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Executed by

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Acronyms

API – Application Programming Interface
ASCDM – automated monitoring data collection system in forest ecosystems
B – *Betuleta*
GDB – geodatabase
myrt – *myrtillosum*
U - *Ulmus*
cal - *callunosum*
GIS – Geographic Information System
SFE – state forestry enterprise
GEF – Global Environment Facility
pol – *polytrichosum*
Pc – *Piceeta*
EU – European Union
Lon xyl – *Lonicera xylosteum*
Sal – *Salix*
ox – *oxalidosum*
A – *Acereta*
Fr – *Frangula alnus*
T – *Tilieta*
Cor – *Corylus avellana*
Jun – *Juniperus communis*
pl – *pleuroziosum*
NASB – National Academy of Science of Belarus
IA – *Incani Alneta*
GA – *Glutinosi Alneta*
SPA – Special protected area
pt – *pterodiosum*
Tr – *Tremuleta*
f-h – *fontinale-herbosum*
Sor – *Sorbus aucuparia*
FC – final cuttings
RUE – Republican Unitary Enterprise
Pn – *Pineta*
TCP – technical codex of common practice
TSC – type of soil conditions
GWL – ground water level
vac – *vaccinosum*

Executive summary

During the last seventy years, the forest-covered area in the Republic of Belarus increased almost two times, mainly due to the transfer of other land categories to forest fund. At the same time, forest fund itself is being transformed by human activity, climate change, forest use, strong winds etc. The mass transformation of natural forests together with the increment of artificial forest area creates probability of future biological diversity and ecosystem stability decrease. At the same time, the results of some researches show that forests with high productivity and stability can be formed by taking active management measures.

It is proven that forest stand composition and structure are being transformed. But there is no any monitoring system for such changes in the country. And so, there is no reliable data to make management decisions aimed at the preservation of forest stability during forest use intensification and climate change.

Thus, the main goal of the work is to define the main tendencies of current forest fund land and forest ecosystem biological diversity dynamic in the result of climate change; to suggest economically and ecologically effective activities to maintain the positive wood supply dynamics, create stable natural forests with high biological diversity during reforestation, afforestation, and forest use in case of unavoidable forest use and human impact intensification; to create a monitoring network to track climatic change influence to the Belarusian forests and to estimate the effectiveness of adaption activities.

Identification and designation of typical and rare biotopes

Currently, forest management plans contain the section on protected species of flora and fauna, but the section on rare biotopes is completely missing. In addition, in accordance with the new Forest Code, the habitats of protected species transferred from individual sites to the category of forests (a higher level). This led to the need to review the entire structure of the forests of forestry enterprises, develop new protection and use regimes, change the estimated cutting area and so on.

Field researches in SFE “Klichevsky leskhoz”, SFE “Gluboksky opytny leskhoz”, SFE “Tolochinsky leskhoz”, and SFE “Bogushevsky leskhoz” were conducted and forest fund areas, which are need to be specially protected according to demands of new Forest Code, were detected. Passports and protective obligations on rare and typical biotopes, habitats of wild animals and plants that are included in the Red Book of Belarus were prepared. Total area of designated sites is 3785 ha (256 passports). Share of rare and typical biotopes is 0.9 % in SFE “Bogushevsky leskhoz” up to 2.8 % in SFE “Gluboksky opytny leskhoz”.

Proposals on limitations of felling types or felling restrictions in the territory of protected biotopes and habitats of protected flora and fauna species were worked out. The division of the forest fund of SFE “Klichevsky leskhoz”, SFE “Gluboksky opytny leskhoz”, SFE “Tolochinsky leskhoz”, and SFE “Bogushevsky leskhoz” was held into the categories of forests according to the new Forest Code.

Development of principles and methods for monitoring the effects of climate change in forest ecosystems

In frames of conducted work analysis of peculiarities of influence of climate changes on Belarusian forest ecosystems was made. Contribution of different factors to the dynamics and death of forest ecosystems was shown.

Principles and methods of monitoring of consequences of climate changes in forest ecosystems were developed. It was suggested to use systems of methods and concrete procedures, which to a certain extent coincide with already existing and well-tested in frames of International cooperative programme (ICP) on estimation and monitoring of influence of air pollution on forests, complex researches of forest ecosystems with ground and remote methods, for the monitoring.

Criteria and indicators of reaction of forest ecosystems on climate changes and of estimation of effectiveness of measures on adaptation of forest management to predicted climate changes add up to:

- achievement of higher forest stability to any scenario of climate dynamics, i.e. preparedness for any changes, either warming, cold snap, stabilization or fluctuations of climate;
- prediction of forest compositioncompounds on the basis of factual data of forest fund inventory, current forest legislation, regulatory technical base of forest management;
- development and realization of recommendations on future forest compounds composition on the basis of zonal and formation-typological approach;
- inventory of main types of felling (final, clear, incidental) and of condition of harmful and beneficial pests and forest diseases, as of a factor, leading to changes in species forest compoundcomposition;
- achievement with means of adaptation of the sector to new weather-climatic changes not only ofthrough overcoming of negative consequences of these changes, but the most full benefit from them;
- integration of recommendations on adaptation to regulatory base of forest management.

The concept and programme for monitoring the effects of climate change in forest ecosystems was designed.

As the result of work in 2018, a network of permanent sample plots (PSPs) to monitor climate change in forest ecosystems has been created. The total numbers of PSPs in the network accounts for 288 plots, 214 of them were created based on forest monitoring plots and 74 – based on the plots of complex ecosystem monitoring in specially protected areas.

PSPs are located in forest stands of 8 forest formations: pine, spruce, oak, ash, linden, birch, black alder and aspen forests. According to Belarusian forest typology, they comprise 31 forest type in 13 types of soil condition. PSPs are located in forest stands aged not less than 60 years old (except for one). 5-year-long observation cycle is planned according to the monitoring plan.

During the year of 2018, the first observation cycle has been conducted to 36 PSPs, in 32 PSPs preliminary survey has been conducted. Work at the PSP includes estimation of stands condition, bush layer, undergrowth, ground vegetation, taking of wood core samples.

Forest stands in PSP observed in 2018 mostly are in a good state: 13 are considered healthy, 18 – healthy with signs of weakness. The same state is characteristic for the most of natural stands in the republic. Only two forest stands were considered weak and three – damaged. The best condition in the species scale (healthy without any sign of weakness) is recorded among the stands of white birch, elm, hornbeam, black alder and aspen. The category “healthy with signs of weakness” includes maple, spruce, pine and silver birch. Even though pine is a pretty stable species, the condition pine and spruce stands is first of all defined by the presence of pests and Heterobasidion annosum outburst areas.

Undergrowth structure of the PSPs has the following species: white and silver birch, pine, spruce, oak, maple, elm, hornbeam, linden, ash, aspen. The structure corresponds to the forest type. The best condition is registered in the stands of white and silver birch – average grade is 1,0 – 1,5. The worst conditions are hornbeam and ash.

The structure of ground vegetation currently corresponds to the forest type, because the most typical plots of the forest types have been selected for the PSPs.

