MINISTRY OF FORESTRY OF THE REPUBLIC OF BELARUS
STATE SCIENTIFIC INSTITUTION
"INSTITUTE OF FOREST OF THE NATIONAL ACADEMY OF SCIENCES OF BELARUS"

BELARUSIAN FORESTRY DEVELOPMENT PROJECT
GEF/THE WORLD BANK
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REPORT No. 4

Report on testing of the technology of reconstruction felling and creation of silvicultures, tending and cultivation of plantations of main broadleaved species (oak, ash, maple), including by organization of experimental sites in the forestries of the Republic of Belarus. Report on finalization of the Guidelines document on the reconstruction of low-value plantations to increase the share of broadleaved forests, according to the results of testing of the technology of reconstruction felling and creation of silvicultures, tending and cultivation of plantations of main broadleaved species

within the framework of the services under contract No. BFDP/GEF/CQS/17/26-36/18, dated September 14, 2018.

Project activity 3.1.5: Improvement and testing of a technology for the reconstruction of low-value stands for the purpose of increasing the share of broadleaved species

Prepared by

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Gomel 2019

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Abbreviations

TES – Temporary experimental sites
SFI – State Forestry Institution
SSI – State Scientific Institution
SPFA – State Production Forestry Institution
GEF –Global Environment Fund
B - Silver birch
WeWi – weeping willow
IF – Institute of Forest
MoF – the Ministry of Forestry of the Republic of Belarus
Guidelines document - Guidelines document on the reconstruction of low-value forest plantations to increase the share of deciduous forests
NAS – National Academy of Sciences of Belarus
Asp – common aspen
GrAl – gray alder
BlAl – black alder
Ppr – white and black poplar
UE - Unitary Enterprise
EFS - experimental forest station

Summary

1. The work was performed in the period from February to November 2019 within the framework of stage **seven** of project activity 3.1.5 under contract No. BFDP/GEF/CQS/17/26-36/18 dated September 14, 2018: "To test the technology of reconstruction felling and creation of silvicultures, tending and cultivation of plantations of main broadleaved species (oak, ash, maple) by laying experimental sites in the territories of forestries of the Republic of Belarus. Number of experimental facilities in the forestries should be optimal for testing of the proposed felling reconstruction technologies, but not less than 6 in each region with a selection of species with regard to the geobotanical zoning". Besides, the work was carried out within the framework of the **eighth** stage "To finalize the Guidelines document on the reconstruction of low-value plantations to increase the share of broadleaved forests, which has been developed before carrying out of practical works under paragraph 5 of these terms of reference, based on the results of testing of the technology of reconstruction felling and creation of silvicultures, tending and cultivation of plantations of main broadleaved species."

2. The object of the research is low-value forest stands in the forest fund of the Ministry of Forestry of the Republic of Belarus, which are of key importance for the reforestation of deciduous forests.

3. The objective of the seventh stage is to test the technology of reconstruction felling and creation of silvicultures, tending and cultivation of the main broadleaved species (oak, ash, maple), including by laying experimental sites in the territories of forestries of the Republic of Belarus.

The objective of the eighth stage is to finalize the Guidelines document on the reconstruction of low-value plantations to increase the share of broadleaved forests, according to the results of testing of the technology of reconstruction felling and creation of silvicultures, tending and cultivation of plantations of main broadleaved species.

4. The seventh and eighth stages were implemented based on the following methods:

expeditionary (trips with the purpose of laying experimental sites in the forest fund of the Ministry of Forestry of the Republic of Belarus) and empirical (systemic analysis of materials for the reconstruction of low-value stands, selection and synthesis of the main components).

5. Now, broad-leaved stands (oak, ash, maples, linden forests) occupy 316.6 thousand hectares in the forest fund of the country, which is 3.8% of the total forest composition of the republic. The search for effective methods for the reforestation of broadleaved forests is of particular relevance for the forestry sector of the Republic of Belarus. One of the effective ways to restore them is to carry out activities for the reconstruction of low-value forest plantations. In accordance with the Strategic Plan for the Development of the Forestry Sector of Belarus for the period from 2015 to 2030, it is planned to increase their share in the forest area from 3.8% to 5.5%.

6. In 2018, reforestation and afforestation were carried out on a total area of 41.2 thous. ha, including 34.8 thous. ha of new forests. Reconstruction of low-value forest stands by silvicultural methods from the total volume of forest sowing and planting was performed on the area of 2.5 thous. ha. Forest plantations of high-value broad-leaved species obtained by means of reconstruction of low-value forest stands were established on an area of 0.2 thousand hectares.

Over the past 15 years, the share participation of broadleaved forest crops created within the framework of the reconstruction of low-value forest stands in the Republic of Belarus has decreased by 11.6%: from 198 hectares in 2003 to 175 hectares in 2017. The largest amount of forest stands created was recorded in 2007, their area was 626 hectares (figure A).

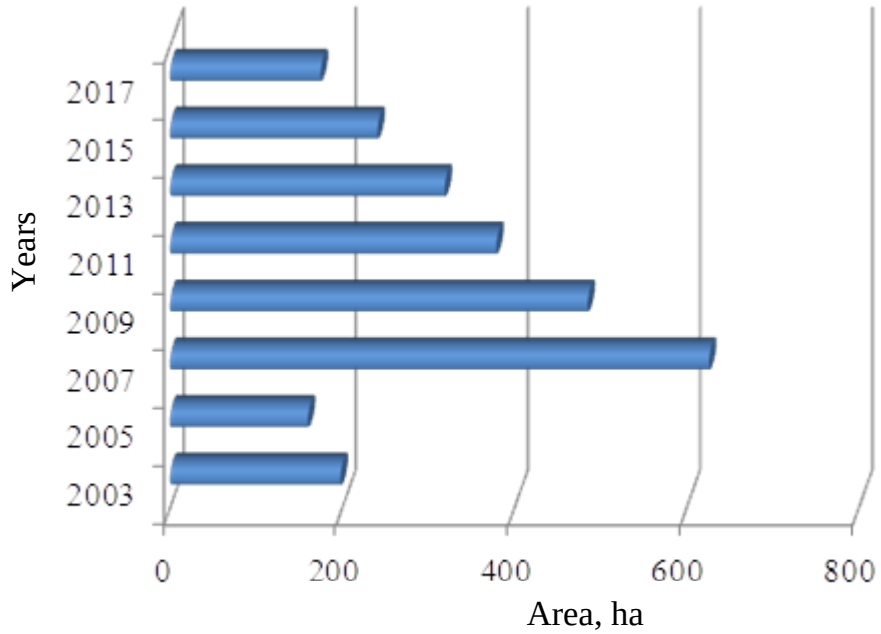


Figure A. Dynamics of creation of broad-leaved species silvicultures created in order to reconstruct low-value forest stands in the forest fund of the Ministry of Forestry of the Republic of Belarus (2003-2017)

7. The largest share of forest plantations of high-value broad-leaved species created in order to reconstruct low-value forest stands was found in Gomel SPFI (1.4 thousand ha), Mogiliov SPFI (0.9 thousand ha) and Vitebsk SPFI (0.6 thousand ha) SPFI (figure B).

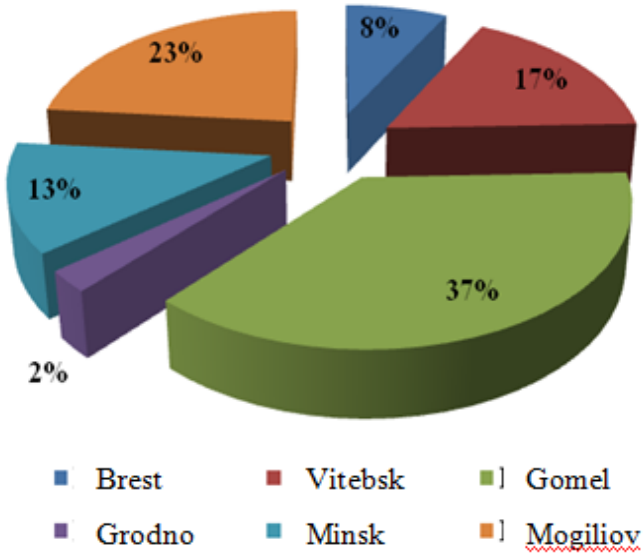


Figure B. Volume of reconstruction of low-value plantations by broad-leaved species in the forest fund of the Ministry of Forestry (2008-2018)

Among the methods for the reconstruction the corridor method of reconstruction is given preference in Brest, Vitebsk, Gomel and Mogiliov SPFI (from 46.2% to 94.0% of the total for individual SPFI). The clear-cutting method of reconstruction is most widely used in the Brest and Grodno SPFI (from 20.3% to 33.6%). The reconstruction by the group regeneration method is carried out mostly in Grodno (50.9%) and Minsk (60.0%) SPFI (figure C).

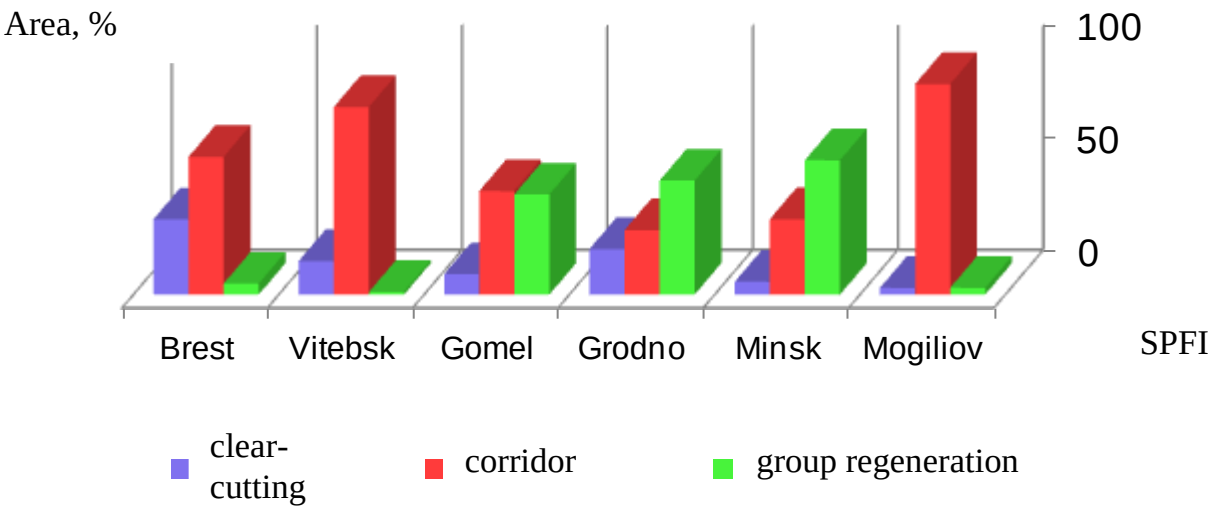


Figure C. Methods for the reconstruction of low-value plantations by creation of broadleaf forest crops

The analysis of the mixing schemes of forest crops created in order to reconstruct low-value plantations has shown that in all SPFIs, except for Vitebsk, for the most part, restoration was carried out with oak plantations (from 58.4% in Minsk SPFI to 91.8% in Mogiliov SPFI during the analyzed period) (figure D).

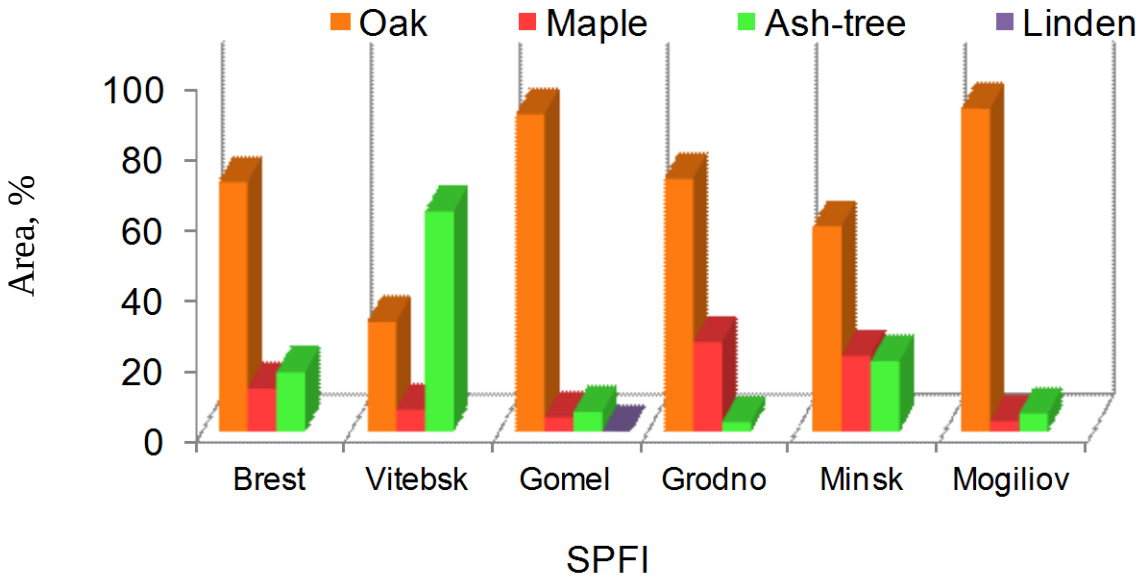


Figure D. Distribution of plantations by main species, created for the reconstruction of low-value plantations, within SPFI in 2006-2018

8. Within the framework of project activity when implementing of the event, a draft Methodological document, and it was sent for consideration and approval to the stakeholders in accordance with the legislation of the Republic of Belarus. Based on the analysis of the feedback report for the draft Methodological document with the stakeholders in accordance with the legislation of the Republic of Belarus within the framework of stage 3 of the event, its final version was developed (figure E).

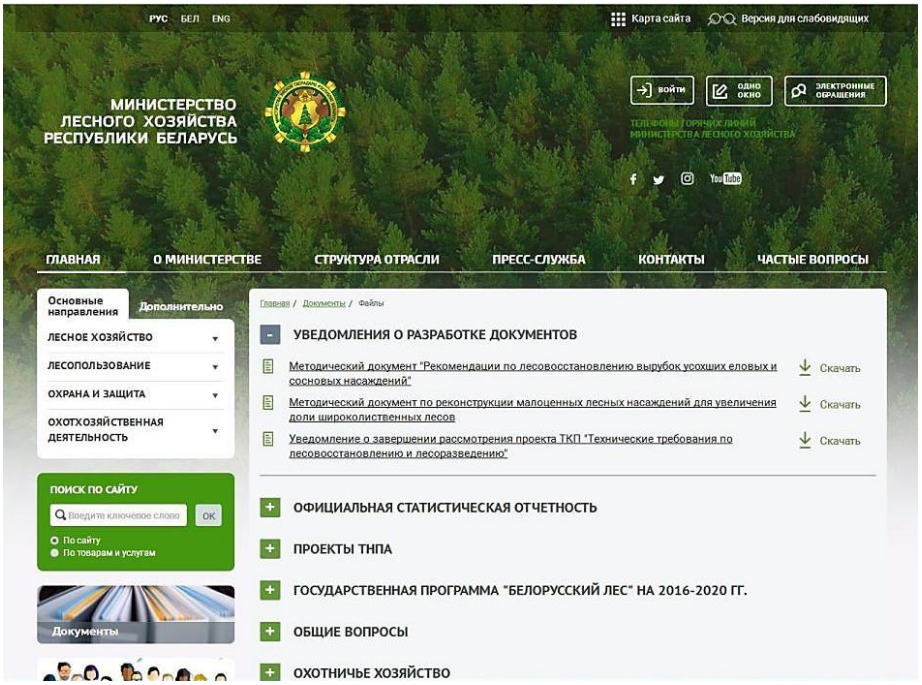


Figure E. Placing of Methodical Document
on the official website of the Ministry of Forestry

Then the Methodological document will be approved and put into effect by the Resolution of the Ministry of Forestry and sent for state registration in the Unitary Enterprise “Belgiproles”.

This Methodological Document establishes the technical requirements for the reconstruction of low-value forest stands with the use of high-value broadleaved species (common oak, Norway maple, common ash, small-leaved linden, European white elm) in the forest fund of the Republic of Belarus on a zonal-typological basis.

Methodical Document prepared on the basis of research materials and generalization of industrial enterprises experience on the reconstruction of low-value forest stands by reconstruction fellings and subsequent creation of forest plantations of high-value broadleaves in the forest fund of Belarus in accordance with the requirements of the Forest Code of the Republic of Belarus and existing legal and technical regulatory and legal acts. Methodical document includes 9 sections (figure F). It discusses the specifics of reconstruction felling of low-value forest stands, their methods, technical requirements for the reconstruction of low-value forest stands by establishment of forest plantations of high-value broad-leaved species, soil cultivating for forest plantations establishment, tending plantations, tending by felling, recommendations on transfer to the category of valuable forest stands, on the selection of planting material as well as the timing of the establishment of forest plantations.

The document presents mixing schemes of tree species for full and partial forest plantations of high-value broad-leaved species establishment by means of reconstruction of low-value forest plantations on a zonal-typological basis. Practical recommendations are given on the technology and mode of fellings in plantations established by means of reconstruction of low-value forest stands using the corridor method. The essence of recommendations is in conducting of fellings in plantations in several stages. The first stage consists in thinning of the tree belts and planting forest plantations, the subsequent ones are in tending partial plantations established in the corridors (figure G).

SECTION 1 SCOPE OF USE

SECTION 2 TERMS AND DEFINITIONS

SECTION 3 GENERAL PROVISIONS

SECTION 4 RECONSTRUCTION FELLING AND ITS METHODS

SECTION 5 RECONSTRUCTING THE LOW-VALUE FOREST STANDS BY CREATING SILVICULTURES OF BROAD-LEAVED SPECIES

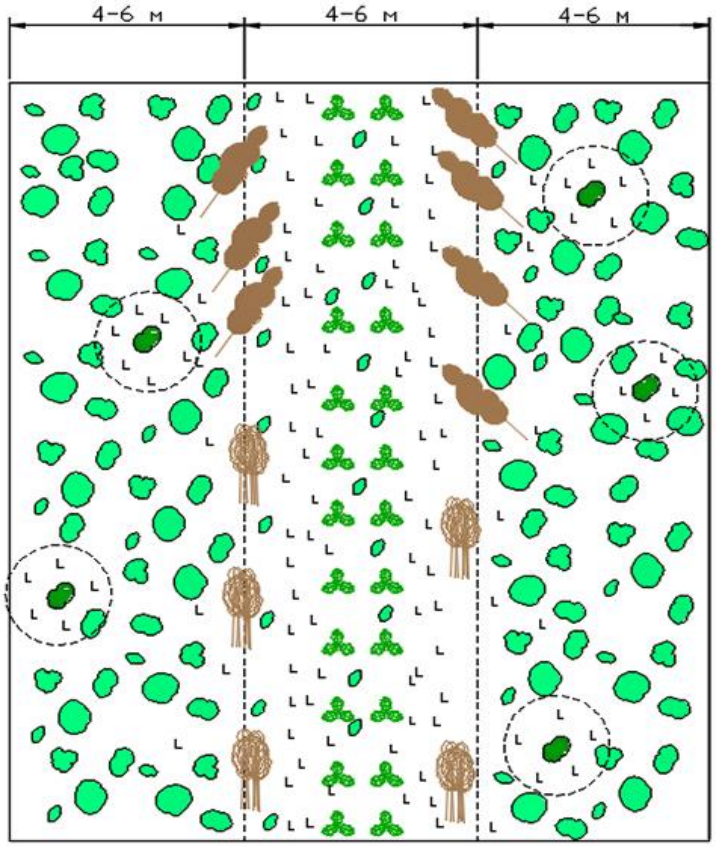
SECTION 6 TILLAGE FOR SILVICULTURES

SECTION 7 TERMS FOR THE CREATION OF SILVICULTURES, PLANTING MATERIAL

SECTION 8 FOREST CARE AND SUPPLEMENTATION OF SILVICULTURES

SECTION 9 TRANSFER INTO THE CATEGORY OF VALUABLE TREE STANDS

Figure F. The structure of the Methodological Document



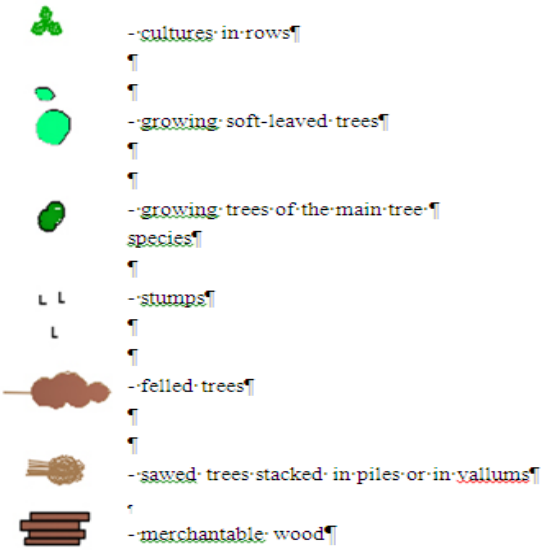


Figure G. Second stage - treatment in coulisses

9. In each region of Belarus in the forest fund of the Ministry of Forestry (figure H) and of the State Scientific Institution "the Institute of Forest of the National Academy of Sciences of Belarus" (IF of NAS of Belarus) were selected pilot sites (2 forest enterprises in Gomel region, 1 forest enterprise in Brest region, 1 forest enterprise and Zhornovka Experimental Frorest Base of IF of NAS of Belarus in Mogilev region, 3 forest enterprises in Minsk region, 2 forest enterprises in Grodno region, 1 forest enterprise in Vitebsk region). There will be held further testing of the technology of reconstruction felling and the establishment of forest plantations, tending and growing of main high-value broad-leaved species (oak, ash, maple) plantations (fig. J, K).

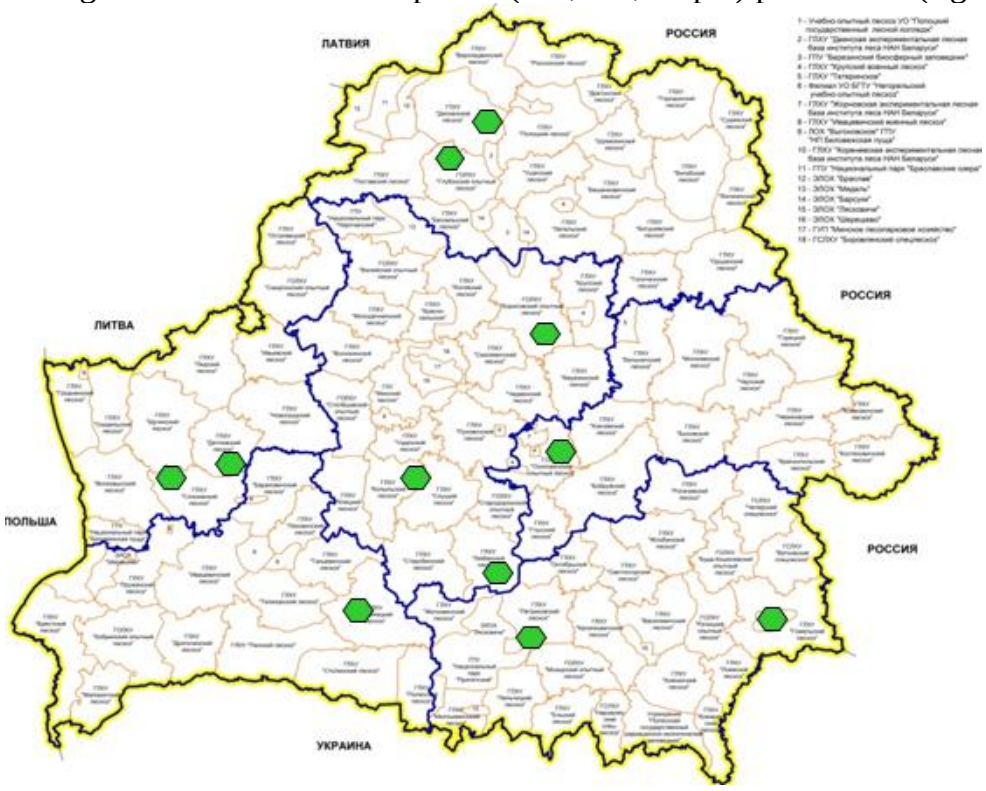


Figure H. Distribution of pilot sites for Methodical Document testing

Figure J. Reconstruction of Carpinetum oxalidosum by establishment of mixed pedunculate oak plantations

Figure K. Reconstruction of Populetum oxalidosum by establishment of mixed pedunculate oak plantations

10 Within the framework of the project activity it was established that, when other conditions being equal, the economic efficiency of the reconstruction of low-value stands by silvicultural techniques is higher if: the overall cost is lower and the implementation period is shorter; the timber of the main species added is more valuable; the share of main species in the composition of plantation is greater; the density of reconstruction cultures felling is higher and the turnover is shorter; reserves per 1 ha are higher, the quality and yield of commercial timber, including large-size, is higher. The greatest economic benefit is obtained by the clear reconstruction method, the lowest - by the corridor method where the highest costs are observed (Figure L).

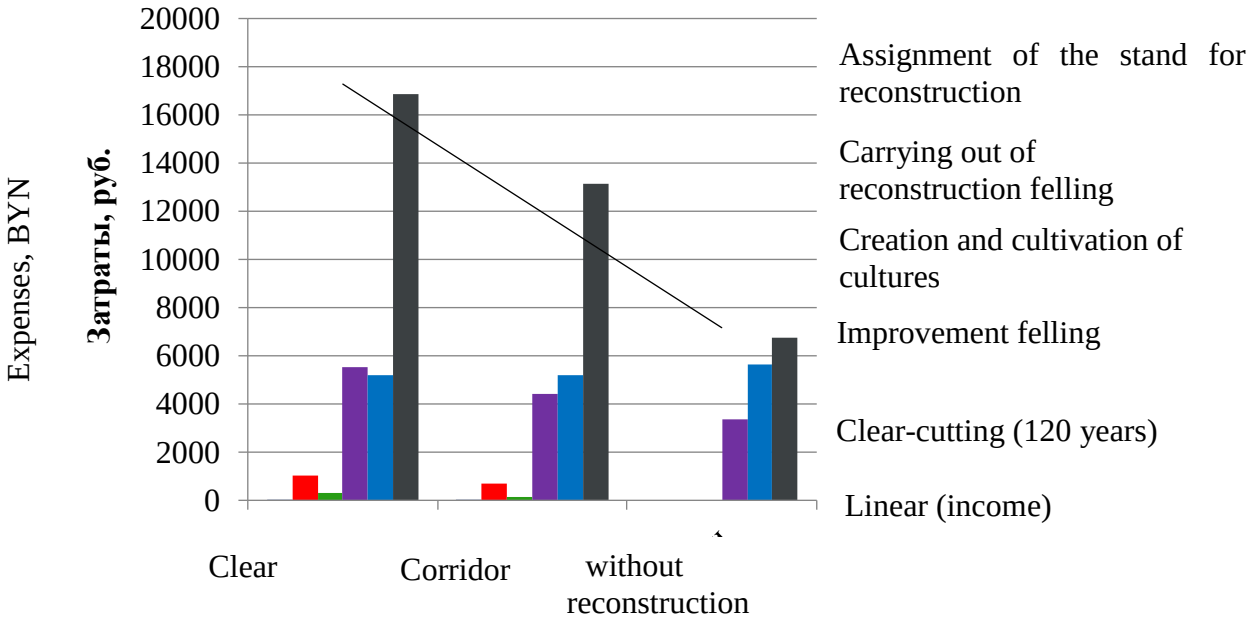


Figure L. Expenses for the reconstruction of low-value forest plantations by creating silvicultures of broadleaved species

The same parameter under the conditions of the natural formation of the stands was twice as high. By the age of maturity after a clear principal felling, the revenue from the sale of timber fully cover all previously incurred costs, even with minimal participation of oak (4 units of the composition). The expected economic effect from the use of reconstruction by clear-cutting and corridor methods in soft-leaved stands is 3.0 and 2.1 thousand BYN/ha, respectively, from the use of the curtain-group method for the reconstruction of low-productive stands of English oak - 3.1 thousand BYN/ha.

11. In areas intended for reconstruction, stands of different ages are currently growing. Analysis of carbon deposition by the phytomass of low-value stands in the context of age groups and prevailing species showed that these stands are in the process of absorption and storage of carbon. Thus, using the example of soft-leaved stands growing in rich forest growing conditions, under the age of 9 years, on average, they deposit carbon with phytomass in the amount of 18.6 tC/ha, of which birch stands deposit the most (43.1%). With age, the carbon deposition increases and reaches an average of 471.6 tC/ha in middle-aged stands, of which 73.4% are aspen. It takes

several years for the level of carbon deposition by plants to reach their highest level. It will take a long time before forestry crops of valuable species planted instead of low-value stands correspond to the level of absorption, the mass of carbon already deposited. Therefore, when choosing sites for reconstruction, preference should be given to younger or very rare low-value forest stands.

12. When evaluating the suitability of sites for reconstruction felling, it is necessary to take into account the risk of damage to trees as a result of eating them by deer and other wild ungulates. In areas of established forestry crops in such a danger, substances approved in the Republic of Belarus should be used to protect them.

13. Scientifically substantiated proposals for amending the regulatory framework in the field of reconstruction of low-value forest stands are given.

14. The report containing the results of testing of the technology of reconstruction felling and creation of silvicultures, tending and cultivation of the main broadleaved species (oak, ash, maple), including by laying experimental sites in the territories of forestries of the Republic of Belarus, and version of the Guidelines document finalized based on the comments, suggestions and test results, was prepared.

Introduction

The search for effective methods for the restoration of broadleaved forests is of particular relevance for the forest sector of the Republic of Belarus. One of the ways to restore them is to carry out activities for the reconstruction of low-value forest plantations. The low-value plantations are the forest stands of low productivity and quality for certain forest growing conditions, the criteria for identifying which are established by the republican body of state administration for forestry.

