown seedlings with a very poorly developed root system were delivered for planting from local forest nursery. The seedlings almost lacked fine roots which could supply the overgrown above-ground part with water and nutrients. Seedlings of this quality are unsuitable for planting in forests. The shock associated with transplantation was probably critical for most of the seedlings at least in the exclosure. It had particularly critical effects on *Psy*, probably because *Lsi* could limit transpiration by regulating needles.

Table 26. Mortality of seedlings planted in Binder (evaluated in September 2023).

ID	Intervention	Mortality (%)			
		Lsi	*Psy*	*Cs*	Total
E1	Planting in exclosure	62	75	-	68
CE1	Planting in control	51	92	-	71
S1	Soil scarification + planting + individual protection	26	90	38	60
I2 + I3 + I4	Planting + individual protection	42	100	71	71

Based on the mortality results from the fenced area (E1), it could be assumed that the influence of all other environmental factors on seedling mortality was rather minor. According to this assumption, it could be concluded that the influence of browsing on mortality was a maximum of 25% for *Psy* (with 75% dedicated to seedling quality). However, an assessment of the damage to the seedlings showed that over 80% of *Psy* seedlings planted outside the fenced area (CE1, S1, I2, I3, I4) were critically damaged by grazing. Damage to *Lsi* by browsing was not so frequent or critical. *Lsi* was able to regenerate (Figure 132) and was probably not as attractive to livestock for feeding as *Psy*, while *Psy* usually lost all their shoots due to browsing (Figure 133). However, in most cases even the seedlings that were not damaged by grazing did not survive (Figure 134).

Repair planting was carried out in September 2023. It was realized only at the fenced plot to maintain protection against browsing. Therefore, repair planting only concerned the E1 plot (Table 26). Higher quality seedlings were used based on the selection of MENDELU experts directly in the local forest nursery. The root system of the newly planted seedlings was treated with hydrogel in the nursery. The individuals were replaced according to the original species design. Living individuals in poor condition with a low chance of survival were also replaced. A total of 57 seedlings (28 *Lsi* + 29 *Psy*) were planted within the repair planting.

Figure 132. Lsi seedlings damaged by browsing were able to regenerate.

Figure 133. Grazing/browsing damage was fatal for Psy seedlings.

Figure 134. If the seedlings survived livestock attacks, they mostly died anyway due to the poor quality of the root system.

4.2.2.5 Forest inventory

The results of the forest inventory on thinning plots are summarized in Table 27 and Table 28. The results summarize the basic descriptive characteristics of forest stands and their development in the case of thinning intervention. Inventory details, including species composition, are part of a separate document. Thinning at plots T1 and T4 was implemented.

Table 27. Forest inventory at thinning plots in Binder.

Plot	H_{sup} (m)	Age_{avg} (years)	Thinning intervention				
			Characteristic (unit)	Pre-thinning	Post-thinning	Thinning	
T1	7.7		BA (m^2/ha)	22.4	10.3	12.1	Intensity = 54%
			DBH_{avgBA}/DBH_{avg} (cm)	6.9	9.0	5.9	
			Density (stems/ha)	6,000	1,625	4,375	
			Vol (m^3/ha)	86	39.7	38.7	
T2	9.2		BA (m^2/ha)	27.4	12.1	15.3	Intensity = 56%
			DBH_{avgBA}/DBH_{avg} (cm)	7.3	10.0	6.2	
			Density (stems/ha)	6,575	1,550	5,025	
			Vol (m^3/ha)	126	55.7	48.9	
C-T3	8.6		BA (m^2/ha)	21.7			Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)	8.7			
			Density (stems/ha)	3,650			
			Vol (m^3/ha)	93.4			
T4	7.9		BA (m^2/ha)	15.2	13.8	1.4	Intensity = 9%
			DBH_{avgBA}/DBH_{avg} (cm)	9.1	9.1	8.8	
			Density (stems/ha)	2,350	2,125	225	
			Vol (m^3/ha)	60	54.3	4.4	
T5	9.2		BA (m^2/ha)	24.7	5.6	19.1	Intensity = 77%
			DBH_{avgBA}/DBH_{avg} (cm)	8.3	5.9	9.9	
			Density (stems/ha)	4,550	2,050	2,500	
			Vol (m^3/ha)	114	26	61.2	
C-T6	8.6		BA (m^2/ha)	21.0			Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)	8.5			
			Density (stems/ha)	3,725			
			Vol (m^3/ha)	90.4			

Table 28. Forest inventory at thinning plots in Binder (Psy corridor).

Plot	H_{sup} (m)	Age_{avg} (years)	Thinning intervention				
			Characteristic (unit)	Pre-thinning	Post-thinning	Thinning	
T1	15.3	74	BA (m^2/ha)	33.4	26.9	6.6	Intensity = 20%
			DBH_{avgBA}/DBH_{avg} (cm)	15.3	17.2	11.3	
			Density (stems/ha)	1,824	1,152	656	
			Vol (m^3/ha)	256	206	21.0	
T-T2	14.6	79	BA (m^2/ha)	33.4	26.9	6.6	Intensity = 20%
			DBH_{avgBA}/DBH_{avg} (cm)	15.3	17.2	11.3	
			Density (stems/ha)	1,824	1,152	656	
			Vol (m^3/ha)	256	206	21.0	

Table 28. (Continued).

T-T3	13.1		BA (m²/ha)	38.3	29.5	8.7	Intensity = 23%
			DBH$_{avgBA}$/DBH$_{avg}$ (cm)	17.9	19.6	14.3	
			Density (stems/ha)	1,520	976	544	
			Vol (m³/ha)	252	194	28.0	
C-T4			BA (m²/ha)				Intensity =
			DBH$_{avgBA}$/DBH$_{avg}$ (cm)				
			Density (stems/ha)				
			Vol (m³/ha)				
T-T5	16.4		BA (m²/ha)	42.8			Intensity =
			DBH$_{avgBA}$/DBH$_{avg}$ (cm)	14.1			
			Density (stems/ha)	2,736			
			Vol (m³/ha)	350			
C-T6			BA (m²/ha)				Intensity =
			DBH$_{avgBA}$/DBH$_{avg}$ (cm)				
			Density (stems/ha)				
			Vol (m³/ha)				
T-T7	16.1	86	BA (m²/ha)	34.6	27.5	7.1	Intensity = 21%
			DBH$_{avgBA}$/DBH$_{avg}$ (cm)	18.1	19.9	14.0	
			Density (stems/ha)	1,344	880	464	
			Vol (m³/ha)	278	221	22.9	
T8	16.4	79	BA (m²/ha)	36.3	29.1	7.2	Intensity = 20%
			DBH$_{avgBA}$/DBH$_{avg}$ (cm)	16.5	20.0	10.9	
			Density (stems/ha)	1,696	928	768	
			Vol (m³/ha)	298	239	23.0	
T-T9	15.3	78	BA (m²/ha)	32.6	26.7	6.0	Intensity = 18%
			DBH$_{avgBA}$/DBH$_{avg}$ (cm)	16.8	19.0	12.0	
			Density (stems/ha)	1,472	944	528	
			Vol (m³/ha)	249	203	19.1	
T10	17.9	89	BA (m²/ha)	35.0	26.3	8.7	Intensity = 25%
			DBH$_{avgBA}$/DBH$_{avg}$ (cm)	16.4	19.5	12.0	
			Density (stems/ha)	1,648	880	768	
			Vol (m³/ha)	313	235	27.9	
T-T11	17.9		BA (m²/ha)	49.0			Intensity =
			DBH$_{avgBA}$/DBH$_{avg}$ (cm)	18.9			
			Density (stems/ha)	1,744			
			Vol (m³/ha)	438			
C-T12			BA (m²/ha)				Intensity =
			DBH$_{avgBA}$/DBH$_{avg}$ (cm)				
			Density (stems/ha)				
			Vol (m³/ha)				

Table 28. (Continued).

T-T13	18		BA (m²/ha) DBH$_{avgBA}$/DBH$_{avg}$ (cm) Density (stems/ha) Vol (m³/ha)	40.5 18.6 1,488 364			Intensity =
C-T14			BA (m²/ha) DBH$_{avgBA}$/DBH$_{avg}$ (cm) Density (stems/ha) Vol (m³/ha)				Intensity =
T15	15	78	BA (m²/ha) DBH$_{avgBA}$/DBH$_{avg}$ (cm) Density (stems/ha) Vol (m³/ha)	30.1 15.2 1,664 225	25.8 16.9 1,152 193	4.3 10.4 512 13.9	Intensity = 14%
T-T16	14.6	77	BA (m²/ha) DBH$_{avgBA}$/DBH$_{avg}$ (cm) Density (stems/ha) Vol (m³/ha)	24.5 17.1 1,072 178	19.1 20.0 608 139	5.4 12.1 464 17.2	Intensity = 22%

4.2.2.6 Recommendations for forest management

Based on experience after the first year since establishment, it is possible to recommend the following management measures for the plots:

- The aim of the forest manager should be primarily to support the production functions of the forest together with their stability and vitality.
- It is necessary to reduce forest grazing.
- The area has a forestry history and potential for forestry development and good forest production. The recommendation is therefore to find a high-quality forest manager who will use the potential of forests and develop it. It can lead to the economic development of the entire soum.
- Regular inspection of the forest (approximately once a month). In the case of natural disasters or a higher risk of the occurrence and impact of negative factors (e.g. long periods of drought, season with high risk of pest outbreaks), it is necessary to carry out inspections more often.
- A plough is sufficient for soil scarification because the competition from weeds is not so strong due to nutrient-poor sandy soils. Soil scarification must be timed to the seed year.
- For successful reforestation, it is necessary to use quality seedlings with a well-developed root system.