Currently one of the main disadvantages of the network is the absence of automated sensors to measure the level of ground water, what makes it impossible to fully estimate the changes occurred to the stands in the future.

Development of software for the collection and analysis of monitoring data in forest ecosystems

The goal of this stage of the work – creation of the software project, which will allow automatizing of data collection and analyses of forest management data in forest ecosystems by filling of standard forms (cards) that contain numeral and qualitative characteristics of forest or other land types of the monitoring plot. This will allow receiving of better quality information about monitoring plots, decreasing of costs of such works and the user will be able to receive a various reports.

Object of automatization is the process of data collection on monitoring areas and forest sites and filling of special standard forms (cards), containing numeral and qualitative characteristics of forest stands or other land types of monitoring area, using laptops with Windows OS.

Users interact with ASCDM through visual graphical interface. The interface of the system is understandable and convenient, not overloaded with graphic elements and provides displaying of screen forms. The navigation elements have understandable to user form. Data input and output, results displaying are being done in interactive mode. All messages, texts of screen forms are written in Russian (except for modules of other producers). The organization of user's graphical interface prevent from user's inaccurate actions. The users can control data input: look through input data; correct input data; decline to input data.

The interface has two screen forms – a window of QGIS project and a form of attributive data input (editing) – and is meant for stylus use. The system is operated with a set of screen menu, buttons, icons, etc. The keyboard input mode is mainly used for filling and/or editing of text and numeral fields of screen forms. Reference books and lists of allowed values are being used as much as possible during input.

Collected information is represented by vector (coordinates) and attributive data, which reflect spatial location and numeral and qualitative characteristics of the plot.

During approval tests the following has been confirmed: corresponding of the structure and compounds of GDB ASCDM to submitted documents of the system; work ability of the system during completion of the text tasks of the module; ability to prevent setup of restricted combinations of values and codes and to notify the operator about data input errors; ability of ASCDM to maintain logical and physical integrity of database, to reflect all the changes in condition of the existing objects and to create new ones; ability of ASCDM to calculate saved in GDB ASCDM characteristics of monitoring plot properly; informativity and convenient data representation in GDB ASCDM; accurate presentation and interpretation of reference books, tables, domains and lists of allowed values in GDB ASCDM,.

For the successful work of specialists in field conditions, a detailed User's manual and a Training program about ASCDM use have been developed. The course includes acquaintance with structure and compounds of GDB about forest fund and forest resources, learning of basic functions of QGIS software, working process of ASCDM in QGIS sphere, working skills with ArcGIS for Desktop, which are enough to upload the working project to the tablet computer and later transfer data back to the system after the end of the field works and are enough for quality to be controlled by ASCDM services.

Convenience of the system use is ensured with correlation of accessible for user instruments of data input, processing, storage and output, system settings and other functional elements. Received software will allow automatized collection of data about forest fund condition and make fast analyses of the results of the examination of forest resources.

Analysis of the change in forest area and the dynamics of the biological diversity of the forest ecosystems of the Republic of Belarus

Scientific data from post-war reports and publications, summaries (1949-2017) on Belarusian flora, databases of forest state, pre-war topographical maps (Belarusian forests have been restored according to these maps) and statistical data have been used for the analyses of the change in forest area and the dynamics of the biological diversity of the forest ecosystems of the Republic of Belarus in the postwar period (1944-2015) with definition of the key factors of the transformation has been conducted.

Changes in forest structure of Belarus in the post-war period were going on in different ways because of numerous outside factors. The main changes can be divided into several groups:

- drastic enlargement of forest-covered area – from 21.5% in 1940 up to 43.7% in 2016;

- decrease of broadleaved (4.0% to 3.5%) and pine (57.6% to 50.2%) forests proportion on one hand, and increase of birch (16.2% to 23.2%) and grey alder (0.8% to 1.9%) forests proportion on the other hand.

- decrease of the most infertile upland forest types proportion: *cladinosum, callunosum, vacciniosum, pleuroziosum* and increase of more fertile forest types proportion: *pteridiosum, oxalidosum, myrtillosum*;

- almost complete disappearance of *sphagnosum* forest type and its transformation to *caricoso-sphagnosum* forest type;

- appearance of pine forests in open raised bogs and white birch in transitional bogs;

- decrease of the proportion of forest types related to bogs: *thelypteridosum, filipendulosum, fontinale-herbosum,* and drastic increase of *filicosum* forest type proportion (most of post-drainage forests);

- transition of continuous diversion of forest-making species to the north: European spruce (20-30 km in some regions), common hornbeam (10-20 km in some regions) and grey alder (50 km);

- periodical large-scale forest death from unfavourable climatic conditions or bark betle attacks; in Belarus 4 to 35 thousand hectares of forest die annually in Belarus, that accounts for 0.1-0.4% of total forest area;

- drastic increase of number of introduced (by 78.3%) and brought (three times) plant species in forest ecosystems;

- drastic increase of introduced species number (42 species).

There are several key factors in these processes. These factors often enhance each other. There are both relatively natural and purely human factors:

1) changes in land use regime (lessening of used agricultural lands) have led to drastic enlargement of forest-covered territory and bog afforestation with tree and shrub vegetation;

2) stable decrease of precipitation by 20% in 1940s and mass drainage in 1950-1970 conducted after these climate changes led to fast bog afforestation with tree and shrub vegetation, decrease of bog forest types proportion, appearance of unstable post-drainage forest types and active appearance of meadow and weedy-ruderal species in forest ecosystems;

3) forest management (first of all cuttings, reforestation and afforestation) has led to simplicity of age, species, and spatial forest structure, decrease of broadleaved and pine forests proportion, increase of birch and grey alder forests proportion; introduction of invasive species to forests (alongside with forest plantings creation);

4) climate warming since 1990s and related longevity and intensity of summer draughts, longer vegetation season have led to changes in the borders of species distribution, forest stands weakening and often pest outbreaks that lead to large-scale forest death.

Other factors that influence forest ecosystems and lead to their transformation but locally include the following:

- forest and peat fires;
- recreational burden of forest ecosystems;
- pollution by industrial emissions;
- hunting farms (larger number of ungulates);
- flooding of some areas because of beaver activity or drainage systems;
- development of communication routes, enlargement/lessening of locality areas.

As the forest management deals with long-living organisms (lifespan of trees accounts for dozens and hundreds of years), all the changes must be taken into account when developing longterm plans. The first thing to be taken into account is maintenance of water regime for tree species. Decrease of precipitation, mass drainage and climate warming led to the violation of hydrological regime set ages before and lack of water for trees. All these have led to worsening of forest stands stability.

Thus, hydrological regime management in drained forest lands, former peat pits and near drained agricultural lands must be one of the priorities in main forest management directions. The other main direction is to create forest stands of complex species and age structure, increase broadleaved species proportion, take into account natural successions during forest management planning. All these together will allow to increase forests stability against natural and human factors.