Currently, broadleaved plantations (oak forests, ash forests, maple forests, linden forests) occupy 316.6 thousand hectares in the forest fund of the country that is 3.8% of the total forest composition of the republic (Forest Cadaster, 2018). In accordance with the State Program "Belarusian Forest" for 2016–2020, in order to increase the share of coniferous and hardwood stands in the forest structure of the republic, it is necessary to select sytrunks and types of principal fellings, providing for the possibility of natural regrowth of the main species. According to the Strategic Plan for the Development of the Forestry Sector of Belarus for the period from 2015 to 2030, it is planned to increase their share in the forest area from 3.8% to 5.5%. A significant increase in the volume of reconstruction is envisaged: in 2016–2020 – average 4.0 thousand hectares per year, in 2021–2025 – 7.0 thousand hectares per year, in 2026–2030 – 6.0 thousand hectares per year.

Taking into consideration the above, currently, one of the main goals and strategic priorities in the Republic of Belarus is the rational use of forests and the creation of sustainable forests, including taking into account the conservation of biodiversity.

Analysis of the practices, methods of reconstruction of low-value forest stands, used in Belarus, allowed to develop the Guidelines document on the reconstruction of low-value forest plantations to increase the share of broadleaved forests, which establishes the procedure for the reconstruction of low-value forest stands through creation of broadleaved species stands in the territory of the Republic of Belarus, which will ensure the recovery of oak and broadleaved group of species under the best site conditions and increase their share in the composition of the forest fund of the Republic of Belarus.

The Guidelines document was sent to all enterprises of the Ministry of Forestry of the Republic of Belarus, all comments and suggestions were taken into account.

The developed and improved technologies of felling reconstruction and silvicultures creation, tending and growing of main broadleaved species stands, included in the developed Guidelines document, were tested by laying experimental and production sites in the forest fund of Gomel, Brest, Minsk, Mogilev, Grodno, Vitebsk SPFA. 36 experimental sites for the reconstruction of low-value forest plantations were laid in the territory of the forestries in every region.

Experimental and production sites where advanced technologies of reconstruction fellings and creation of silvicultures, tending and cultivation of plants of main broadleaved species had been tested, were used as demonstration sites during training workshops (report No.5 will contain the detailed information about their organization and holding).

1. Characteristics of experimental and production sites for the reconstruction of low-value forest plantations in the territory of the forestries of the republic

The developed and improved technologies of reconstruction felling and silvicultures creation, tending and growing of main broadleaved species stands were tested by laying experimental and production sites in the forest fund of Gomel, Brest, Minsk, Mogilev, Grodno, and Vitebsk SPFA. At least 6 experimental sites for the reconstruction of low-value forest plantations by creating broadleaved species silvicultures were laid in each SPFA (Annex A).

In Gomel region, the enhanced technologies of low-value forest plantations reconstruction were tested by laying experimental and production sites in Gomel Experimental Forestry (3 sites) and Petrikov forestry (3 sites).

3 sites were laid in Gomel experimental forestry:

1. *Quarter 93, section 18, area 0.7 ha, Makeyevka forest district* (site No. 1)

Objective for the creation of the experimental site: English oak reconstruction.

Brief description of the site:

The plantation is represented by partial silvicultures of oak and maple created in spring of 2018 by planting the target species in the corridors. Forest type – ashweed aspen, FCT – D_3, bonitet class I. Spacing for plantings 1.75 × 1 m. Composition scheme 2r.O1r.M. Planting density 5700 plants/ha.

194 plants of maple, 366 plants of oak were taken into account in the corridors at the experimental site by continuous count. Total 560 plants (Figure 1.1). Height of maple - 0.5 m, of oak - 0.2 m. Root-taking rate of the silvicultures is 85.4% (uneven in the site).

Birch dominates in the coulisses, coulisses composition is 6B3Asp1H+O (in stock), 6B2Asp2H+O (by number of trunks). Density is 0.8 (Table 1.1).

Table 1.1 - Mensurational characteristics of low-value forest plantation in the coulisses left at experimental site No. 1

Parameter	**Oak**	**Hornbeam**	**Birch**	**Aspen**	*Stand*
N, plants/ha	405	1847	7320	2027	11599
∑G, m^2/ha	0.0318	0.9411	4.6240	2.3084	7.91
V per ha, m^3	0.05	1.68	12.17	5.80	19.7
D av., cm	1.0	2.5	2.8	3.8	3
H av., m	1.4	2.9	3.9	4.7	4

Figure 1.1 - Experimental site in Gomel experimental forestry No. 1

According to the evaluation of the silvicultures, in May 2019 the preservation of the plants was satisfactory, that proved the success of the carried out activity, at the same time by the end of June, part of the young plants had died because of lack of rainfall and high air and soil surface temperatures.

Conclusions: Droughts recurring in the recent years caused by the climate change have a negative impact not only on success of forest growth, and, above all, artificially created, but also lead to drying up of young plants. This requires addition of silvicultures on these sites.

Corridor method for the reconstruction of softwood stand with planting of oak and maple can be used in the forestry management practice.

2. *Quarter 272, section 10, area 6.5 ha, Priborskoye forest district (site No. 2)*

Objective for the creation of the experimental site: ash and maple reconstruction.

Brief description of the site:

It is represented by partial cultures of ash and maple created in spring 2011 by planting of the main species in the corridors spacing in the corridor - 2.7 × 0.67 m). Soil preparation - cutting furrows by plow PKL-70, planting method - manually, using Kolesov's planting iron, planting material used - wild growing plants of ash and maple. The density of silvicultures is 5560 plants/ha. Spacing scheme 7Ash3M. In 2018, the site was transferred to the forest-covered area with plantation composition 3Ash2M4Asp1B, density was 0.7.

Cleaning felling was held in 2019. Composition after felling is 8M1H1Asp+O+Ash+B. Hav = 6.0 m, Dav = 4.7 cm. Stock 29 m^3/ha.

Thinning cutting – cleaning – was carried out in 2019 (Figure 1.2). Composition after thinning is 8M1H1Asp+O+Ash+B. Average height was 6.0 m, diameter 4.7 cm, planting stock – 29 m^3/ha (Table 1.2). Some trees at the site are damaged by wild ungulates. The presence of natural regrowth of maple is observed in the stand, the total of which is more than 4.0 thousand plants per hectare.

Figure 1.2 - Experimental site No. 2: after thinning (cleaning)

Table 1.2 – Mensurational characteristics of low-value forest plantation in the coulisses left at experimental site No. 2

Parameter	**Maple**	**Hornbeam**	**Aspen**	**Oak**	**Ash-tree**	**Birch**	*Stand*
N, plants/ha	4081	481	431	75	6	56	5130
∑G, m^2/ha	7.1	0.2	0.9	0.01	0.002	0.1	8.3
V per ha, m^3	26	0.26	2.7	0.02	0.002	0.3	29
D av., cm	4.7	2.5	5.8	1.6	1.0	4.8	4.7
H av., m	6.0	2.0	5.2	1.4	1.0	5.0	6.0

***Conclusions**:* We consider that, in general, the reconstruction of low-value stand by corridor method can be considered successful, because it resulted in replacement of the aspen stand with the main tree species (Norway maple). However, the maple stand formed instead of the ash forest with maple.

3. *Quarter 11, section 4, area 0.8 ha, Priborskoye forest district (site No. 3)*

Objective for the creation of the experimental site: European ash reconstruction.

Brief description of the site:

It is represented by silvicultures of European ash created in spring 2004 by planting of the main species with spacing – 2.5 × 0.75 m. Soil preparation - cutting furrows by plow PKL-70, the method of planting - manually, using Kolesov's planting iron, planting material used - 2-year-old ash seedlings. The density of silvicultures is 5333 plants/ha. Type of silvicultures - complete (10Ash). Forest type – sorrel ash forest, FCT - D_2, bonitet class I, age of the stand - 15 years.

The site is created to test the technology of tending in the reconstructed plantation to restore the European ash plantation.

In 2019 the composition of the plantation was 6Ash4B+O+Asp+W+Apple, density was 0.95, stock - 62 m^3/ha. $H_{av.}$= 5.5 m, $D_{av.}$= 5.3 cm. Amount of ash trees in the area was 4940 plants/ha (Table 1.3). The plantation has a natural regeneration of ash.

Table 1.3 – Mensurational characteristics of the plantation being reconstructed at experimental site No. 3

Parameter	**Ash**	**B**	**Asp**	**O**	**WeWi**	**Apple**	*Stand*
N, plants/ha	4940	760	60	20	20	80	5880
∑G, m^2/ha	10.69	4.4	0.03	-	-	-	15.12
V per ha, m^3	40	21	0.2	-	-	-	62
D av., cm	5.3	8.6	8	-	-	-	5.3
H av., m	5.5	9.4	9	-	-	-	5.5

The trees at the experimental site were assigned for felling (Figure 1.3), and the felling was held to reduce the density from 0.95 to 0.70.

Figure 1.3 - Experimental site No. 3: assigning trees for felling

Conclusions*:* We consider that the successful reconstruction of ash, first of all, requires corresponding forest-growing conditions in which it is created. This stand grows on the edge of the mire, and probably this allows ash trees to get necessary moisture, despite the repeatedly recurring drought periods. We consider that the reconstruction of low-value plantation by creating ash silvicultures has been successful. Method of clear reconstruction of small-leaved stand with ash planting in conditions suitable for its growth may be applied in the forestry practice.

3 sites were laid in Petrikov forestry:

1. *Quarter 70, section 29, area 1.4 ha, Kopatkevichskoye forest district (site No. 4)*

Objective for the creation of the experimental site: English oak reconstruction.

Brief description of the site:

It is represented by partial oak silvicultures created in spring of 2010 by planting of the main species in corridors (spacing in the corridor - 3.5 × 0.6 m), with 4 meters between the coulisses. Soil preparation - cutting furrows by plow PKL-70, the method of planting - manually, using Kolesov's planting iron, planting material used - 2-year-old oak seedlings. The density of silvicultures is 4760 plants/ha. Type of the silvicultures - complete (10O).

The site is created to test the technology of tending in the reconstructed birch stand to restore the English oak plantations.

In 2010 the composition of the reconstructed plantation was 8B2Asp, density – 0.7. Forest type - bilberry birch forest, FCT - C_3.

In 2019 the number of oak was 2554 plants/ha.. $H_{av.}$= 1.4 m, $D_{av.}$= 1.2 cm, composition of the coulisses was 9B1P+H+Asp+W+Apple. Stand density was 0.85, the stock - 85 m^3/ha. $H_{av.}$= 10.8 m, $D_{av.}$= 7.6 cm (Table 1.4).

Table 1.4 – Mensurational characteristics of the birch plantation being reconstructed at experimental site No. 4

Forest type FCT	Composition	Age, years	Average height, m	Average diameter, cm	Sum of section areas, m^2/ha	Density	Bonitet class	Quantity of trees, plants/ha	Stock, m^3/ha
Bilberry birch forest. C_3	coulisse								
	9B	30	10.8	7.6	14.4	0.75	II	3231	77
	1P	–	5.1	4.6	1.30	0.03	–	615	4
	+WeWi	–	1.4	1.5	1.97	0.07	–	10615	3
	+H	–				–	–	–	–
	+Asp								
	+Apple								
	Total				17.7	0.85	II	14461	84
	corridors								
	10O	10	1.4	1.2				2554	

In coordination with the representatives of the forestry, the trees were selected for felling during organization of the experimental site, to test the technology of tending in plantation under reconstruction. The intensity of thinning cutting in the area was 30%.

The reconstruction by the corridor method in the 20-year-old bilberry birch forest shows that in 9-10 years the difference in the average heights of oak cultures and in the coulisses will be significant and will amount to more than 7.5 times. The oppressing effect of the upper canopy of broadleaved species is clearly seen when comparing the rows of oak cultures along the edge of

the plot and deep in plantation (Figure 1.4). Besides, currently, the felling of large birch trees is difficult, as there is a likelihood of damaging the oak trees.

a) b)

Figure 1.4 - Rows of English oak cultures
at corridor reconstruction of bilberry birch forest
a) deep in plantation; b) at the edge of the stand

Conclusions: State of the oak silvicultures is satisfactory. Corridor reconstruction method of broadleaved stands with planting of oak can be used in forest management practice provided that timely thinning fellings in corridors and remaining coulisses are conducted.

2. *Quarter 69, section 38, Koshevichi forest district*, area 3.6 ha (site No. 5)

Objective for the creation of the experimental site: English oak reconstruction.

Brief description of the site:

This site is represented by 9-year-old high-density aspen forest with presence of birch trees, and admixture of oak and hornbeam of natural origin, composition 8Asp2B+O+H, forest type - sorrel aspen forest, FCT D_2, bonitet class I, stand density 1.0, stock - 18 m^3/ha. $H_{av.}$= 3.9 m, $D_{av.}$= 3.1 cm.

The composition includes oak stands of natural origin in the amount of 388 plants/ha, $H_{av.}$ = 1.4 m, $D_{av.}$ = 1.0 cm (Table 1.5).

The plantation is assigned into reconstruction felling within forest management. A feature of the site is the presence of a stand of oak trees of natural origin, which are uniformly located over the area, but mostly confined to one part of the section with 3.1 hectares of area (Figure 1.5). During improvement felling in this part by intensive felling of aspen trees, an increase in the share of oak in the stand composition was observed, which allowed to introduce the aspen stand in valuable farming. The reconstruction by corridor method is planned in the remaining territory (3.6 ha), where experimental site No. 5 is laid.

Table 1.5 – Mensurational characteristics of the aspen plantation being reconstructed at experimental site No. 5

Forest type FCT	Composition	Age, years	Average height, m	Average diameter, cm	Sum of section areas, m^2/ha	Density	Bonitet class	Quantity of trees, plants/ha	Stock, m^3/ha
Sorrel aspen forest D_2	8OAsp	9	3.9	3.1	6.2		I	8487	14
	2B		4.0	3.1	1.2		–	1638	3
	+O		1.4	1.0	0.03			388	0.5
	+H		2.1	1.7	0.07			287	1
			3.9	3.1	7.5	1.0		10800	18.5

Figure 1.5 – Content of naturally growing oak in 9-year-old aspen plantation

The site was laid to evaluate reconstruction felling technology by corridor method and soil preparation for further creation of silvicultures (Figure 1.6).

Currently, the low-value cultures were felled in 4 m wide corridors using mulcher (cutters), leaving 6 m wide coulisses. Thinning was carried out through felling of large trees at the edges of the coulisses, and the tending of the oak trees of natural origin was carried out.

In spring of 2020 oak silvicultures will be created in double rows.

Figure 1.6 - Corridor reconstruction in 9-year-old high-density sorrel aspen forest

***Conclusions**:* Reconstruction felling is time-consuming and costly measure, and, unfortunately, does not always allow to obtain positive results. Therefore, when performing a task on reconstruction of broadleaved forests, production workers should take into account the peculiarities of the plantations assigned for reconstruction. The example of experimental site No. 5 shows that the presence of the main species trees (oak) in a low-value stand makes it possible to introduce it (or its part) into the valuable group by intensive improvement fellings without reconstruction felling. This significantly reduces costs. Furthermore, the presence of oak trees in the remaining part of the section allows to leave 6 or more meters wide coulisse at 4-meter-width corridor. In this case tending the naturally growing oak trees is obligatory. During subsequent tending procedures, it is efficient to extend the corridors to 4 m by felled trees in the coulisses until their complete removal, which will allow to use the mechanized skidding of the harvested wood in the future. However, if the trees of the main species are not found in the coulisses, the extension of corridors is required in the case of heavy shading of the silvicultures by secondary tree species and undesirable trees.

The age of felling start is important during reconstruction felling by corridor method. The earlier it starts, the greater the chances of success, because: first, if there are trees of the main species, it is possible to preserve them; second, it is easier to regulate the ratio of heights of trees of the main and secondary species in the coulisses; third, the greater probability of a complete felling of the coulisse as soon as possible, and lower labor intensity of felling.

3. *Quarter 70, section 28, Koshevichi forest district*, area 2.5 ha (site No. 6)

Objective for the creation of the experimental site: English oak reconstruction.

Brief description of the site:

It is represented by oak silvicultures created in spring of 2010 by planting of the main species. Soil preparation was carried out by cutting furrows by plow PKL-70, planting method - manually, using Kolesov's planting iron, planting material used - 2-year-old oak seedlings. The density of silvicultures is 4800 plants/ha. Type of the silvicultures - complete (10O).

In 2019 the composition of plantation was 3O1P5B1W+Asp+H+Apple. Forest type - bracken oak forest, FCT - C_2. Density – 0.85, stock - 21 m^3/ha. Number of oak trees - 3860 plants/ha. $H_{av.}$= 2.7 m, $D_{av.}$= 2.6 cm (Table 1.6). Figure 1.7 shows a young oak plantation created by a clear reconstruction of low-value forest plantation.

Table 1.6 – Mensurational characteristics of the birch plantation being reconstructed at experimental site No. 6

Forest type FCT	Composition	Age, years	Average height, m	Average diameter, cm	Sum of section areas, m^2/ha	Density	Bonitet class	Quantity of trees, plants/ha	Stock, m^3/ha
Bracken oak forest C_2	3O	9	2.9	2.7	2.0		II	3860	6
	1P		4.9	5.4	0.4			300	2
	5B		8.7	7.0	2.2			570	10
	1W		2.5	3.5	0.9			900	2
	+Asp							40	1
	+H								
	+Apple								
			2.9	2.7	5.5	0.85		5670	21

In coordination with the representatives of the forestry, the trees were selected for felling during organization of the experimental site to test the technology of tending in plantation under reconstruction. Intensity of tending was 35%.

Figure 1.7 - Complete English oak silvicultures at experimental site No. 6

***Conclusions**:* Plantation under reconstruction is in satisfactory condition. Clear reconstruction was successful.

In Grodno region, the enhanced technologies of low-value forest stands reconstruction were tested by laying experimental and production sites in Slonim (2 sites) and Dyatlovo (4 sites) forestries.

2 sites were laid in Slonim forestry:

1. *Quarter 115, section 16, Senkovshchina forest district*, area 1.2 ha (site No. 7)

Objective for the creation of the experimental site: formation of mixed silvicultures of Norway maple created within reconstruction of low-value stand by clear-cutting method.

Brief description of the site:

It is represented by oak silvicultures created in spring of 2019 by planting of the main species. Soil preparation was carried out by cutting furrows by plow PKL-70, planting method - manually, using Kolesov's planting iron, planting material used - 1-year-old maple seedlings. The density of silvicultures is 4600 plants/ha. Type of silvicultures - mixed (5M5S) (Figure 1.8).

In 2018 the composition of the plantation before felling was 5H4B1S, density was 0.8, stock - 200 m^3/ha. The average age is 50 years, forest type - sorrel hornbeam forest, FCT – D_2.

Characteristics of the silvicultures: Composition: 5M5S, density - 4.6 thousand plants/ha, including maple - 2.3 thousand plants, spruce - 2.3 thousand plants. Species composition scheme: 5 rows of maple 5 rows of spruce.

In coordination with the representatives of the forestry, the trees were selected for felling during organization of the experimental site to test the technology of tending in plantation under reconstruction. Intensity of tending was 35%.

Figure 1.8 - Mixed Norway maple silvicultures
at experimental site No. 8

Conclusions: reconstruction by a clear-cutting method in 10-year-old and older low-value stands by mixed silvicultures of Norway maple planting by placing it in ordinary biogroups ($M^{1.5-2.5}M$) can be used in the forestry management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry.

2. *Quarter 121, section 9, Senkovshchina forest district*, area 1.5 ha (site No. 8)

Objective for the creation of the experimental site: formation of mixed silvicultures of Norway maple created within the reconstruction of low-value stand by clear-cutting method.

Brief description of the site:

It is represented by oak silvicultures created in spring of 2019 by planting of the main species. Soil preparation was carried out by cutting furrows by plow PKL-70, planting method - manually, using Kolesov's planting iron, planting material used - 1-year-old maple seedlings. The density of silvicultures is 4800 plants/ha. Type of silvicultures - mixed (5M5S) (Figure 1.9).

In 2018 the composition of the plantation before felling was 6H2B2Asp+S, density was 0.8, stock - 200 m^3/ha. The average age is 43 years, forest type - sorrel hornbeam forest, FCT – D_2.

Characteristics of the silvicultures: Composition: 5M5S, density - 4.8 thousand plants/ha, including maple - 2.4 thousand plants, spruce - 2.4 thousand plants. Species composition scheme: 5 rows of maple 5 rows of spruce.

Figure 1.9 - Mixed Norway maple silvicultures
at experimental site No. 9

Conclusions: reconstruction by a clear-cutting method in 10-year-old and older low-value stands by mixed silvicultures of Norway maple planting by placing it in ordinary biogroups ($M^{1.5-2.5}M$) can be used in the forestry management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry.

It should be noted that sites 8 and 9 are characterized by intensive overgrowth with aspen, which reaches the height of 3 m or more. Due to this fact, it is necessary to increase the quantity of annual silvicultures tending in the area by 2 times.

4 sites were laid in Dyatlovo forestry:

1. *Quarter 45, section 22, Rogotno forest district*, area 0.5 ha (site No. 9)

Objective for the creation of the experimental site: formation of mixed silvicultures of English oak created within the reconstruction of low-value stand by clear-cutting method.

Brief description of the site:

It is represented by oak silvicultures created in spring of 2010 by planting of the main species. Soil preparation was carried out by cutting furrows by plow PKL-70, planting method - manually, using Kolesov's planting iron.

Characteristics of the plot before creation of silvicultures: composition of the plantation: 6Asp2B1O1S, average age is 11 years, forest type - bracken aspen forest, FCT – B_2. The stand is planned for the reconstruction by corridor method with 30% selection in 2009.

Characteristics of the silvicultures:

Composition: 5O5S, density - 2.5 thousand plants/ha, planting material: 1-year-old oak seedlings, two-year-old spruce plants. Species composition scheme: 2.5×0.8.

Root-taking rate of the silvicultures: 1st year – 92%, 3-rd – 86,6%.

Silvicultures tending was carried out in 2014, 2016 (cleaning), addition of silvicultures - in 2016.

In 2017, forest plantation was transferred to the category of valuable (composition 2O2M2S3Asp1B).

This year, the silvicultures composition is 5O5S (Figure 1.10), the age is 9 years, preservation rate - 75%.

Figure 1.10 - Mixed English oak silvicultures
at experimental site No. 9

Conclusions: reconstruction in 11-year-old bracken aspen forest by corridor method did not give positive results due to strong shadowing of silvicultures by secondary tree species and undesirable trees. Transfer to the category of valuable plantations was carried out due to the good preservation of spruce trees, presence of natural regrowth of maple. Clear reconstruction felling will be much more efficient in this area.

2. *Quarter 96, section 15, Rogotno forest district*, area 1.1 ha (site No. 10)

Objective for the creation of the experimental site: formation of mixed silvicultures of English oak created within the reconstruction of low-value stand by corridor method.

Brief description of the site:

It is represented by mixed oak cultures created in spring of 2010 by planting (Figure 1.11).

Figure 1.11 - Mixed English oak silvicultures
at experimental site No. 10

Characteristics of the plot before creation of silvicultures: composition of the plantation: 10Asp, the average age is 11 years, forest type - sorrel aspen forest, FCT – D_2.

Characteristics of the silvicultures:

Composition: 5O5S, density - 2.5 thousand plants/ha, including oak - 1.3 thousand plants, spruce - 1.2 thousand plants, planting material: 1-year-old oak seedlings, two-year-old spruce plants.

Species composition scheme: 2.5×0.8. Root-taking rate of the silvicultures: 1st year – 94%, 3-rd – 86%.

The average width of the corridor is 18 m.

Silvicultures tending was carried out in 2014, 2015, 2017.

This year, the composition of the silvicultures is 2O8S, age 9 years, preservation - 80%, average height of oak - 0.9 m, thickness - 2.3 thousand plants/ha. Composition of the stands in coulisses – 4Asp3H2O1WeWi, density 0.9, stock - 103.2 m^3/ha. Aspen is the most numerous in the coulisses (2.6 thousand plants/ha).

The site requires thinning of trees in the coulisses by expanding the corridors (to 2-3 m). We selected the trees shadowing the plantation for felling (stock of 12 m^3/ha) (Figure 1.12).

Figure 1.12 - Selection of trees for felling at experimental site No. 10

Conclusions: Reconstruction in 11-year-old sorrel aspen forest by corridor method did not give positive results due to strong shadowing of silvicultures by secondary tree species and undesirable trees. Transfer to the category of valuable plantations was carried out due to the good preservation of spruce trees (2O8S). Clear reconstruction felling will be much more efficient in this area.

3. *Quarter 96, section 2, Rogotno forest district,* area 1.0 ha (site No. 11)

Objective for the creation of the experimental site: formation of mixed silvicultures of English oak created within the reconstruction of low-value stands by clear-cutting method.

Brief description of the site:

It is represented by mixed oak cultures created in spring of 2012 by planting (Figure 1.13).

Characteristics of the plot before creation of silvicultures: composition of the plantation: 7H2O1S, the average age is 56 years, forest type - sorrel hornbeam forest, FCT – D_2.

Figure 1.13 - Mixed English oak silvicultures
with natural regeneration of Norway maple at experimental site No. 11

Characteristics of the silvicultures: Composition: 3O7S, density – 5.3 thousand plants/ha, including oak – 1.6 thousand plants, spruce – 3.7 thousand plants, planting material: 1-year-old oak seedlings, two-year-old spruce plants. Species composition scheme: 2.5×0.75. Root-taking rate of the silvicultures: 1st year – 94%, 3-rd – 87%.

Silvicultures tending was carried out in 2015.

This year, the composition of the silvicultures was 7M2S1O, the age was 7 years, density – 5.8 thousand plants/ha, average diameter of oak – 1.5 m, height – 2.0 m, preservation of oak and spruce trees – 33%.

Conclusions: Formation of mixed maple-spruce stands with presence of English oak is possible at the site due to abundant natural regrowth of Norway maple.

4. *Quarter 45, section 15, Rogotno forest district*, area 2.1 ha (site No. 12)

Objective for the creation of the experimental site: formation of mixed silvicultures of Norway maple created within the reconstruction of low-value stand by curtain-group method.

Brief description of the site:

It is represented by mixed Norway maple silvicultures created in spring of 2012 by planting in clearings and stand windows (Figure 1.14).

Characteristics of the plot before creation of silvicultures: composition of the plantation: 6O3S1Asp, the average age is 75 years, forest type - sorrel oak forest, FCT – D_2., density - 0.3.

Figure 1.14 - Mixed Norway maple silvicultures
at experimental site No. 12

Characteristics of the silvicultures: Composition: 3M7S, density - 1.6 thousand plants/ha, including maple - 0.5 thousand plants, spruce - 1.1 thousand plants, planting material: 1-year-old oak seedlings, two-year-old spruce plants. Species spacing scheme: 2.5×0.75.

Root-taking rate of the silvicultures: 1st year – 95%, 3-rd – 87%.

This year, the composition of the silvicultures was 3M2P5S, age - 7 years, preservation of maple and spruce - 80%.

Conclusions*:* The clearing at the site allowed to increase the density of Norway maple silvicultures. Spruce plants (H_{av}.=0.9 m) were planted in the plow furrows under the canopy of the stand. We consider that the reconstruction of low-value plantation by creating Norway maple silvicultures has been successful.

In Minsk region, the enhanced technologies of low-value forest stands reconstruction were tested by laying experimental and production sites in Borisov experimental (3 sites), Lyuban (1 site) and Kopyl (2 sites) forestries.

3 sites were laid in Borisov experimental forestry:

1. *Quarter 130, section 6.1, Prigorodnoye forest district*, area 1.1 ha (site No. 13)

In 2018 the composition of stand before felling was 5WeWi3Asp1Lin1S+O, the average age was 12 years, FCT – D_2. The site has been assigned by forest management for the reconstruction by corridor method, but according to the current requirements such felling is assigned at the age of 10 years.

The site is represented by mixed Norway maple silvicultures created in spring of 2019 by planting of the main species.

Soil preparation was carried out by cutting furrows by plow PKL-70, planting method – manually, using Kolesov's planting iron, planting material used – 3-year-old maple seedlings, 3-year-old spruce plants. The density of silvicultures is 4200 plants/ha. Type of silvicultures – mixed (7M3S) (Figure 1.15). Spacing scheme: 3.0×0.9 m. Root-taking rate of the silvicultures – 85%.

Figure 1.15 - Mixed Norway maple silvicultures
at experimental site No. 13

Because of the lack of rainfall and high air and soil surface temperatures, part of the young plants died. The site requires additional silvicultures next year.

Conclusions: reconstruction by a clear-cutting method in 10-year-old and older low-value stands by planting mixed silvicultures of Norway maple by placing it in ordinary biogroups ($M^{1.5-2.5}M$) can be used in the forestry management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry.

2. *Quarter 52, section 15, Mstizh forest district*, area 1.3 ha (site No. 14)

Objective for the creation of the experimental site: formation of silvicultures of Norway maple created within the reconstruction of low-value stand by curtain-group method.

Brief description of the site:

It is represented by Norway maple silvicultures created in spring of 2010 by planting in clearings and stand windows (Figure 1.16) without soil preparation. Planting material: wild growing plants of Norway maple. In 2017, the plantation was transferred to the category of valuable (composition 4M4S1Lin1B).

Characteristics of the plot before creation of silvicultures: composition of the plantation: 5S3B2Asp, the average age is 20 years, forest type - bracken spruce forest, FCT – C_2., density - 0.3.

Figure 1.16 - Mixed Norway maple silvicultures
at experimental site No. 14

Characteristics of the stand (2019): Composition: 1 tier 8O2S / 2 tier 6Lin3S1M, (density – 1.5 thousand plants/ha, Dav 9.1 cm, Hav 12.6 m, stock 55.6 m^3/ha).