- Regular inspection of the condition of the fencing (at least once a month). It is also advisable to check the situation after extreme events such as storms and strong winds. Branches or whole trees can fall on fences and seriously damage them. If even one goat gets into the exclosure, all the seedlings can be damaged within a few hours.
- Regular inspection of the condition of the seedlings in the exclosures (approximately once every two weeks). Accordingly, it is possible to plan further necessary interventions (e.g. weeding, special action for seedling protection against game, livestock, insect pests and pathogens).
- Regular weeding approximately once per year depending on the rains and the situation in the exclosures. The expected suitable month with the necessary first weeding intervention is July. It is sufficient to implement weeding only in the immediate vicinity of the seedlings (50 × 50 cm). The weeded biomass is left spread around the seedling as a mulch to improve soil moisture conditions and prevent further rapid weed growth. Protecting seedlings from damage is a priority, so weeding must be done carefully by a responsible worker.
- As soon as the seedlings outgrow weeds and the risk of terminal browsing (1.5–2 m), it is possible to remove the fences and use the mesh to build new exclosures where necessary. This may take approximately 7–10 years.
- The application of the repellent must be done carefully to avoid damaging tree (seedling) buds. This damage can also be caused by a too thick layer of repellent, which prevents needles or leaves from sprouting in the spring. Damage of a similar nature was rarely recorded on *Lsi* terminal shoots.
- Implementation of marked thinning interventions and transport of wood from the forest. With regard to the missing permit and the complicated provision of skidding, it was not possible to implement thinning interventions at most of the thinning plots. However, their implementation is essential in the forest. The forest manager's task this year will therefore be to implement the marked interventions dedicated to realization and to apply their principle to other parts of the forest.
- Utilization of wood from precommercial and commercial thinning. Despite the implementation of thinning and the preparation of wood for transport from the forest, the wood remained on the site (Figure 135). This led to its unnecessary deterioration. Wood biomass from these tending interventions has the potential to be used, for example, for fences, heating, etc.

- To develop the vitality, stability and economic value of the forest, it is necessary to practice forest regeneration, protection and tending. The layout of these activities must be based on a responsible SFM and forest management plan. Therefore, updating and following the existing plan is essential.

Figure 135. An example of wood from a tending intervention ready for use but left on the site.

4.2.3 Bayan-Adarga

4.2.3.1 Site introduction

Bayan-Adarga forest-steppe site (48°32'12.1"N 111°06'45.2"E) is characterised by an intensive pastureland utilization and complexes of *Psy* forests growing on sandy soils (Table 29). The area was affected by a fire approximately two decades ago, after which an extensive part of the *Psy* forest failed to recover successfully. The remaining newly developed forest stands consist primarily of pioneer tree species such as *Pt* and *Bp*. These species create suitable conditions for the growth of *Psy*.

Table 29. Basic site characteristics of Bayan-Adarga.

Elevation (m a.s.l.)	Parent rock	Soil type	Dominating ecosystem	Forest composition
1,105	Eolian sediments (sand)	Eutric Arenosol Ochric (Turbic)	Forest-steppe	*Psy* forest

After the fire, the forest opened for livestock, and especially the edge zones suffer from strong grazing pressure, due to which the forest stopped regenerating naturally. Heterogeneity of the forest has so far only been modelled by fires, and this represents great uncertainty about the future of such forests in times of advancing climate change and associated impacts on Mongolia's ecosystems. Although the current state can be considered more balanced than in the past, it is necessary to learn from it and extend the concept of heterogeneity to the entire forest complex.

As the Bayan-Adarga town is adjacent to the forest; there is a high potential for direct providing of ecosystem services and recreation. This represents a good opportunity for the development of forestry, application of SFM, education about it and the development of the recreational function of forests. For this reason, extensive artificial reforestation was implemented, but was only partially successful. In the forests, forestry management and forest protection do not work properly. There is a lack of I) sustainability (especially in the edge zones), III) forest protection and III) management and tending of the young and premature forest stands. However, the area has potential for both the development of productive and non-productive forest functions.

Unstocked forest area has a potential to be naturally colonized by the pioneer species within several decades. During this time, however, the forest functions will not be provided, and the site will continue to degrade. In the context of advancing climate change and high grazing pressure, which also prevents successful growth of natural regeneration in the remains of the *Psy* forest, there is uncertainty regarding future development. The continuous threat of forest loss caused by intensive grazing at the forest-steppe transition and fires is accompanied by consequences such as wind speed increase, soil erosion, temperature growth, aridization and loss of wood resources. For this reason, forestry intervention is appropriate.

4.2.3.2 Objectives of SFM measures

Local forestry measures should serve as a practical manual for studying proper forest management and contribute to the forest restoration in the post-fire unstocked forest area. Partial demonstrations should represent ways of I) supporting and protecting natural forest regeneration, II) artificial forest regeneration and protection, III) improving forest stability and health and IV) increasing economic value of timber and the forest in general. On the site, it is necessary to find a balance between the productive and ecological functions of forests.

The planned activities will help to maintain the forest in its natural range and enable its simultaneous sustainable utilization in a way that could support local community Higher profits from better quality timber will provide financial resources for the forest protection and healthy and resilient forest will reliably provide ecosystem functions for current and future generations. In addition, long-term research and monitoring of natural conditions will support the local management and enable the evaluation of the situation on a wider scale.

The aim of the measures should be:

- To restore forest on the unstocked forest areas with unsuccessful natural regeneration.
- To improve stability, health, and perspective of the forest.
- To increase economical value of the forest.
- To support natural forest regeneration.
- To highlight the importance of pioneer tree species.
- To support local forest production and community.
- Awareness raising & knowledge sharing.

4.2.3.3 Forest management measures

With regard to the character and state of the forest, the implemented SFM measures (Figure 136, Table 30) can be divided into three main categories:

1) Forest regeneration (reforestation)
2) Forest protection
3) Forest tending

They are located in three different types of forest:

a) Fire-destroyed unstocked forest area
b) Mature *Psy* forest
c) Successional mixed forest (*Bp*, *Pt*, *Psy*)

In total, 17 demonstration plots were established at Bayan-Adarga site (Figure 136, Table 30).

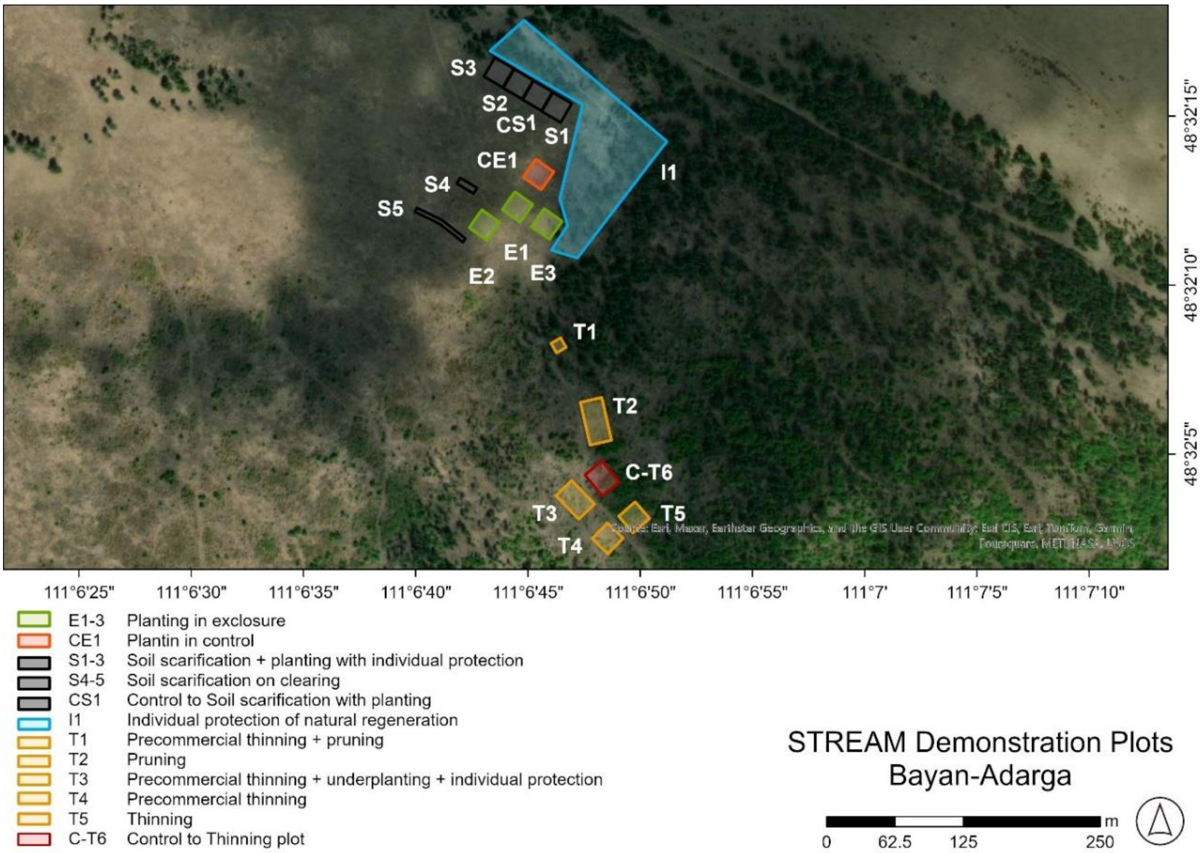

Figure 136. The distribution of forest management measures at the Bayan-Adarga site.