Development of a system of measures to prevent degradation of forest lands

Features of economic use of natural and territorial resources of Belarus cause degradation of lands and soils which may have more than 20 types and forms. The main causes of land degradation are water and wind erosion of soils, quarrying of peat and construction materials, waterlogging and submergence, as well as excessive recreational, technical and other anthropogenic loads. As a result of hydrotechnical drainage and peat extraction for use as fuel of organic fertilizers, peat bogs have undergone the greatest transformation.

289 thousand hectares of forest lands was reclaimed by drainage and 1.5 million hectares of forests were influenced by drainage networks located on farmlands after mass drying-out of wetlands in the 60-80s of the last century. Hydrological regime of these lands has been significantly changing due to raising of the underground water level in the last 20-25 years. As a result of waterlogging, submergence and silting of forest stands the spread of pests and diseases, the reduction in their growth rate and transformation into less valuable and lowly productive types of woody and shrubby vegetation is observed. Basic and additional criteria for assessing of the stage of waterlogging process in forest stands have been developed to prevent (eliminate) its negative consequences. Depending on the condition of waterlogged lands, the following directions of rehabilitation of forest fund lands are singled out: forestry; nature conservation; water management and recreation.

More than 150 thousand hectares of the drained fen-peat soils have completely disappeared as a result of deep drainage and their fast biochemical decomposition, wind erosion and fires in Belarusian Polesie region. The peat horizons burn out completely during the fire and the mineral layers (usually gley) come to the surface. The latter are enriched with ash-forming elements, but impoverished by nitrogen. The development of measures for fertility recovery of peat soils degraded by fire in order to decrease their negative impact on the environment is necessary.

Disturbed lands cover over 250 thousand hectares in Belarus and are presented, in general, by cut-over peatlands and quarries of non-ore construction materials (gravel, sand, clay, lime). The use of such areas for agriculture is unprofitable and therefore they are generally given to the forestry. The practical use of cut-over peatlands as woodland is provided only for areas with weak or without sod cover and average water table lower than 0.6 m. Forest plantations could be established on cut over peatlands according to four technological processes. The choice of the process is made on a basis of the type of mire, categories of areas and method of soil cultivation. The quarries where non-ore materials were extracted are subject to the slope leveling immediately after the end of mining. The slope leveling and the technical stage of reclamation are made immediately after the end of mining. The next stage of area recultivation is the creation of pure or mixed pine plantations according to chose technology. Pure or mixed forest plantations of the main forest-forming species (pine, spruce, oak, birch, alder, aspen) are established taking into account the soil fertility.

Large-scale use of forests for recreation began in Belarus in the late 60s – the beginning of the 70s of the XX century. At present about 1.5 million ha of forests are mainly used for recreational purposes. This area is about 20% of the total woodland area of the republic and five times more than in 70s of XX century. The average load in summertime is daily 2.9 people per hour per ha (3-4 thousand people per hour per ha per year). Negative consequences of recreation are observed in the forests. They are trail degradation, undesirable transformation of woodlands, increase in the number of wildfires and some others.

Natural complexes of national parks recreational zones as well as green zone forests are exposed to significant anthropogenic and recreational influence, which endanger them. Establishment of the regime of protection and restriction of use of natural resources on the territories mentioned not always and not fully guarantees protection of the ecosystems against existing threats.

Forest management measures have been developed to reduce the recreational load and prevent forest degradation. These include: a comprehensive assessment of the recreational potential of forests; analysis and optimization of recreational forestry; forecast changes in the quality of stands and identify of their dynamic trends.

The system of measures to prevent degradation of forest lands was developed, which was discussed at working meetings at the Institute of Experimental Botany NAS of Belarus, as well as at the Ministry of Forestry. The system includes: general provisions of the system of measures to prevent land degradation of the forest fund; reclamation of waterlogged woodlands; forestry reclamation of disturbed lands; decrease in recreational load and prevention of forests digression. The system of measures is aimed, in general, at recovery, rehabilitation and increase of resistance and sustainability of forest stands, as well as decrease in recreational load and creation of forest plantations for prevention of degradation of forest lands.

Development of the system of activities for preservation of plants of natural origin and biological diversity during reforestation, afforestation and forest use.

The analysis of assigned and conducted final cuttings has shown that clear cuttings prevail among final cuttings (more than 70%). Among the selected final cuttings, stripe-gradual cuttings, which are very similar to previously used narrow-stripe ones, become more and more widespread.

Ground vegetation is often destroyed during final cuttings – only in 60% of cutting sites it is damaged in less than 10% of the area. In some sites (10%) in non-bog forest types ground vegetation is destroyed on more than 50% of the area. At the same time, successful restoration of the cover is registered in more than 60% of sites, including those where forest plantings have been done. Only in 12% of examined cutting sites more than 10 trees of first canopy layer per hectare were left in order to preserve biological diversity. Only in 10% of cutting sites, remains of coarse woody debris, which are a required substrate for the growth of a range of insect species, have been registered.

In all non-bog forest types, artificial reforestation is preferred in cutting sites. Cutting sites left for natural reforestation account for 4% in *pleuroziosum* and 58% in *oxalidosum* forest types. Only in over-moistened forest types all the cutting sites are left for natural reforestation.

Taking into account the peculiarities of different types of cutting and reforestation technologies, a system of activities for preservation of biological diversity when carrying out activities has been developed. It is based on the documents regulating forest management and has its own features, including the following:

- a list of main species used for reforestation and afforestation and a list of species to be cut down during thinning have been developed for every geobotanical region;
- restrictions on reforestation and afforestation with invasive and introduced tree and shrub species have been developed;
- six categories of forest plantings sites (instead of five) have been suggested – separating such areas as former agricultural sites, open pits, etc.;
- forest structure recommendations have been developed with taking into account TSC and category of forest reforestation site for every geobotanical zone;
- full cycle of forest management activities is recommended to be planned before the final cutting for the whole cutting cycle (up to 80-100 years);
- target stands compositions have been developed with taking into account forest type for every geobotanical zone;
- main directions of forest management for mainTSC have been developed with taking into account natural successions;

criteria (pcs/ha or m^3) have been developed for preservation of different elements of biological diversity in cutting sites such as seed trees, broadleaved species, big trees with hollows, died trees.

Currently, some of the developed activities on preservation of biological diversity are defined by forest management documents: the Forest Code of the Republic of Belarus, the Cutting Rules in the Republic of Belarus, in particular – prohibition of clear final cuttings in protected forests, criteria for some biological diversity elements to be left during cuttings, enlargement of non-continuous cuttings, creation of mixed forest stands.