Conclusions: The reconstruction in the low-density sorrel spruce forest did not give a positive result because of strong shadowing of the silvicultures by the trees of the upper tier. The stands were transferred to the category of valuable plantations due to well-preserved spruce trees and abundant natural regrowth of Norway maple and small-leaved linden, which will allow to form a mixed maple and spruce plantation with linden in the future.

3. *Quarter 52, section 16, Mstizh forest district*, area 1.5 ha (site No. 15)

Objective for the creation of the experimental site: formation of Norway maple silvicultures created within the reconstruction of low-value stand by curtain-group method.

Brief description of the site:

It is represented by Norway maple silvicultures created in spring of 2010 by planting in clearings and stand windows (Figure 1.17) without soil preparation. Planting material: wild growing plants of Norway maple. In 2017, the plantation was transferred to the category of valuable (composition 4M3S1Lin1B1O).

Characteristics of the plot before creation of silvicultures: composition of the plantation: 3S1O1M3B2Asp, the average age is 20 years, forest type - bracken spruce forest, FCT – C_2., density - 0.3.

Figure 1.17 - Mixed Norway maple silvicultures
at experimental site No. 15

Characteristics of the stand (2019): Composition: 1 tier 4S3B3Asp/ 2 tier 7M3S, (density – 1.8 thousand plants/ha, Dav 3.9 cm, Hav 9.4 m, stock 51.8 m^3/ha).

Conclusions: The reconstruction in the low-density sorrel spruce forest did not give a positive result because of strong shadowing of the silvicultures by the trees of the upper tier. The stands were transferred to the category of valuable plantations due to well-preserved spruce trees and abundant regrowth of Norway maple, which will allow to form a mixed maple and spruce plantation in the future.

1 site was laid in Lyuban forestry:

1. *Quarter 4, sections 8, 19 Lyuban forest district*, area 17.3 ha (site No. 16)

Reconstruction at the site was carried out by corridor method in the underbrush with composition 4B3Asp+S. Forest type series - bracken, type of growth conditions – C_2, bonitet class I, site terrain - even, ground - sod-bleached, loamy, fresh.

Site creation technology: in 2008 the site preparation included organization of 4.5-meter corridors and 6-meter coulisses; in spring of 2008 the soil was tilled by cutting furrows in the corridors (MTZ-82+PKL-70) and planting of cultures; 2 furrows were cut for planting in the corridors. The species being created were alternating in corridors MM - couliss - SS. Spacing schme 5.0 × 0.5 m. Initial composition of silvicultures – 4M6S.

Root-taking rate of 1-year-old plantations is high. Silvicultures growth results are presented in Table 1.7.

Table 1.7 – Silvicultures growth index in 2019

Tree species	$D_{av.}$, cm	$H_{cm.}$, m	$G_{gen.}$, cm^2/ha	$M_{gen.}$, m^3/ha
Norway maple	1.5	2.2	0.39	3.2
Norway spruce	2.2	2.0	0.43	2.8

The curtain canopy has already closed in this area, which adversely affects the growth of the silvicultures. Thinning cutting (cleaning) was carried out in 2013 (Figure 1.18).

A) B)

Figure 1.18 – Reconstruction of low-value plantations by corridor method: A) - maple cultures B) - spruce cultures (spring 2019)

This year regular tending was held, which envisage cutting of coulisses, the average height of which makes 14.3 m (Table 1.8).

Table 1.8 – Characteristics of low-value plantation in the coulisses at site No. 16

Composition	Dav., cm	Hav., m	$N_{gen.}$, ha	$G_{gen.}$, cm^2/ha	$M_{gen.}$, m^3/ha
8Asp1B1H	10.3	14.3	1293	6.7	70.0

Conclusions: reconstruction by corridor method in low-value stands by creating mixed silvicultures of Norway maple can be used in the forest management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry provided that timely tending for the silvicultures in the corridors and improvement felling in the coulisses are held.

2 sites were laid in Kopyl forestry:

1. *Quarter 20, section 50, Koly forest district*, area 2.6 ha (site No. 17)

Reconstruction felling by corridor method was assigned in 3-year-old low-value stand of 8Asp2B composition. The average height of the stand in the coulisses was 2.9 m, average diameter - 2.0 cm, stock - 18 m^3/ha. Forest type series - sorrel, type of growth conditions – C_2, bonitet class I, site terrain - even, ground - sod-bleached, loamy, fresh.

Site creation technology: in 2016 the site preparation included organization of 4-meter corridors and 4-meter coulisses; in spring of 2017 the soil was tilled by cutting furrows in the corridors (MTZ-82+PKL-70) and planting of cultures; planting material - 2-year-old seedlings of English oak and Norway maple, arrangement scheme of oak and maple in corridors in two rows: $M^{2m}M^{4m}O^{2m}O^{2m}O^{2m}O^{4m}M^{2m}M$ (2 rows of maple, 4 rows of oak, etc.). The initial composition of cultures – 7O3M. Planting density – 2507 plants/ha.

Root-taking rate of 1-year-old plantations is high. Biometric growth index of silvicultures is presented in Table 1.9.

Table 1.9 – Biometric growth index of English oak silvicultures (2019)

Tree species	Dav., cm	Hav., cm	Zav., cm
European oak	0.91±0.02	49.5±0.11	10.6±0.10
Norway maple	0.77±0.01	42.8±0.10	7.2±0.10

Aspen forest 8Asp2B plants of S, O, H with average height of 4 m; average diameter – 3.5 cm, stock – 25 m^3/ha (Figure 1.19) grows in the coulisses.

A) B)

Figure 1.19 - Reconstruction of low-value plantation by corridor method: A) - oak cultures B) - maple cultures (spring 2019)

Every year agrotechnical care was carried out in the corridors at the site, the corridors need to be expanded or the coulisses need to be thinned in the next 2 years, because high density coulisses about 4 meters high will have adverse impact on the lighting conditions and growth of the cultures.

Conclusions: reconstruction by corridor method in low-value stands by creating silvicultures of English oak and Norwat maple can be used in the forest management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry provided that timely care for the silvicultures in the corridors and improvement fellings in the coulisses are conducted.

2. *Quarter 45, section 33, Staritsa forest district*, area 4.3 ha (site No. 18)

Reconstruction felling by corridor method was assigned in 3-year-old low-value stand of 8Asp1H1Lin composition with density 1.0. The average height of plants in plantation is 2.5 m, stock – 25 m^3/ha. Forest type series - sorrel, type of growth conditions – D_2, bonitet class Ia, site terrain - even, soil - sod-bleached, loamy, fresh.

Site creation technology: site preparation included organization of 4-meter corridors and 4-meter coulisses; in spring of 2015 the soil was tilled by cutting furrows in the corridors (MTZ-82+PKL-70) and planting of cultures; planting material - 1-year-old seedlings of English oak, spacing scheme of English oak: double row biogroups: 4.0×2.0×0.98 m; root-taking rate during the 1st year was 90% (Table 1.10, Figure 1.20).

Table 1.10 – Biometric growth index of English oak silvicultures

Observation year	Dav., cm	Hav., cm	Zav., cm
2018	1.03±0.03	69.68±0.12	27.0±0.10
2019	1.05±0.02	78.0±0.11	18.6±0.10

A) B)

Figure 1.20 - Reconstruction of low-value plantation by corridor method:
A) planting before reconstruction (autumn 2015);
B) planting after reconstruction felling by corridor method (autumn 2018)

In the reporting year the stand in the coulisses was thinned to density 0.7. The average height of the upper canopy - 7.0 m, diameter - 4.0 cm. Composition of the coulisses – 8Asp1W1Hazel. The canopy of coulisses does not close, but in view of rich growth conditions the site is characterized by strong overgrowth of grassy vegetation (nettle, sorrel, ashweed, weaselsnout, etc.).

Conclusions: reconstruction by corridor method in low-value stands by creating silvicultures of English oak can be used in the forest management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry. The final stage of the reconstruction - clear felling of coulisses - is recommended in the site in 2-3 years.

In Mogilev region, the enhanced technologies of low-value forest stands reconstruction were tested by laying experimental and production sites in Osipovichi experimental forestry (4 sites), and Zhornovskaya EFS of the IF of the National Academy of Sciences of Belarus (2 sites).

4 sites were laid in Osipovichi experimental forestry:

1. *Quarter 77, section 2, Kamenichi forest district*, area 2.2 ha (site No. 19)

The objective of creation of the experimental and production site: reconstruction of low-value forest plantation by silvicultural method. Year of creation: 2013.

Characteristics of the stand before the appointment of reconstruction measures: 35-year-old low-value stand with composition 4B4Asp2S, bonitet class Ia, density 0.6, stock - 170 m^3/ha; forest types series - sorrel, growth conditions – C_2, site terrain - even, soil - sod-bleached, sandy loam, fresh.

Site creation technology: in 2013 clear felling of low-value stand was carried out; soil was prepared in autumn by cutting furrows (MTZ-82 + PKL-70) and silvicultures were planted; planting material - 1-year-old seedlings of English oak, English oak spacing scheme: double row biogroups: 4.5×2.0×0.7 m. Initial composition – 10O. Root-taking rate during the first year was 91%.

Cleaning was performed at the site this year.

Conclusions: reconstruction in low-value stands by creating continuous silvicultures of English oak can be used in the forest management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry provided that timely care for the silvicultures is carried out.

2. *Quarter 84, section 28, Oktyabrsky forest district*, area 5.6 ha (site No. 20)

In 2018, reconstruction of low-value plantation by clear method and planting of English oak silvicultures was carried out.

The site preparation included clear felling of 60-year-old plantation with composition 6H3Asp1B+S, M, O. Series of forest types - sorrel, type of forest growth conditions – D_2, bonitet class of plantation Ia with density 0.7. Terrain of the territory is even. Soil is sod-bleached, sandy loam, fresh.

Soil preparation included cutting of furrows 10-15 cm deep using plow PKL-70 in assembly with tractor MTZ-82, 3.3 m from each other, planting step - 0.9 m. Silvicultures were planted according to the scheme OOOBlAl (3r. oak 1r black alder). Planting material - 1-year-old seedlings (oak), 1-year-old seedlings (alder).

The initial composition of cultures – 7O3BlAl. Root-taking rate during the first year was 90.3%. Biometric growth rates at the end of the vegetation period are presented in the table.

Cleaning was performed at the site this year.

Biometric rates of the stands obtained during their examination in 2019, are presented in Table 1.11.

Table 1.11 – Biometric growth index of oak silvicultures at site No. 20

Tree species	Dav., cm	Hav., m	Zav., cm
English oak	0.33±0.09	10.86±0.90	7.2±0.26
Black alder	0.29±0.11	12.3±0.50	11.2±0.15

Conclusions: reconstruction of low-value stands by creating silvicultures of continuous English oak can be used in the forest management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry.

3. *Quarter 84, section 9, Oktyabrsky forest district*, area 3.4 ha (site No. 21)

In 2016, Zhornovskaya experimental forest station participated in creation of the experimental and production site for the reconstruction of low-value plantation by clear-cutting method and planting of English oak cultures.

The site preparation included clear felling of 58-year-old plantation with composition 6H3Asp1B+S, M, O. Forest types series – sorrel, forest growing conditions – D_2, stand of bonitet class I^a, density 0.7, stock of felled tree stand is 260 m^3/ha. Terrain of the territory is even. Soil is sod-bleached, sandy loam, fresh.

Soil preparation in spring of 2016 included cutting of furrows 10-15 cm deep using plow PKL-70 in assembly with tractor MTZ-82, 2.5-3.0 m from each other, planting step - 0.75 m. The silvicultures were planted according to the scheme OOLinSLin (2r. oak 1r linden 1r. spruce 1r. linden). Planting material - 2-year-old seedlings (oak, spruce), 1–3-year-old seedlings (linden).

Table 1.12 shows the results of biometric indices of the stands at the end of the first year of cultivation.

Table 1.12 − Biometric index of oak, spruce and linden at the end of the first year of cultivation at site No. 21

Parameters	Tree species		
	English oak	Norway spruce	Small-leaved linden
Average age, years	2	2	1-3
Average height, cm	19.97±0.90	27.2±0.59	21.8±2.22
Average diameter (at root collar), cm	0.53±0.02	0.78±0.02	0.86±0.18
Increase in height, cm	6.6±0.49	8.3±0.41	11.61±1.53
Root-taking rate, %	96.3	93.3	89.2

Biometric parameters of the stands obtained during their examination in 2018 are presented in Table 1.13.

Table 1.13 – Biometric growth index of English oak silvicultures in 2019 at site No. 21

Tree species	Dav., cm	Hav., cm	Zav., cm
English oak	0.62±0.12	42.0±0.12	6.2±0.16
Norway spruce	0.86±0.21	36.2±0.21	7.2±0.24
Small-leaved linden	0.98±0.45	32.5±0.45	2.11±0.16

The first years after the reconstruction in low-value plantation give us some information about the processes of formation of the future plantation. In this case, high-quality and timely tending is required. Agrotechnical tending was carried out in 2016, 2017, clearing - in 2019.

Conclusions: reconstruction in low-value stands by creating continuous mixed silvicultures of English oak can be used in the forest management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry provided that timely care for the silvicultures is carried out.

4. *Quarter 66, section 10, Britslovichskoye forest district*, area 0.4 ha (site No. 22)

Characteristics of the site: 9-year-old aspen forest, bonitet class Ia, forest type series - sorrel, growth conditions type – D_2, site terrain - even, soil - sod-bleached, loamy, underlain by loamy clay, fresh.

Corridors with width no more than the height of the reconstructed plantation were organized according to the regulatory requirements. In this case, the corridor width was 8 m, the width of the remaining coulisses is also within 8 m.

The partial planting of silvicultures without soil preparation was carried out according to the scheme 2rows of Oak 1row of Spruce (Douglas-fir) ($O^{\underline{2m}}O^{\underline{4M}}S(Df)$). This type of silvicultures is applicable for the reconstruction of low-value stands according to the Recommendations on the reforestation of broadleaved forests, approved by the Ministry of Forestry on June 30, 2016. The biometric measurements were carried out at the end of the growing period (Figure 1.21, Table 1.14).

Table 1.14 – Biometric growth index of English oak silvicultures in 2019 at site No. 22

Tree species	Dav., cm	Hav., cm	Zav., cm
English oak	0.55±0.01	11.2±0.13	2.1±0.16
Norway spruce	0.49±0.01	25.3±0.10	3.1±0.24
Douglas-fir	0.48±0.01	21.6±0.23	2.11±0.16

The oak was planted like at the sites of Zhornovskaya experimental forest station with its arrangement in the ordinary biogroups (closely spaced rows) that corresponds to the ecological and biological characteristics of the species, thus ensuring the biological stability of the future planting, and helps to simplify the technology of oak tending, contributes to the reduction of coenosis impact of spruce, as the main competitor of oak, under the conditions of simultaneous growth in a subzone of hornbeam-oak-dark-coniferous forests.

Figure 1.21 - Reconstruction of low-value forest plantation by corridor method (spring 2019)

For experimental purposes the silvicultures were planted with alternation of rows of spruce and rows of Douglas-fir according to the used composition scheme. The alternation of the composition schemes was made in corridors OOS-OODf-OOS ... According to the publications (long-term observations of the scientists of the Central Botanical Garden of NASB), when Douglas-fir is introduced, it, along with native tree species maintains high rates of growth and its wood productivity and quality is higher than that of the main forest-forming species of Belarus - pine and spruce. The site will be a source of observation of peculiarities of growth and formation of the mixed English oak stand with Norway spruce and Douglas-fir, created during reconstruction of low-value plantation.

Conclusions: reconstruction of low-value stands by creating silvicultures of partial English oak can be used in the forest management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry. Further formation of mixed English oak plantations with Norway spruce and Douglas-fir is possible provided that timely improvements of the silvicultures in corridors and thinning in the coulisses are conducted.

2 sites were laid in Zhornovskaya EFS of IF of the National Academy of Sciences of Belarus:

1. *Quarter 204, section 10, Lapichi forest district,* area 0.4 ha (site No. 23)

The objective of creation of the experimental and production site: curtain-group reconstruction of low-value plantation. Year of creation: 2019.

Characteristics of the stand before the appointment of reconstruction measures: as a result of dying of Norway spruce silvicultures created in 2007, (due to unfavorable climatic conditions) the stand at the site is formed by curtains, so in 2019 it was offered to replace the curtains with

low-value stands (aspen-birch stand with participation of English oak) with partial cultures of English oak.

Forest type series - sorrel-ashweed, type of growth conditions – D_{2-3}, bonitet class I, site terrain - even, soil - sod-bleached, loamy, fresh-wet depending on the weather and climatic conditions.

Site creation technology: in 2019, preparation of the site included felling of low-value stand in curtains, cutting furrows (MTZ-82 + PKL-70), and spring and autumn planting of English oak silvicultures in curtains. Planting material - 2-year-old English oak seedlings. The initial composition of cultures – 10O.

The objective of the reconstruction envisages formation of uneven coniferous-hardwood stand.

Conclusions: reconstruction of low-value stands by creating silvicultures of partial English oak can be used in low-density underwood of low-value stands to increase the share of broadleaved species in the forest fund of the Ministry of Forestry.

2. *Quarter 1, section 22, Zhornovka forest district*, area 0.9 ha (site No. 24)

The objective of creation of the experimental and production site: reconstruction of low-value forest plantation by silvicultural method. Year of creation: 2019.

Characteristics of the plantation before appointment of reconstruction measures: 6-year-old aspen forest, bonitet class Ia, forest type series - ashweed, growth conditions type – D_3, site terrain - even, soil - sod-bleached, loamy, wet.

Site creation technology: in 2019 the site preparation included organization of 6-meter corridors and 6-meter coulisses; in autumn the soil was tilled by cutting furrows in the corridors (MTZ-82+PKL-70) and planting of cultures; 2 furrows were cut for planting of English oak partial silvicultures in each corridor. Placing scheme 5.0 × 0.7 m. Planting density - 2857 plants/ha. Planting material - initial composition of cultures – 10O.

Conclusions: reconstruction of low-value forest plantations by creating partial silvicultures of English oak can be used in the forest management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry provided that timely care for the silvicultures is carried out.

In Brest region, the enhanced technologies of low-value forest stands reconstruction were tested by laying experimental and production sites in Luninets (7 sites) forestry.

1. *Quarter 10, sections 14, 28, Sitnitsa forest district*, area 2.4 ha (site No. 25)

Objective for the creation of the experimental site: formation of mixed silvicultures of English oak created within the reconstruction of low-value stands by clear-cutting method.

Brief description of the site:

It is represented by mixed English oak silvicultures created in spring of 2019 by planting of the main species. Soil preparation was carried out by cutting furrows by plow PKL-70, planting method - manually, using Kolesov's planting iron. Type of silvicultures - mixed (Figure 1.22).

Figure 1.22 - Mixed English oak silvicultures
at experimental site No. 25

Characteristics of the plot before creation of silvicultures: composition of the plantation: 7H1B1M1O, the average age is 75 years, forest type - sorrel hornbeam forest, FCT – D_2

Characteristics of the silvicultures: Composition: 6O3M1P, density - 4.4 thousand plants/ha, including oak - 2.8 thousand plants, maple 1.1 thousand plants, pine - 0.5 thousand plants. Planting material: 1-year-old seedlings of oak, two-year-old seedlings of maple and pine, spacing scheme: oak - 2.9 × 0.75 m, maple - 2.9 × 0.85 m, pine - 2.9 × 0.75 m. Composition scheme: 2rO1rM2rO1rM2rO1rM1rP. The root-taking rate of the silvicultures was 95%.

Conclusions: reconstruction by a clear-cutting method in 10-year-old and older low-value stands by mixed silvicultures of English oak planting by placing it in ordinary biogroups ($O^{1.5-2.5}O$) can be used in the forestry management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry.

It should be noted that the mixed oak silvicultures were created in accordance with the recommendations of the Guidelines document. The state of the cultures is good. Reconstruction should be considered successful. In future, taking into account the large number of wild ungulates in the territory of the forest district and a high degree of forest damage they cause to adjacent sections, the plants should be treated with special substances (Cervakol) or fenced to preserve it.

2. *Quarter 10, sections 14, 28, Sitnitsa forest district (area 3.1 ha)* (site No. 26)

The site is created to test the technology of tending in the hornbeam stand under reconstruction to restore English oak plantations. Forest type - sorrel hornbeam forest, FCT – D_2.

In 2013, oak was planted using Kolesov's planting iron into plow furrows created by PKL-70. Spacing for plantings: O - 2.5 × 0.85 m; M - 2.5 × 0.75 m. Number of planting spots 5704 per 1 ha. Planting material: 2-year-old seedlings of oak and maple. Root-taking rate of cultures in 2015 - 93.4%. In 2015, 2000 plants/ha of oak seedlings were added.

In 2019 the composition of plantation by number of trunks is: 5M2O3B+H+Wi (Figure 1.23, Table 1.15). Maple of natural origin is observed at the site, 40% of which grows between

the rows. A high share of birch, 23%, is observed in the stand. Hazel curtains with height to 4 m, singly buckthorn, are also observed in the stand.

Figure 1.23 - Mixed English oak silvicultures
at experimental site No. 26

Table 1.15 – Mensurational characteristics of the plantation in the birch forest being reconstructed at experimental site No. 26

Parameter	Species					Stand
	M	O	B	Wi	H	
N, plants/ha	6000	2785	3000	642	571	12998
∑G, m^2/ha	1.67	0.43	1.69	0.21	0.21	4.21
P (canopy density)						1.0
V per ha, m^3	2.9	0.7	4.2	0.34	0.12	8
D av., cm	1.9	1.4	2.7	2	2.2	1.9
H av., m	2.5	1.5	3.6	2	3.2	2.5
Composition of the stand by number of trunks: 5M2O3B+H+Wi						

In 2019, the silvicultures tending was carried out according to the Guidelines document.

Conclusions: It should be noted that tending in the mixed oak silvicultures was carried out in accordance with the recommendations of the Guidelines document. The state of the cultures is good. Reconstruction should be considered successful. In future, taking into account the large number of wild ungulates in the territory of the forest district and a high degree of forest damage they cause to adjacent sections, the plants should be treated with special substances (Cervakol) or fenced to preserve it that, in its turn, will allow to form a mixed pine-oak stand.

3. *Quarter 19, section 32, Sitnitsa forest district,* area 1.9 ha (site No. 27)

Objective for the creation of the experimental site: formation of mixed silvicultures of English oak created within the reconstruction of low-value plantation by clear-cutting method.

Brief description of the site:

It is represented by mixed English oak silvicultures created in spring of 2014 by planting of the main species. Soil preparation was carried out by cutting furrows by plow PKL-70, planting method - manually, using Kolesov's planting iron. Type of silvicultures - mixed (Figure 1.24).

Figure 1.24 - Mixed English oak silvicultures
at experimental site No. 27

Characteristics of the plot before creation of silvicultures: composition of the plantation: 5B3Asp2BlAl, average age is 20 years, forest type - fern birch forest, FCT – C_4.

Characteristics of the silvicultures: Composition: 5O5P, density – 3.6 thousand plants/ha, including oak – 1.7 thousand plants, pine – 1.9 thousand plants. Planting material: 1-year-old seedlings of oak and pine. Spacing for plantings: O – 2.8 × 0.75 m; P – 3.8 × 0.75 m. Root-taking rate of the cultures in 2015 was 95.5.%. In 2014-2019, forest plantations tending was carried out, in 2015 – addition of silvicultures.

The site is created to test the technology of tending (clearing) in the birch plantation under reconstruction by clear-cutting method to restore the English oak plantations.

In 2019 the composition of plantation by number of trunks is: 2O8P+B+M+H (Table 1.16). Intensive natural regrowth of pine is observed in the plantation, 35% of the total number of which grows between the rows.

Table 1.16 – Mensurational characteristics of the low-value plantation being reconstructed at experimental site No. 27

Parameter	Species					Stand
	O	P	M	B	H	
N, plants/ha	1263	6035	193	438	123	8052
∑G, m^2/ha	0.2	0.91	0.04	0.16	0.03	1.34
P (canopy density)						0.9
V per ha, $\mathbf{m^3}$	0.3	1.5	0.07	0.4	0.02	2.29
D av., cm	1.4	1.4	1.7	2.2	1.9	1.4
H av., m	1.3	1.7	2.2	2.3	1.6	1.5
Composition of the stand: 2O8P+B+M+H						

***Conclusions**:* reconstruction by a clear-cutting method in 10-year-old and older low-value plantations by mixed silvicultures of English oak planting can be used in the forestry management to increase the share of broadleaved species in the forest fund of the Ministry of Forestry.

It should be noted that the improvement in the mixed oak silvicultures was carried out in accordance with the recommendations of the Guidelines document. The state of the cultures is good. Reconstruction should be considered successful. In future, taking into account the large number of wild ungulates in the territory of the forest district and a high degree of forest damage they cause to adjacent sections, the plants should be treated with special substances (Cervakol) or fenced to preserve it that, in its turn, will allow to form a mixed pine-oak stand.

4. *Quarter 16, section 7, Sitnitsa forest district*, area 2.2 ha (site No. 28)

The site is created to test the technology of tending in the reconstructed aspen plantation to restore the main species stands (oak, maple, ash). Forest type – bilberry aspen forest, FCT - C_3.

In 2017, corridor reconstruction was carried out (Figure 1.25), and in 2018, cultures were planted in the corridors using 2-year-old seedlings of oak, maple and ash using Kolesov's planting iron into plow furrows (PKL-70).

Composition scheme and planting spacing: 3r.M1r.Ash1r.O3r.Ash; O – 3.0 × 0.7; M – 3.0 × 0.7; Ash – 3.0 × 0.7. Number of planting spots in the section is 5239 plants. The root-taking rate of the silvicultures in 2019 – 95.7%. In 2019, oak seedlings (171 plants) and maple (300 plants) were added.

In 2019, the composition of the silvicultures by number of trunks in the corridors was 7M3Ash, in the coulisses by stock: 5Asp3M2B+H (Table 1.17). Because of the lack of rainfall and high air and soil surface temperatures, part of the young plants (oak, ash) died. The site requires thinning fellings in the corridors and additional silvicultures.

Figure 1.25 - Mixed Norway maple silvicultures
at experimental site No. 28

Table 1.17 – Mensurational characteristics of the plantation in the birch forest being reconstructed at experimental site No. 28

Parameter	Species		Stand
	M	Ash	
N, plants/ha	2142	857	2999
Canopy density			0.8
D av., cm	1.4	1.0	1.4
H av., m	1.5	1.2	1.5
Composition of the stand: 7M3Ash			

The maple of natural origin (19.6%) is observed at the site in the coulisses. A high share of birch, 23%, is observed in the stand. (Table 1.18). Buckthorn with height of 1.8 m in an amount of 90 plants/ha is also observed in the stand.

Table 1.18 – Mensurational characteristics of the plantation in the coulisses of the plantation being reconstructed at experimental site No. 28

Parameter	Maple	Hornbeam	Birch	Aspen	Stand
N, plants/ha	455	818	182	864	2319
∑G, m^2/ha	3.5	3.6	2.91	6.14	16.15
V per ha, m^3	18.7	2	12.17	34	66.8
D av., cm	9.9	7.4	14.2	9.5	9.5
H av., m	10.8	8.0	11.6	10.7	10.7
Composition: 3M5Asp2B+H (by stock) 2M4Asp4H+B (by number of trunks)					

In 2019, silvicultures tending was carried out according to the Guidelines document.

Conclusions: It should be noted that the mixed oak silvicultures tending was carried out in accordance with the recommendations of the Guidelines document. The state of the cultures is good. Because of the lack of rainfall and high air and soil surface temperatures, part of the young plants died. The site requires additional silvicultures next year. Reconstruction should be considered successful, provided timely improvements of silvicultures are carried out.

5. *Quarter 12, section 4, Sitnitsa forest district,* area 3.8 ha (site No. 29)

The site is created to test the technology of tending (clearing) in the hornbeam plantation under reconstruction by clear-cutting method to restore the English oak plantations. Forest type - sorrel hornbeam forest, FCT – D_2. Clear reconstruction felling was carried out in 2014. In 2016, planting was carried out using the Kolesov's planting iron into the plow furrows (PKL-70).

Characteristics of the plot before creation of silvicultures: composition of the plantation: 5H3Asp2B, the average age is 50 years, forest type - sorrel hornbeam forest, FCT – D_2.

Characteristics of the silvicultures: Composition: 3O5P2R, density - 5.5 thousand plants/ha, including oak - 1.9 thousand plants, pine 2.5 thousand plants, rowanberry - 1.1 thousand plants. Planting material: two-year-old seedlings of oak and pine, wild growing plants of rowanberry. Spacing for plantings: 3.2×0.7 m. In 2016, silvicultures tending was carried out, in 2017 – addition of silvicultures. Root-taking rate of cultures in 2016 - 90.1%, in 2017 - 77.3%.

In 2019, the composition of plantations by number of trunks is: 9O1M+B+H (Table 1.19). Approximately 40% of maple has natural origin and is found between the rows, it is 6.5 times higher than oak of average height. Birch is also found. Hazel curtains with height up to 4 m, singly buckthorn, are also observed.

Table 1.19 – Mensurational characteristics of the low-value plantation being reconstructed at experimental site No. 29

Parameter	Species				Stand
	O	B	M	H	
N, plants/ha	4000	108	428	71	4607
∑G, m^2/ha	0.3	0.008	0.03	0.006	0.34
P (canopy density)					0.8
V per ha, m^3	0.4	0.02	0.04	0.003	0.5
D av., cm	0.9	1.0	6.0	1.0	0.9
H av., m	1.0	1.4	6.5	1.0	1.0
Composition of the stand by number of trunks 9O1M+B+H					

Conclusions: It should be noted that thinning fellings were carried out in accordance with the Guidelines document. The state of the silvicultures is good. Reconstruction should be considered successful. In future, taking into account the large number of wild ungulates in the territory of the forest district and a high degree of forest damage they cause to adjacent sections, the plants should be treated with special substances (Cervakol) or fenced to preserve it.