Table 30. A summary of interventions at Bayan-Adarga site.

ID	Intervention	Ecosystem	General category	Main goal	What do we want to show	Description	Size (m)	Area (ha)
E1	Planting in exclosure	Unstocked forest	Reforestation	Reforestation in the burned forest area and protection of planted seedlings from browsing	How to do artificial reforestation with a high level of seedling protection in unstocked forests (high difficulty)	Fully fence-protected seedlings (*Psy*) in the unstocked forest with extreme climatic conditions (no shadow)	20×20	0.04
CE1	Planting in control	Unstocked forest	Reforestation control		How to do artificial reforestation with low level of seedling protection in unstocked forests: Is it possible to do it successfully?	Seedlings (*Psy*) with terminals protected by repellent planted in the unstocked forest (control to Bay_E1)	20×20	0.04
E2	Planting in exclosure	Unstocked forest	Reforestation		How to do artificial reforestation with a high level of seedling protection in unstocked forests (medium difficulty)	Fully fence-protected seedlings (*Psy*) in the unstocked forest with partial protection by the *Pt* island (potential for expansion of *Pt*)	20×20	0.04
E3	Planting in exclosure	Unstocked forest	Reforestation		How to do artificial reforestation with a high level of seedling protection in unstocked forests (low difficulty)	Fully fence-protected seedlings (*Psy*) in the unstocked forest with partial protection by the *Psy* forest edge	20×20	0.04
S1	Soil scarification + planting + individual protection	Unstocked forest	Reforestation	Improvement of conditions for natural forest regeneration in the burned forest area + reforestation and protection of planted seedlings from browsing	How to increase the success (successful germination) of natural forest regeneration in unstocked forests + artificial reforestation with a low level of seedling protection	Soil scarification at the forest edge with the seed trees + seedlings (*Psy*) with terminals protected by repellent planted	20×20	0.04
S2	Soil scarification + planting + individual protection	Unstocked forest	Reforestation			Soil scarification at the forest edge with the seed trees + seedlings (*Psy*) with terminals protected by repellent sparsely (one-third numbers) planted	20×20	0.04

Table 30. (Continued).

S3	Soil scarification + planting + individual protection	Unstocked forest	Reforestation	Improvement of conditions for natural forest regeneration in the burned forest area + reforestation and protection of planted seedlings from browsing	How to increase the success (successful germination) of natural forest regeneration in unstocked forests + artificial reforestation with a low level of seedling protection	Soil scarification at the forest edge with the seed trees + seedlings (*Psy*) with terminals protected by repellent sparsely (one-third numbers) planted + living fence made of C	20×20	0.04
CS1	Control to soil scarification with planting	Unstocked forest	Reforestation	Improvement of conditions for natural forest regeneration in the burned forest area	How to increase the success (successful germination) of natural forest regeneration in unstocked forests: Is the planting sufficiently beneficial?	Soil scarification at the forest edge with the seed trees (control to Bay_S1)	20×20	0.04
S4	Soil scarification on a clearing	Unstocked forest	Reforestation	Improvement of conditions for natural forest regeneration in the burned forest area	How to increase the success (successful germination) of natural forest regeneration in unstocked forests	Soil scarification in the unstocked forest near the *Pt* island	18×6	0.01
S5	Soil scarification on a clearing	Unstocked forest	Reforestation	Improvement of conditions for natural forest regeneration in the burned forest area		Soil scarification in the unstocked forest near the *Pt* forest	52×4	0.02
I1	Individual protection of natural regeneration	*Psy* forest	Forest protection	Protection of naturally-occurring seedlings	How to increase the success (successful growth) of natural forest regeneration with a low to medium level of seedling protection	Naturally-occurring seedlings with terminals protected by repellent or individually fenced	-	1.11
T1	Precommercial thinning + pruning	*Psy* forest	Forest tending	Creation of the stand structure and its support + support of knot-free wood production	How to increase the stability, vitality and economic value of forest and value of future timber/lumber	Precommercial thinning + pruning	10×10	0.01
T2	Pruning	*Psy* forest	Forest tending	Support of knot-free wood production	To increase the economic value of future timber/lumber	Pruning in the sparse *Psy* stand	20×40	0.08

Table 30. (Continued).

T3	Precommercial thinning + underplanting + individual protection	*Psy-Pt-Bb* forest	Forest tending	Support of target trees (modification of the spatial structure) + reforestation under the protection of the shelterwood/current stand and protection of planted seedlings from browsing	How to increase target trees volume growth, quality and health + how to do artificial reforestation with a low level of seedling protection in sparse forests	Release of promising *Psy* individuals, support of naturally-occurring *Psy* seedlings + seedlings with terminals protected by repellent planted in appropriate places (20 *Psy* in total)	20×30	0.06
T4	Precommercial thinning	*Psy-Pt-Bb* forest	Forest tending	Support of target trees (modification of the spatial structure)	How to increase target trees volume growth, quality and health	Precommercial thinning, release of target individuals, health and shape selection, support of *Psy* growth	20×20	0.04
T5	Thinning	*Pt-Bp* forest	Forest tending	Light availability management of the forest (modification of the spatial structure)	How to stimulate natural forest regeneration and mature tree volume growth	Health and quality selection, support of *Psy* regeneration and growth	20×20	0.04
C-T6	Control to thinning	*Pt-Bp* forest	Tending control	Monitoring of the development of unmanaged forest	How an unmanaged forest develops	Unmanaged control for the realized interventions in the *Pt-Bp* stand	20×25	0.05

E1 Planting in exclosure

The demonstration of necessary artificial reforestation in the burned forest area with extreme conditions (without the shade of trees and related microclimate regulation with high weed and bushes competition) where natural regeneration has failed and without artificial intervention or another fire is unlikely in the horizon of several decades. Artificial intervention is therefore necessary to provide continued provision of forest functions. The goal is to show the artificial forest regeneration with an emphasis on the introduction of commercial tree species (*Psy*) adapted to local conditions with a high level of seedlings protection from browsing by fencing (Figure 137).

CE1 Planting in control

The description is the same as in the case of the E1 plot, the difference is that there is low protection against browsing by repellent applied to terminal shoots (Figure 138). The plot is also used to compare the effectiveness of seedling protection by repellent and fencing.

E2 Planting in exclosure

The description is the same as in the case of the E1 plot, the difference is that the extremity of the conditions is mitigated by a partial protection provided by the young *Pt* forest island (the trees provide shade and regulate microclimate) (Figure 139). In addition, there is a potential for further *Pt* expansion into the exclosure. This was confirmed by the inventory of *Pt* individuals one year after the establishment of the exclosure. The exclosure was colonized by 14 individuals of *Pt* in the direction of *Pt* forest island.

E3 Planting in exclosure

The description is the same as in the case of the E1 plot, the difference is that the extremity of the conditions is mitigated by a partial protection provided by the mature *Psy* forest edge (the trees provide shade and regulate microclimate) (Figure 140). One year after the original planting, ten seedlings taken from the surrounding stands were experimentally planted in the summer (June) 2023. In addition, there is a potential for natural regeneration and natural *Psy* expansion into the exclosure. The protection of this character can be decisive for the successful restoration of the forest. It is always advisable to start from the forest edge.

Figure 137. Fencing protecting planted seedlings from browsing in the burned forest area (E1). Regular weeding is necessary (approximately once a year).

Figure 138. Planted seedlings with individual protection by repellent at the plot in the burned forest area (CE1).

Figure 139. Fencing protecting planted Psy seedlings from browsing in the burned forest area (E2) with several individuals of Pt forming a protective group of trees (in the background).

Figure 140. Fencing protecting planted Psy seedlings from browsing in the burned forest area (E3) with a protective mature Psy forest stand (in the background).

S1 Soil scarification with plantings with individual protection

The demonstration of support of natural forest regeneration through improvement of conditions for seed germination by soil scarification accompanied by full planting at the forest edge and protection of planted *Psy* seedlings from browsing (Figure 141, Figure 142). Soil scarification was implemented with an unsuitable but available plough. However, due to sandy soil conditions, even this method of scarification can be effective (Figure 146). Soil scarification also serves as protection against weeds for planted seedlings, so it is not necessary to carry out weeding. The goal is to contribute to reforestation by support of natural processes and improving conditions for natural forest regeneration and by sparse planting. Planted seedlings were protected against browsing by repellent applied to terminal shoots.

S2 Soil scarification with plantings with individual protection

The description is the same as in the case of the S1 plot, the difference is that soil scarification was accompanied only by sparse *Psy* planting (Figure 141, Figure 143).

S3 Soil scarification with plantings with individual protection

The description is the same as in the case of the S1 plot, the difference is that soil scarification was accompanied by sparse planting (Figure 141, Figure 144). In addition, several individuals of *Cs* were planted experimentally as a hedge with a protective function due to the thorns.

CS1 Control to soil scarification with planting

The description is the same as in the case of the S1 plot, the difference is that soil scarification was not accompanied by *Psy* planting (Figure 141, Figure 145).