Development and implementation of special monitoring of the results of forestry activities on forest growth of high productivity, sustainability and biodiversity during land use planning

Based on the analysis of a typical form of forest management project and the projects carried out in some forestry enterprises, it was determined that forest stability, productivity and biodiversity monitoring data are very well represented there, in particular:

Biological diversity:

- assessment of forest biological diversity;
- stands distribution by dominant species and age groups;
- stands distribution by forest types;
- stands distribution by types of soil conditions;
- bog forest distribution by bog types and dominant species;
- characteristics of natural reforestation on non-forest-covered lands;
- characteristics of young growth under the canopy of pre-mature, mature and over-mature stands;
- analysis of hardwood stands reproduction;
- forest division by category;
- forest division as of its ecological, economic and social significance;
- specially protected nature areas;
- habitats of protected plant and animal species;
- typical and rare landscapes and biotopes;
- forest plots of restricted forest use;

Productivity:

- stands distribution by bonitet class;
- stands distribution by density;
- wood stock by dominant species;
- dynamics of average forest stands attributes;
- total stock of phytomass and carbon accumulation;

Stability:

- stands distribution by biological stability categories;
- forest stands condition;
- data on forest fires;
- forestry enterprise territory distribution by fire danger categories;
- sanitary condition of forests and activities for their pest and illness protection;
- assessment of forest maintenance effectiveness.

At the same time there is a range of gaps in aggregated data not allowing to fully assess the changes in forest species and age structure, its productivity, stability and biological diversity. Thus, new forms (tables) have been designed and added to the standard form of the explanatory note (is currently being approved by the Ministry of Forestry):

- dynamics of forest death during the previous project;
- distribution of forest-covered lands and stands stock by age categories and dominant species;
- dynamics of specially protected nature areas;
- dynamics of habitats of protected plant and animal species listed in the Red Book of the Republic of Belarus and transferred into protection of forestry enterprises;
- dynamics of typical and rare landscapes and biotopes transferred into protection of forestry enterprise.

The data represented in such forms allow to objectively assess the effectiveness of forest management activities on preservation and increase of forest biological diversity, productivity and stability. This will allow developing forest management plans taking into account changes in place, define and review wrong decisions made during the previous revision period. This, this will promote preservation and strengthening of environment-making, water-protective, protective, sanitary, recreational and other forest functions.

1. Inventory and preparation of specifications and security obligations on the rare and typical biotopes, habitats of wild animals and wild plants belonging to the species included in the red book of the Republic of Belarus, and development of the proposals for improvements to be made to the forest management activities plans

The updated version of “Law on Protection of Environment” No. 18-3 dated January 22, 2013 contains a concept “rare and typical biotopes under special protection”, and also identifies main attitudes to their protection. These biotopes were picked out according to the list of biotopes of Annex 1 of Directive on habitats of the Bern convention (Natura 2000 biotopes). Interpretation manual of European Union habitats was used as a guide for identification. Monograph on biotopes, included in Annex 1 of Directive on protection of natural biotopes, wild animal and plant species that are found in the territory of Belarus, was published in 2013 (Belarus’ rare biotopies / Puhacheuski A.V. (eds.) et al. Minsk, 2013. – 236 p. (in Russian)).

Rare biotopes are the natural and semi-natural (partly transformed or created by human, but with natural vegetation) biotopes, which due to their natural characteristics are unique for the country’s territory: areas with relict flora and fauna, azonal, with specific landscape forms, soil, hydrochemical regime etc.; are situated on the area not larger than 1% of the country’s area (“Law on Protection of Environment” No.18-3).

Typical biotopes are natural and semi-natural biotopes, which are widely spread over the country and reflect the most typical characteristics of natural zones, but due to management or changes in land tenure are being transformed or have tendency to lose their area (“Law on Protection of Environment” No.18-3).

The updated version of Forest Code of The Republic of Belarus (dated January 1, 2017) has a concept “typical and rare biotopes”. According to Article 16 of the Code:

“1. In compliance with ecological, economical and social meaning of forests, their location and functions, forests are divided by the next categories:

1.1 Conservation forests;…

2. Conservation forests include:

2.1 Forests located in the boundaries of SPA

2.2 Forests located in the boundaries of habitats of wild animals and plants included in the Red Book of Belarus that are protected by land and/or water users, in order prescribed by the Council of Ministers.”

Thereby, identification of typical and rare biotopes, of protected wild animals’ and plants’ habitats in the territory of forest fund and their registration in forest management projects are a valid solution within the framework of legislation in Belarus.

The following tasks were completed during the implementation of the project:

1. Forest management materials of SFE “Klichevsky leskhoz”, SFE “Gluboksky opytny leskhoz”, SFE “Tolochinsky leskhoz”, and SFE “Bogushevsky leskhoz”were analyzed. Potential areas, where forest and other management limitations are needed, were selected.

The following criteria were used for the selection:

Biotope 6.1 (# by TCEP 17/12-06-2014 (02120)) – Western taiga:

Pine forests: *Pinetum callunosum, P.vacciniosum, P.pleuroziosum, P.pteridiosum, P.oxalidosum, P.myrtillosum, P.polytrichosum* forest types not less than 95 years old or *P.fontinale-herbosum* not less than 80 years old;

Spruce forests: *Piceetum vacciniosum* not less than 80 years old, P.*pleuriziosum, P.oxalidosum, P.pteridiosum, P.myrtillosum, P.polytrichosum* not less than 95 years old;

Birch forests: *Betuletum pleuroziosum, B.pteridiosum, B.oxalidosum, B.myrtillosum, B.polytrichosum, B.fontinale-herbosum* not less than 70 years old;

Aspen forests: *Tremuletum pleuroziosum, T.oxalidosum, T.pteridiosum, T.myrtillosum* not less than 70 years old.

Biotope 6.2 – South taiga and sub-taiga broad-leaved forests with spruce and hornbeam:

Oak forests: *Querceta oxalidosum, Q.aegopodiosum, Q.urticosum, Q.pteridiosum* not less than 95 years old;

Ash forests: *Fraxineta oxalidosum, F.aegopodiosum, F.urticosum, F.pteridiosum* not less than 70 years old;

Lime forests: *Tilietum oxalidosum, T.aegopodiosum, T.urticosum, T.pteridiosum* not less than 70 years old;

Maple forests: *Aceretum oxalidosum, A.aegopodiosum, A.urticosum, A.pteridiosum* not less than 70 years old.

Biotope 6.3 – Herb-rich spruce forests:

Spruce forests: *Piceetum oxalidosum* not less than 95 years old, *P.aegopodiosum, P.urticosum, P.pteridiosum, P.fontinale-herbosum* not less than 80 years old;

Aspen forests: *Tremuleta oxalidosum* not less than 70 years old, *T.aegopodiosum, T.urticosum, T.pteridiosum, T.fortinale-herbosum* not less than 60 years old;

Black alder forests: *Glutinoso-alnetum oxalidosum* not less than 70 years old, *G.aegopodiosum, G.urticosum, G.pteridiosum, G.fortinale-herbosum* not less than 60 years old;

Birch forests: *Betuletum fortinale-herbosum* not less than 60 years old.

Biotope 6.6 – Black alder and birch forests on excessively moist soils or in swamps:

Black alder forests: *Glutinoso-alnetum pteridiosum, G.thelypteridosum, G.filipendulosum, G.caricosum, G.salicosum* not less than 70 years old;

Birch forests: *Betuletum thelypteridosum, B.caricoso-herbosum, B.salicosum* not less than 70 years old.