6. *Quarter 12, section 4, Sitnitsa forest district,* area 11.1 ha (site No. 30)

The site is created to test the technology of tending (clearing) in the hornbeam plantation under reconstruction by clear-cutting method to restore the English oak plantations. Forest type – sorrel hornbeam forest, FCT – D_2. Clear reconstruction felling was carried out in 2013. In 2014, planting of oak and maple was carried out using the Kolesov's planting iron into the plow furrows (PKL-70).

Characteristics of the plot before creation of silvicultures: composition of the plantation: 5H3Asp2B, the average age is 50 years, forest type - sorrel hornbeam forest, FCT – D_2

Characteristics of the silvicultures (Figure 1.26): Composition: 6O4M, density - 3.8 thousand plants/ha, including oak - 2.3 thousand plants, maple 1.5 thousand plants. Planting material: 2-year-old seedlings of oak and maple. Species composition scheme: 2.8×0.76. In 2014, 2015, silvicultures tending was carried out, in 2015 and 2017 - addition of silvicultures.

Figure 1.26 - Mixed English oak silvicultures
at experimental site No. 30

Root-taking rate of silvicultures in 2015 – 95.6 %. 5640 oak seedlings were added in 2015, and 5916 oak seedlings and 1757 maple seedlings were added in 2017.

In 2019, the composition of plantation by number of trunks is: 7O2M1P (Table 1.15). Natural regrowth of pine is observed at the site. 1.5-2.0 m high rowanberry is observed in the stand. In 2019, silvicultures tending was carried out according to the Guidelines document.

Table 1.20 – Mensurational characteristics of the low-value plantation being reconstructed at experimental site No. 30

Parameter	Species				Stand
	O	P	M	Rb	
N, plants/ha	3739	782	1043	217	5781
∑G, m^2/ha	0.2	0.14	0.28	0.01	0.63
P (canopy density)					0.8
V per ha, m^3	0.3	0.3	0.5	0.05	1.2
D av., cm	0.8	1.5	1.8	1.5	0.8
H av., m	1.0	1.8	2.0	1.6	1.0
Composition of the stand by number of trunks 7O2M1P					

Conclusions: It should be noted that thinning fellings were carried out in accordance with the Guidelines document. The state of the silvicultures is good. Reconstruction should be considered successful. In future, taking into account the large number of wild ungulates in the territory of the forest district and a high degree of forest damage they cause to adjacent sections, the plants should be treated with special substances (Cervakol) or fenced to preserve it.

7. *Quarter 62, section 5, Mikashevichi forest district*, area 1.6 ha (site No. 31)

The site is created to test the technology of tending in the birch plantation under reconstruction to restore European ash (Figure 1.27). Forest type - sorrel birch forest, FCT – D_2.

A) B)

Figure 1.27 - European ash silvicultures at experimental site No. 31
A) before thinning felling; B) after thinning felling (demonstration at the workshop)

The site has a complex shape: part of it is located along the road in the form of an elongated rectangle, which from the middle of the side opposite to the road goes deeper into the birch stand in a tapered strip. Complexity of the site configuration caused the simultaneous use of two methods: clear reconstruction and corridor (corridor width 4 m). Principal felling was carried out in 1998, by spring of 2008 the site was covered with a 10-year-old low-value plantation. In 2008, reconstruction was carried out: along the road – by creation of continuous silvicultures and deep in the birch forest – partial (cutting plow furrows creating silvicultures in the corridors). In 2009 oak and ash were planted using Kolesov's planting iron into the plow furrows (PKL-70).

Characteristics of the plot before creation of silvicultures: composition of the plantation: 7B2BlAl+O, Ash, the average age is 10 years, forest type – fern birch forest, FCT – C_4., density – 0.4.

Characteristics of the silvicultures: Composition: 5O5Ash, density - 3.2 thousand plants/ha, including oak – 1.6 thousand plants, ash – 1.6 thousand plants. Planting material: 1-year-old seedlings of oak and ash-tree. Composition scheme and planting spacing: 5O5Ash, O – 3.8 × 0.80 m, Ash – 3.8 × 0.80 m. Number of planting material: O – 1604 plants/ha, Ash – 1604 plants/ha. Root-taking rate of silvicultures in 2009 – 90.5%, in 2011 – 85.2%. Plants adding was carried out in 2011. In 2016, the site was transferred to the forest-covered area with the stand composition 5O5Ash, density 0.7. In 2009 and 2019, silvicultures tending was carried out, in 2011, 2014, 2015 and 2016 - addition of silvicultures.

According to the data obtained at the experimental sites laid in 2019, mensurational indices by species are presented in Table 1.21.

Table 1.21 – Mensurational characteristics of the low-value plantation being reconstructed at experimental site No. 31

Parameter	Tree species								Composition
	Ash	O	M	H	Elm	P	B	Asp	
part of the continuous silvicultures									
D av., cm	4.5	-	-	-	-	4.0	1.7	1.5	6Ash3Asp1B+P (by number of trunks)
H av., m	5.1	-	-	-	-	4.0	1.8	1.8	
part with partial silvicultures (in corridors)									
D av., cm	4.1	1.0	0.7	2.0	-	-	-	-	9Ash1M+O+H (by number of trunks)
H av., m	5.0	0.9	0.8	1.9	-	-	-	-	
coulisse									
D av., cm	7.1	-	8.8	2.0	6.0	-	10.2	-	7B3M+Ash+B+H (by stock)
H av., m	7.3	-	9.0	2.1	6.2	-	11.0	-	
Stand									
N, plants/ha	1506	17	445	41	138	26	658	316	3147

Ash-tree growing in the part of the section where continuous cultures were created is oppressed by soft-wood species, mainly aspen, tending is required. We selected trees for felling. In 2019, silvicultures tending was carried out according to the Guidelines document.

Natural regrowth of ash in the amount of 1.0 thousand plants/ha, the height of which with undergrowth is 2.5 m, is observed under the canopy in part of the section. It should be noted that birch in the coulisses is 1.5 higher than ash-tree. We gave recommendations to expand the corridors by felling the trees along the edges of the coulisses. In general, ash-tree is in satisfactory state.

Conclusions: We believe that the experimental approach in European ash regrowth solution by combining of clear-cutting and corridor methods of low-value plantation reconstruction at the part with complex configuration, is commendable. Planting is in good condition, predominance of ash-tree is ensured, other broadleaved species (maple, elm, oak and hornbeam) are observed in the composition. Type of forest growing conditions (C_4) is suitable for ash-tree, but not quite to oak, which has likely died in the first years of life (due to waterlogging). Testing of the tending technology in accordance with the Guidelines document was successful.

In Vitebsk region, the enhanced technologies of low-value forest stands reconstruction were tested by laying experimental and production sites in Glubokoye experimental forestry (5 sites), and Dvinskaya EFS of IF of the National Academy of Sciences of Belarus (1 site).

5 sites were laid in Glubokoye experimental forestry:

1. *Quarter 131, section 62, Tumilovichskoye forest district* (site No. 32)

The site is created to test the technology of tending (clearing) in the gray alder plantation under reconstruction by clear-cutting method to restore oak and maple plantations. Forest type – bilberry gray alder forest, FCT - C_3. Reconstruction felling was carried out in 2010. In 2011, oak acorns and maple seeds were planted using the Kolesov's planting iron into the plow furrows (PKL-70).

Characteristics of the plot before creation of silvicultures: Composition of the stand: 6GrAl3Asp1S, 25 years, forest type – Bl.Ald., FCT – C_3.

Characteristics of the silvicultures (Figure 1.28): Composition: 5O2M3S, density - 3.7 thousand plants/ha. Planting material: oak acorns, spruce plants, maple seeds. Spacing scheme: 2.4×1.1 m.

Figure 1.28 - Mixed English oak silvicultures
at experimental site No. 32

The average width of the corridor is 6 m, coulisses - 4 m.

In 2011-2015, 2017, silvicultures tending was carried out, in 2012 and 2014 – addition of silvicultures. In 2018, the site was transferred to the category of valuable plantations. Composition is 4O1M3S2Asp.

In 2019, the composition of the stand was 3O3S2Asp2GrAl+M, density 3.3 thousand plants/ha, completeness 0.5, stock 35 m^3/ha. In 2019, silvicultures tending (clearing) was carried out according to the Guidelines document.

Conclusions: It should be noted that the thinning fellings were carried out in accordance with the Guidelines document. The state of the silvicultures is good. Reconstruction should be considered successful.

2. *Quarter 134, section 33, Tumilovichskoye forest district* (site No. 33)

The site is created to test the technology of tending (clearing) in the birch stand under reconstruction by clear-cutting method to restore oak and ash-tree plantations. Forest type - bilberry birch forest, FCT – C_3. Reconstruction felling was carried out in 2005. In 2006, planting of oak, ash-tree and spruce was carried out using the Kolesov's planting iron into the plow furrows (PKL-70).

Characteristics of the plot before creation of silvicultures: Composition of the stand: 8B1Asp1GrAl, 11 years, forest type – bilb.B., FCT – C_3.

Characteristics of the silvicultures (Figure 1.29): Composition: 4O3Ash3S, density - 4.3 thousand plants/ha. Planting material: 2-year-old seedlings of oak and ash, spruce plants. Spacing scheme: 2.0×0.7 m. The average width of the corridor is 6 m, coulisses - 4 m.

In 2006 (2 improvements), 2007-2008, 2010, 2013, improvements of the silvicultures were carried out, in 2006, 2007 and 2012 – addition of silvicultures. In 2013, the site was transferred to the category of valuable plantations. Composition is 4O3S1GrAl1Asp1P+M.

In 2019, the composition of the stand was 5O4S1GrAl, M, density 3.4 thousand plants/ha, completeness 0.5, stock 35 m^3/ha. In 2019, silvicultures tending (clearing) was carried out according to the Guidelines document. Ash-tree died because of lack of rainfall and dry summer.

Conclusions: It should be noted that thinning fellings were carried out in accordance with the Guidelines document. The state of the silvicultures is good. Reconstruction should be considered successful.

3. *Quarter 134, section 18, Tumilovichskoye forest district* (site No. 34)

The site is created to test the technology of tending (clearing) in the aspen plantation under reconstruction by corridor method to restore the oak plantations. Forest type – sorrel aspen forest, FCT – D_2. Reconstruction felling was carried out in 2000. In 2001, oak acorns were planted using the Kolesov's planting iron into the plow furrows (PKL-70).

Characteristics of the plot before creation of silvicultures: Composition of the stand: 8Asp2GrAl, 5 years, forest type – sorr.asp., FCT – D_2.

Characteristics of the silvicultures (Figure 1.30): Composition: 10O, density - 4.0 thousand plants/ha. Planting material: oak acorns. Spacing scheme: 2.5×1.0 m.

A)

B)

Figure 1.29 - Mixed English oak silvicultures
at experimental site No. 34: A) oak cultures in the corridor after thinning felling;
B) felled coulisse

The average width of the corridor is 20 m, coulisses - 4 m.

In 2001 -2004, 2006, 2008, 2013, improvements of the silvicultures were carried out, and in 2012 - addition of silvicultures. In 2008, the site was transferred to the category of valuable plantations. Composition is 4O2S1P2Asp1GrAl.

In 2019, the composition of the stand was 10O+M, Asp, S, GrAl, density 2.2 thousand plants/ha, completeness 0.4, stock 34 m^3/ha. In 2019, silvicultures tending (cleaning) was carried out according to the Guidelines document.

Conclusions: It should be noted that the thinning felling was carried out in accordance with the Guidelines document. The state of the silvicultures is good. Reconstruction should be considered successful.

4. *Quarter 131, section 6, Tumilovichskoye forest district* (site No. 35)

The site is created to test the technology of tending (clearing) in the aspen plantation being reconstructed by clear-cutting method to restore oak and linden plantations. Forest type – sorrel aspen forest, FCT – D_2. Reconstruction felling was carried out in 2010. In 2011 oak and linden were planted using the Kolesov's planting iron into the plow furrows (PKL-70).

Characteristics of the plot before creation of silvicultures: Composition of the plantation: 7Asp3GrAl, 5 years, forest type – sorr.asp., FCT – D_2.

Characteristics of the silvicultures (Figure 1.30): Composition: 5O5Lin, density - 3.6 thousand plants/ha. Planting material: 1-year-old seedlings of oak and maple. Spacing scheme: 2.8 × 1.0 m

Figure 1.30 - English oak silvicultures
at experimental site No. 34

In 2019, the composition of the stand was 5O5Lin+S, density 0.8 thousand plants/ha, completeness 0.3, stock 26.5 m^3/ha. In 2019, silvicultures tending (clearing) was carried out according to the Guidelines document.

Conclusions: It should be noted that the thinning felling was carried out in accordance with the Guidelines document. The state of the silvicultures is good. Reconstruction should be considered successful.

5. *Quarter 137, section 11, Tumilovichskoye forest district* (site No. 36)

The site is created to test the technology of tending (clearing) in the aspen plantation under reconstruction by clear-cutting method to restore oak silvicultures. Forest type – sorrel aspen forest, FCT – D_2. Reconstruction felling was carried out in 2010. In 2011, oak acorns were planted using the Kolesov's planting iron into the plow furrows (PKL-70).

Characteristics of the plot before creation of silvicultures: Composition of the stand: 8Asp2GrAl, 5 years, forest type – sorr.asp., FCT – D_2.

Characteristics of the silvicultures (Figure 1.31): Composition: 5O2M3S, density - 3.7 thousand plants/ha. Planting material: oak acorns, spruce plants, maple seeds. Spacing scheme: 2.4×1.1 m.

Figure 1.31 - English oak silvicultures
at experimental site No. 36

In 2019, the composition of the stand was 10O+S, GrAl, density 2.5 thousand plants/ha. In 2019, silvicultures tending (clearing) was carried out according to the Guidelines document.

Conclusions: It should be noted that thinning fellings were carried out in accordance with the Guidelines document. The state of the silvicultures is good. Reconstruction should be considered successful.

1 site was laid in Dvinskaya EFS of IF of the National Academy of Sciences of Belarus:

1. *Quarter 7, section 48, Psuevskoye forestry*, area 0.4 ha (site No. 37)

The site is created to test the technology of tending (clearing) in the gray alder plantation under reconstruction by clear-cutting method to restore oak silvicultures. Forest type – bracken gray alder forest, FCT - C_2. Reconstruction felling was carried out in 2019. In autumn of 2019, oak and spruce were planted using the Kolesov's planting iron into the plow furrows (PKL-70). Type of silvicultures - mixed.

Characteristics of the plot before creation of silvicultures: Composition 8GrAl2P, age 35 years, completeness 1.0, stock 175 m^3/ha, forest type – br.gr.al., FCT – C_2. Hilly terrain.

Characteristics of the silvicultures (Figure 1.31): Composition: 7O3S, density - 6.8 thousand plants/ha. Planting material: oak seedlings with closed root system, spruce plants (large size). Spacing scheme: 2.4 × 1.1 m. Planting spacing: oak 2.5 × 0.8 m; spruce 3.5 × 0.8 m; species composition scheme – $O^{1.5\text{-}2.5m}O^{3\text{-}3.5m}S^{3\text{-}3.5m}$… (2rO1rS). Silvicultures were created according to the Guidelines document.

A) B)

Figure 1.32 - Mixed English oak silvicultures
at experimental site No. 37: A) general view; B) oak seedling with CRS

***Conclusions**:* It should be noted that silvicultures are created by close biological groups in accordance with the Guidelines document. The state of the silvicultures is good. Reconstruction should be considered successful.

Thus, 37 experimental sites were laid in the territory of the forestries of the Ministry of Forestry for the reconstruction of low-value silvicultures by means of creation of broadleaved species stands, which, in accordance with the Terms of Reference, included:

1. Sites designed by forest management for reconstruction fellings to develop and test the technology for reconstruction felling and creation of silvicultures;

2. Sites where reconstruction fellings were previously carried out and silvicultures were planted in order to test the planting and cultivation technology;

3. Other sites for testing new technologies for planting and growing forest stands of broadleaved species.

Besides, temporary experimental sites were laid on parts of the broadleaved species silvicultures to evaluate the effectiveness of the reconstruction, created for the reconstruction of low-value stands in Vasilevichi, Kalinkovichi, Rechitsa experimental, Osipovichi, Lyuban, and Disna forestries, Zhornovskaya EFS of IF of NASB.

38 temporary experimental sites were laid to evaluate the effectiveness of low-value silvicultures reconstruction (Table 1.22).

Table 1.22 - Mensurational characteristics of plantations formed as a result of the reconstruction of low-value forest plantations

No.	Quarter / sect.	Mensurational characteristics of the plantation						
		Reconstruction felling parameters				after reconstruction felling		
		Composition of Low-value stand	reconstruction method	Average width of the corridor, m	Average width of the coulisses, m	cultures: composition, average height (m); coulisses: composition, average height (m), stock (m^3/ha)	age, years	cultures: density (plants/ha); coulisses: density (plants/ha), completeness
1	2	3	4	5	6	7	8	9
Borisov experimental forestry, Rogotno forest district								
1	116/39	5S2P1O1B1Asp	consolidation			10S, 0.8 m		3716
2	82/5	3O2M5H+Lin+P+Asp	consolidation			6O4S, 1.0 m		4542
3	116/30	8Asp1H1S+M	consolidation			6O4S, 1.0 m		2746
6	116/22	4O4S2Asp	consolidation			6S4O, 1.4 m	9	820 (curt.)
7	116/21	5S2P1O1Asp1B	consolidation			8M2O, 0.3 m	7	3200 (curt.)
8	44/20	5O4P1S	consolidation			6M4O, 0.4 m	8	2500 (curt.)
Rechitsa experimental forestry, Rovenskaya Sloboda forest district								
9	65/11	4B4Asp1Al1M	consolidation			8M2Asp, 1.9 m	11	3050
10	36/6	6Asp3Al1O	corridor.	6	6	5Ash4O1H, 1.3 m	7	3500
11	10/1	9Asp1B	corridor.	4	7	7O2H1Asp+B, 1.8 m (coulisse – 8Asp2H, 12 m, 117 m^3/ha)	7	3380 (coulisse – 5600, completeness – 0.9)
12	2/26	6B4Asp	corridor.	6	8	5O5P +Asp, M, 0.7 m (coulisse – 9Asp1B, 5.3 m)	4	1950, (coulisse – 5560)
Kalinkovichi forestry, Kalinkovichi forest district								
13	128/97	5B2Asp2M1H	consolidation			7M3Ash, 1.8 m	5	2291
14	25/34	6B2Asp2BlAl	consolidation			5Ash5M, 1.7 m	5	3800

Table 1.22 continued

1	2	3	4	5	6	7	8	9
15	24/36	6B2Asp2BlAl	consolidation			7Ash3M, 1.6 m	5	2483
16	61/4	7B1Asp2P	consolidation			3O3P4B, 1.4 m	10	4650
17	6/4	8B2P	corridor.	2	7	10O+B, 1.3 m (coulisse - 8B2P, 11 m)	9	3350
Kalinkovichi forestry, Uzhinetskoye forest district								
18	8/78	5P5B	consolidation			8O2B+P, 1.6 m	6	1900
19	8/84	5P5B	consolidation			8O2P, 1.4 m	6	2180
20	22/6	6B2Asp1P1O	corridor.	8	10	5O5B, 1.4 m (coulisse – 10B+O, H, P, 12 m, 116 m^3/ha)	8	1020, (coulisse – 4510, completeness 1.0)
21	57/4	7B2Asp1BlAl	corridor.	6	10	10O, 0.9 m (coulisse – 6Asp2B1O1WeWi, 12 m, 60 m^3/ha)	8	3420, (coulisse – 2146, completeness 0.5)
22	104/33	8B2Asp	corridor.	5	5	8O2P, 1.4 m (coulisse – 6Asp4B+O, 11 m 124 m^3/ha)	11	2583, (coulisse – 2708, completeness 0.8)
Disna forestry, Yazno forest district								
23	117/22	8GrAl2B	corridor.	5	5	7S3Ash, 0.4 m	5	4067
24	40/6	8GrAl 2B	corridor.	4	15	10S	7	
25	39/5	7Asp2B1S	corridor.	4	20	10S	7	
26	62/22	5B2Asp3S	corridor.	13	13	9S1Ash, 0.6 m (coulisse -10Asp, 12 m)	3	3942
27	121/5	8GrAl1B1Asp	corridor.	13	13	9S1Ash, 0.4 m (coulisse – 10Al, 15 m)	4	3500
28	52/26	9B1Asp	corridor.	6	8	6O2S2Lin + M	2	2872
Disna forestry, Prozoroki forest district								
29	87/19	10GrAl	corridor.	6	8	5S5Ash, 0.8 m (coulisse –10B, 12 m)	6	1312

Analysis of the results of evaluation of the efficiency of low-value plantations reconstruction showed that in the corridor parts of the reconstruction, the largest part of broadleaved species in cultures requires adding and tending, including the remaining coulisses 4 m to 20 m wide are not affected by felling, and as a result the deciduous stands in them have high completeness, which has adverse impact on shade density of the silvicultures.

In areas with curtain-group reconstruction (consolidation of forest stands), 90% of deciduous species planted under the canopy of the tree stand die in the result of strong shading. 80% or more also die in areas with consolidated stands on former agricultural lands. Such cultures cannot be considered reconstructing, because these are the silvicultures created for the purposes of afforestation. If clearings exist, planting of broadleaved species in plow furrow gives good results under rich forest growing conditions. Transfer of such cultures to the valuable stands is also complicated because of their damage during further thinning fellings of the upper parent tree stand.

Zhornovskaya EFS of IF of NASB has extensive experience in reconstruction of low-value stands by different methods. Let's take a look at some of them. One of the demonstration sites in the territory of Zhornovskaya EFS of IF of NASB was laid in 2008 in Lapichi forest district (quarter 178, section 8, square - 1.3 ha) (TES 30).

Before the reconstruction measures were assigned, 16-year-old low-value plantation with composition 6Asp5B grew in the site; series of forest types - ashweed, type of growth conditions - D_3, Norway spruce was rarely observed among the natural regrowth. Site creation technology: felling of low-value crops in 6 meters wide corridors every 4-meter coulisses; planting material - 1-year-old seedlings of English oak, 4-year-old seedlings of Norway spruce; the initial composition of the silvicultures – 7O3S; English oak placing scheme: double-row biogroups 8.0-2.0 × 0.8 m, Norway spruce: 12.0 × 0.7 m. Currently, silvicultures are characterized by high growth rates (Table 1.23).

Table 1.23 – Growth index of silvicultures at TES 30

Tree species	Dav., cm	Hav., m	Ggen., cm^2/ha	Mgen., m^3/ha
English oak	4.0	4.4	0.11	4.70
Norway spruce	4.0	3.2	0.09	2.69
Total	-	-	0.02	7.39

English oak silvicultures created for the reconstruction are characterized by strong growth in height (Figure 1.33)

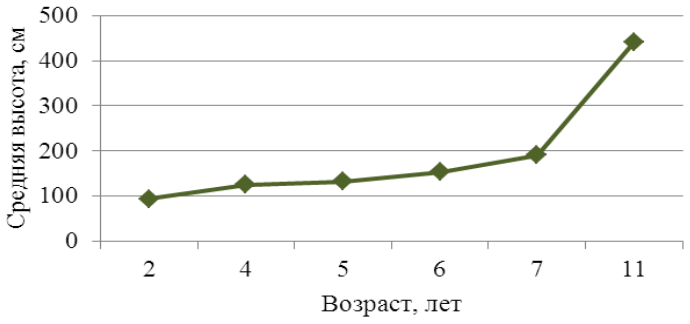


Figure 1.33 - Dynamics of the average height of English oak silvicultures at TES 30

Silvicultures tending (2009) and thinning of coulisses (2010-2011, 2013) were carried out at the site. This year, the average height of a birch tree stand in the coulisses reached 17.8 meters, which required felling of coulisses to create optimal shade density conditions for the broadleaved stand being formed as a result of reconstruction measures (Figure 1.34, Table 1.24).

A - coulisse before felling (spring 2019)

B - coulisse was felled with preservation of valuable species (autumn 2019)

Figure 1.34 - Photofragments characterizing the reconstruction activities at TES 30

Table 1.24 - Characteristics of plantations in the coulisses

Composition	Dav., cm	Hav., m	Ngen., ha	Ggen., cm^2/ha	Mgen., m^3/ha
6B3S1H+M, Asp ed. W, O	17.5	17.8	487	8.0	51.0

Scheme of corridors felling and remaining coulisses was organized in such a manner that after felling of low-value plantation, mixed cultures were formed at the site according to the scheme $O^{\underline{2m}}O^{\underline{4m}}S^{\underline{4m}}O^{\underline{2m}}$ O. This arrangement scheme was proposed in the Recommendations for the creation of mixed cultures of English oak in the subzone of hornbeam-oak-dark coniferous forests of Belarus (2011).

In 2012, in Zhornovka forest district (quarter 130, section 13, area - 1.1 ha (TES 31)), corridor reconstruction was assigned in a 15-year-old plantation with composition 6B2Asp1M1Lin+O, W plants of H, and completeness 0.8. Forest series type – sorrel, growth conditions type – C_4. Average growth rates: height - 7.0 m, diameter - 4.8 m. Bonitet class - I, plantation stock – 45 m^3/ha.

Site creation technology: felling of low-value plantation in 4 meters wide corridors every 6-meter coulisses; planting material - 2-year-old seedlings of English oak; initial composition of the silvicultures – 10O; English oak spacing scheme: double row biogroups 8.0-2.0 × 0.8 m. The repeated observations of the silvicultures are carried out (Table 1.25).

Table 1.25 – Biometric growth index of English oak silvicultures at TES 31

Observation year	Dav., cm	Hav., cm	Zav., cm
2015	0.70±0.02	55.8±0.12	15.7±0.09
2019	0.76±0.02	68.2±0.11	14.6±0.10

Root-taking rate of the silvicultures during the 1st year was 90.8%, third year - 88.8%. Silvicultural care was carried out in 2013, clearing in the corridors - in 2015. In 2017 coulisses felling was assigned after detection of oppression of oak plantations by the closing coulisses canopy. 32 m^3/ha were felled. Obviously, over time the wider coulisses (6 m) suppress the corridors with smaller width (4 m). Therefore, three years after planting of cultures in this area, if the coulisses are not thinned, they should be felled completely beacuse of the possible suppression and oppression of the created cultures.

The history of the experimental and production site located in the territory of Lapichi forest district (quarter 177, section 2, area 2.9 ha (TES 32)) is characteried by interesting options of arrangement of main and additional corridors in low-value plantation in 1986 in 5-year-old stand with composition 8.3Asp0.5B0.5H0.2M0.1Lin0.4Hazel, average height – 3.8 m and an average diameter – 1.9 cm, where the corridor reconstruction was assigned. Forest series type – sorrel, TLC – D_2.

Organization of corridor reconstruction options with arrangement of the corridors being felled in the parallel and perpendicular direction envisaged:

1) in the entire area – felling of major corridors by the feller RKR-1.5, 3 m wide, distance between the centers of corridors – 6 m;

2) at ⅓ of the area – felling of additional 3 m wide corridors perpendicular to main corridors, distance between the centers of corridors – 9 m;

3) at ⅓ of the area – felling of additional 3 m wide corridors perpendicular to main corridors, distance between the centers of corridors – 6 m

In 1987, English oak cultures were planted by mechanical method in the main corridors of the plantation under reconstruction, by manual planting – in additional corridors. Initial composition of cultures: 10O, density - 3.9 thousand plants/ha. Planting material: 2-year-old seedlings of oak. Spacing scheme - 3.5 × 0.75 m.

In 1987-1988, agrotechnical tending was carried out, in 1989 – thinning by roller KOK-2 by passing from one side of the row of the cultures, in 1994, 1998, 2020, 2008 improvement felling was held.

The observation materials shaw that the best growth performance of 25-year-old English oak and plantation in general were generally characteristic to the option with 3-meter main and additional corridors (option 3) (Table 1.26).

Table 1.26 - Characteristics of 25-year-old plantation as a result of reconstruction measures at TES 32

Composition	Dav., cm	Hav., m	Ngen., ha	Ggen., cm^2/ha	Mgen., m^3/ha
5O3S1M1W	11.6	11.0	2324	13.50	80.0

Experimental area was laid with the same option 8 years later. It was established that oak is absent in the additional corridors, only main corridors were seen (Figure 1.35). The stand is characterized by composition 4O1S1M2B2Asp. Average height and diameter parameters are, respectively, 13.8 m and 14 cm. Completeness of the stand is 0.7. Stock is 115 m^3/ha. It should be noted that despite the additional corridors, it was impossible to save them and increase the number of oak. Besides, creation of one row of oak in wide corridors is not sufficient, because in this case at the age of 33 years, 40% of plantation is occupied by low-value species, given the low density of the stand - 0.7.

Figure 1.35 - Photofragment of the main corridor with well seen row of English oak

In the territory of Oktyabrsky forest district of Osipovichi experimental forestry (quarter 10, section 21, area - 2.0 ha (TES 33)), English oak silvicultures were planted in 2015 after the clear-cutting reconstruction without soil preparation under composition scheme – 3r.O1r.S with spacing - 2.9 × 0.85 m, density 4000 plants/ha. Planting material – 2-year-old English oak seedlings and spruce plants. Root-taking rate of silvicultures in 2015 was 93.8%. Improvements were carried out in 2015, 2017 (twice), 2018, 2019.

Forest type series - sorrel, type of growth conditions – C_2, bonitet class I, site terrain - even, ground - sod-bleached, loamy, fresh.

Currently, the 4-year-old English oak silvicultures are characterized by average height of 1.0 m, that is a success, if we take into account the regulatory average height of English oak silvicultures when transferred to forest covered land (Table 1.27, Figure 1.36).