S4 Soil scarification

The demonstration of support of natural forest regeneration through improvement of conditions for seed germination by soil scarification in the burned forest area near the Pt island. Thanks to root disturbance, vegetative reproduction is also possible (Figure 147). The goal is to contribute to reforestation by support of natural processes and improving conditions for natural forest regeneration.

S5 Soil scarification

The description is the same as in the case of the S4 plot (Figure 148).

Figure 141. General overview of plots S1–S3 and CS1.

Figure 142. Psy seedlings coated with a protective repellent in the furrows after soil scarification (S1).

Figure 143. Sparsely planted Psy seedlings coated with a protective repellent in the furrows after soil scarification (S2).

Figure 144. Planted Cs on the edge of the plot S3.

Figure 145. Soil scarification control plot without planting at the edge of a Psy forest (CS1)

Figure 146. One year after soil scarification, the first Psy seedlings from natural regeneration appear in the furrows.

Figure 147. Soil scarification enabled effective vegetative reproduction of Pt (S4), however, almost all new sprouts were damaged by browsing.

Figure 148. Considering the thick sod in this area, ploughing was not very effective (S5).

I1 Individual protection of natural regeneration

The demonstration of protection of naturally occurring seedlings. The goal is to show how to increase the success (successful growth) of natural forest regeneration with a low to medium level of seedling protection from browsing by repellent or individual fencing, respectively (Figure 149, Figure 150).

Figure 149. An example of terminal shoots of Psy seedling coated with a protective repellent (I1).

Figure 150. An example of an individual fencing made from the remains of mesh from the construction of local exclosures (I1).

T1 Precommercial thinning with pruning

The demonstration of creation of the stand structure and its support together with support of knot-free wood production in young dense *Psy* stand (Figure 151). The goal is to show how to stimulate tree growth and increase the stability, vitality and economic value of forest and value of future timber/lumber.

T2 Pruning

The demonstration of support of knot-free wood production in the sparse *Psy* stand (Figure 152). The goal is to show how to increase the economic value of future timber/lumber. Considering the time and financial demands, it is better to prune only high-quality individuals.

T3 Precommercial thinning with underplanting with individual protection

The demonstration of the modification of the spatial structure with the support of promising target trees in the young dense mixed stand. In this thinning intervention, promising individuals (target trees) were supported by removing competing trees (Figure 153). The main goal is to stimulate and support growth of the remaining trees. The intervention will help to create living space for the remaining trees and thereby improve their growth, quality and vitality, contributing to the stabilization of the forest stand. In addition, the plot is a demonstration of forest regeneration by underplanting of *Psy* seedlings in the forest canopy openings (Figure 154). Planted seedlings are protected from browsing by repellent applied to terminal shoots.

T4 Precommercial thinning

The demonstration of the modification of the spatial structure with the support of promising target trees in the young dense mixed stand. In this thinning intervention, promising individuals (target trees) were supported by removing competing trees (Figure 155). The main goal is to stimulate and support growth of the remaining trees. The intervention will help to create living space for the remaining trees and thereby improve their growth, quality and vitality, contributing to the stabilization of the forest stand.

Figure 151. Psy stand after the intervention implementation (T1).

Figure 152. Pruned high-quality Psy individuals in the sparse Psy forest stand (T2).

Figure 153. Mixed stand after the intervention implementation (T3). Competing trees (marked in the circles) were removed to create living space. Smaller trees were left for self-pruning.

Figure 154. Psy seedlings underplanted in a canopy opening in the sparse mixed forest.

Figure 155. Marked intervention at the T4 plot with the aim of releasing an economically valuable Psy surrounded by Pt. Trees to be felled are marked with a red dot.

T5 Thinning

The demonstration of light availability management through the modification of the spatial structure in the *Bp-Pt* forest (Figure 156). The difference compared to the original natural forest without intervention is clearly visible (Figure 157). The goal is to stimulate and support natural forest regeneration and mature tree volume growth. In this thinning intervention, young *Psy* individuals were released, especially by removing low-quality *Bp* individuals and by improving light conditions, the natural regeneration of the forest stand will be stimulated and supported. The intention is to introduce more *Psy* seedlings naturally into the stand. Furthermore, promising *Bp* individuals (target trees) were supported by removing competing trees. Strong stump re-sprouting indicates ability to quickly regenerate and the potential for coppicing type of management (Figure 158, Figure 159).

CT6 Control to thinning

Monitoring of the development of unmanaged *Bp-Pt* forest stand (Figure 157). The goal is to show how an unmanaged forest develops compared to the neighbouring managed one.

Figure 156. Bp-Pt forest after thinning intervention realization (T5) in autumn 2022.

Figure 157. Control plot in Bp-Pt forest stand (C-T6) with a visibly higher density and more complex competitive environment compared to plot T5.

Figure 158. Bp-Pt forest development after the thinning (T5) (July 2023). Stump sprouts are starting to grow.

Figure 159. Bp-Pt forest development after the thinning (T5) (August 2023). Stump sprouts are starting to dominate in the undergrowth.

4.2.3.4 Tree planting

In autumn 2022, 452 seedlings from Binder forest nursery were planted in Bayan-Adarga (Table 31). Of this number, 439 were *Psy* seedlings and 13 were *Cs* seedlings. *Cs* seedlings were used rather experimentally and to a limited extent. Other tree species were not used due to their natural absence in the locality or potential for natural regeneration (*Bp*, *Pt*).

Spacing for plantings was designed 2.2×2.2 m for plantings in the open area with regard to the natural potential of local forest stands.

Table 31. Numbers of seedlings planted in Bayan-Adarga in 2022.

ID	Intervention	Main goal	*Psy*	*Cs*	Total
E1	Planting in exclosure	Reforestation in the burned forest area and protection of planted seedlings from browsing	79		79
CE1	Planting in control		79		79
E2	Planting in exclosure		75		75
E3	Planting in exclosure		75		75
S1	Soil scarification + planting + individual protection	Improvement of conditions for natural forest regeneration in the burned forest area + reforestation and protection of planted seedlings from browsing	77		77
S2	Soil scarification + planting + individual protection		27		27
S3	Soil scarification + planting + individual protection		27	13	40
Total planted seedlings in Bayan-Adarga			439	13	452

The success rate of plantings was medium to low (Table 32). This was caused by two decisive factors – the quality of the seedlings and the grazing of livestock. Overgrown seedlings (Figure 160) with a very poorly developed root system were delivered for planting from Binder forest nursery. The seedlings almost lacked fine roots which could supply the overgrown above-ground part with water and nutrients. Seedlings of this quality are unsuitable for planting in forests. The shock associated with transplantation was probably critical for most of the seedlings at least in the exclosure.

Based on the mortality results from the fenced areas (E1, E2, E3), it could be assumed that the influence of all other environmental factors on seedling mortality was rather minor. According to this assumption, it could be concluded that the influence of browsing on mortality was a maximum of 20% (with 80% dedicated to seedling quality). However, an assessment of the damage to the seedlings showed that over 90% of *Psy* seedlings planted outside the fenced area (CE1, S1, S2, S3) were critically damaged by grazing (browsing, disappeared, broken). Browsing-damaged *Psy* seedlings usually lost all their shoots (Figure 161). However, in most cases even the seedlings that were not damaged by grazing did not survive (see the fenced areas results; Table 32; Figure 160).

Table 32. Mortality of seedlings planted in Bayan-Adarga (evaluated in September 2023).

ID	Intervention	Mortality (%)		
		Psy	*C*	Total
E1	Planting in exclosure	81		91
CE1	Planting in control	85		85
E2	Planting in exclosure	69		69
E3	Planting in exclosure	64		64
S1	Soil scarification + planting + individual protection	99		99
S2	Soil scarification + planting + individual protection	93		93
S3	Soil scarification + planting + individual protection	96	85	93