Biotope 6.8 – Coniferous and birch mire forests:

Pine forests: *Pinetum ledosum, P. sphagnosum not less than 110 years old, P.caricoso-sphagnosum* not less than 100 years old;

Spruce forests: *Peceetum caricoso-sphagnosum* not less than 50 years old;

Birch forests: *Betuletum caricoso-sphagnosum, B.erioforioso-sphagnosum* not less than 70 years old.

Biotope 6.9 – Deciduous forest in river valleys:

Ash forests: *Fraxinetum urticosum, F. filipendulosum* not less than 60 years old;

Black alder forests: *Glutinoso-alnetum urticosum, G.filipendulosum, G.caricosum, G.thelypteridosum* not less than 60 years old.

Biotope 6.10 – Flood plain oak forests:

Oak forests: *Querceta fluvialis, Q.subalveto-fluvialis, Q.nemoroso-fluvialis, Q.graminoso-fkuvialis, Alneto-Quercetum fluvialis, Fraxineto-Quercetum fluvialis* not less than 50 years old.

Biotope 6.11 – Pine forests: *Pinetum cladinosum*: not less than 60 years old.

During the preliminary selection the next concourses were used: space images, topographic and other theme maps, materials of scientific researches.

2. Field research was conducted on the territory of Klichev, Glubokoe, Tolochin and Bogushev Forestry Enterprises. As a result, areas of forest fund, which need special protection according to the updated Forest Code (Article 16), were identified;

3. Specifications and Security Obligations on rare and typical biotopes, Red Book wild animals' and plants' habitats were prepared: Klichev SFE – 46 Security Obligations (1026,5 ha); Tolochin SFE – 77 (812,8 ha); Bogushevsk SFE – 51 (727,7 ha); Glubokoe SFE – 82 (1218,0 ha) (tables 1.1-1.4, figures. 1.1-1.4).

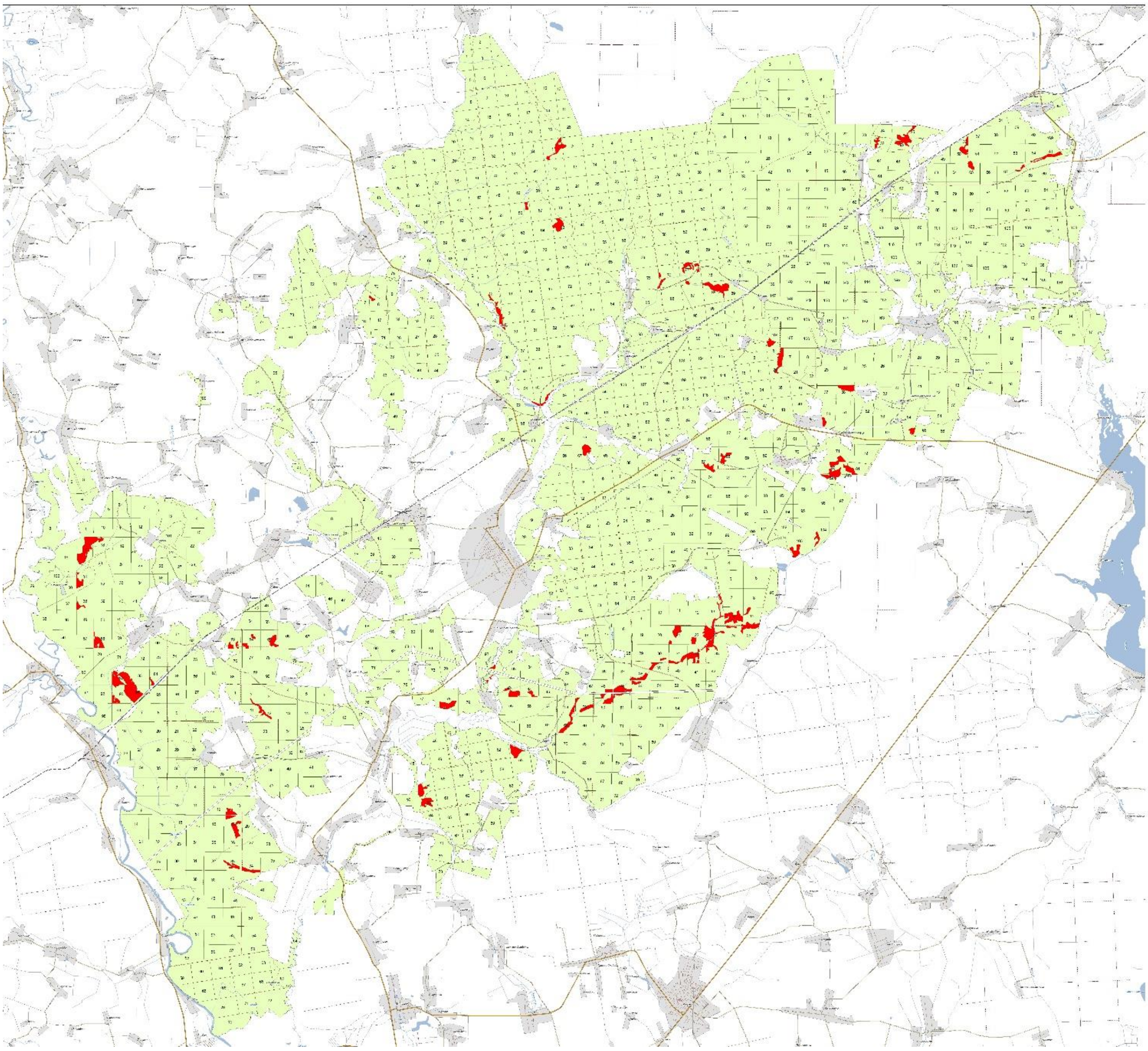

Figure 1.1 – Distridution of designated rare and typical biotops in SFE “Klichevsky leskhoz”

Table 1.1 – Rare and typical biotopes, habitats of protected plants, which have titles of protection, and area under protection in the territory of SFE “Klichevsky leskhoz”

Biotope Species name	Area, ha	Square/site	Number of specifications
Virkovskoye forestry department			
Western taiga	15.5	Square 17 (sites 20-22, 31, 32)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	5.0	Square 58 (site 24)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	19.9	Square 63 (sites 8,10), sq. 64 (12,18)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	6.0	Square 17 (site 10)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	3.8	Square 84(site 30)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	17.3	Square 65 (site 19)	1
Herb-rich spruce forests	18.5	Square 17 (site 9), sq.	1