Table 1.27 – Biometric growth index of English oak silvicultures in 2019 at TES 33

Tree species	Dav., cm	Hav., m	Zav., cm
English oak	1.07±0.15	1.29±0.23	35.2±0.10
Norway spruce	0.98±0.20	0.64±0.13	12.0±0.10

Figure 1.36 - Clear reconstruction of low-value plantation by planting English oak silvicultures without tillage (summer 2019).

Tree species of seed origin (left after felling) grow at the site – small-leaved linden, English oak, Norway spruce.

In the territory of Oktyabrsky forest district of Osipovichi experimental forestry (quarter 58, section 11, area - 2.6 ha (TES 34)), low-value plantation reconstruction was carried out in 2009 by corridor method with planting of English oak partial silvicultures in the furrows according to the scheme 10r.O with spacing 3.3 m × 1.0 m and density 3050 plants/ha. Planting was carried out in 10 m wide corridors through 10 m wide coulisses.

Planting material - 2-year-old English oak seedlings.

Prior to the assignment of reconstruction activities, the stand with composition 4B6Asp+S was growing at the site. Forest type series - sorrel, growth conditions type – D_2, bonitet class I, site terrain - even, soil - sod-bleached, loamy, fresh. Living ground cover is characteristic of the site.

Root-taking rate in 2009 was 95.4%. Improvements were carried out in 2010, 2012, 2014, 2016. Clear felling of the coulisses was carried out in 2019.

Despite the high density of the partial cultures planting, they are characterized by high preservation and growth rates (Table 1.28, Figure 1.37).

Table 1.28 – Growth index of silvicultures at TES 34

Tree species	Dav., cm	Hav., cm	Ggen., cm^2/ha	Mgen., m^3/ha
English oak	2.1	2.9	0.2	5.1

Figure 1.37 - Reconstruction of low-value plantation by corridor method (spring 2019)

Reconstruction site is adjacent to the plus plantation of English oak. During felling of the coulisses the tree species of seed origin, English oak, Norway spruce, were left.

In 2016, Zhornovskaya experimental forest station participated in creation of the experimental and production site for the reconstruction of low-value plantation by clear-cutting method and planting of English oak cultures in Oktyabrsky forest district of Osipovichi experimental forestry (quarter 84, section 9, area 3.4 ha, (TES 35)).

The site preparation included clear felling of 58-year-old plantation with composition 6H3Asp1B+S, M, O. Forest types series – sorrel, forest growing conditions – D_2, plantation of bonitet class Ia, density 0.7, stock of felled tree stand is 260 m^3/ha. Terrain of the territory is even. Soil is sod-bleached, sandy loam, fresh.

Soil preparation in spring of 2016 included cutting of furrows 10-15 cm deep using plow PKL-70 in assembly with tractor MTZ-82, 2.5-3.0 m from each other, planting step - 0.75 m. The silvicultures were planted according to the scheme OOLinSLin (2r. oak 1r. linden 1r. spruce 1r. linden). Planting material - 2-year-old seedlings (oak, spruce), 1-3-year-old seedlings (linden).

The living ground cover was represented by sorrel, ashweed, nettle, wood anemone, buttercup, lady fern, willow-herb, wild strawberry, raspberry. Table 1.29 shows the results of biometric observations at the end of the first year of cultivation.

Table 1.29 - Biometric index of oak, spruce and linden at the end of the first year of cultivation

Parameters	Tree species		
	English oak	Norway spruce	Small-leaved linden
Average age, years	2	2	1-3
Average height, cm	19.97±0.90	27.2±0.59	21.8±2.22
Average diameter (at root collar), cm	0.53±0.02	0.78±0.02	0.86±0.18
Increase in height, cm	6.6±0.49	8.3±0.41	11.61±1.53
Root-taking rate, %	96.3	93.3	89.2

Biometric indices in 2018 are presented in Table 1.30.

Table 1.30 – Biometric growth index of English oak silvicultures in 2019

Tree species	Dav., cm	Hav., cm	Zav., cm
English oak	0.62±0.12	42.0±0.12	6.2±0.16
Norway spruce	0.86±0.21	36.2±0.21	7.2±0.24
Small-leaved linden	0.98±0.45	32.5±0.45	2.11±0.16

The first years after reconstruction of low-value plantation give us some information about the processes of future plantation formation. In this case, high-quality and timely tending is required. Agrotechnical tending was carried out in 2016, 2017, clearing - in 2019.

Ripe aspen forest 7Asp1O1B1H was felled in Lyuban forestry at the site for the reconstruction of low-value plantation in Yaminsk forest district (quarter 7, section 1, area - 0.8 ha (TES 36)) in 2010. Three years later, at the location of the renewed aspen, reconstruction was carried out by corridor method.

Forest type series - sorrel, type of growth conditions – D_2, bonitet class I, site terrain - even, soil – sod-bleached, loamy, fresh.

Site creation technology: preparation of the site included arangement of 6-meter corridors and 5m coulisses; the cultures were in corridors in 3 rows. The species being created were alternating in corridors OOO - couliss - SSS. Spacing scheme 3.5 × 0.7 m. Initial composition of silvicultures – 5O5S.

The living ground cover is represented by sorrel, May lily, copperleaf, weaselsnout, moss. Root-taking rate of the silvicultures during the 1st year was 94%, third year - 89.9%. Biometric growth indices of silvicultures are presented in Table 1.31.

Table 1.31 – Silvicultures growth index in 2019 at TES 36

Tree species	Dav., cm	Hav., m	Ggen., cm^2/ha	Mgen., m^3/ha
English oak	0.8	1.0	2.70	1.8
Norway spruce	1.2	1.16	3.0	2.0

Aspen forest 8Asp1M1O with average height 8.0 m; average diameter – 6.0 cm, stock – 25 m^3/ha (Figure 1.38) grows in the coulisses.

A B

Figure 1.38 - Reconstruction of low-value plantations by corridor method: A - spruce coulisse, B - oak coulisse (spring 2019)

The canopy of the coulisse did not close in this part. This is facilitated by wide corridors (6 meters) and the age of plantations. Agrotechnical tending was carried out in 2014 and 2017, in 2018 - thinning. It is now necessary to thin the coulisses, and fell them completely in 3 years.

2 Analysis of creation of under-canopy silvicultures of broadleaved species in low-density English oak plantations

In 2017 in "Zhornovskaya EFS of the Institute of Forest of the National Academy of Sciences of Belarus" SFI (Lapichi forest district, quarter 148, section 8, area 0.6 ha, (TES 37)) an experimental and production site was created to study the growth of English oak cultures under the canopy of young oak, which formed after the reconstruction felling in 2012 in the stand with the composition 5Asp2B1O1Lin1W, in the result of which the density was reduced to 0.5.

Forest types series - sorrel-ashweed, growth conditions type – D_2-D_3, site terrain - even, ground - sod-bleached, sandy loam underlain by loam with layers of clay, fresh.

Reconstruction felling in softwood-oak stand contributed to the formation of mixed stand with the main share of English oak. Currently, 32-year-old oak stand with composition 4O2M3B1Asp+BlAl with completeness 0.7 is growing at the site. The average height and diameter are, respectively, 13 m and 12 cm, stock - 110 m^3/ha.

English oak silvicultures were created without soil treatment in accordance with spacing scheme 2.4 m × 1,0 m. Planting was carried out using 2-year-old seedlings. The initial composition of cultures – 10O.

The living ground cover is represented by sorrel, May lily, copperleaf, weaselsnout, ashweed, speedwell germander, liver-leaf hepatica, moss, etc. Biometric growth index of silvicultures is presented in Table 1.32.

Table 1.32 – Silvicultures growth index in 2019 at TES 37

Tree species	Dav., cm	Hav., cm	Zav., cm
English oak	0.72±0.15	40.0±0.11	5.6±0.15

Application of the silvicultural method for the reconstruction of low-production English oak stands takes into account the requirements of the species being cultivated for the light conditions.

The main feature of the shade density regime in forest is the mosaic nature of the shade density and continuous pulsation of light beams penetrating the forest canopy. Light deficiency is particularly important for woody plants. In case of poor lighting, regrowth of trees either delays in development, being oppressed, or dies. Its fate is determined by the shade-tolerance of the species. Many studies have shown that light conditions of the first half and the middle of the day are particularly important for woody plants.

To create the best growth conditions for the created cultures, it is necessary to maintain low completeness of the upper canopy to provide sufficient lighting for the under-canopy oak cultures. Researches by O.I.Yevstigneyev have shown that broadleaved species are divided into three groups by their relation to light. Thus, small-leaved linden and Norway maple belong to the group with a relatively high tolerance to low light, slower (compared to English oak) growth rate and a large number of growth "waves", and the possibility of long-term existence under the forest canopy.

Under conditions of insufficient light, Norway maple can transfer into quazi-senile state from the age of 18 years, small-leaved linded - from 22 years, English oak - much earlier, already from 7 years).

In 2015 on the territory of Zhornovskaya EFS (Lapichi forest district, quarter 161, section 9, area - 1.7 hectares (TES 38)) under-canopy cultures of small-leaved linden were created in the cultural phytocenosis of English oak to study the processes of growth and formation of complex stand of mixed composition (Figure 1.39). Reconstruction was carried out in 31-year-old cultures of English oak with composition 9.0O0.4B0.3Lin0.2M0.1W, density 0.6 and the average diameter and height 13.9 m and 14.5 cm, respectively.

Forest types series - sorrel, growth conditions type – D_2, site terrain - even, soil - sod-bleached, sandy loam underlain by loam with layers of clay, fresh.

Site creation technology: preparation of the site included cutting of furrows using plow PKL-70 in wide aisles - 4 m; planting was carried with linden plants according to the spacing 4.0 × 0.7 m. Root-taking rate during the 1st year of creation was 95%.

The living ground cover is represented by sorrel, May lily, copperleaf, weaselsnout, moss, etc.

Information about the tending shows that thinning was carried out in 2015 to prepare the site for planting of under-canopy cultures. Agrotechnical tending was performed in 2016 and 2017.

Figure 1.39 - Reconstruction of low-density culture phytocenosis of English oak by creating partial silvicultures of small-leaved linden

Materials of measurements of light under the canopy of 34-year-old culture phytocenosis of English oak with completeness 0.6, where 3-year-old cultures of small-leaved linden created for the reconstruction grow, indicate low flow of physiologically active radiation. For the most part 0 to 4% of light penetrates under the canopy as compared to the light in the open space (Figure 1.40).

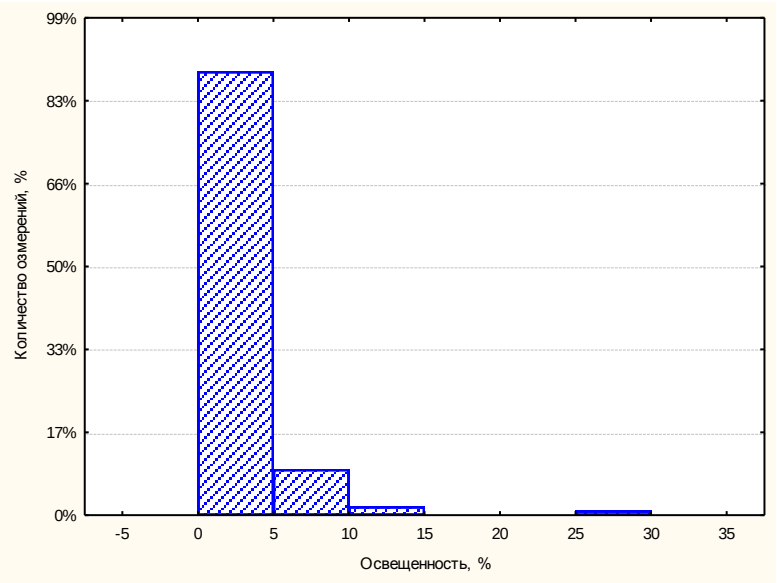


Figure 1.40 - Distribution of shade density under the canopy of 34-year-old culture phytocenosis of English oak

Typical biometric indices of growth, at the time of light measurement are the following: average height - 50.4 cm, average diameter - 0.7 cm, average increment - 2 cm. Low light results in low increment of linden, which indicates unfavorable conditions for its growth.

3 Testing of the technology of reconstruction felling and creation of silvicultures, tending and cultivation of plantations of main broadleaved species (oak, ash, maple)

Based on the previously accumulated experience in the field of reconstruction measures, it should be noted that, in practice, all low-value stands reconstruction methods are applied – clear-cutting, corridor and curtain-group. The corridor method for reconstruction of low-value stands is preferred in the forest fund of the Ministry of Forestry. It should also be noted that reconstruction is first of all performed on low-value stands in sorrel and ashweed types of forest.

When designing oak silvicultures for the reconstruction of low-value plantations, first of all, the attention is paid to the conditions of the growing area, and the possibility of creating of a mixed culture of deciduous tree species is not excluded. In addition to pure silvicultures of deciduous trees, broad-fir (ash-tree) cultures are among promising rich growth conditions, where the participation of spruce (ash) should be based on the factor of increasing the overall productivity of stands and conservation of biodiversity, but not on determining the main species in the stand.

Corridor and clear reconstruction methods should be preceded by reconstruction felling. Determination of width of the corridors and the remaining coulisses is very important for the corridor method. Standards established that the width of the corridor should be not less than, and the width of the coulisses not more than, the maximum height of the plantation under reconstruction. It was determined that planting of partial silvicultures of broadleaved species in the corridors of up to 4 meters results in difficult conditions for their successful growth. Quickly closing of the canopy of the remaining coulisses of low-value plantation prevents the delivery of the necessary volume of light to young silvicultures, and as a result, they soon become oppressed in the absence of a plan for improvement of the coulisses.

The growth and development of broadleaved species silvicultures created in wide corridors (6 meters or more) is affected by strong growth of grass and shrubs. In case of such deep width of the corridors, partial silvicultures grow in the conditions close to clear felling, i.e. there is no positive effect of the canopy of the remaining coulisses. When organizing the reconstruction with wide corridors, it is necessary to envisage planting in no more than 2 rows at the same time placing them by row-group method.

When creating the partial silvicultures by curtain-group method, it is recommended to carry out the reconstruction at earlier age (young softwood and hardwood to 20 years). According to light analysis on the example of 34-year-old English oak culture phytocenosis with density 0.6, where 3-year-old cultures of small-leaved linden created for the purposes of reconstruction grow, low flow of physiologically active radiation is formed under the canopy in the middle-age low-density plantations. For the most part 0 to 4% of light in open space penetrates under the canopy, eventually leading to their death.

The reconstruction was successful at all sites with *clear-cutting method*. However, in some cases, selection of tree species based on the type of forest growth conditions caused some problems. For instance, the continuous ash silvicultures have better root-taking rate in presence of good moisture content of the soil, while oak, on the contrary, is oppressed under such conditions.

Some areas with clear-cutting reconstruction were characterized by presence of natural regrowth of the main species (pine, maple, etc.), which should be maintained

during the maintenance of silvicultures. It is also necessary to treat the areas of silvicultures with special substances to protect them against wild ungulates, because the plants in a number of areas are strongly damaged.

During the reconstruction by *corridor method* it should be noted, that:

- Reconstruction felling is time-consuming and costly measure, and does not always allow to obtain positive results. Therefore, when performing a task on the reconstruction of broadleaved forests, the peculiarities of the plantations assigned for reconstruction should be taken into account. The presence of low-value plantation of the main species trees in the composition makes it possible to introduce it (or its part) into the valuable group by intensive thinning fellings without reconstruction felling. This significantly reduces costs;

- Tending naturally growing oak trees in the coulisses is obligatory. During subsequent tending procedures, it is efficient to extend the corridors to 4 m due to felled trees in the coulisses until their complete removal, which will allow to use the mechanized skidding of the harvested wood in future. However, if trees of the main species are not found in the coulisses, the extension of corridors is required in the case of heavy shading of the silvicultures by secondary tree species and undesirable trees;

– The age of start of the felling is one of the main criteria during reconstruction felling. The earlier it starts, the greater the chances of success, because: first, if there are trees of the main species, it is possible to preserve them; second, it is easier to regulate the ratio of heights of trees of the main and secondary species in the coulisses; third, the greater probability of a complete felling of the coulisse as soon as possible, and lower labor intensity of felling;

- If large softwood trees are present in the coulisses, their removal can damage the main species of trees in the cultures. In this regard, we recommend to observe the ratio of heights of trees of the main and secondary species at the sites with corridor reconstruction. Based on the fact that the remaining coulisses are represented by broadleaved species, it is recommended to regulate the difference in their heights before planting silvicultures by thinning the curtains with the removal of large trees, especially at the edges of the coulisses.

During further tending (2nd-3rd year and 5th-7th year) it is also recommended to thin the coulisses, including by expanding the corridors due to the felling of trees at the edges of the coulisses, which will help to reduce the average height of the trees in the coulisses and, therefore, will not result in the oppression of broadleaved species in the rows.

Implementation of the low-value plantations reconstruction by creation of silvicultures requires knowledge of biological characteristics of trees growth, influence of the site conditions, taking into account the change in the climatic standards. Schemes of mixing the broadleaved species proposed for use in the planning of reconstruction activities were developed (Annex B).

The proposed methods for the reconstruction of low-value plantations were developed taking into account the conditions of the growth site, typical for the cultivation of broadleaved stands and are based on the use of strip-group planting of the main species.

4 Economic effectiveness of reconstruction of low-value plantation by creating broadleaved forestry crops

The feasibility of reconstruction felling should be determined by environmental, social and economic effects. The environmental effect is manifested in the restoration of indigenous stands, conservation of the biodiversity inherent in these stands, and an increase in their carbon-depositing ability; the social effect is in the aesthetic quality of mixed indigenous stands, their stability and life duration compared to low-value stands; the economic effect will be ensured by selling cut down mature timber of the target species and by ensuring the recovery of costs of the reconstruction felling and further forest cultivation.

These studies are based on specific low-value stands (birch forests, aspen forests, grey alder forests and hornbeam forests), where reconstruction activities have been carried out and experimental facilities have been laid.

To establish the economic efficiency of the reconstruction of low-value stands, the following conditions are adopted:

1) The period of forest growth for oak is 100 years, for birch - 60 years, for aspen and grey alder - 40 years. When calculating the cultivation of several generations of soft-leaved tree species, the forest growing period was adopted: for 2 generations of birch – 120 years, 3 generations of aspen and grey alder — 120 years. The principal felling age for oak is -120 years, respectively.

2) The calculation of the economic efficiency of the reconstruction of low-value birch and aspen stands was carried out in the following options:

- clear reconstruction (A)
- corridor reconstruction (B)
- control (leaving under natural regeneration) (C).

Considering that the objects for clear and corridor reconstruction are different in age, density, and composition of forest stands, to compare economic indicators, we conventionally adopted a birch stand of the same age, composition and density, and based on the averaged data, the items of expenses and incomes at the reconstruction felling using a corridor and clear method in comparison with the stand of similar characteristics but without reconstruction were calculated.

We will consider the economic efficiency of the reconstruction of birch forests.

The calculations were carried out on the basis of averaged indicators for a number of forestries of the Gomel SPFA. The initial characteristic of the low-value plantation of Kalinkovichi Forestry of Kalinkovichi forest district: composition 7B3Asp, sorrel birch forest, D_2, allotment area is 1.4 ha. In the year 2010, oak cultures (10O) were created.

Cost-effectiveness of reconstruction by corridor and clear methods at the time of principal felling is compared with the control in Table 4.1. Reconstruction costs are determined by the average values of their cost. The costs of conducting reconstruction felling are established depending on the average intensity of felling and the average cost of their conduct: cleaning - 46.5 BYN. - per 1 m^3, clearing - 41.8 BYN, thinning - 63.6 BYN and increment thinning - 19.47 BYN, respectively. The costs of carrying out clear principal felling are determined taking into account the average cost of 1 m^3 - 21.67. Calculations of the proceeds from the sale of timber obtained at the improvement felling and clear principal felling are shown in Tables 4.1 and 4.2.

Table 4.1 - Cost effectiveness of the reconstruction of low-value birch forest using corridor and clear-cutting methods at the time of principal felling

Indicators	Option			Note
	A	B	C	
1	2	3	4	5
Initial composition of the stand	*7B3Asp*	*7B3Asp*	*7B3Asp*	
Age, years	*10*	*10*	*10*	
Reconstruction costs, BYN per 1 ha				
Reconstruction felling	1056	730	-	
Creation of forestry crops (10O)	307	153	-	
Agrotechnical tending, 3-fold	180	90	-	
Total	*1543*	*973*		
Costs of improvement felling, BYN per 1 ha				
Cleaning (2-fold)	465	325	-	
Clearing (2-fold)	1087	760	1087	
Thinning	1590	1590	1590	
Increment thinning	680	680	680	
TOTAL	*3822*	*3355*	*3357*	
Total costs	*5365*	*4328*	*3357*	
Revenue from the sale of timber harvested in the process of forest growing, BYN per 1 ha[1]				
When conducting cleaning (2-fold)	-	-	-	There is no merchantable wood
When conducting clearing (2-fold)	250	200	250	
When conducting thinning	262	262	262	
When conducting increment thinning	386	386	515	
TOTAL revenue from improvement felling	*898*	*848*	*1027*	
Cost effectiveness excluding revenue from sales of mature timber	-85%	-81%	-69%	

Table 4.1 continued

1	2	3	4	5
Characteristics of mature stand				
Composition by age of principal felling	*6O3Asp1B*	*4O4Asp2B*	*5B5Asp*	
Age, years	*100*	*100*	*60*	
Density	*0.6*	*0.6*	*0.6*	
Stock by maturity age	*240*	*240*	*260*	
Costs of clear principal felling, BYN per 1 ha				
	5201	*5201*	*5634*	
Revenue from the sale of mature timber, per 1 ha[2]				
	15986	*12286*	*5741*	
Forestry cost effectiveness				
TOTAL COSTS	10566	9529	8991	
TOTAL REVENUE	16884	13134	6768	
COST EFFECTIVENESS	60%	38%	-25%	
[1] Price on the terms of ex-upper log dump according to Price List No. 1 (STB 1712-2007 GOST 17462-84 Round Timber); Price for firewood according to Price List No. 4 Firewood STB 1510-2012 on the terms of a ex-upper log dump.				
[2] Price on the terms of ex-upper log dump according to Price List No. 1				

The cost-effectiveness of reconstruction by corridor and clear-cutting methods at the time of principal felling (120 years) compared with the control when growing two generations of birch trees is shown in Table 4.2. The calculations of the revenue from the sale of timber at the improvement felling and clear principle felling are presented in Tables 4.3 and 4.4.

Table 4.2 - Cost effectiveness of the reconstruction of low-value birch forest using corridor and clear-cutting methods in comparison with control when growing two generations of birch forest

Indicators	Option			Note
	A	B	C[1]	
1	2	3	4	5
Initial composition of the stand	*7B3Asp*	*7B3Asp*	*7B3Asp*	
Age, years	*10*	*10*	*10*	
Reconstruction costs, BYN per 1 ha				
Reconstruction felling	1056	730	-	
Creation of forestry crops (10O)	307	153	-	
Agrotechnical tending, 3-fold	180	90	-	
Total	*1543*	*973*	-	
Costs of improvement felling, BYN per 1 ha				
Cleaning (2-fold)	465	325	-	
Clearing (2-fold)	1087	760	2174	
Thinning	1590	1590	3180	

Table 4.2 continued

1	2	3	4	5
Increment thinning (2-fold)	1360	1360	1360	
TOTAL	*4502*	*4035*	*6714*	
Total costs	*6045*	*5008*	*6714*	
Revenue from the sale of timber harvested in the process of forest growing, BYN per 1 ha				
When conducting clearing (2-fold)	250	200	500	
When conducting thinning	262	262	524	
When conducting increment thinning (2-fold)	772	772	1030	
TOTAL revenue from improvement felling	*1284*	*1234*	*2054*	
Cost effectiveness excluding revenue from sales of mature timber	-81%	-76%	-69%	
Characteristics of mature stand				
Composition by age of principal felling	*7O2Asp1B*	*5O3Asp2B*	*5B5Asp*	
Age, years	*120*	*120*	*120*	First generation - 60 years Second generation - 60 years
Density	*0.6*	*0.6*	*0.6*	
Stock by maturity age	*250*	*250*	*260*	
Costs of clear principal felling, BYN per 1 ha				
	5418	*5418*	*11268*	
Revenue from the sale of mature timber, per 1 ha				
	18903	*15041*	*11482*	
Forestry cost effectiveness				
TOTAL COSTS	11463	10426	17982	
TOTAL REVENUE	20187	16275	13536	
COST EFFECTIVENESS	76%	56%	-25%	

[1] Costs and revenues for option C are calculated as the sum for 1 and 2 generations of stands

Table 4.3 - Calculation of income from the sale of timber at the improvement felling, per 1 ha

Option	Type of improvement felling	Tree species	Volume of logged timber, m^3/ha	Wood products	Price, BYN	Cost, BYN
A, C	clearing	birch	3	balances	11.81	35.43
		aspen	10	firewood	9.00	90.00
		total				125.43
A, B, C	thinning	birch	13	balances	11.81	153.53
		aspen	12	firewood	9.00	108.00
		total				261.53
A, B	increment thinning	birch	25	balances	11.81	295.25
		aspen	10	firewood	9.00	90.00
		total				385.25
C	increment thinning	birch	7	plywood log	33.38	233.66
			5	firewood	10.35	51.75
			8	balances	11.81	94.48
		aspen	15	firewood	9.00	135.00
		total				514.89

Table 4.4 - Calculation of income from the sale of timber at clear principal felling (oak - the age of 100 years, birch - the age of 60 years)

Option	Composition by forest elements	Stock, m^3/ha	commercial firewood, %	Commercial stock Firewood stock, m^3/ha	Commercial price The price of firewood, BYN	Commercial cost The cost of firewood, BYN	Total cost, BYN
A	6O	144	70 12	100 17	140 10	14000 170	14170
	3Asp	72	51 44	36 32	23 9	828 288	1116
	1B	24	65 24	16 6	40 10	640 60	700
	Total						15986
B	4O	96	70 12	67 12	140 10	9380 120	9500
	4Asp	96	51 44	49 42	23 9	1127 378	1505
	2B	48	65 24	29 12	40 10	1160 120	1280
	Total						12286
C	5B	130	65 24	85 31	40 10	3400 310	3710
	5Asp	130	51 44	66 57	23 9	1518 513	2031
	Total						5741

Calculation of the revenue from the sale of timber obtained during clear principal felling by the age of 120 years for oak is shown in table 4.5.

Table 4.5 - Calculation of income from the sale of timber at clear principal felling by the age of 120 years for oak, per 1 ha

Option	Composition by forest elements	Stock, m^3/ha	Commercial / Firewood, %	Stock commercial / stock of firewood m^3/ha	Price commercial / price of firewood, BYN	Cost of commercial / cost of firewood BYN	Total cost, BYN
A	7O	175	70 12	123 21	140 10	17220 210	17430
	2Asp	50	51 44	25 22	23 9	575 198	773
	1B	25	65 24	16 6	40 10	640 60	700
	Total						18903
B	5O	125	70 12	88 15	140 10	12320 150	12470
	3Asp	75	51 44	38 33	23 9	874 297	1171
	2B	50	65 24	32 12	40 10	1280 120	1400
	Total						15041

Thus, the costs of broad-leaved stands restoration through both clear and corridor reconstruction of low-value underbrush birch stand will pay off only by the maturity age of the created oak forestry crops. It should be noted that by the time the improvement felling is finished, the revenue from the sale of timber obtained during its performance does not recover the costs incurred by this moment.

By the age of maturity after a clear principal felling, the revenue from the sale of timber fully recover all previously incurred costs, even with minimal participation of oak (4 units of the composition). The amount of revenue depends on the proportion of target species in the composition of the mature stands. In this regard, clear reconstruction has advantages, since initially, per unit area, the amount of oak is almost 2 times more. In addition, the left coulisses cannot always be removed for a number of reasons (density, etc.), and the proportion of soft-leaved species up to the age of maturity remains significant, which reduces the total cost of mature timber.

As the calculations showed (Table 4.6), in the birch forest, despite lower costs in the process of forest cultivation and higher revenue from the sale of timber from improvement felling compared with the formed oak grove, the cost effectiveness is negative by the age of maturity.