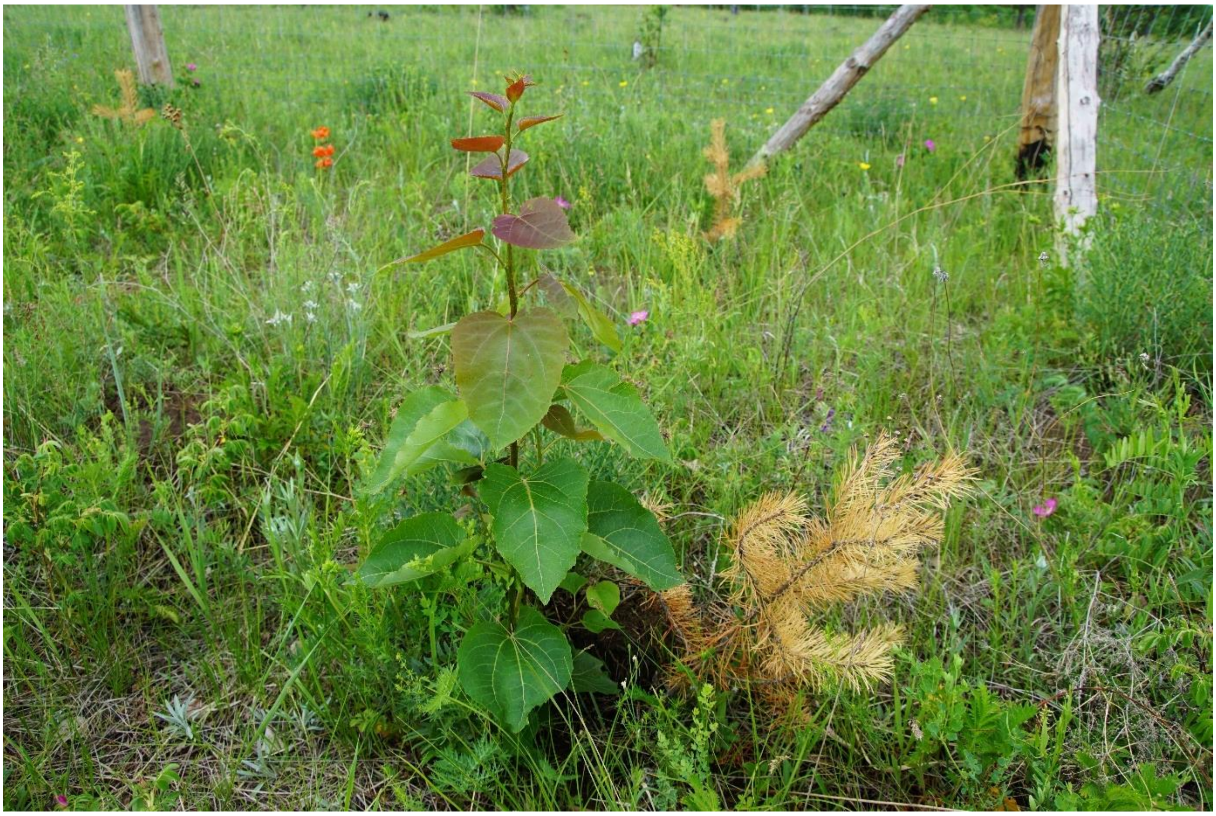

Figure 160. An A seedling from natural regeneration replaced the dead artificially planted Psy seedling in the fenced area of "Pt" exclosure (E2).

Repair planting was carried out in September 2023. It was realized only at the fenced plots to maintain protection against browsing. Therefore, repair planting only concerned the E1, E2 and E3 plots (Table 31, Table 32). Repair planting also included planting seedlings to empty places according to the original planting design, which were omitted during the first planting in

2022. Higher quality seedlings were used based on the selection of MENDELU experts directly in the local forest nursery. The root system of the newly planted seedlings was treated with hydrogel in the nursery. The individuals were replaced according to the original species design. Living individuals in poor condition with a low chance of survival were also replaced. Repair planting was supported by extra hydrogel application. Side branches of the seedlings were cut. Mulching was done at E1 plot. A total of 176 *Psy* seedlings were planted within the repair planting.

Figure 161. Critical seedling damage by browsing.

4.2.3.5 Forest inventory

The results of the forest inventory on thinning plots are summarized in Table 33. The results summarize the basic descriptive characteristics of forest stands and their development in the case of thinning intervention. Inventory details, including species composition, are part of a separate document. Thinning at plots T3 and T5 was implemented.

Table 33. Forest inventory at thinning plots in Bayan-Adarga.

Plot	H_{sup} (m)	Age_{avg} (years)	Thinning intervention				
			Characteristic (unit)	Pre-thinning	Post-thinning	Thinning	
T1			BA (m^2/ha)				Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)				
			Density (stems/ha)				
			Vol (m^3/ha)				
T2			BA (m^2/ha)				Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)				
			Density (stems/ha)				
			Vol (m^3/ha)				
T3			BA (m^2/ha)				Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)				
			Density (stems/ha)				
			Vol (m^3/ha)				
T4			BA (m^2/ha)				Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)				
			Density (stems/ha)				
			Vol (m^3/ha)				
T5	8.7		BA (m^2/ha)	841			Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)	94.5			
			Density (stems/ha)	1,200			
			Vol (m^3/ha)	3642			
C-T6			BA (m^2/ha)				Intensity =
			DBH_{avgBA}/DBH_{avg} (cm)				
			Density (stems/ha)				
			Vol (m^3/ha)				

4.2.3.6 Recommendations for forest management

Based on experience after the first year since establishment, it is possible to recommend the following management measures for the plots:

- The aim of the forest manager should be primarily to find a balance between the productive and ecological functions of the forest together with support of its stability and vitality.
- It is necessary to reduce forest grazing.
- Regular inspection of the forest (approximately once a month). In the case of natural disasters or a higher risk of the occurrence and impact of negative factors (e.g. long periods of drought, season with high risk of pest outbreaks), it is necessary to carry out inspections more often.

- A plough is sufficient for soil scarification because the competition from weeds is not so strong due to nutrient-poor sandy soils. Soil scarification near *Pt* forest can increase the speed and success of reforestation due to vegetative reproduction by disrupting the root system of *Pt*.
- For successful reforestation, it is necessary to use quality seedlings with a well-developed root system.
- Regular inspection of the condition of the fencing (at least once a month). It is also advisable to check the situation after extreme events such as storms and strong winds. Branches or whole trees can fall on fences and seriously damage them. If even one goat gets into the exclosure, all the seedlings can be damaged within a few hours.
- Regular inspection of the condition of the seedlings in the exclosures (approximately once every two weeks). Accordingly, it is possible to plan further necessary interventions (e.g. weeding, special action for seedling protection against game, livestock, insect pests and pathogens).
- Regular weeding approximately once per year depending on the rains and the situation in the exclosures. The expected suitable month with the necessary first weeding intervention is July. It is sufficient to implement weeding only in the immediate vicinity of the seedlings (50 × 50 cm). The weeded biomass is left spread around the seedling as a mulch to improve soil moisture conditions and prevent further rapid weed growth. Protecting seedlings from damage is a priority, so weeding must be done carefully by a responsible worker.
- As soon as the seedlings outgrow weeds and the risk of terminal browsing (1.5–2 m), it is possible to remove the fences and use the mesh to build new exclosures where necessary. This may take approximately 7–10 years.
- The application of the repellent was very effective in protecting seedlings from natural regeneration when reaching heights of approximately 0.8 m and above. It is therefore recommended to continue protecting *Psy* saplings with repellent, as this can be significantly beneficial for them.
- Strong stump re-sprouting indicates ability to quickly regenerate and the potential for coppicing type of management. Its development in birch stands may contribute to SFM. On the other hand, *Bp* sprouts may be competitors for the target *Psy* and thus cleaning intervention may be necessary.

- Utilization of wood from precommercial and commercial thinning. Despite the implementation of thinning and the preparation of wood for transport from the forest, the wood remained on the site. This led to its unnecessary deterioration. Wood biomass from these tending interventions has the potential to be used, for example, for fences, heating, etc.
- For the development of forestry in the area and the protection of local forests, it is necessary to stop neglecting pioneer tree species (*Bp*, *Pt*). Despite their lower economic potential compared to *Psy*, it is possible to increase their economic value by appropriate forest tending. Management of these common species and their promotion for the wood processing industry as well as for use in households (e.g. as firewood) is the way to sustainability. In addition, they have the greatest potential to naturally reforest unstocked forest areas destroyed by fire that have not been successfully reforested with *Psy*. Pioneer species prove to be excellent preparatory trees under which *Psy* grows successfully.
- To develop the vitality, stability and economic value of the forest, it is necessary to practice forest regeneration, protection and tending. The layout of these activities must be based on a responsible SFM and forest management plan. Therefore, updating and following the existing plan is essential.

5. GENERALIZED RECOMMENDATIONS FOR SUSTAINABLE FOREST MANAGEMENT IN MONGOLIA

5.1 Forest management models introduction

It is necessary to emphasize that SFM must be based on respect for natural conditions. It is advisable to support local tree species and respect provenance. Seeds from local stands are highly preferred for local nurseries and future local planting. It is necessary to restore or expand forests in places where the forest grows naturally or has recently grown naturally. On the other hand, it is unsustainable to plant forest vegetation on the steppe, where it can only survive by artificial watering. With reforestation, it is always advisable to start from the forests.

Based on natural conditions, it is possible to merge some of the localities and thus propose generalized recommendations in a simple scheme of forest management models. Similar models have already been developed for Mongolia, but they are not developed sufficiently and, what is the main thing, they are not used in practice. Several more years of cooperation between research (mainly environmental, economic and social) and forestry practice are needed to create long-term and functional forest management models based on natural conditions. It is the only key to SFM in Mongolia and therefore should be among the priorities of the forestry sector in Mongolia.

Decisive factors for the generalization of forest management models are soil and moisture conditions, the density and composition of the herb layer, the tree species composition of natural forests and the main goal (function) of planting tree vegetation/forests. Of course, this is also related to altitude, geomorphological and climatic conditions.

It is natural that even at individual sites there will be considerable differences in environmental conditions, and a uniform model for a site will not always be sufficient. A simple example is Binder, where there will different management (I) in the alluvium by the river (Figure 162, Figure 163), (II) at the slope bases (Figure 164), (III) on the slopes (Figure 165), and (IV) in the recreational forest (Figure 166). It is therefore necessary to use the models variably according to the specific situation and conditions. This should be based on the experience of the forest manager. Such experience requires their long-term and multidisciplinary education and practicing. It is not possible to replace this with one workshop. It is not possible to replace education with one or two workshops, on the contrary, workshops are highly desirable for practicing.

Figure 162. A view of the floodplain forests in the river alluvium. The soils are well supplied with water and nutrients.