Biotope Species name	Area, ha	Square/site	Number of specifications
		18 (1)	
Black alder and birch forests on overmoistened soils and swamps	21.8	Square 58 (sites 22, 25, 26, 27)	1
Black alder and birch forests on overmoistened soils and swamps	94.9	Square 82 (sites 10, 11, 15, 22), sq. 83 (32), sq. 93 (3, 5, 7, 24, 31, 39),sq. 94 (1, 22)	1
Total	**202.7**		**9**
Biordovskoye forestry department			
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	5.5	Square 15 (site 2)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	41.2	Square 14 (sites 8-11,15,16,29,30)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	12.7	Square 49 (sites 10,14,15,18)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	8.4	Square 22 (site 19)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	18.5	Square 21 (site 3)	1
Herb-rich spruce forests	7.0	Square 44 (site 28)	1
Black alder and birch forests on overmoistened soils and swamps	43.5	Square 14 (sites 19,20,22,23), sq. 15 (21-23), sq. 24 (2-6), sq.25 (1,14)	1
Black alder and birch forests on overmoistened soils and swamps	18.0	Square 43 (site 45)	1
Decidous forests in river valleys	72.5	Square 37 (site36), sq. 38 (31,33), sq. 48 (19,20) sq. 49 (3-5,7-9,12,13), sq. 50 (1,5), sq.60 (6)	1
Decidous forests in river valleys	45.5	Square 58 (sites 19, 27), sq. 59 (2, 16, 21), sq. 68 (7, 31)	1
Decidous forests in river valleys	2.7	Square 38 (site 15), sq. 39 (2, 14)	1
Decidous forests in river valleys	5.6	Square 39 (sites 3, 55)	1
Nemoral broad-leaved forests with hornbeam	2.6	Square 30 (site 19)	1
Dentaria bulbifera *Allium ursinum* *Listera ovata* *Platanthera chlorantha* *Neckera pennata*	31.1	Square 22 (sites 7, 11), sq. 23 (2, 7, 10)	1
Total	**314.8**		**14**
Usakinskoye forestry department			
Decidous forests in river valleys	21.9	Square 88 (sites 2-4, 9, 14, 21, 24), sq. 89 (9-11)	1
Decidous forests in river valleys	5.0	Square 75 (site 77), sq. 76 (35)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	1.1	Square 75 (sites 78, 82)	1
South taiga and sub-taiga broad-leaved for-	3.9	Square 76 (sites 9, 10,	1

Biotope Species name	Area, ha	Square/site	Number of specifications
ests with spruce and hornbeam		23)	
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	26.0	Square 77 (sites 4, 11, 12, 14, 16, 18, 21, 23, 30, 34, 54, 60, 68)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	25.7	Square 87 (sites 31, 40, 44, 49), sq. 88 (36, 38, 41)	1
Total	**83.6**		**6**
Gonchanskoye forestry department			
Herb-rich spruce forests	20.1	Square 87 (sites 31, 40, 44, 49), sq. 88 (36, 38, 41)	1
Black alder and birch forests on overmoistened soils and swamps	110.9	Square 71 (site 38), sq. 80 (3-5, 8, 9, 12-15), sq. 81 (1, 13), sq. 82 (2-6)	1
Black alder and birch forests on overmoistened soils and swamps	27.4	Square 67 (sites 33, 44, 45, 50, 51), sq. 68 (21, 22)	1
Black alder and birch forests on overmoistened soils and swamps	43.3	Square 4 (site 41), sq. 6 (2, 27), sq. 7 (1), sq. 20 (4, 5, 12)	1
Nemoral broad-leaved forests with hornbeam	8.1	Square 64 (site 48)	1
Dentaria bulbifera *Festuca altissima* *Neckera pennata*	21.2	Square 38 (site 2-9)	1
Total	**231.0**		**6**
Bacevichskoye forestry department			
Black alder and birch forests on overmoistened soils and swamps	26.7	Square 53 (sites 2, 60)	1
Total	26.7		1
Zapolskoye forestry department			
Black alder and birch forests on overmoistened soils and swamps	14.3	Square 34 (site 19)	1
Coniferous and birch forests on mires	43.4	Square 13 (site 31), sq. 19 (2, 16, 18), sq. 26 (5)	1
Total	57.7		2
Potokskoye forestry department			
Coniferous and birch forests on mires	19.8	Square 65 (site 46), sq. 67 (6)	1
Total	19.8		1
Dolgovskoye forestry department			
Spruce forests with reach grassy flora	8.1	Square 32 (sites 4, 20)	1
Spruce forests with reach grassy flora	2.8	Square 25 (site 54)	1
West taiga	18.9	Square 33 (sites 15-19, 26, 33, 47, 54, 55)	1
West taiga	21.0	Square 36 (sites 4, 6), sq. 37 (12), sq. 50 (3, 7, 9, 12)	1
Coniferous and birch forests on mires	10.0	Square 51 (site 39), sq. 65 (5)	1
Total	60.8		5

Biotope Species name	Area, ha	Square/site	Number of specifications
Klichevskoye forestry department			
Black alder and birch forests on overmois-tened soils and swamps	15.3	Square 77 (sites 57,58), sq. 78 (36,37)	1
Western taiga	14.1	Square 77 (site 66), sq. 78 (34)	1
Total	29.4		2
Total in the enterprise	1026.5		46