Table 4.6 - Regulatory and technological chart for the reconstruction felling using clear-cutting method and the creation of complete forestry crops

Names of works	Unit of measurement	Scope of work	Unit brand	Rate category, number of workers	Performance rate	Needed number		Expenses for maintenance and operation of equipment, BYN		Piece rate, BYN	Standard wages fund, BYN	Sum of direct costs, BYN
						machine shifts	human days	per 1 machine shift	Total, BYN			
1	2	3	4	5	6	7	8	9	10	11	12	13
Preparatory works												
1 Cutting of boundary sights, the hanging at the fullness 0.7-0.5	km	0.51	Manually	IV-1	2.41	0.21	0.21	–	–	3.884	1.98	1.98
2 Measurement of sights with steel tape with main pegs after 100 m	km	0.60	Manually	IV-1	4.46	0.13	0.13	–	–	2.099	1.26	1.26
3 Production of plot poles L = 1.8 m, D = 0.12-0.16 m and their staging	pcs	11	Manually	IV-1	11	1.0	1.0	–	–	0.851	9.36	9.36
4. Complete tree counting	Ha	1.3	Manually	III-1	2.7	0.48	0.48			3.467	4.51	4.51
Total per 1 ha	–	–	–	–	–	1.82	1.82	–	–	10.301	17.11	17.11
Basic logging operations												
1 Felling trees with gasoline saws Coniferous and soft-leaved	m^3	14.3	Stihl	VI-1 IV-1	20.6	0.69	0.69	20.00	13.80	0.458	6.55	20.35

Table 4.6 continued

1	2	3	4	5	6	7	8	9	10	11	12	13
Spruce and hardwood	m^3	70.4	Stihl	VI-1 IV-1	16.5	4.28	4.28	20.00	85.60	0.572	40.27	125.87
2 Cutting of knots with gasoline saws in the cutting area with harvesting without burning Coniferous and soft-leaved	m^3	14.3	Stihl	IV-1	14.6	0.98	0.98	20.00	19.60	0.641	9.17	28.77
Spruce and hardwood	m^3	70.4	Stihl	IV-1	11.6	6.07	6.07	20.00	121.40	0.807	56.81	178.21
3 Bucking of whips with gasoline saws in the upper warehouse; 2.0 m-length firewood Coniferous and soft-leaved	m^3	14.3	Stihl	IV-2	13.4	1.07	1.07	20.00	21.40	0.699	10.00	31.40
Spruce and hardwood	m^3	70.4	Stihl	IV-2	11.6	6.07	6.07	20.00	121.40	0.807	56.81	178.21
4 Timber skidding	m^3	84.7	MPT 461.1	VI-1	15.6	5.43	5.43	50.00	271.5	0.610	51.67	323.17
5 Soil preparation, cutting furrows	ha	1.3	MTZ-82 with PKL-70 plows	IV-1	2.0	0.65	0.65	35.00	19.50	4.32	5.62	25.12
6. Planting forestry crops on medium soil	thousand pcs.	4.17	Kolesov's planting iron	IV-1	0.775	5.38	5.38	-	-	11.15	46.50	46.50
Total	–	–	–	–	–	30.62	30.62	–	674.20	20.064	285.40	957.60
Total	–	–	–	–	–	32.44	32.44	–	674.20	30.365	302.51	974.71
In terms of 1 ha	–	–	–	–	–	24.95	24.95	–	518.62	23.358	232.7	749.78
Note: working conditions are summer, the average volume of the whip is 0.09 m^3, normal conditions. Average skidding distance is 300m.												

It is necessary to take into account that the birch stand under consideration is of little value, with a predominance of trees of vegetation origin, and when calculating the cost effectiveness in the birch forest, we did not take into account the possibility of plantation formation for obtaining special assortments (plywood logs).

We made an attempt to compare economic indicators when growing one generation of oak stand and two generations of birch stand. It has been established that by the age of 120 years, the double revenue from the sale of birch timber does not exceed the revenue from the sale of oak timber of one generation, and the costs are doubled, which also leads to negative cost effectiveness.

In this regard, the conduct of reconstruction felling in low-value birch forests is expedient.

We will consider the cost effectiveness of low-density hornbeam forests reconstruction. Calculation of economic indicators was carried out on the example of a clear reconstruction of a low-density hornbeam forest of the Starobin Forestry.

The regulatory and technological chart for the reconstruction felling using clear-cutting method and the creation of complete forestry crops is given in table 4.6.

Calculation of the reconstruction felling cost was carried out taking into account all charges, surcharges and bonuses, as well as taking into account the costs of maintaining and operating the equipment.

Expenses for the maintenance and operation of equipment included the maintenance and operation of equipment, the cost of auxiliary equipment, tools and materials. The sum of all the above costs is the direct costs of reconstruction felling, which, after adding the administrative and management costs, make up the full cost of reconstruction felling.

Calculation of the cost of felling is presented in Table 4.7.

Table 4.7 - Calculation of the total cost of the reconstruction felling using clear-cutting method

S.No.	Expenditure articles	Economic indicators, BYN
1	Standard wages fund	232.7
2	Surcharges and bonuses	93.08
3	Basic salary	325.78
4	Additional salary	39.09
5	Charges on wages	131.35
6	The costs of maintaining and operating the equipment	518.62
	Total direct costs	1014.84
7	Administrative and management expenses	121.78
	Total cost of felling per 1 ha	1136.62
	including per 1 m^3	13.41

When calculating the revenue from the sale of timber at clear reconstruction felling (Table 4.8), the current price list of selling prices of the Starobin forestry was used.

Table 4.8 - Cost of sold timber that was produced within clear reconstruction (ex-intermediate warehouse)

Species	Wood products	Price per 1 m^3, BYN	Clear reconstruction felling	
			volume, m^3	Cost, BYN
Hornbeam	Firewood	12.63	55.4	699.7
Oak	Firewood	12.63	8.2	103.57
Aspen	Firewood	11.30	11.9	134.47
Ash-tree	Firewood	12.63	6.8	85.88
Alder	Firewood	11.33	2.4	27.12
Total:			84.7	1050.74
Total per 1 ha			65.2	808.26

Table 4.9 presents the calculations of economic indicators of clear reconstruction felling of a low-density hornbeam forest.

Table 4.9 – Cost effectiveness of clear reconstruction felling of low-density hornbeam forest

S.No.	Indicators	Clear reconstruction
1	*Composition of the stand being reconstructed*	*7H1Ash1O1Asp+BlAl*
2	*Density*	*0.4*
3	*Type of forest/FCT*	*sorrel hornbeam forest / D_2*
4	Stock, m^3/ha	65.2
5	Cost of felling, BYN per 1 ha	1136.62
6	Revenue from the sale of timber, BYN per 1 ha	808.26
7	Cost effectiveness of the reconstruction felling,%	-29

The purpose of the reconstruction is to restore indigenous stand of the target tree species - oak, spruce, and ash-tree, and at the stage of removal of low-value low-density stands and planting of silvicultures of economically valuable species, as shown by the above calculations, the costs incurred do not pay off.

Table 4.10 presents the calculation of the cost effectiveness of felling at the time of principal felling for forestry crops created in the process of reconstruction.

Table 4.10 - Cost effectiveness of clear reconstruction felling

Indicators	Clear reconstruction felling
Cut volume, m ^{3}/ha	*65.2*
The cost of reconstruction felling, BYN	1137
Revenue from the sale of timber, BYN	808
Cost of creating forestry crops, BYN	172
Composition of forestry crops	*6O2M2Lin*
Costs of forestry crops tending, BYN	150
Costs of improvement felling, BYN	4505
Revenues from sold timber from improvement felling, BYN	1200
Assumed stand composition by maturity age	*6O2M2Lin*
Assumed stock per 1 ha by maturity age	*280*
Costs of clear principal felling, BYN	6068
Assumed revenue from sold mature timber, BYN per 1 ha by maturity age	12520
TOTAL costs, BYN per 1 ha	12032
TOTAL revenue from timber sold, BYN	14528
Cost effectiveness at the time of principal felling,%	21

Thus, the cost of restoration of broad-leaved stands by means of a clear reconstruction of a low-density hornbeam plantation will pay off only after 100 years. Herewith, it worth noting that restored indigenous formations, along with the raw material functions, also bear enormous environmental significance, which manifests itself much earlier than the maturity age, they have a high level of biological diversity, are stable and long-living. However, in these calculations, the cost estimates of the environmental benefits of oak stands are not taken into account.

Let's consider the economic efficiency of reconstruction of aspen forests (grey alder forests). Calculation of economic indicators was carried out on the basis of averaged data for Kalinkovichi forestry. Initial characteristic of low-value plantation: bilberry aspen forest (C_3) of natural origin, the age of 10 years, density 1.0, stock - 86 m^3/ha. The dense undergrowth is represented by brittle buckthorn, hazel. Allocated area is 1.1 ha. In summer of 2019, partial cultures of English oak were created manually using a planting pipe. Planting material - 1-year-old oak seedlings with a closed root system.

The cost effectiveness of reconstruction of low-value aspen forest through corridor and clear-cutting methods at the time of principal felling are presented in Table 4.11.

Table 4.11 - Cost effectiveness of the reconstruction of aspen forest using corridor and clear-cutting methods at the time of principal felling

Indicators	Option			Note
	A	B	C	
Initial composition of the stand	*6Asp2O2B*	*6Asp2O2B*	*6Asp2O2B*	
Age, years	*10*	*10*	*10*	
Reconstruction costs, BYN per 1 ha				
Reconstruction felling	975	615	-	
Creation of forestry crops (10O)	189	90	-	
Agrotechnical tending, 3-fold	150	80	-	
Total	*1314*	*785*		
Costs of improvement felling, BYN per 1 ha				
Cleaning (2-fold)	1162	813	465	
Clearing (2-fold)	2090	1525	836	
Thinning	2226	2226	2226	
Increment thinning	680	680	680	
TOTAL costs	*6160*	*6029*	*4207*	
Total cost of reconstruction felling and improvement felling	*7474*	*6814*	*4207*	
Revenue from the sale of timber harvested in the process of forest growing, BYN per 1 ha[1]				
When conducting cleaning (2-fold)	-	-	-	There is no merchantable wood
When conducting clearing (2-fold)	225	171	99	
When conducting thinning	352	356	513	
When conducting increment thinning	397	365	433	
TOTAL revenue from improvement felling	*974*	*892*	*1045*	
Cost effectiveness excluding revenue from sales of mature timber	-87%	-87%	-75%	
Characteristics of mature stand				
Composition by age of principal felling	*6O4Asp+B*	*4O4Asp2B*	*7Asp3B*	
Age, years	*100*	*100*	*40*	
Density	*0.6*	*0.6*	*0.6*	
Stock by maturity age	*240*	*240*	*260*	
Costs of clear principal felling, BYN per 1 ha				
	5201	*5201*	*5634*	
Revenue from the sale of mature timber, per 1 ha[2]				
	16881	*13223*	*5956*	
Forestry cost effectiveness				
TOTAL COSTS	12675	12015	9841	
TOTAL REVENUE	17855	14115	7001	
COST EFFECTIVENESS	33%	17%	-29%	

[1] Price on the terms of ex-upper log dump according to STB 1712-2007 GOST 17462-84 Round Timber; Price for firewood according to Price List No. 4 Firewood of STB 1510-2012 on the terms of ex-upper log dump;
[2] Price on the terms of ex-upper log dump according to Price List No. 1

Calculation of the cost of timber obtained in the process of improvement felling of the stands under reconstruction is shown in table 4.12.

Table 4.12 - Calculation of income from the sale of timber at the improvement felling in a stand under reconstruction, per 1 ha

Type of improvement felling	Option	Wood species	Volume of logged timber, m^3/ha	Wood products	Price, BYN	Cost, BYN
cleaning	A	aspen	25.0	firewood	9.00	225.00
	B		19.0	firewood	9.00	171.00
	C		11.0	firewood	9.00	100.00
thinning	A	aspen	5.7	plywood log	18.5	105.45
			29.3	firewood	8.4	246.12
		total				351.57
	B	birch	2.5	plywood log	20.40	51.00
			3.0	balances	19.00	57.00
		aspen	29.5	firewood	8.40	247.80
		total				355.8
	C	birch	6.0	plywood log	18.5	111.00
			5.0	balances	19.00	95.00
			5.0	firewood	9.00	45.00
		aspen	6.0	plywood log	18.5	111.00
			18.0	firewood	8.4	151.2
		total				513.3
increment thinning	A	birch	0.8	Plywood log	20.40	16.32
			0.2	firewood	9.00	1.80
		aspen	4.6	Plywood log	18.5	85.1
			4.0	Plywood log	20.15	80.6
			25.4	firewood	8.4	213.36
						397.18
	B	birch	0.5	Plywood log	20.40	10.20
			0.5	firewood	9.00	4.50
		aspen	5.0	Plywood log	20.15	100.75
			2.2	Technological wood raw materials	15.0	33.0
			25.8	firewood	8.4	216.72
		total				365.17
	C	birch	1	plywood log	20.40	20.40
			0.5	firewood	9.0	4.50
		aspen	5.6	Plywood log	18.5	103.60
			5.6	Plywood log	20.15	112.84
			22.8	firewood	8.4	191.52
		total				432.86

It should be noted that during a 2-fold cleaning in clear reconstruction, 50 m^3/ha were cut down, of which 25 m^3/ha - merchantable wood; during corridor reconstruction - 35 m^3/ha, of which 19 m^3/ha - merchantable wood. During clearing felling under the control, only merchantable wood was cut down, because large trees that interfered with oak growth were removed.

The cost of mature timber obtained during clear principal felling is presented in Table 4.13.

Table 4.13 - Calculation of income from the sale of timber at clear principal felling by the age of 100 years for oak and 40 years for aspen, per 1 ha

Option	Composition by forest elements	Stock, m^3/ha	Output of commercial / firewood %	Stock of commercial / firewood, m^3/ha	Price of commercial / firewood, BYN	Cost of commercial / firewood, BYN	Total cost of timber, BYN
A	6O	138	71 12	98 17	152.5 10.82	14945 184	15129
	4Asp	92	51 44	47 41	23 9	1081 369	1450
	+B	10	65 24	7 2	40 10.82	280 21.64	301.64
		240					16880.64
B	4O	96	70 12	67 12	152.5 10.82	10218 130	10348
	4Asp	96	51 44	49 42	23 9	1127 378	1505
	2B	48	65 24	31 12	40 10.82	1240 130	1370
		240					13223.00
C	7Asp	182	51 44	93 80	23 9	3400 310	3710
	3B	78	65 24	51 19	40 10.82	2040 206	2246
		260					5956.00

Thus, the costs of oak stand restoration through both clear and corridor reconstruction of low-value underbrush aspen plantation will pay off only by the age of maturity of the created oak forestry crops. At the same time, as in the cases with reconstructed birch forests, by the time of the end of improvement felling, the revenue from the sale of timber obtained during its performance does not recover the costs incurred by this moment, and only by the age of maturity after the principal felling the reconstruction can be considered profitable.

It should be noted that the cost effectiveness index of the reconstruction of low-value aspen forests compared with birch forests is twice lower.

Calculations have shown that in an aspen low-value stand not affected by reconstruction, despite lower costs in the process of forest cultivation and higher revenue from the sale of timber from the improvement felling compared to the formed oak forest, the cost effectiveness is negative by the age of maturity.

When comparing the economic indicators of cultivation for 120 years of one generation of oak stand and three generations of aspen stands, it was found that by 120 years of age, the triple revenue from the sale of soft-leaved wood may even exceed the revenue from the sale of oak wood. However, the cultivation of three generations of aspen requires costs, which also increase

three times, while their payback is not ensured, which also leads to a negative cost effectiveness of forest cultivation of aspen three generations.

In this regard, carrying out reconstruction felling in low-value aspen forests is expedient.

A feature of the growth and formation of oak grove is a long period of forest cultivation, the need for labor-intensive and repeated tending of oak, and the payback of the costs incurred at that occurs only at the age of oak maturity, i.e. not earlier than 101 years. Money invested for 100 years is depreciated, but a cost-discount factor is used in such cases for conducting calculations.

The expected economic effect at the time of maturity is calculated taking into account the area of reconstruction, the cost of additional timber per 1 ha, the growing period (100 years) and the discount coefficient.

$$Ээф = \frac{S * P * Kд}{t} \quad (1)$$

,

where $Ээф$ is the expected economic effect, BYN.

S - area, ha

P - valuation of timber, BYN.

$Kд$ - the coefficient of discounting costs

t - the period for which funds are invested (100 years).

The cost discount factor is calculated by the formula:

$$Kд = \frac{1}{(1+E)^t} \quad (2)$$

where E is the discount rate (3%),

t - the period for which funds are invested (100 years).

For the calculations from Table 4.1 (line *Revenue from the sale of mature timber per 1 ha*), the following values were taken: revenue from the sale of mature timber of a 100-year-old plantation passed with clear reconstruction of the birch forest, - 16884 BYN, and revenue from the sale of soft-leaved wood of the plantation without reconstruction - 6768 BYN. The difference between these values is additional revenue - 10116 BYN, obtained as a result of restoration of the oak stand - the goal of reconstruction.

$$Ээф = \frac{100 * 10116}{(1+0{,}03)^{100}} = 5$$ (BYN) .)

A calculation was also made for the corridor reconstruction of the birch forest.

$$Ээф = \frac{100 * 6366}{(1+0{,}03)^{100}} = 3$$ (BYN))

Thus, if we accept 100 ha as the annual volume of reconstruction within the republic, i.e. on average less than 1 hectare per forestry, then by the age of 100 years, the expected annual economic effect will amount to 52,660 BYN in restored oak plantations which underwent a clear reconstruction, and 33138 BYN - in plantations which underwent a corridor reconstruction.

As noted above, we made calculations for 120-year-old oak plantations in comparison with two generations of birch forests, i.e. also by the age of 120.

For the calculations from Table 4.2 (the line *Revenue from sales of mature timber per 1 ha*), the following was taken: the values of revenue from the sale of mature timber of a 120-year-old plantation passed with clear reconstruction felling of the birch forest - 18903 BYN, and the revenue from the sale of soft-leaved wood of two generations of plantation without reconstruction

amounted to - 11482 BYN. The difference between these values is the additional revenue - 7421, obtained as a result of restoration of the oak stand - the goal of reconstruction.

$$Ээф = \frac{100 * 7421}{(1+0{,}03)^{120}} = 21 \text{ (BYN) .)}$$

$$Ээф = \frac{100 * 3559}{(1+0{,}03)^{120}} = 10 \text{ (BYN))}$$

In aspen forests reconstructed using a clear-cutting method, by the age of 100 years, in comparison with soft-leaved stands that have not undergone a reconstruction felling, the expected economic effect is 56500 BYN, with a corridor method of reconstruction - 37030 BYN.

In economic calculations, the compositions we have adopted at the time of their principal felling are averaged over actual values. They probably can't be fully considered optimal in connection with the presence of soft-leaved species which are significantly inferior to oak in value. Foresters need to strive to remove soft-leaved species before the end of improvement felling.

In this regard, it is expedient to calculate the expected economic efficiency of the reconstruction by the amount of additional oak timber.

In such a way, in a birch stand which passed clear reconstruction by the maturity age, we have 144 m^3/ha of additional oak timber. At a cost of 1 m^3 of oak timber equal to 200 US dollars we get - 57600 Belarusian rubles.

$$Ээф = \frac{100 * 57600}{(1+0{,}03)^{120}} = 29 \text{ (BYN))}$$

Thus, the expected economic efficiency of the clear reconstruction of low-value stands with its volume of 100 hectares will amount to 299843 BYN, or 2998 BYN (1460 US dollars) per 1 ha.

During the corridor reconstruction of low-value stands, we additionally receive approximately 100 m^3/ha. Accordingly, the expected economic efficiency will be - 208224 per 100 hectares, or 2082 BYN (1015 US dollars) per 1 hectare.

$$Ээф = \frac{100 * 40000}{(1+0{,}03)^{120}} = 20 \text{ (BYN) .)}$$

In addition to the above two methods of reconstruction, which are carried out by appropriate felling, the curtain-group method is also applied in low-density coniferous and hard-leaved stands. The calculation of the economic efficiency of reconstruction using the example of low-density, low-productive stand of English oak was made according to the formula (1):

$$E_l = [(R_n - Z_n) - (R_b - Z_b)] \times A, \qquad (1)$$

where R_b and R_n - the cost of products received from 1 ha of forest per felling turnover, before and after the implementation of the measure, BYN;

Z_b and Z_n - the costs of forest cultivation per 1 ha, before and after the implementation of the measure, BYN;

A - the volume of implementation of the measure (1 ha).

The indicator Z_b reflects the technological cost of forestry products (works) determined in accordance with the current methodology and standards, Z_n - the technological cost which additionally includes the following types of work: reconstruction felling, creating forestry crops, cleaning, clearing, thinning. Costs of improvement felling are calculated in accordance with existing standards, i.e. taking into account the group of stand, the intensity of improvement felling by stock and the frequency of its conduct. The cost of creation and cultivation of forestry crops was calculated based on the actual data of Mozyr Experimental Forestry (Table 4.14).

The income from the sale of timber at its principal felling was calculated based on the assumed compositions of English oak stands by the age of maturity, the stock of mature timber and the average cost of 1 m^3 of commercial timber for taxation category II determined by Decree of the Council of Ministers No. 1033 of December 28, 2017. The economic effect of the sale of timber from the principal felling in a low-productive stand where the reconstruction felling was conducted, is 3901.4 BYN/ha (Table 4.15).

Table 4.14 - Cost of the creation and cultivation of forestry crops (for 2017), BYN / ha

Name of measure	Costs, BYN / ha
1 Silvicultural works	–
- tillage	35.14
- planting of forestry crops	100.15
- addition of forestry crops	20.7
- silvicultural tending (3-fold)	112.4
Total	268.39
2 Forestry works	–
- reconstruction felling	420.8
- cleaning (2-fold)	154.56
- clearing (1-fold)	181.61
- thinning (2-fold)	789.28
- increment thinning (3-fold)	822.87
Total	2369.12
Total (US dollars)	2637.51/1289

Table 4.15 - Economic effect of the sale of English oak mixed cultures on the principal felling, BYN / ha

Stand cultivation method	Assumed composition of stand by age of maturity	Tree species	Stock of timber, m^3	Cost of 1 m^3 of commercial timber for taxation category II BYN/m^3	Income from the sale of timber at principal felling, BYN/ha	Economic effect, BYN/ha
Without conducting a reconstruction in a low-productive stand	5HL5SL (3O2Hb3B2Asp)	oak hornbeam	120 40	21.53 3.52	2 583.6 140.8	-
		birch aspen	100 50	3.52 0.70	352.0 35.0	
		-	310	-	3111.4	
With conducting measures of reconstruction	9HL1SL (5O4M1B)	oak maple	200 120	21.53 21.53	4 306.0 2 583.6	3 901.4
		birch	35	3.52	123.2	
			355	–	7 012.8	

Expected economic effect of reconstruction measures and creation of shade-tolerant tree species under the canopy of the main tier of English oak (*El*) will be:

$$E_l = (7012.8 - 3060.46) - (3111.4 - 2216.71) = 3057.65 \text{ BYN/ha (1495 US dollars)}$$

The expected economic effect from implementation of reconstruction of low-productive stands of English oak by the silvicultural method is 3.06 thousand BYN/ha.

If we consider low-value forest stands from ecological point of view, it should be noted that in the territories intended for reconstruction, stands of different ages are currently growing. Based on the previously obtained data, the analysis of carbon deposition by phytomass of low-value stands in the context of age groups and dominant tree species was carried out (Table 4.16).

Table 4.16 - Carbon deposition by phytomass of low-value stands by age groups and dominant tree species

Low-value forest stands		Area, ha	Total stock of stand, m^3	Carbon accumulation, tC	Carbon accumulation, tC/ha
Soft-leaved young stand under the age of 10 years	B	3883.2	56450.0	24.1	0.006
	Asp	4892.6	70610.0	22.6	0.005
	GrAl, BlAl	1590.8	22708.0	9.3	0.006
Soft-leaved young stands aged 10 years and older	B	14925.8	96747.0	412.6	0.028
	Asp	6994.8	513393.0	164.0	0.023
	GrAl, BlAl	5899.6	37574.0	15.3	0.003
Middle-aged soft-leaved stands	B	91.9	10840.0	4.6	0.050
	Asp	7599.1	1162673.0	371.5	0.049
	GrAl, BlAl	17382.0	2542874.0	1038.8	0.060
Hornbeam plantations	up to 10 years	5.0	45.0	0.027	0.005
	10-40 years old	1011.5	118137.0	69.8	0.069
	40-80 years old	5436.1	1023015.0	604.1	0.111

These stands are in the process of absorbing and storing carbon. In such a way, using the example of soft-leaved stands growing in rich forest growing conditions, under the age of 9 years, on average, they deposit carbon with phytomass in the amount of 18.6 tC/ha, of which birch stands deposit the most (43.1%). With age, the carbon deposition increases and reaches an average of 471.6 tC/ha in middle-aged stands, of which 73.4% are aspen. It takes several years for the level of carbon deposition by plants to reach its highest level. It will take a long time before forestry crops of valuable species planted instead of low-value stands correspond to the level of absorption, the mass of carbon already deposited. Therefore, when choosing sites for reconstruction, preference should be given to younger or very rare low-value forest stands. At the same time, the period of time necessary to exceed the current deposit capacity will be the shortest and, therefore, such sites will represent the greatest return in terms of ecosystem services.

5. Information on finalization of the Guidelines document on the reconstruction of low-value plantations to increase the share of broadleaved forests, according to the results of testing of the technology of reconstruction felling and creation of silvicultures, tending and cultivation of plantations of main broadleaved species

Based on the analysis of the data presented by the forestries, the results of expedition trips to the state forestry institutions of Brest, Vitebsk, Gomel, Grodno, Minsk and Mogilev SPFA, field surveys of experimental sites and tests of the technology of reconstruction felling and the creation of silvicultures, tending and cultivation of plants of main broadleaved species were carried out, the systemic analysis of which allowed to finalize its final version (Annex B).

6. Scientific grounding for amending the regulatory framework in the field of reconstruction of low-value forest plantations

State Scientific Institution "Institute of Forest of the NAS of Belarus" within the framework of the project activity 3.1.5 "Improvement and testing of a technology for the reconstruction of low-value plantations for the purpose of increasing the share of broadleaved species" under contract No. BFDP/GEF/CQS/17/26-36/18 of the GEF/THE WORLD BANK *Belarus Forestry Development Project* TF0A1173 conducted a comparative analysis of the requirements of regulatory legal and technical regulatory acts on the reconstruction of low-value forest plantations, the success, forestry and economic efficiency of the reconstruction of low-value forest plantations.

Currently, a reconstruction of low-value forest stands in the Republic of Belarus is carried out on the basis of the following documents:

A) Laws and regulations:

- Forest Code of the Republic of Belarus No. 332-Z of December 24, 2015;
- STB 1361-2002 Sustainable forest management and forest use. Intermediate logging (Approved and enforced by Decree of the State Standard of the Republic of Belarus No. 54 of December 9, 2002. New edition (May 2011) with Amendment No. 1 approved in April 2007. (Information signage of Technical regulations No. 4-2007), Amendment No. 2 approved in February 2011. (IS TR No. 2-2011), Amendment No. 3 approved in May 2018. (IS TR No. 3-2018).

B) Technical regulations:

- The Rules for Forest Felling in the Republic of Belarus (Approved by Decree of the Ministry of Forestry of the Republic of Belarus No. 68 of December 19, 2016 "On the Approval of the Rules for Forest Felling in the Republic of Belarus";
- Regulation on the Procedure for Reforestation and Afforestation (Approved by Resolution of the Ministry of Forestry of the Republic of Belarus No. 80 of December 19, 2016 "On Some Issues of Forest Reproduction in the Area of Reforestation and Afforestation".

The legal framework for the reconstruction of low-value forest plantations in the Republic of Belarus is quite developed. However, a wide range of the reconstruction fund of low-value stands, differences in forest growing conditions, taxation indicators and the state of the stands under reconstruction require a number of issues to be solved: adjustment of the criteria for classifying as low-value forest stands and their grounding, assignment and procedure for improvement felling in forest stands created within reconstruction. In accordance with the Forest Code, low-value forest plantations mean forest plantations of low productivity and quality for certain forest growing conditions. The objects of reconstruction specified in the Rules for Forest Felling in the Republic of Belarus do not fully meet the criteria of low-value forest stands.

6.1 Amendments to the Rules for Forest Felling in the Republic of Belarus

As part of stage 3 of the project activity, proposals were made to improve the existing regulatory framework for the reconstruction of low-value forest plantations with the aim of creating valuable stands and their grounding. We offer the following criteria for classifying stands as low-value forest stands, which are presented in Table 6.1.

As of January 1, 2019 (according to Belgosles RUE) the total area of plots on which reconstruction is possible is 126.6 thousand ha (table 6.2), of which: shrubs - 0.01%; young stands of soft-leaved stands of vegetative origin (aspen, black alder, birch forests) - 65.6%; middle-aged soft-leaved stands (aspen, black alder, birch forests) - 11.9%; young stands of grey alder, weeping willow, hornbeam, poplar, Jack pine - 5.9%; middle-aged stands of grey

alder, weeping willow, hornbeam, poplar, Jack pine - 16.1%; middle-aged coniferous and hard-leaved stands with a density of 0.4 or less - 0.5%, there are no stands of invasive tree species.

An analysis of this information in the context of a series of forest types (Table 6.3) showed that 55.4% of the total area of plots available for reconstruction are suitable for creating broad-leaved forestry crops, 44.6% for conifers.