Figure 163. A view of the degraded riparian forest vegetation in the river alluvium. A forest should grow here too. The soils are well supplied with water and nutrients.

Figure 164. A sparse forest at the slope base. At the transition to the steppe, a strong interaction with grazing management is typical. The content of water and nutrients in the soil decreases compared to the alluvium.

Figure 165. A view of the forest on the slope. The content of water and nutrients in the soil is low and rock content is growing. Risk of erosion.

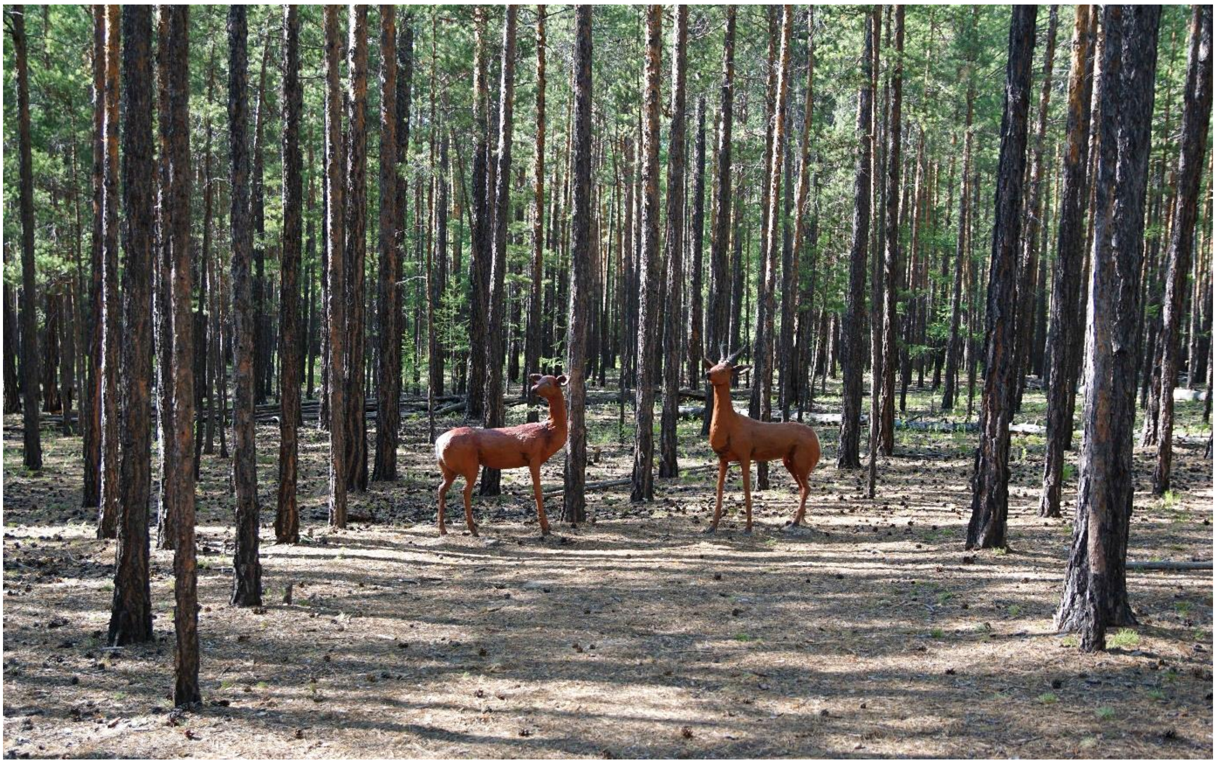

Figure 166. Recreational forest differs mainly in terms of its cultivation goal. However, the environmental conditions are also different compared to the forests at the slope bases, with regard to the high proportion of sand in the soil and expected lower nutrient and water content.

5.2 Forest management models

In a simplified way, it is possible to generalize forest management at project sites into the following models:

- Light taiga – poor – dry (1) (Figure 167)
- Light taiga – rich – dry (2) (Figure 168)
- Light taiga – rich – influenced by water (3) (Figure 169)
- Steppe – affected by water (alluvial, permafrost, enriched) (4) (Figure 170)

It is also possible to specify the function and type of planted vegetation in the forest management models:

- stabilizing shrubs
- stabilizing trees
- production *Psy*
- production *Lsi*
- production broadleaf
- production mixed

STREAM sites with forest management can be categorized as follows (shelterbelt hedgerow excluded):

- Tunkhel mixed forest – 3 (production mixed)
- Javkhlant riverbank – 4 (stabilizing trees – stabilizing shrubs)
- Bugant *Bp* forest – 3 (production broadleaf)
- Bugant *Psy* corridor – 1 (production *Psy*)
- Bugant mixed forest – 1 (production mixed)
- Umnudelger *Lsi* forest – 2 (production *Lsi* – stabilizing trees)
- Binder mixed forest – 1 (production mixed)
- Binder *Psy* corridor – 1 (production *Psy*)
- Bayan-Adarga mixed forest – 1 (production *Psy* – production mixed)

Figure 167. Light taiga – poor – dry (1) in Binder Psy corridor.

5.2.1 Light taiga – poor – dry (1)

Forest regeneration:

1) **Possibilities of natural regeneration** – There is a good potential for natural regeneration based on the habitat conditions, which are very suitable thanks to the soil characteristics unfavourable for the herb layer development. It is essential to disturb the

not completely compact sod by ploughing, disc harrows or simple scarificators. Natural regeneration can be facilitated by fire, which, however, is undesirable due to the economic importance of the forest. Soil sod can be disturbed chemically with herbicides, which cannot be recommend due to the preservation of Mongolian nature. Another condition for successful natural regeneration is the proximity of fruiting seed trees, this can be ensured by the creation of small-scale clearcuttings with the possibility of leaving marginal stands, or seed trees (standards) in the number of 5–20 individuals per hectare. In places further away from the seed trees, a mixture of pioneer species will prevail in natural seeding.

2) **Possibilities of artificial regeneration** – Artificial regeneration should be used in places far from seed trees, and in places where other economically usable tree species should be introduced (including *Pt* and S), which have no chance for natural regeneration. Artificial regeneration is recommended by pit (hole) or slit planting, depending on the maturity of the planting material (seedlings). Hole planting can be done with the help of an earth auger. Very important is the handling of planting material, which should be under thorough care from harvesting in forest nursery to planting. Due to the habitat conditions, it is possible to use smaller planting material, which has better survival rate. Planting design details are given in Table 34.

Table 34. Recommended hectare numbers of artificially planted seedlings and their spacing.

Tree species	Individuals/ha	Spacing (m)
Pinus sylvestris	2,000	2.2×2.2
Pinus sibirica	1,500	2.6×2.6
Larix sibirica	1,500	2.6×2.6

<u>Forest tending:</u>

1) **Tending of successional stands with a predominance of pioneer trees**:
    a. **Precommercial thinning**: Well-timed interventions to modify stand stability, quality and species composition. Intensity should be moderate to strong. The first interventions should be carried out already at a stand height of 5 m, leaving a spacing of approximately 2 m around the selected trees. Positive species (*Psy*, *Lsi*) or quality (straight trunks) selection interventions predominates. It is necessary to take care of the tree species diversity. Wood produced can be used, for example, for heating. Cutting of trees <7 cm DBH prevails.

b. **Commercial thinning**: The first thinning takes place at a stand height of approximately 10 m and a DBH of approximately 15 cm. The interventions are aimed at supporting target individuals in the number of approximately 50–200 individuals per hectare, depending on the quality of the forest. Interventions are not necessary in places with low stand density. Cutting further focuses on health selection and damaged individuals that can be removed. The harvested wood has a potential for regional use.

2) **Tending of stands with a predominance of commercial species**:

   a. **Precommercial thinning**: In groups or in larger single-species stands of *Psy*, it is advisable to carry out precommercial thinning in a negative way with the aim of removing qualitatively deformed individuals and health-impaired individuals. The first precommercial thinning should be carried out at a stand height of 5 m. Maintaining a closed canopy will help to shape the trunks. The harvested wood has a limited utilization potential (e.g. firewood).

   b. **Commercial thinning**: These interventions start when the stand height is about 10 m. They are of have high to very hight intensity. The aim is to carry out positive selection interventions with the goal of releasing 50–200 *Psy* individuals of high-quality. *Psy* individuals in sparse groups with too extensive branching should be pruned at a height of 7 m. The goal is to grow a trunk at least 5 m long without knots. The harvested wood has a very promising potential for use in the region.

Forest regeneration methods:

1) **Clearcutting methods** – Small-scale cuttings up to a width of approximately 50 m, proceeding from the north, to ensure shading in the winter and spring months, this measure will limit the damage to seedlings by climatic factors. It is advisable to leave standards (seed trees) in such a distribution that they do not significantly limit the subsequent preparation of the soil.
2) **Shelterwood and selection methods** – Cutting of target trees while leaving high-quality seed trees until the occurrence of natural seeding and new growth, then harvesting the remaining seed trees (shelterwood method), or gradual group cutting with the aim of creating a more complex forest structure (group selection method). In the case of stands composed of *Psy*, it is necessary to open the harvested seed stands more intensively with greater emphasis on good light conditions in understory.