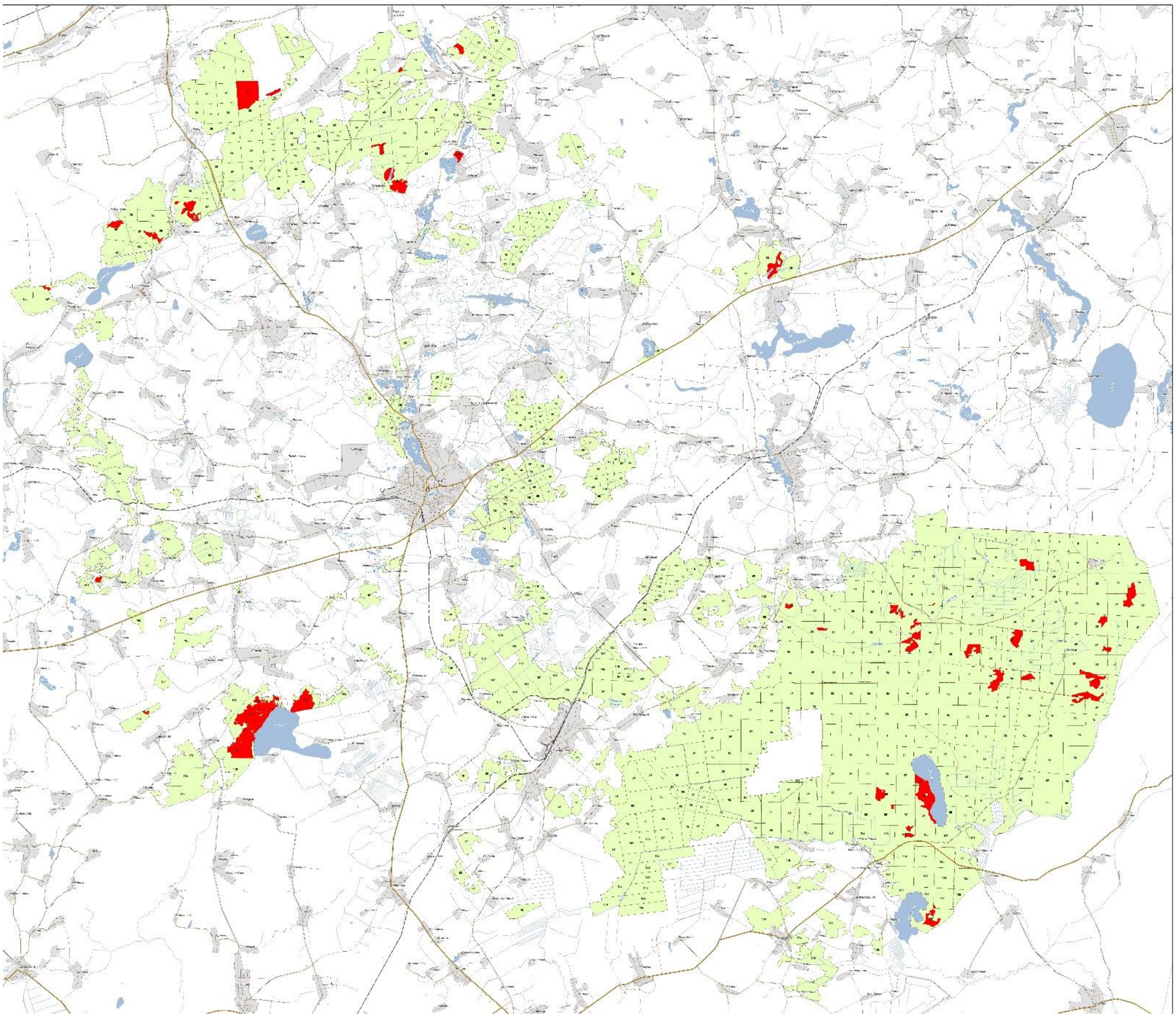

Figure 1.2 – Distridution of designated rare and typical biotops in SFE “Gluboksky opytny leskhoz”

Table 1.2 – Rare and typical biotopes, habitats of protected plants, which have titles of protection, and area under protection in the territory of SFE “Gluboksky opytny leskhoz”

Biotope Species name	Area, ha	Square/site	Number of specifications
Lipovskoye forestry department			
Western taiga	31.5	Square 24 (site 13, 19), sq. 31 (21), sq. 32 (1, 11, 42, 43)	1
Western taiga	7.2	Square 65 (site 7)	1
Western taiga	15.5	Square 60 (sites 14, 15)	1
Coniferous and birch forests on mires Salix myrtilloides Moneses uniflora	4.1	Square 38 (site 8)	3
Coniferous and birch forests on mires	7.5	Square 46 (sites 28, 35), sq. 47 (23)	1
Coniferous and birch forests on mires	30.8	Square 59 (site 25), sq. 60 (32)	1
Coniferous and birch forests on mires	26.6	Square 52 (site 31), sq. 53 (24), sq. 60 (1)	1
Aquila pomarina	8.2	Square 11 (sites 14, 15, 17)	1
Pandion haliaetus	30.5	Square 42 (site 6)	1
Huperzia selago *Carex paupercula*	4.4	Square 31 (site 32)	2
Huperzia selago *Salix myrtilloides* *Moneses uniflora*	3.2	Square 39 (site 2)	3
Huperzia selago *Carex paupercula*	1.7	Square 39 (site 4)	2
Huperzia selago	1.4	Square 60 (site 7)	1
Salix myrtilloides *Moneses uniflora*	2.6	Square 39 (site 1)	2
Listera ovata	2.3	Square 41 (site 30)	1
Total	**177.9**		**22**
Tumilovichskoye forestry department			
Coniferous and birch forests on mires	177.9	Square 1 (sites 2, 3), sq. 2 (2-7), sq. 10 (2, 4), sq. 11 (1, 2, 5, 6)	1
Coniferous and birch forests on mires	127.0	Square 33 (sites 2-4), sq. 34 (2, 6), sq. 53 (1, 4, 7, 20), sq. 54 (1-6, 8-12, 15-17), sq. 55 (1-3, 5-7, 9-16, 18	1
Western taiga	4.1	Square 54 (site 14), sq. 55 (19)	1
Western taiga	26.9	Square 129 (sites 25, 28, 35, 36, 60)	1
Western taiga	29.8	Square 28 (sites 7-10, 16, 17, 21)	1
Western taiga	67.6	Square 54 (sites 13, 14), sq. 55 (17, 19-23), sq. 56 (8, 14, 20, 21), sq. 86 (6)	1
Western taiga	12.6	Square 104 (sites 7, 9, 34, 40)	1

Biotope Species name	Area, ha	Square/site	Number of specifications
Western taiga	1.5	Square 127 (sites 30, 32)	1
Black alder and birch forests on overmoistened soils and swamps	16.4	Square 28 (sites 11, 18, 22, 23)	1
Black alder and birch forests on overmoistened soils and swamps	8.7	Square 129 (sites 14, 20)	1
Total	**472.5**		**10**
Uzrechskoye forestry department			
Western taiga	2.1	Square 87 (sites 17, 67)	1
Western taiga	13.5	Square 103 (sites 1-4, 7, 10-14)	1
Black alder and birch forests on overmoistened soils and swamps	9.1	Square 96 (sites 7, 8, 10, 45)	1
Black alder and birch forests on overmoistened soils and swamps	5.9	Square 96 (site 4)	1
Black alder and birch forests on overmoistened soils and swamps	39.7	Square 95 (sites 17, 29)	1
Black alder and birch forests on overmoistened soils and swamps	4.3	Square 107 (site 4)	1
Meles meles	14.9	Square 97 (site 20), sq. 98 (23, 24, 33, 38)	1
Meles meles	33.8	Square 87 (sites 23, 24, 32, 36)	1
Meles meles	2.7	Square 33 (site 2)	1
Meles meles	10.6	Square 20 (sites 3, 4, 6, 9, 12, 13)	1
Grus grus	11.6	Square 76 (sites 6, 15, 30)	1
Oeneis jutta *Oxycoccus microcarpus*	87.3	Square 14 (site 1)	2
Brachytron pretense	23.6	Square 91 (sites 23, 25)	1
Trollius europaeus	3.1	Square 59 (site 20)	1
Trollius europaeus	0.3	Square 75 (site 3)	1
Huperzia selago	6.4	Square 107 (site 1)	1
Huperzia selago	6.3	Square 107 (site 32)	1
Betula nana	4.8	Square 86 (site 1)	1
Salix myrtilloides *Corallorhiza trifida* *Baeothryon alpinum* *Eriophorum gracile* *Hammarbya paludosa*	8.4	Square 91 (site 23)	5
Salix myrtilloides	12.8	Square 93 (site 2)	1
Listera ovata	1.6	Square 107 (site 28)	1
Total	**302.8**		**26**
Golubichskoye forestry department			
Western taiga	6.2	Square 34 (site 9)	1
Western taiga	4.7	Square 29 (sites 23,24), sq. 30 (27)	1
Western taiga	5.8	Square 103 (sites 36, 46)	1
Western taiga	21.6	Square 42 (sites 15, 2224, 30, 45, 46), sq.	1