Table 6.1 - Criteria for classifying plantations as low-value forest plantations

Used up to present time	Proposed (for creating broad-leaved forestry crops)
shrubs (with exception of shrubs growing in forest areas subject to water and wind erosion, as well as shrubs specified in the first clause of paragraph 3 of Article 64 of the Forest Code of the Republic of Belarus)	shrubs (with exception of shrubs growing in forest areas subject to water and wind erosion, as well as bilberry willow bushes, Lapland willow, yellow rhododendron, Cotoneaster melanocarpus, German broom)
young plantations of soft-leaved forest plantations of vegetation origin, as well as middle-aged small-leaved stands of vegetation origin with a density of 0.5 and below	young plantations of soft-leaved forest plantations of vegetation origin (aspen forests, birch-woods (except curly birch plantations)), as well as middle-aged soft-leaved plantations of vegetation origin (aspen forests, birch-woods) with a density of 0.5 and less
young and middle-aged plantations of grey alder, willow, hornbeam, poplar, aspen, Jack pine	young and middle-aged grey alder stands of vegetation origin (except ashweed grey alder forests), hornbeam, tree-shaped willows (except plantations with the dominance of white willow, poplar, Jack pine)
middle-aged coniferous and hard-leaved stands with a density of 0.4 and less, assigned to the second and third classes of biological stability in accordance with the Sanitary Rules in the Forests of the Republic of Belarus	without changes - coniferous and hard-leaved low-density forest stands under age of 20 years
stands of invasive wood species	without changes

Table 6.2 - Presence of an area (thousand ha) of low-value forest plantations in the forest fund of the Ministry of Forestry for conducting a reconstruction

Area of low-value stands	Total, thousand ha	Including					
		Bushes	Soft-leaved young stands of aspen, birch, black alder	Middle-aged stands of aspen, birch, black alder	Soft-leaved young stands of grey alder, weeping willow, hornbeam, poplar, Jack pine	Middle-aged stands of grey alder, weeping willow	Middle-aged stands of coniferous and hard-leaved species with a density of 0.4 and <
According to the forest inventory for the year 2018	3484.3	20.0	369.9	1139.4	20.4	45.9	1888.7
Available for reconstruction (Belgosles RUE)	126.6	0.01	83.0	15.1	7.5	20.4	0.6

Table 6.3 - Presence of an area of low-value forest plantations on which reconstruction is possible by creating broadleaved and coniferous silvicultures in the context of a series of forest types

Low-value forest stands	Forest type series		Total according to Ministry of Forestry
	sorrel, ashweed	cowberry ericetal, mossy, bracken, bilberry	
Shrubs	-	0.01	0.01
Soft-leaved young stands (B, Asp, BlAl, GrAl) under the age of 10 years	10.4/9.5	7.8	18.2/17.3
10-year-old and older soft-leaved young stands (B, Asp, BlAl, GrAl)	27.8/23.6	43.4	71.2/67.0
Middle-aged soft-leaved stands B, Asp, BlAl, GrAl)	25.1/13.3	4.8	29.9/18.1
Soft-leaved stands (WeWi, Ppr)	0.46	0.04	0.5
Hornbeam stands: young stands	1.0	0.1	1.1
middle-aged stands	5.4	0.2	5.6
Coniferous and hard-leaved stands with a density of 0.4 and less (excl. hornbeam)	0.04	0.06	0.1
Total/by proposed criteria	70.2/53.3	56.4	126.6/109.7
Note: in the denominator there stands the area taking into account the proposed criteria, thousand ha			

Taking into account the proposed criteria (Table 6.3), the total area of low-value stands suitable for creating forestry crops will decrease by 16.9 thousand ha and amount to 109.7 thousand ha. Moreover, under rich forest growing conditions, the area of such stands is 53.3 thousand ha, which is 48.6% of their total area. The remaining area where low-value stands determined in accordance with the criteria of the Rules for Forest Felling in the Republic of Belarus grow, for a number of reasons, is not suitable for creating forestry crops of the main tree species. However, they are of great environmental importance because they perform a number of functions (water protection, soil protection, etc.), as well as maintain the biological diversity of forests in accordance with the Convention on Biological Diversity (1992) and the Strategic Plan for the Conservation and Sustainable Use of Biodiversity for 2011-2020. We consider it inappropriate to include in the low-value forest stands the forest stands growing on areas unsuitable for creating forestry crops with the aim of replacing them with more valuable species, since it is economically unjustified.

In this regard, we propose the following wording of the first clause of paragraph 54 of the Rules for Felling in the Republic of Belarus: “Low-value forest plantations include forest plantations with low productivity and quality of timber, growing in areas suitable for creating forestry crops of valuable tree species, corresponding to the following criteria:".

The reconstruction in the Rules for Forest Felling (clause 3, paragraph 54) shall be prescribed for young soft-leaved forest stands of vegetative origin, as well as middle-aged soft-leaved stands of vegetative origin with a density of 0.5 and less. We consider that the third clause of paragraph 54 needs to be clarified. In forestry, the exceptional ability of aspen to reproduce by root suckers is known. According to a number of scientists (D.V. Averyanov, A.V. Nomerovskikh, L.Ye. Mikhaylov, A.M. Ilyin), the presence on the site of trees of aspen in the amount of 10 pcs/ha evenly distributed over the area ensures that, after their felling, the felled area will be intensively overgrown with root suckers of aspen, some of which will fall away but the rest will grow very quickly and crowd other more valuable species (pine, oak, etc.). The growth rate of aspen suckers in the first years of life is 15 times faster than its self-sowing. It is able to give root suckers in all types of forests in normal undisturbed natural conditions, and this ability is its important natural adaptation in the struggle for existence. Abundant aspen root suckers are formed after tree felling, as a result of wounding of the roots during skidding (especially summer), exposure to fire (forest fires, fire clearing of forest cutting areas), ungulate animals, etc.

Many authors (L.Ye. Mikhaylov, A.M. Ilyin, I.I. Gushchin, V.V. Smirnov, V.M. Glazyrin, B. Ye. Chizhov and others) note that in most cases, regardless of the forest type, aspen young stands are represented mainly by young plants of vegetative origin. In this regard, when creating valuable species of forestry crops on aspen felling, for their preservation and success of further growth, it is necessary to conduct intensive and repeated (2-3 for the growing season) tending, which is expensive. In addition, aspen is an intermediate host in the development cycle of a rust fungus (*Melampsora pinitorqua* Braun), a pine pathogen - pine twisting rust. In this regard, taking into account the labor-consuming and expensive nature of the reconstructing measures, classification of aspen plantations to low-value stands with their subsequent reconstruction is considered inappropriate if the aspen share in the forest fund (forestry) is less than 1% of the forested area.

Grey alder and black alder are well renewed by stump sprouts and retain their shoot-forming capacity for a long time (A.P. Shimanyuk, Ye.O. Yurchenko, V.B. Zvyagintsev and others). According to Belgosles RUE, 4.6 thousand ha of black alder forests and 21.2 thousand ha of grey alder forests are included in the list of plots that are available for reconstruction. Taking into account that black alder is an indigenous forest formation, we consider it appropriate to classify sprout black alder young stands as low-value stands with their further reconstruction (1.4 thousand ha). It should be noted that in the forest fund there are grey-alder stands of the ashweed type of forest (1.7 thousand ha), which, according to the growth tables, up to thirty years of age are higher in productivity than spruce stands in this type of forest. In addition, in Vitebsk region, the creation of forestry crops is problematic since these areas are periodically excessively wet (especially in the spring).

To a greater extent, birch forests are also suitable for the reconstruction of young stands of vegetative origin, as birch is a formation derived from pine, as well as from oak and spruce, and it covers an area exceeding the optimal values in the composition of the forests of the Republic.

According to the data of plot taxation of Belgosles RUE, young and middle-aged (low-density) birch stands are included in the list of objects suitable for reconstruction felling with a total area of 66.0 thousand ha and 662.1 ha, respectively (as of 01.01.2019). At the same time, low-quality timber and its low yield (according to the Assortment Tables of 2011 — less than 15%) is observed in young birch stands in lichen, cowberry and ericetal forest types (1.0 thousand ha). Low-density middle-aged stands growing under conditions favorable for the creation of broad-leaved forestry crops (ashweed, sorrel and bilberry series of forest types - 309.2 ha) are expedient to be included in the reconstruction fund since valuable stands can be restored by reconstruction under these conditions. Proceeding from this, low-value forest stands include young birch stands of the third and lower bonitet classes (lichen, ericetal and cowberry birch forests) and low-density, middle-aged stands growing under conditions favorable for the creation of forestry crops of main tree species because they are of low productivity.

It is not recommended to assign young birch stands of I-II bonitet class being in good condition to reconstruction. It is expedient to leave them standing with conducting appropriate improvement felling, and by the age of maturity, taking into account the presence (or absence) of target species undergrowth, to carry out appropriate principal felling and reforestation. Stands of curly birch should also be excluded from the reconstruction fund, as their wood is unique and very expensive.

Untimely selection of soft-leaved trees in the coulisses prevents the growth of forestry crops created in the process of reconstruction of low-value forest stands, especially under the age of 10 years. When creating partial forestry crops (corridor reconstruction method) by planting seedlings of English oak with double-row biogroups in the absence of improvement felling for 3 years, their preservation is reduced by 15-20%, and by the age of 6-7 years - by 30-40%,

respectively (M.S. Lazareva, V.F. Reshetnikov). In this regard, we propose the second clause of paragraph 34 of the Rules for Felling in Forests of the Republic of Belarus to be reworded as follows: "When carrying out improvement felling in forest stands created within the reconstruction procedure, the type of improvement felling is determined by the age of the forestry crops created."

In the forestry practice, there was a problem of determining the age of the stands where reconstruction felling will be carried out by the corridor method. Previous approaches (TCCP 143-2008 "Rules for Forest Felling in the Republic of Belarus") did not substantiate this indicator. At the same time, according to paragraph 5.3.5.6 of STB 1361-2002 (IS TR No. 2-2011), corridors are cut in young stands, underbrushes and middle-aged stands with an area of more than 0.5. In the year 2018, in the amendment of the IS TR No. 3-2018 of this document, a new version of the paragraph was adopted where corridors are cut in young stands under the age of 10 years.

The limitation of the maximum age of low-value forest stands for the purpose of reconstruction felling by the corridor method is closely connected with the height of the stands under reconstruction. According to the growth progress tables (Regulatory Materials for Forest Taxation of the Byelorussian SSR, V.F. Baginsky, 1984), the average height of 10-year-old stands of soft-leaved species (birch, aspen, alder) does not exceed 8-10 m. Studies have shown that in the stands to be reconstructed that are older than 10 years (consequently, that have higher average height), the reconstruction by corridors is ineffective. According to V.F. Reshetnikov, K.M. Storozhishina (2011-2016) in stands older than 10 years, which were passed with reconstruction felling using the corridor method, a low preservation of forestry crops (less than 50%) in the corridors was discovered and their unsatisfactory condition was noted as a result of insufficient light due to shading by rapidly growing soft-leaved tree species growing in the coulisses.

Having regard to the above, we propose the following amendments to the Rules for Felling in the Republic of Belarus:

Paragraph 34. The second clause should be reworded as follows: "*When carrying out improvement felling in forest stands created within the reconstruction procedure, the type of improvement felling is determined by the age of the forestry crops created.*";

Paragraph 54. The first clause shall be reworded as follows: "*Low-value forest plantations include forest plantations with low productivity and quality of timber, growing in areas suitable for creating forestry crops of valuable tree species, corresponding to the following criteria:*";

Paragraph 54. The third paragraph shall be reworded as follows: "*young plantations of soft-leaved forest plantations of vegetation origin (aspen forests, birch-woods (except curly birch plantations)), as well as middle-aged soft-leaved plantations of vegetation origin (aspen forests, birch-woods (except curly birch plantations)) with a density of 0.5 and less;*

young and middle-aged grey alder and black alder stands of vegetation origin (except ashweed alder forests), hornbeam, tree-shaped willows (except plantations with the dominance of white willow), poplar, Jack pine);

middle-aged coniferous and hard-leaved stands with a density of 0.4 and less, assigned to the second and third classes of biological stability in accordance with the Sanitary Rules in the Forests of the Republic of Belarus;

young coniferous and hard-leaved low-density forest stands under age of 20 years";

Paragraph 55 shall be reworded as follows: "*Reconstruction felling is carried out using clear (clear cutting) or corridor (corridor cutting) methods for the purpose of subsequent reforestation, depending on the forest growing conditions and the intended purpose of forests. Reconstruction felling using the corridor method is carried out in young stands under the age of 10 years and shrubs*."

6.2 Amendments to the Regulation on the Procedure for Reforestation and Afforestation

According to the results of evaluation of the effectiveness of broad-leaved forestry crops creation within reconstruction of low-value forest stands, the most successful is the clear reconstruction while the corridor one raises a number of questions. One of them is the optimal ratio of the width of the corridors and the coulisses, where:

- firstly, the minimum number of plants of the main tree species and the timely closeness of their crowns is ensured;
- secondly, soft-leaved part (soft-leaved stand in the coulisses) suppression of forestry crops is reduced that contributes to better growth of trees of the main tree species;
- thirdly, conditions for the mechanization of forest cultivation and tree harvesting of principal felling are being created.

In the previously used and existing regulatory databases, the width of the corridors during the reconstruction of low-value forest stands shall be no less than the average height (TCCP 047-2009) or the maximum height (Regulation on the Procedure for Reforestation and Afforestation) of low-value stands, and the width of the coulisses shall not exceed its height. At the same time, in the field conditions, the definition of these indicators is subjective and not always accurate. Therefore, we consider it inappropriate to use these parameters to determine the width of the corridors and coulisses.

The width of the corridors shall be optimal for growing new forests, and the width of the coulisses shall allow the formation of stands and carrying out forestry measures.

In paragraph 24 of this Regulation, it is recommended to introduce the width parameters of the cut corridors and the left coulisses when reconstructing low-value forest stands using a corridor method in order to optimize the technology and practical application of these parameters.

The effectiveness of reconstruction is largely determined by the specific gravity of the main species in the stand at the time of principal felling. It is known that with a clear-cutting method of reconstruction, the share of the main tree species is higher than with a corridor method (V.F. Reshetnikov, K.M. Storozhishina). In this regard, in order to achieve greater economic efficiency of corridor reconstruction, it is expedient to increase the amount of planting material of the main tree species per area unit. This can be achieved by increasing corridor width and, consequently, the number of rows of forestry crops. This requires such parameters of the width of the corridors and coulisses where low-value forest stands up to a certain age would serve as an undergrowth for the main tree species, and protect crops from negative climatic factors. Taking into account modern technologies of felling, the following parameters are recommended: the width of the corridors is at least 15 m, the width of the coulisses is no more than 15 meters.

We recommend 5 m coulisses width as the optimum width since in the future, after its removal, this area can be used as technological corridors for harvesting timber with multi-operation machines.

The width of the coulisses of 5 meters after its removal will allow to use this area in young stands as technological corridors; at the age of improvement felling, the coulisses are completely cut down. By the age of maturity, the created technological corridors can be used when harvesting timber with multi-operation machines. At the same time, the width of the coulisses is consistent with the outreach of the multi-operational machines (Figure 6.1).

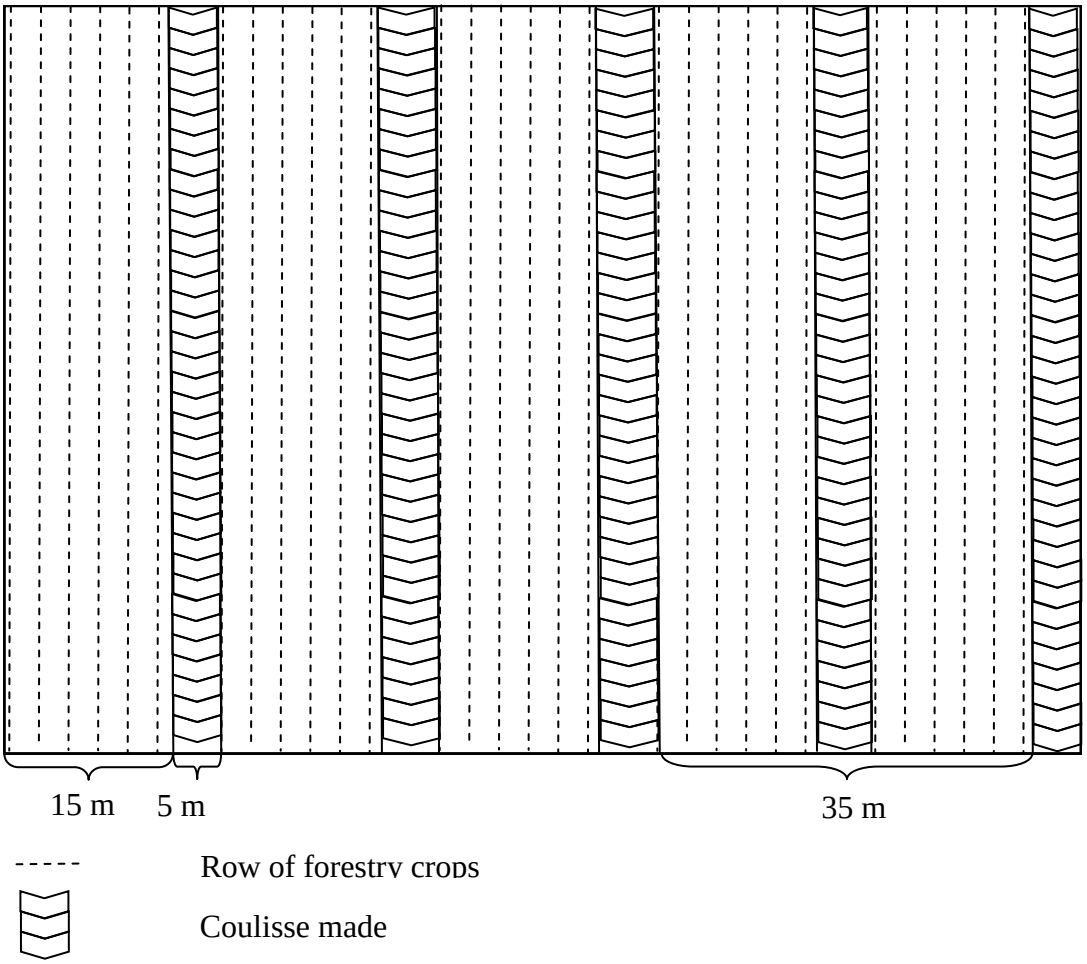


Figure 6.1 - Technology of cutting corridors in the corridor method of low-value forest plantations reconstruction

With a coulisse width of up to 15 meters, an improvement felling is planned in several stages. The first stage consists in thinning of the coulisses in the 2nd-3rd year after planting of partial forestry crops with an intensity of up to 50-60%, the second stage - in the 6th-7th year with an intensity of up to 50-60%, while the density of the stands in the coulisses shall not fall below 0.3, the third stage is the clear-cutting of the coulisses on the 10th-12th year, leaving the main tree species of natural origin.

When preparing an area with a width of corridors of 15 meters (compared to 6-8 meter corridors), the use of mills and mulchers is more efficient, which will also reduce labor costs. At the same time, it is expedient to use mills if it is necessary to reduce the time for preparing sites for creating forestry crops or with limited labor resources. Herewith, it is necessary to take into account the costs, which are more than 2 times higher in automated development of a site compared to manual labor.

With a width of corridors of 15 meters in each corridor there are 6 rows of main tree species with the amount of planting material with the most common spacing scheme 2×0.75-0.8 m - 3750 - 3990 pcs/ha. This will allow to get the optimal number of main tree species and the closeness of forestry crops in the rows when introducing forestry crops into the category of valuable stands, according to paragraph 85 of this Resolution.

In this regard, we propose to reword the last clause of paragraph 24 as follows:

"*The number of trees planted on the site under the corridor method shall be more than 50% of the minimum number of forest plants established in accordance with Appendix 3. The width of the corridors shall not be less than 15 meters, and the width of the coulisses shall be no more than 15 meters*."

To form broad-leaved stands when determining the optimum width of the coulisses, it is necessary to take into account the tasks that they perform in this case. First of all, we are talking about their biological significance for the created forestry crops in the corridors. Based on our research (V.F. Reshetnikov, K.M. Storozhishina) it was established that with the corridors 4-6 meters wide, favorable lighting conditions are created by stands in the coulisses for young crops in the first years after their creation, which is important especially recently due to an increase in the climatic standards of the spring-summer period, when burns are observed in hardwood. If there are signs of shading of forestry crops, it is necessary to carry out the first stage of tending proposed in the developed methodological document. In corridors with a width of more than 6 meters, forestry crops grow under conditions close to the conditions of clear-cutting, which is intensively overgrown with grassy vegetation, especially in rich conditions of habitat. In their turn, these conditions are the main criterion for the effectiveness of reconstruction by creating broad-leaved forestry crops, which are very labor-intensive. In this regard, it is recommended to apply the bio-group spacing of cultivated species when creating forestry crops.

The effectiveness of corridor reconstruction using the method of creating broad-leaved forest species is achieved by a combination of factors: the bio-group spacing provides faster closure of crops in rows, which facilitates the favorable growth and formation of crops, the optimal width of corridors of 4-6 meters ensures a uniform and sufficient distribution of light in the created partial forestry crops (V.F. Reshetnikov, K.M. Storozhishina).

One of the main indicators for introducing forestry crops into the category of valuable forest stands is the index of their closeness. In accordance with the current Regulation on the Procedure for Reforestation and Afforestation, forestry crops created by the corridor method of low-value stands reconstruction that are to be included in the category of valuable forest stands must be closed in rows (par. 85).

The minimum age for entering in the valuable category is currently 7 years. However, not always the stands reach the required parameters at the age of 7. In the mixed forest zone of the European part of Russia, in the presence of 4.0 thousand pcs/ha of trees in conditions C_2, the complete closure of forestry crops occurs for pine at the age of 9 years, spruce - 13 years (M.D. Merzlenko). With the corridor method of reconstruction with a minimum width of corridors of 15 m and the presence of 4.0 thousand pcs/ha of trees at the age of 7 years, it is not always possible to ensure their 100% closure. Therefore, there are three options for resolving the issue:

1) to increase the width of the corridors, consequently, the number of planted plants;

2) to increase the age of entry of forestry crops into the category of valuable;

3) to reduce requirements for the degree of closeness of forestry crops in the rows - at least 3/4 at the age of 7 years.

The best option for the conditions of Belarus is the third option. With a closeness in the rows of at least 3/4, the plants of forestry crops already have a depressing effect on undesirable vegetation, including due to lateral shading. At the same time, such a degree of plant closure in a row is achievable in conditions of Belarus at the age of 7 years of forestry crops, which does not require a revision towards increasing the age of introducing forestry crops into the valuable category. In this regard, paragraph 85 in part one is supplemented with a wording adjusting the closeness parameter in the rows of forestry crops created by the corridor method of low-value forest stands reconstruction. In addition, this paragraph is supplemented by a part establishing the requirements for determining the degree of closure of the main tree species in the rows of forestry

crops. These additions are aimed at establishing a criterion for evaluating the degree of closure of the main species of trees in the rows of forestry crops. It is recommended as optimal for the parameter of the closure in rows at least ¾ of their length.

We propose the following changes to the first clause of par. 85: "*Forest crops created by the corridor method of low-value stands reconstruction, closed in rows of at least 3/4 of their length and having a height set in accordance with Appendix 18, shall be included in the category of valuable forest stands. If they are shaded by soft-leaved species, the plots will be included in the category of valuable forest stands only after tending*."

Conclusion

During implementation of the services within seventh and eighth stages, based on the results of tests of reconstruction and creation of silvicultures, tending and cultivation of plants of main broadleaved species, the Guidelines document for the reconstruction of low-value forest plantations to increase the share of broadleaved forests was finalized and its final version was developed.

Field surveys were carried out at 37 experimental sites for the reconstruction of low-value forest plantations. At least 6 experimental sites were laid in each region of the Republic of Belarus. The efficiency of the reconstruction of low-value stands by creating silvicultures of broadleaved species was evaluated.

The economic efficiency of different methods of reconstruction of low-value plantations by creating silvicultures of broadleaved species was evaluated. Other conditions being equal, the economic efficiency of the reconstruction of low-value stands by silvicultural techniques is higher if: the overall cost is lower and the implementation period is shorter; the timber of the main species added is more valuable; the share of main species in the composition of plantation is greater; the density of reconstruction cultures felling is higher and the turnover is shorter; the reserves per 1 ha are higher, the quality and yield of commercial timber, including large-size, are higher.

The greatest economic effect was obtained in case of clear-cutting reconstruction method - 2457 rubles/ha, the lowest – in case of the corridor method (the costs for the felling and further care was twice as high). In case of the natural formation of plants the same parameter was 1.5-2 times higher. The economic effect of applying the curtain-group reconstruction method, obtained in the result of sale of wood from felling in low-density broadleaved plantation where reconstruction felling was carried out, is 3058 rubles/ha.

The scientific grounding is given for introducing amendments to the regulatory framework in the field of reconstruction of low-value forest stands.

The guidelines document “Recommendations on the Reconstruction of Low-Value Forest Plantations to Increase the Share of Deciduous Forests” was developed, which was tested in each region of the republic in the forest fund of the Ministry of Forestry and State Scientific Institution “Institute of Forest of the National Academy of Sciences of Belarus” at reconstruction felling and creation of broad-leaved forestry crops.

Based on the study performed, the report containing the results of testing of the technology of reconstruction felling and creation of silvicultures, tending and cultivation of the main broadleaved species (oak, ash, maple), including by laying experimental sites in the territories of forestries of the Republic of Belarus, was prepared, and final version of the Guidelines document finalized based on the comments, suggestions and test results, was prepared.

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Annex A

GUIDELINES DOCUMENT ON THE RECONSTRUCTION OF LOW-VALUE FOREST PLANTATIONS TO INCREASE THE SHARE OF BROADLEAVED FORESTS (FINAL VERSION)

MINISTRY OF FORESTRY
OF THE REPUBLIC OF BELARUS

NATIONAL ACADEMY OF SCIENCES OF BELARUS
INSTITUTE OF FOREST

GUIDELINES DOCUMENT

RECOMENDATIONS ON THE RECONSTRUCTION OF LOW-VALUE FOREST PLANTATIONS TO INCREASE THE SHARE OF DECIDUOUS FORESTS

Minsk 2020

APPROVED

Resolution of
the Ministry of Forestry
of the Republic of Belarus
___ _____ 2020 No.

RECOMENDATIONS ON THE RECONSTRUCTION OF LOW-VALUE FOREST PLANTATIONS TO INCREASE THE SHARE OF DECIDUOUS FORESTS

SECTION 1
SCOPE

1.1 This Guidelines document establishes the procedure for the reconstruction of low-value forest plantations of deciduous species (English oak, Norway maple, common ash, small-leaved linden, European white elm) in the forest fund of the Republic of Belarus on a zonal-typological basis. The provisions of this Guidelines document are advisory and are intended for use by legal entities engaged in forestry.

SECTION 2
TERMS AND DEFINITIONS

2.1 The following terms with the corresponding definitions are used in this Guidelines document:

2.1.1 trees of the main species: Trees that under certain forest and economic conditions best meet the forest management purposes [1].

2.1.2 addition of silvicultures: Sowing of seeds and (or) replanting of planting material of forest plants in silvicultures in the areas of dead forest plants [1].

2.1.3 natural regrowth of forests: Formation of a new generation of forests in a natural way [1].

2.1.4 silvicultures: Forest plantations created by sowing seeds and (or) planting the planting stock of forest plants [1].

2.1.5 forest plantations: tree and shrub vegetation growing on a plot of forest fund of a certain species composition and ground cover [1].

2.1.6 the best trees: Healthy trees that are predominantly of the main species, having straight, full-wood trunks cleared of lower limbs, uniformly formed crowns, as well as trees that, by their condition and quality indicators, most fully meet the economic goals [2].

2.1.7 low-value forest stands/plantations: Forest stands of low productivity and quality for certain forest conditions, the criteria for identifying which are established by the republican body of state administration for forestry [1].

2.1.8 undesirable trees: The trees adversely affecting the growth and formation of the best and auxiliary trees, including dead standing, windfall, snowfall, damaged, crooked, misshapen, tapered, dying, trees with the damage of the stem (cavities, cracks, mechanical damage, etc.) and other similar trees of any wood species [2].

2.1.9 tillage for silvicultures: Mechanical or chemical treatment of the soil in the entire forest area or its parts, providing favorable conditions for the growth of cultivated plants [3].

2.1.10 undergrowth of the main species: Woody forest plants of natural origin, growing under the forest canopy and capable of stand forming, the height of which does not exceed 1/4 of the height of the main canopy trees [3].

2.1.11 reconstruction of low-value forest plantations: Forestry activities carried out in order to replace low-value forest plantations with coniferous and (or) hardwood tree stands by creating silvicultures or conducting reconstruction fellings [1].

2.1.12 reconstruction felling: Fellings carried out in order to replace low-value forest plantations, and forest plantations that lose their environment-forming, water protection, protective, sanitary and hygienic, recreational and other functions [1].

2.1.13 complete silvicultures: Silvicultures with a relatively uniform distribution of cultivated species, ensuring their predominant participation in the composition of the stands [3].

2.1.14 forest growing conditions type: Silvicultural classification category, characterized by homogeneous forest conditions of land covered and not covered with forest [3].

2.1.15 forest plantations tending: Removal of trees, shrubs and other vegetation that interferes with the growth of trees of the main species, and addition of silvicultures [1].

2.1.16 partial silvicultures: Silvicultures, located in the area, in places devoid of young growth of the main species, to increase the completeness or improve the species composition of the plantings [3].

SECTION 3
GENERAL PROVISIONS

3.1 The Guidelines document was prepared on the basis of the scientific research and generalization of production experience on the reconstruction of low-value forest plantations by reconstruction fellings and subsequent creation of deciduous silvicultures in the forest fund of Belarus in accordance with the requirements of the Forest Code of the Republic of Belarus [1] and existing legal and technical regulations [2-7].

3.2 The Guidelines document defines the procedure for the reconstruction of low-value forest plantations by creating silvicultures of broadleaved species, depending on their purpose, the species composition of plantations, their structure and health condition on a zonal-typological basis.

3.3 The purpose of the Guidelines document is to improve the technology of reconstruction of low-value forest plantations by creating silvicultures of broadleaved species (the main tree species are English oak, Norway maple, common ash, Scotch elm, European white elm, and the secondary - small-leaved linden) to increase the efficiency of these measures, restore the broadleaved group of species under the best forest growing conditions and increase their share in the forest fund of the Republic of Belarus.

SECTION 4
RECONSTRUCTION FELLING AND ITS METHODS

4.1 Criteria for low-value forest plantations

4.1.1. Reconstruction felling is carried out in forest areas occupied by low-value forest plantations.

4.1.2. Low-value plantations include forest plantations characterized by low productivity and quality, that do not comply with the economic and ecological purposes, growing in areas suitable for the creation of coniferous and/or broadleaved silvicultures that meet the following criteria:

- shrubs (with exception of shrubs growing in forest areas subject to water and wind erosion, as well as bilberry willow bushes, Lapland willow, yellow rhododendron, Cotoneaster melanocarpus, German broom [1];
- young plantings of soft-wooded forest plantations of coppice origin (aspen forests, birch-woods (except silver birch plantations)), as well as middle-aged soft-wooded plantations of coppice origin (aspen forests, birch-woods (except silver birch plantations)) with completeness of 0.5 and less;
- young and middle-aged plantations of gray alder of growth origin (except ashweed gray alder forests), hornbeam, tree-shaped willows (except plants with the dominance of white willow [5]), poplar, gray pine);
- middle-aged conifers and broadleaved plantations with completeness of 0.4 and less, which belong to the second and third classes of biological sustainability in accordance with the Sanitary Rules in the forests of the Republic of Belarus [6];
- invasive species plantings.