Forest protection measures:

1) **Prevent grazing in forest stands** – For the success of forest regeneration, it is necessary to limit or completely exclude grazing, this measure can be carried out by defining large grazing blocks, always in agreement with the local community. Alternatively, it is possible to carry out individual small-scale exclosures according to the need for reforestation goals. Game browsing is insignificant.
2) **Elimination of unwanted herbaceous vegetation in young stands (weeding)** – Herbaceous vegetation on these sites is not a major obstacle to the growth of young stands. In the case of a higher incidence of unwanted weeds, it is possible to carry out individual weeding around the seedlings for two years after planting.
3) **Fire risk management** – Due to the frequent occurrence of fires, it is advisable to divide forest complexes with suitable firebreaks passable for machinery. The width of the firebreaks should be at least 4 m and distance between the partial firebreaks at least 200 m. It will be possible to use them for management-related accessibility of forests.

5.2.2 Light taiga – rich – dry (2)

Forest regeneration:

1) **Possibilities of natural regeneration** – There is a good potential for natural regeneration based on the habitat conditions, which are relatively suitable thanks to the moisture conditions unfavourable for the herb layer development. Due to the poorer moisture conditions, the competition of weeds is low and not very compact, the mineral substrate is often exposed on slopes. The occurrence of natural regeneration is quite frequent. Natural regeneration can be supported by soil scarification with rotary tillers. The proximity of fruiting seed trees is essential for successful natural regeneration, this can be ensured by the creation of small-scale clearcuttings with the possibility of leaving marginal stands, or seed trees (standards) in the number of 5–20 individuals per hectare. In places further away from the seed trees, a mixture of pioneer broadleaf species will prevail in natural seeding.
2) **Possibilities of artificial regeneration** – Artificial regeneration should be used in places far from seed trees, and in places where other economically usable tree species should be introduced (including *Pt* and *S*), which have no chance for natural regeneration. Artificial regeneration is recommended by pit (hole) or slit planting, depending on the maturity of the planting material (seedlings). Hole planting can be

done with the help of an earth auger. Very important is the handling of planting material, which should be under thorough care from harvesting in forest nursery to planting. Due to the habitat conditions, it is possible to use smaller planting material, which has better survival rate. Planting design details are the same as in the case of the first model (Table 34).

Figure 168. Light taiga – rich – dry (2) in Umnudelger.

Forest tending:

1) **Tending of successional stands with a predominance of pioneer trees**:
   a. **Precommercial thinning**: Well-timed interventions to modify stand stability, quality and species composition. Intensity should be moderate to strong. The first interventions should be carried out already at a stand height of 5 m, leaving a spacing of approximately 2 m around the selected trees. Positive species (*Psy*, *Lsi*, *Bp*) or quality (straight trunks) selection interventions predominates. It is necessary to take care of the tree species diversity. Wood produced can be used, for example, for heating. Cutting of trees <7 cm DBH prevails.
   b. **Commercial thinning**: The first thinning takes place at a stand height of approximately 10 m and a DBH of approximately 15 cm. The interventions are

aimed at supporting target individuals in the number of approximately 50–200 individuals per hectare, depending on the quality of the forest. Interventions are not necessary in places with low stand density. Cutting further focuses on health selection and damaged individuals that can be removed. The harvested wood has a potential for regional use.

2) **Tending of stands with a predominance of commercial species**:
   a. **Precommercial thinning**: In groups, in larger single-species stands or mixed stands (*Lsi*, *Psy*) it is advisable to carry out precommercial thinning in a negative way with the aim of removing qualitatively deformed individuals and health-impaired individuals. The first precommercial thinning should be carried out at a stand height of 5 m. Maintaining a closed canopy will help to shape the trunks. The harvested wood has a limited utilization potential (e.g. firewood).
   b. **Commercial thinning**: These interventions start when the stand height is about 10 m. They are of have high to very hight intensity. The aim is to carry out positive selection interventions with the goal of releasing 50–200 high-quality individuals. Individuals in sparse groups with too extensive branching should be pruned at a height of 7 m. The goal is to grow a trunk at least 5 m long without knots. The harvested wood has a very promising potential for use in the region.

Forest regeneration methods:

1) **Clearcutting methods** – Small-scale cuttings up to a width of approximately 25 m (strip cutting) should follow slope direction, so that they connect to the forest road network. These narrow small-scale cuttings will guarantee the maintenance of a suitable microclimate important for the growth of a new generation of forest and reduce the potential for extensive erosion. It is important to maintain mature forest strips between each cutting (of at least the same width, i.e. approximately 25 m) until the stage of successful growth of the new forest.
2) **Shelterwood and selection methods** – Cutting of target trees while leaving high-quality seed trees until the occurrence of natural seeding and new growth, then harvesting the remaining seed trees (shelterwood method), or gradual group cutting with the aim of creating a more complex forest structure (group selection method). In the case of stands composed of *Lsi* and *Psy*, it is necessary to open the harvested seed stands more intensively with greater emphasis on good light conditions in understory.

Forest protection measures:

1) **Prevent grazing in forest stands** – For the success of forest regeneration, it is necessary to limit or completely exclude grazing, this measure can be carried out by defining large grazing blocks, always in agreement with the local community. Alternatively, it is possible to carry out individual small-scale exclosures according to the need for reforestation goals. Game browsing is insignificant.
2) **Elimination of unwanted herbaceous vegetation in young stands (weeding)** – Herbaceous vegetation on these sites is not a major obstacle to the growth of young stands. In the case of a higher incidence of unwanted weeds, it is possible to carry out individual weeding around the seedlings for two years after planting.
3) **Fire risk management** – Due to the frequent occurrence of fires, it is advisable to divide forest complexes with suitable firebreaks passable for machinery. The width of the firebreaks should be at least 4 m and distance between the partial firebreaks at least 200 m. It will be possible to use them for management-related accessibility of forests.

5.2.3 Light taiga – rich – influenced by water (3)

Forest regeneration:

1) **Possibilities of natural regeneration** – The potential for natural regeneration is limited and conditioned by disturbances such as fire or mechanical scarification. The reason is strong competition from weeds and a thick layer of sod. For the expected success of natural regeneration, the occurrence of fertile seed trees and a significant disturbance of the soil cover is necessary. In slope areas with a shallow soil, natural regeneration occurs more often mainly due to less vital competing vegetation. Natural regeneration should take place in small-scale (0.05–0.2 ha) regeneration cuttings in the form of group selection or group shelterwood cuttings. In large open areas, the success of natural regeneration is uncertain.

   Natural regeneration can be supported by intensive mechanical disturbance of the soil sod. Soil preparation by mechanical means can be in furrows or over the whole area. Chemical treatment with herbicides is not recommended.

   The occurrence of pioneer species from natural seeding is highly desirable for the formation of a suitable climate on larger open areas.

   For natural regeneration, it is advisable to maintain stand density (stocking) of 5–2; in large open areas, the competition of herbaceous vegetation will be too strong, and the success of natural regeneration will be small.

2) **Possibilities of artificial regeneration** – Artificial regeneration in nutrient-rich habitats is the basis for rapid and comprehensive reforestation of logged-over or degraded forest habitats. Before artificial regeneration, it is advisable to disturb the soil sod by ploughing, with planting in the disturbed places. Pit (hole) planting can be done with hoes or an earth auger with a larger diameter. Very important is the handling of planting material, which should be under thorough care from harvesting in forest nursery to planting. Due to the habitat conditions, it is advisable to use higher planting material (the height of the above-ground part of the seedlings should be >30 cm), which has better chance of succeeding in the competition for light with weeds and higher survival rate. The use of high-quality container seedlings is very suitable. Planting design details are the same as in the case of the first model (Table 34).

Figure 169. Light taiga – rich – influenced by water (3) in Bugant.

Forest tending:

1) **Tending of successional stands with a predominance of pioneer trees**:
   a. **Precommercial thinning**: In stands with low stand density (stocking), it is advisable maximum support of broadleaf species (*Bp*, *Pt*) with the retention of individuals with poorer health and quality. In places with a higher stand density,

the goal should be to support stronger, better-quality individuals. Priority care focuses on the stability of individuals – the entire stand. The first precommercial thinning should be done at a stand height of 5 m, spacing between individuals should be 2–5 m. Wood is usable for local energy purposes.

b. **Commercial thinning**: The first thinning takes place at a stand height of approximately 10 m and a DBH of approximately 15 cm. The interventions are aimed at supporting target individuals in the number of approximately 50–200 individuals per hectare, depending on the quality of the forest. Interventions are not necessary in places with low stand density. Cutting further focuses on health selection and damaged individuals that can be removed. In case of occurrence of valuable conifers (*Psy*, *Lsi*), it is beneficial to carry out very strong releasing interventions of these species. The harvested wood has a potential for regional use.

2) **Tending of stands with a predominance of commercial species**:
   a. **Precommercial thinning**: In groups, in larger single-species stands or mixed stands (*Lsi*, *Psy*) it is advisable to carry out precommercial thinning in a negative way with the aim of removing qualitatively deformed individuals and health-impaired individuals. The first precommercial thinning should be carried out at a stand height of 5 m. Maintaining a closed canopy will help to shape the trunks. The harvested wood has a limited utilization potential (e.g. firewood).
   b. **Commercial thinning**: These interventions start when the stand height is about 10 m. They are of have high to very hight intensity. The aim is to carry out positive selection interventions with the goal of releasing 50–200 high-quality *Lsi* and *Psy* individuals. It is not necessary to cut the other components of the stands, as they will fulfil an important tending function (e.g. self-pruning). *Lsi* and *Psy* individuals in sparse groups with too extensive branching should be pruned at a stand height of 7 m. The goal is to grow a trunk at least 5 m long without knots. The harvested wood has a very promising potential for use in the region.