4.2 Reconstruction felling methods

4.2.1. Reconstruction fellings are carried out in low-value forest plantations by clear (clear felling) or corridor cutting (cutting through corridors) with the aim of subsequent reforestation depending on the forest-growing conditions, the purpose of forests and the intensity of forestry activities. The type of reconstruction felling method is determined by a full-scale survey of the plots and depends on the mensurational indicators (composition of plantings, age, completeness) and the sanitary condition of the reconstructed low-value forest plantation (Appendix A).

4.2.2. Clear reconstruction felling is carried out:

- in young (10 years and older) and middle-aged broadleaved forest plantations of growth origin (birch forests (except Karelian birch stands), aspen forests, gray alder forests), tree-shaped willow stands (except plants with the dominance of white willow [5]), hornbeam, poplar, gray pine.

4.2.3. Corridor felling is carried out:

- in shrubs;

- in young (less than 10 years) stands of growth origin (birch forests (except Karelian birch stands), aspen forests, gray alder forests), tree-shaped willow stands (except plants with the dominance of white willow [5]), hornbeam, poplar, gray pine.

4.2.4. The width of the corridors should be not less, and the width of the coulisses should be not more, than the maximum height of the trees in the reconstructed low-value forest plantation.

4.2.5. It is recommended to carry out reconstruction felling in June-September in order to reduce the growth capacity of trees of the reconstructed low-value forest plantations.

4.2.6. The undergrowth of the trees of the main species should be preserved during reconstruction felling, care for which is carried out in accordance with the requirements of paragraph 28 [2].

4.2.7. The felling plots are cleaned during the reconstruction in accordance with paragraph 74 [2].

4.2.8. The forest plots for reconstruction felling of low-value forest stands are allocated in accordance with TCP 622 [7].

SECTION 5
RECONSTRUCTION OF LOW-VALUE FOREST PLANTATIONS BY CREATING SILVICULTURES OF BROADLEAVED SPECIES

5.1 The low-value forest plantations are reconstructed by creating silvicultures using clear, corridor and curtain-group methods.

5.2 Depending on the reconstruction felling method, reforestation is carried out by creating partial and complete silvicultures. Complete silvicultures are created after clear reconstruction felling in low-value forest plantations, partial - after corridor felling. In low-density young stands (less than 20 years), in presence of viable forest plants of trees of the main tree species from 1.0 to 3.0 thousand plants/ha, partial silvicultures are created in curtains or groups in plots without upper canopy trees.

5.3 The broadleaved species in low-value forest plantations for the creation of silvicultures are selected depending on the growing conditions and the presence of main species trees in the plots.

5.4 When choosing the type of silvicultures, created for the reconstruction of a low-value forest plantation in order to form and cultivate oak plantings, a strip-group planting method should be used, which involves placement of English oak by common biological groups ($O^{1,5\text{-}2,5}O$ or $O^{1,5\text{-}2,5}O^{1,5\text{-}2,5}O$). Depending on forest growing conditions, it is possible to use schemes for mixing oak with spruce, pine, linden, maple and ash (Appendix B).

5.5 When choosing the type of forest cultures created for the reconstruction of a low-value forest plantation in order to form and grow common ash tree plantations, preference should be given to mixed Depending on the forest growing conditions, it is possible to use the schemes of mixing ash-tree with spruce, oak, maple, elm, less often linden (Appendix B).

5.6 When choosing the type of Norway maple forest crops, preference should be given to both pure (with curtain-group reconstruction) and mixed (with continuous and corridor methods of reconstruction) crops. Depending on forest growing conditions, it is possible to mix maple with oak, spruce, ash, linden (Appendix B).

5.7 Reconstruction in shrubs is carried out by cutting furrows in the corridors using tillage equipment followed by the creation of broadleaved forest cultures.

5.8 When creating partial forest crops in curtains or groups, it is recommended to use seedlings, plants or forest wild growing plantings of broadleaved species, as well as sowing seeds in the tilled soil in places that are not characterized by the natural regeneration of main tree species.

SECTION 6
TILLAGE FOR SILVICULTURES

6.1 Tillage for silvicultures is carried out in the year preceding the planting of crops or in the year of planting (Fig. 1). When carrying out reconstruction felling (clear-cutting and corridor), it is necessary to ensure that the row spacing, the straightness and parallelism of the rows are maintained, which will make it possible to use the mechanisms when planting forest crops, as well as to simplify agrotechnical and forestry care.

6.2 Before complete and partial silvicultures of broadleaved species are created, clear or strip removal of softwood species and shrub vegetation is carried out.

6.3 Tillage for planting silvicultures is performed by mellowing (milling) of the soil, cutting plow furrows and earthing up the layers (in wet and moist soils). The soil is tilled by cutting plow furrows with the minimum depth of the plow entry (10-12 cm), ensuring the removal of the sod mat, while preserving the fertile soil layer as much as possible.

6.4 When creating the partial silvicultures (curtain-group reconstruction), first the existing undergrowth of coniferous and broadleaved species (all trees and shrubs that are shading them are cut down) are treated (if necessary). After that, the soil is cultivated for forest cultures and broadleaved species are planted in plots without regrowth of main tree species.

SECTION 7
TERMS FOR THE CREATION OF SILVICULTURES, PLANTING MATERIAL

7.1 Silvicutures are preferably created in early spring, before bud break. It is allowed to create silvicultures in autumn. Planting material with closed root system can be used in forest growing area during the whole growing season.

7.2 Planting of silvicutltures is carried out using the standard planting material. When creating silvicultures of broadleaved species, 1-2-year-old seedlings (plants) with open and closed root systems are used. Creation of forest cultures by sowing acorns (acorn seeding depth is 5–8 cm, seeding rate is 25–100 kg/ha) and planting of wildlings are allowed.

7.3 The number of trees of the main species planted on the plot using corridor and curtain-group reconstruction methods must meet the requirements of clauses 20, 24 [3].

SECTION 8
SILVICULTURES TENDING

8.1 When felling forest plantations created for the reconstruction, the type of felling is determined by the age of the forest cultures created.

8.2 Agrotechnical tending using tillage tools or mowing is carried out in the biological groups of broadleaved species and along the rows of planted species, while maintaining a protective zone of at least 0.2-0.3 m on each side of the plant, during the first three years. Chemical treatment of broadleaved species silvicultures is allowed. Agrotechnical tending is carried out in May-July before shading of silvicultures by shrubs and woody vegetation.

8.3 Addition of forest cultures is carried out in accordance with clause 67 [3] by method of planting forest plants and is assigned to plots where the survival rate is 25–85% according to the inventory results, in plots with uneven placement of trees of the main species - with any survival rate, and also based on the commission decision - with survival rate below 25%.

8.4 Planting material of forest cultures, the age of which differs from the biological age of the supplemented forest cultures by not more than three years, is used to supplement forest cultures [3].

8.5 The improvement felling of silvicultures created for the reconstruction of low-value forest plantations using the corridor method are carried out in accordance with Appendix B.

8.6 When carrying out improvement felling, all the trees of main species are preserved in the corridors.

8.7 During the improvement felling in the coulisses, secondary tree species and undesirable trees shading the silvicultures, are removed. If the broadleaved trees and conifers (pine, fir) are present in the coulisses, the care for them is provided. The healthy trees of the broadleaved and coniferous tree species with a smooth trunk, characterized by the greatest increase in height and with a well-developed crown, are preserved as the best samples.

8.8 Forest cultures, created by the corridor method for the reconstruction of low-value forest stands, are treated in accordance with Appendix 3 [2]. It is recommended to carry out improvements in the coulisses in several stages. The first stage is to thin the coulisses during the 2nd-3rd year after partial planting of silvicultures with the intensity up to 50-60%, the second stage - during the 6th-7th year with an intensity of up to 50-60%, while the density of plants in the coulisses should not fall below 0.3, the third stage - clear felling of the coulisses during the 10th-12th year, while leaving the main species of natural origin. In case of strong shading of silvicultures in the presence of high-density plants in the coulisses, with the width 6 m or more, it is recommended to extend the width of the corridors to 4.0 m in both directions by the felling secondary and undesirable trees, in case of narrow coulisses (less than 6 m) - by continuous felling, while leaving the trees of the main species.

SECTION 9
TRANSFER TO THE CATEGORY OF VALUABLE FOREST PLANTATIONS

9.1. Forestry crops created by the corridor reconstruction method of low-value forest plantations, which are closed in rows of at least 3/4 of their length and have an average height established under Appendix 18 [3], should be transferred into the category of valuable forest plantations. If soft-leaved species shade them, the plots are transferred to the category of valuable forest plantations only after tending.

9.2 Forestry crops by the curtain-group method, without further clear felling of trees and shrubs of natural origin are entered into the category of valuable forest plantations, after they reach the average height established under Appendix 18 [3]. At the same time, as part of the forest plantation, the number of trees of the main species should be not less than the number established in the second part of clause 60 [3].

9.3 The degree of closure of the main tree species in the rows of forestry crops is defined as the ratio of the length of the horizontal projections of the crowns of the main tree species in the rows (without taking into account the length of their overlap) to the total length of the rows on the test plot.

9.4. The term for the transfer of the forest plantations created within the reconstruction by corridor and curtain-group methods, is equal to the age of transfer of forestry crops plots to forest-covered lands.

APPENDIX A
(recommended)

Methods of reconstruction of low-value forest stands based on their zone and type

Type of planting being reconstructed	Type of forest-growing conditions	Method of reconstruction felling	Method of reconstruction by creating silvicultures
Shrubs	C_2, C_3 D_2, D_3	corridor	corridor
Young aspen and birch (except silver birch) of coppice origin: less than 10 years old	C_2, C_3 D_2, D_3	corridor	corridor
10 years and older		clear	clear
Young gray alder, willow, hornbeam, poplar and gray pine: less than 10 years old	C_2, C_3 D_2, $D_{3\ (except\ GrAl)}$	corridor	corridor
10 years and older		clear	clear
Middle-aged stands of aspen, birch (except silver birch) of coppice origin with thickness of 0.5 and less	C_2, C_3 D_2, D_3	clear	clear
Middle-aged plantations of gray alder, willow, hornbeam, poplar and gray pine.	C_2, C_3 D_2, $D_{3\ (except\ GrAl)}$	clear	clear
Coniferous and hard-leaved low-density forest stands under the age of 20 years	C_2, C_3 D_2, D_3	–	curtain-group, partial
Young stands (20 years old and older) and middle-aged stands of conifers and hardwoods with a density of 0.4 and less and the biological stability classes 2 and 3	C_2, C_3 D_2, D_3	clear	clear, complete

APPENDIX B
(recommended)

Tree species mixing schemes
when creating silvicultures of broad-leaved species (oak, maple, ash-tree)
reconstruction of low-value forest plantations in the context of geobotanic subzones
and type of forest growing conditions

Type of forest-growing conditions	Tree species mixing schemes using the reconstruction method by creating silvicultures*	
	clear (clear silvicultures)	corridor (partial silvicultures)
Subzone of oak-dark coniferous forests		
C_{2-3}, D_{2-3}	1) O (Ash,M)$^{1.5\text{-}2.5m}$O (Ash,M)$^{3\text{-}3.5m}$S$^{3\text{-}3.5m}$…; 2) O (Ash)$^{1.5\text{-}2.5m}$ O (Ash)$^{3\text{-}3.5m}$Lin$^{3\text{-}3.5m}$ S$^{3\text{-}3.5m}$Lin$^{3\text{-}3.5m}$…; 3) Ash$^{2.5\text{-}3m}$Ash$^{3\text{-}3.5m}$E (M, Lin)$^{3\text{-}3.5m}$...; 4) M (M$^{2.5\text{-}3.0m}$M)$^{3\text{-}3.5m}$Ash (S, E)...	1) 2r. oak^{coulisse}; 2) 2r. oak (ash-tree, maple) 1-2r. spruce^{coulisse}; 3) 2r. ash-tree 1r. elm (maple or linden)^{coulisse}
Subzone of hornbeam-oak-dark coniferous forests		
C_{2-3}, D_{2-3}	1) O$^{1.5\text{-}2.5m}$O$^{4\text{-}6m}$ …; 2) O$^{1.5\text{-}2.5m}$O$^{1.5\text{-}2.5m}$O$^{4\text{-}4.5m}$S$^{4\text{-}4.5m}$…; 3) O$^{1.5\text{-}2.5m}$O$^{3\text{-}3.5m}$Lin(M)$^{3\text{-}3.5m}$...; 4) O (Ash)$^{1.5\text{-}2.5m}$O (Ash)$^{3\text{-}3.5m}$Lin$^{3\text{-}3.5m}$ S$^{3\text{-}3.5m}$Lin$^{3\text{-}3.5m}$…; 5) Ash$^{2.5\text{-}3m}$Ash$^{3\text{-}3.5m}$O (E, M, Lin)$^{3\text{-}3.5m}$; 6) M$^{1.5\text{-}2.5m}$M$^{3\text{-}3.5m}$O (S)$^{3\text{-}3.5m}$…; 7) M$^{1,5\text{-}2.5m}$Lin (E, Ash)$^{1,5\text{-}2.5m}$M$^{3\text{-}3.5m}$ …	1) 2r. oak (ash-tree, maple) 1r. spruce^{coulisse}; 2) 2r. oak^{coulisse}; 3) 2r. oak 1r. linden (maple)^{coulisse}; 4) 2r. ash-tree 1r. oak (elm, maple or linden) 2r. ash-tree^{coulisse}; 5) 1-2r. maple 1-2r. linden (ash-tree or elm)^{coulisse} 6) 2r. maple (oak, ash-tree)^{coulisse}2r. maple (oak, ash-tree)^{coulisse}1-2r. spruce…
Subzone of broad-leaved and pine forests		
C_{2-3}, D_{2-3}	1) O$^{1.5\text{-}2.5m}$O$^{4\text{-}6m}$ …; 2) O (Ash)$^{1.5\text{-}2.5m}$O (Ash)$^{3\text{-}3.5m}$Lin$^{3\text{-}3.5m}$ P$^{3\text{-}3.5m}$Lin$^{3\text{-}3.5m}$…; 3) O$^{1.5\text{-}2.5m}$O$^{3\text{-}3.5m}$Lin(M)$^{3\text{-}3.5m}$...; 4) Ash$^{2.5\text{-}3m}$Ash$^{3\text{-}3.5m}$O (P, E, M, Lin)$^{3\text{-}3.5m}$ …; 5) M$^{1,5\text{-}2,5m}$Lin (E, Ash)$^{1,5\text{-}2.5m}$M$^{3\text{-}3,5m}$ …	1) 2r. oak(ash-tree)^{coulisse}; 2) 2r. oak 1r. maple (linden)^{coulisse}; 3) 2r. oak 1-2r. linden (maple)^{coulisse}; 4) 2r. ash-tree 1r. oak (pine, elm, maple or linden) ^{coulisse}

Note: * – O – common oak, Ash – common ash, M – Norway maple, Lin – small-leaved linden, E – European white elm;

Planting step of the cultivated tree species: O (oak) – 0.75-0.80 m (with planting material height more than 0.3 m planting step should be increased to 1.0 m), S (spruce) – 0.75-0.80 m, P (pine) – 0.75-0.80 m, Lin (linden), M (maple) – 1.0 m.

APPENDIX C
(recommended)

Technology and mode of thinning in stands created within the reconstruction of low-value forest stands using the corridor method

Reconstructed stand	Improved felling technology and mode
Young tree stands of aspen, birch of a coppice origin up to 10 years old Young gray alder, willow, hornbeam, poplar and gray pine up to 10 years old Shrubs	***First stage*.** During the 2nd-3rd year. Felling of secondary tree species and unwanted trees shading forestry crops. ***Felling intensity up to 50-60%*** ***Second stage* –** during the 6th-7th year. Tending in the corridors. Felling of secondary tree species and unwanted trees along rows of forestry crops with their stacking in heaps on empty places in corridors or coulisses (Fig. 2). Tending in coulisses. Thinning the coulisses by cutting down secondary tree species and unwanted trees that shade forestry crops. In case of strong shading of silvicultures in the presence of high-density plants in the coulisses, with the width 6 m or more, it is recommended to extend the width of the corridors to 4.0 m in both directions by the felling secondary and undesirable trees, in case of narrow coulisses (less than 6 m) - by continuous felling, while leaving the trees of the main species. If there are main tree species in the coulisses, they are tended by the crown-thinning method (Fig. 3). Cut down trees are stacked in heaps on empty places in the corridors or coulisses (Fig. 4). ***Felling intensity up to 50-60%.*** ***Third stage*** - during the 10th-12th year. Tending in the corridors. Felling along the rows of forestry crops of secondary tree species and unwanted trees with their stacking in heaps on empty places in the corridors or coulisses. Tending in coulisses. Continuous felling of minor secondary species and unwanted trees, leaving the main species of natural origin that are being tended. Merchantable wood is placed on empty places along the edge of the coulisses. *Technical means* – manual brush cutters, chainsaws up to 2.5 kW, cutters. *Treatment season* – June - September (to reduce the preservation of coppice regeneration).

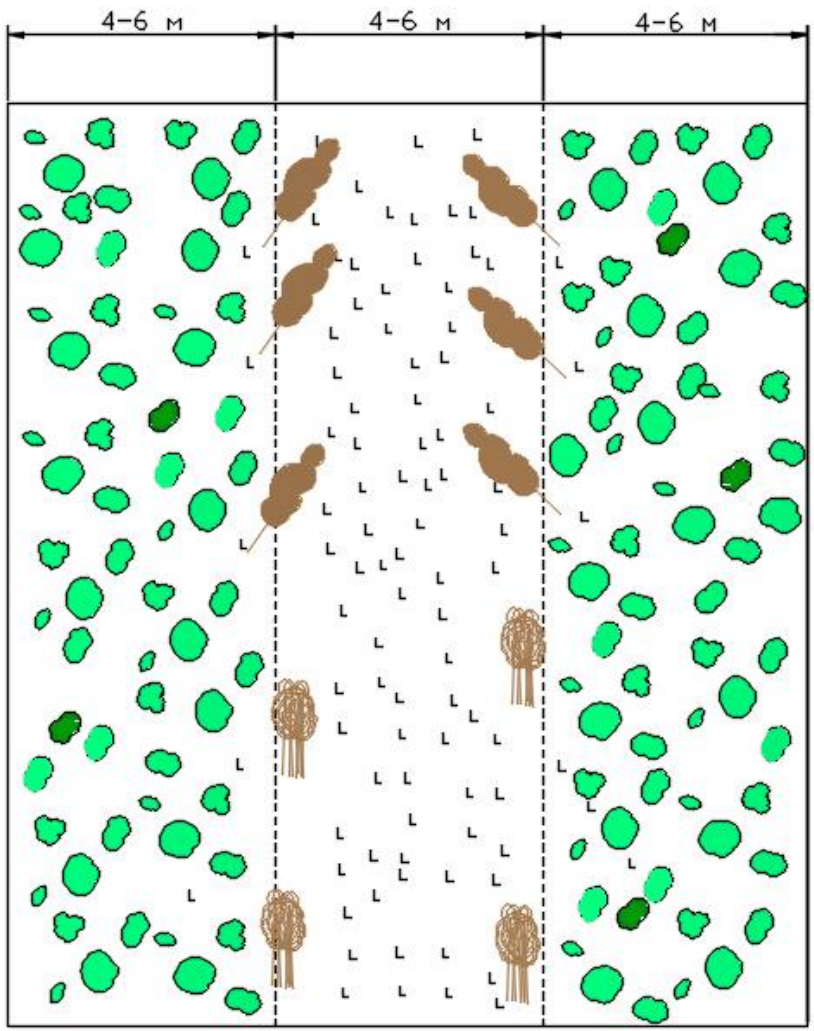

Figure 1 - Felling of secondary tree species and unwanted trees before creating forestry crops

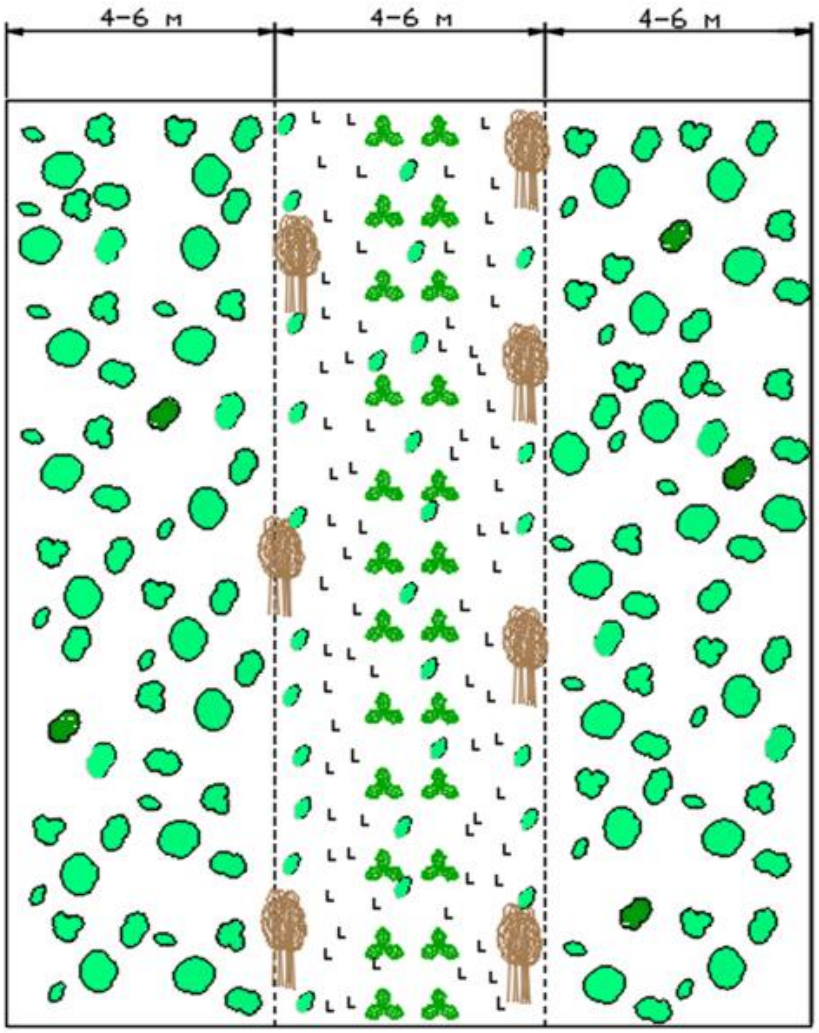

Figure 2. Forestry crops in the corridors tending (second stage)

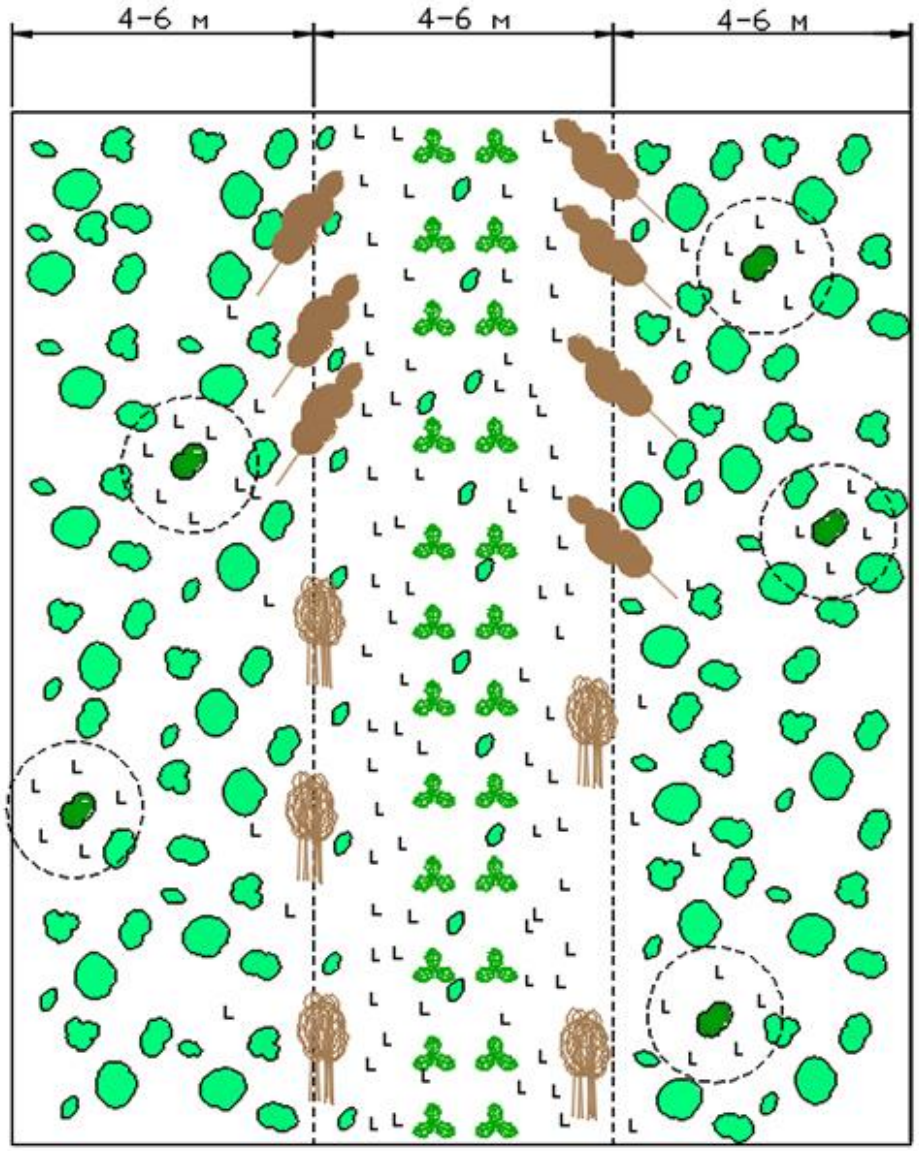

Figure 3 - Tending in the coulisses of the main tree species using crown-thinning method (second stage)

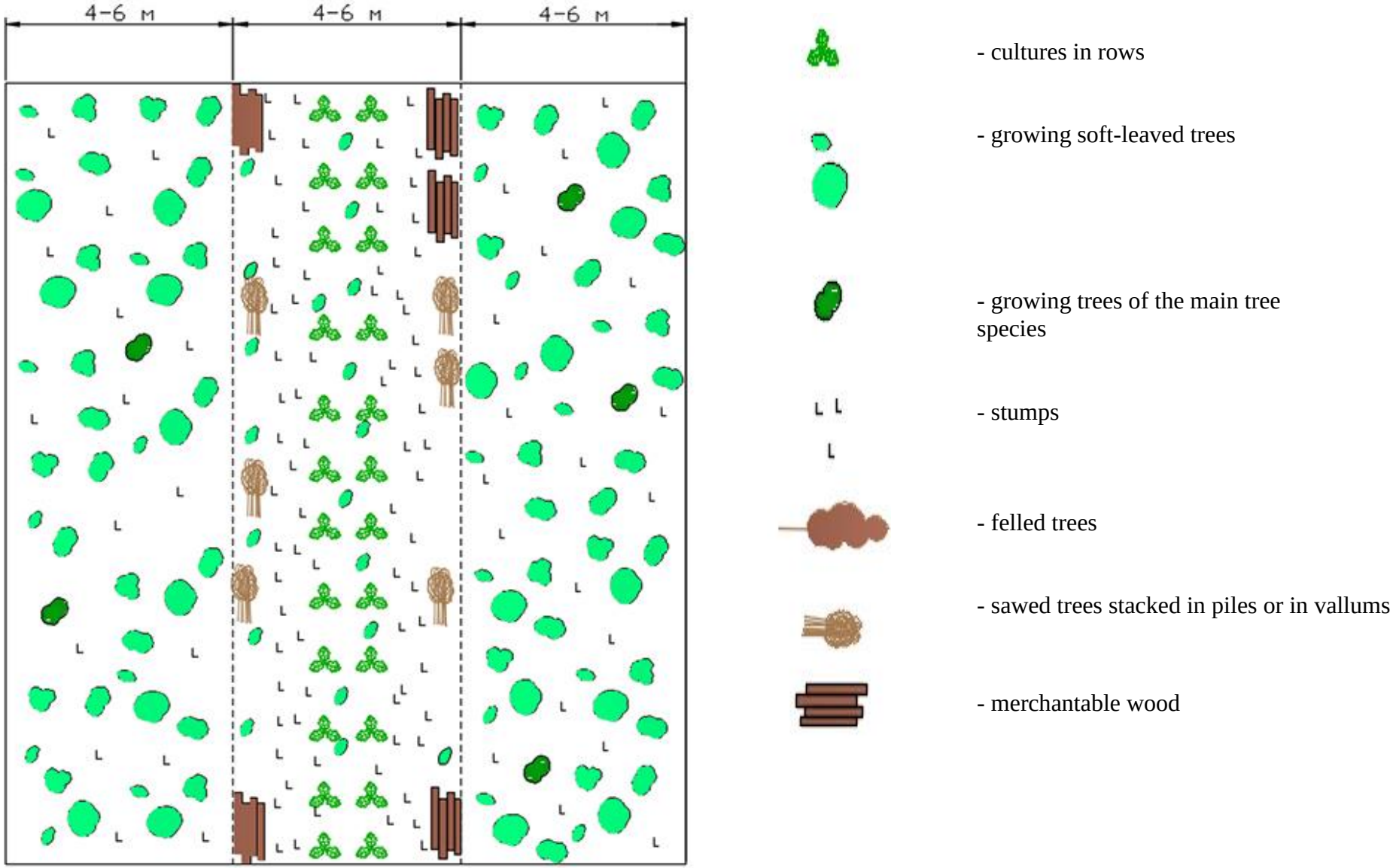

Figure 4 Third stage – treatment in coulisses

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