Forest regeneration methods:

1) **Clearcutting methods** – Only small-scale cuttings should be used. On accessible locations, it is possible to create group clearcuttings up to an area of 0.4 ha, with a cutting width of up to 30 m. Narrow cuttings will be easier to prepare mechanically and

at the same time the localities will retain a favourable microclimate. In less accessible terrains and slope locations, it is advisable to perform group shelterwood cuttings with reduced stand density (to 5-3), the cuttings can be both small-area and large-area. When reducing the seed stand it is necessary to focus on pioneer tree species. In the case of commercial tree species, damaged and qualitatively unsuitable individuals should be reduced. By keeping the best individuals, the genetic quality of the newly formed stands is supported. The remaining trees will further realize a light-related increment.

2) **Shelterwood and selection methods** – Cutting of target trees while leaving high-quality seed trees until the occurrence of natural seeding and new growth, then harvesting the remaining seed trees (shelterwood method), or gradual group cutting with the aim of creating a more complex forest structure (group selection method). In the case of stands composed of *Lsi* and *Psy*, it is necessary to open the harvested seed stands more intensively with greater emphasis on good light conditions in understory.

Forest protection measures:

1) **Prevent grazing in forest stands** – For the success of forest regeneration, it is necessary to limit or completely exclude grazing, this measure can be carried out by defining large grazing blocks, always in agreement with the local community. Alternatively, it is possible to carry out individual small-scale exclosures according to the need for reforestation goals. Game browsing is insignificant.
2) **Elimination of unwanted herbaceous vegetation in young stands (weeding)** – Herbaceous vegetation on these sites is an important obstacle for the success of both natural and artificial regeneration. Therefore, it is necessary to carry out weeding at least around the seedlings for approximately 3–5 years after planting.
3) **Fire risk management** – Due to the frequent occurrence of fires, it is advisable to divide forest complexes with suitable firebreaks passable for machinery. The width of the firebreaks should be at least 4 m and distance between the partial firebreaks at least 200 m. It will be possible to use them for management-related accessibility of forests.

4.2.4 Steppe – affected by water (alluvial, permafrost, enriched) (4)

Silviculture goal

The main task in these sites is to establish or re-establish vegetation with woody species to provide ecological functions (e.g. water protection, soil protection, climate regulation).

In addition, social and aesthetic functions of these forests are important, especially in populated areas.

Selection of sites for creating vegetation belts

The sites are chosen so that the natural conditions in the given places are favourable for the successful growth of established stands. The most suitable are valley locations temporarily or permanently affected by groundwater, locations with suitable soil conditions, and locations recommended by the local community for reforestation. Maintenance and restoration of woody vegetation along rivers should be a priority.

Species composition

Vegetation belts in the steppe are best established with broadleaf tree species (*S*, *P*, *B*, *Up*, *Hr*, etc.) with local use of coniferous trees (*Psy*, *Lsi*). Production forests are not the main target of these plantings.

Planting material

For the establishment of *P* and *S* stands, it is possible to use vegetative reproduction material such as cuttings. In the exclosures, it is possible to do spring seeding of *B* seeds on exposed (scarified) plots. It is advisable to choose the maturity of the planting material according to the size of the surrounding herbaceous vegetation, in the fence the herbaceous vegetation will always be significantly higher, because it will not be grazed by livestock.

Planting

Planting is carried out by pit planting, always in such a way that the relevant root system is not deformed, it is also possible to plant with the help of an earth auger. Container seedlings can be planted during most of the growing season, except for very dry summer periods. Bare-root seedlings are planted in spring and autumn outside the main vegetative growth of trees. When planting, it is necessary to take into account the sensitivity of the root system to frost and drying.

Protective measures

Protection from grazing and browsing is priority. Artificial regeneration must be preceded by the construction of high-quality exclosures (fences), as they will be very often attacked by livestock. Livestock will often use the fence and the vicinity of the fence to rest from sunlight and for scratching. In this way, there will be a risk of the fences being destroyed or damaged.

For the maintenance of the fencing, it is necessary to clearly define the responsible persons who will check the fencing and repair it immediately in the case of a damage. Education among the local community is also important, so that local people are clearly aware of the importance of these vegetation belts and practice regulated and controlled grazing.

Due to strong weed competition, it may be necessary to carry out weeding for the first 2–3 years.

Figure 170. Steppe – affected by water (alluvial, permafrost, enriched) (4) in Javkhlant.

6. GENERALIZED MODEL OF THE ORGANIZATIONAL STRUCTURE OF A FORESTRY COOPERATIVE

Forestry cooperatives are always tied regionally to the relevant territorial unit with an area of 5,000–100,000 ha. Smaller units are more organized, and it is easier to carry out and control forest activities in them. Forest units must be divided into units accessible for more intensive forms of forest management and units whose main goal is to protect the forest and preserve forest ecosystems in a non-intervention mode. An important condition for successful management is the preparation of even simple FMPs the application of the resulting conditions and rules for sustainable management based on these plans. Forest management planning is a fundamental component of SFM, and its role is to determine and express the objectives of forest management in a specified area of forest and to set out the steps to be taken to achieve those objectives. The plan further clearly defines the mandatory activities in the forest. Although FMPs are often prepared and available for local FUGs, their content and implementation are generally insufficient.

Among the binding provisions of FMPs should be:

- Maximum annual allowable cut based on the state of the forest stand and its potential annual growth.
- Obligation to tend young stands up to 50 years of age with at least two tending interventions during this period.
- Preservation of forest sustainability: restoration of damaged and harvested forests within 10 years from deforestation.
- Harvesting of mature forest stands (main felling) can be carried out by shelterwood (unlimited in size), selection or clearcutting (up to a maximum area of 0.5 ha) methods.

<u>Organizational model structure of a forestry cooperative</u>

1. ***Head of the forestry cooperative***
    - Responsible to the authorities of regional organizations (districts).
    - Responsibility for the state of the forest.
    - Direct management of foresters (assignment of tasks, control, training).
    - Controls and coordinates the activities of the service centre.
    - Responsible for drawing subsidies.

- Responsibility for the economic results of the cooperative.
- Communication with the public.
- Assigning the creation of FMP, accepts the prepared FMP, responsible for fulfilling the binding provisions of the FMP.

2. ***Administrative office***
   - Property and material records
   - Records of services and production activities in the forest
   - Wages of employees and subcontractors
   - Subsidy
   - Working with the public

3. **Foresters**
   - The forester is responsible for 1,500–5,000 ha of managed forest according to the distribution and complexity of the tasks arising from the FMP and the diversity of the forest.
   - Responsibility for the state of the forest.
   - Plans activities in the forest according to the recommendations of the FMP and according to his own experience.
   - Marks areas for artificial reforestation.
   - Marks the road network in agreement with the head of the forest administration.
   - Marks tending interventions in forests.
   - Plans main felling in mature forests.
   - Organizes and assigns activities in the forest to the production department.
   - Takes over and controls the activity carried out in the forest.
   - Enters an instruction to reimburse the costs for the production activity performed.
   - Prepares the payroll and production agenda for the administrative office.
   - Responsible for legal provisions

4. **Service centre**
   - Chief engineer is responsible to the head of the forest cooperative.
   - Responsible for purchases, subsidies and operation of heavy equipment intended for forest work.

- Possible purchase of small equipment and rental of machines to workers.

Manual labour in forests (ensure the activities by private workers – self-employed persons):

- Artificial planting.
- Construction of exclosures.
- Weeding.
- Tree felling in premature forests – precommercial and marked commercial thinning.
- Pruning.
- Tree felling in mature forests with a chainsaw.
- Forest roads preparation and maintenance (by tree felling).
- Minor earthworks.
- Seed collection.
- Manual work in forest nurseries.

Main activities with heavy and financially expensive equipment in forests:

- Forest fire fighting and related services.
- Ensuring forest accessibility – creation/construction of roads, fords (crossings), bridges.
- Logging and wood transport – mainly wood extraction, skidding and timber transport.
- Forest pest control.
- Development and care of forest nurseries.
- Sawmill production.
- Operation and management of other production components (charcoal, wood chips, pellets, briquettes, etc.).
- Machine maintenance and service.

7. SUMMARY

Within the sustainable forest management measures realized under the STREAM project:

- 104 management measures were designed and implemented at 6 project sites
- 2,161 seedlings were planted within originally designed and realized plots in 2022
- 620 seedlings were planted within 2 new plots in 2023
- 422 seedlings were planted within repair planting in 2023
- 3,203 seedlings were planted in total
- 8 woody species were planted: *Lsi*, *Psy*, *S*, *P*, *Hr*, *Cs*, *Up* and *Am*
- 8 main categories of forestry interventions with 9 subcategories were realized
- 43 forest tending plots were established (thinning, training thinning and pruning)
- 4 generalized forest management models were prepared and presented

Title: SUSTAINABLE FOREST MANAGEMENT MEASURES REALIZED WITHIN THE STREAM PROJECT

Authors: Václav Pecina et al.

Publisher: Mendel University in Brno, Zemědělská 1, 613 00 Brno

Website: https://mendelu.cz/en/

More information:

https://forest4mongolia.mendelu.cz/en/

https://www.facebook.com/forest4mongolia

Mendel University in Brno