Biotope Species name	Area, ha	Square/site	Number of specifications
		43 (11, 13, 20)	
Black alder and birch forests on overmoistened soils and swamps	2.2	Square 25 (site 45)	1
Black alder and birch forests on overmoistened soils and swamps	29.4	Square 46 (sites 5-8, 12)	1
Black alder and birch forests on overmoistened soils and swamps	38.0	Square 15 (sites 46, 33), sq. 24 (9, 14, 15, 28), sq. 25 (29, 35)	1
Black alder and birch forests on overmoistened soils and swamps *Botaurus stellaris*	64.4	Square 42 (sites 4, 5, 8, 12-14, 59), sq. 43 (1, 4-6, 10, 12, 14, 21-27) Square 43 (site 6)	2
Botaurus stellaris	34.4	Square 34 (site 43), sq. 43 (7)	1
Strix uralensis	0.9	Square 17 (site 54)	1
Total	**207.6**		**11**
Glubokskoye forestry department			
Forests in ravines and on steep slopes along rivers and around lakes *Carex rhizina*	7.5	Square 25 (sites 2, 4)	2
Forests in ravines and on steep slopes along rivers and around lakes *Alcedo atthis* *Carex rhizina*	12.4	Square 24 (sites 36-38, 42) Square 24 (sites 36, 37, 42)	3
Meles meles	6.3	Square 101 (sites 23, 24, 49)	1
Meles meles	2.8	Square 165 (site 16)	1
Alcedo atthis *Carex rhizina*	16.1	Square 24 (sites 25, 31)	2
Huperzia selago	3.0	Square 25 (site 27)	1
Carex rhizina	3.9	Square 25 (site 19)	1
Carex rhizina	2.8	Square 25 (site 26)	1
Carex rhizina	2.8	Square 25 (site 34)	1
Total	**57.6**		**13**
Total in the enterprise	**1218.0**		**82**

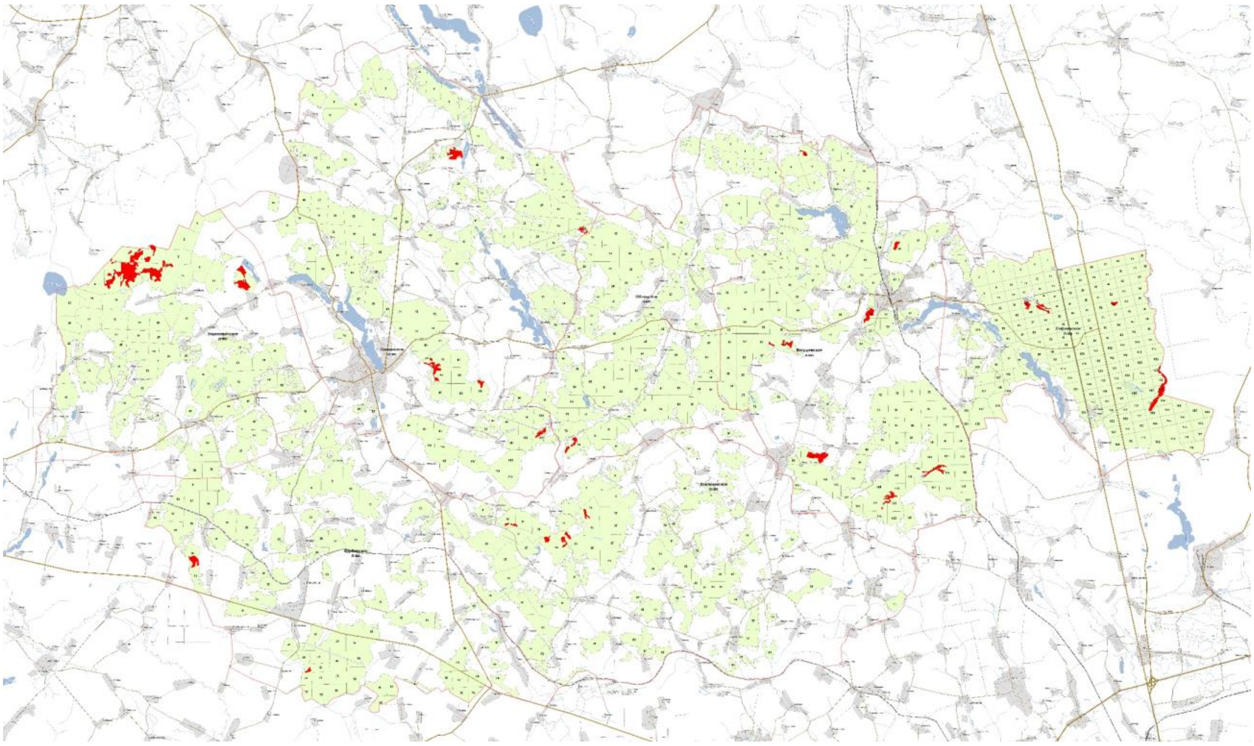

Figure 1.3 – Distridution of designated rare and typical biotops in SFE “Bogushevsky leskhoz”

Table 1.3 – Rare and typical biotopes, habitats of protected plants, which have titles of protection, and area under protection in the territory of SFE “Bogushevsky leskhoz”

Biotope Species name	Area, ha	Square/site	Number of specifications
Bogushevskoye forestry department			
Western taiga	2.4	Square 123 (site 51)	1
Western taiga	13.3	Square 64 (sites 11, 16, 17, 18, 29, 33)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam Muscardinus avellanarius	44.7 And also 12.0	Square 91 (sites 6-9, 12, 33) Square 91 (sites 8, 9)	2
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam Aquila pomarina	5.8	Square 1 (site 34)	2
Herb-rich spruce forests *Glaucidium passerinum* *Dendrocopos leucotos*	25.9 And also 11.7 3.4	Square 50 (sites 10, 13, 14, 17, 31), sq. 58 (1, 4) Square 50 (site 10) Square 50 (site 13)	3
Herb-rich spruce forests	2.0	Square 122 (site 6), sq. 123 (1, 5)	1
Black alder and birch forests on overmoistened soils and swamps	6.4	Square 110 (site 25), sq. 122 (29, 35, 36)	1
Black alder and birch forests on overmoistened soils and swamps *Dendrocopos leucotos*	10.0	Square 29 (site 23)	2
Black alder and birch forests on overmoistened soils and swamps	10.7	Square 64 (sites 19, 20, 24, 28)	1
Decidous forests in river valleys	17.0	Square 113 (sites 9,	1

Biotope Species name	Area, ha	Square/site	Number of specifications
		10), sq. 114 (1, 3)	
Decidous forests in river valleys	6.8	Square 110 (site 30), sq. 122 (29, 37), sq. 123 (6)	1
Total	**145.0**		**16**
Burbinskoye forestry department			
Black alder and birch forests on overmoistened soils and swamps	24.5	Square 24 (site 11)	1
Total	**24.5**		**1**
Kokovchinskoye forestry department			
Western taiga	10.2	Square 14 (site 23), sq. 16 (3)	1
Western taiga	13.0	Square 13 (sites 57, 62, 65), sq. 24 (42, 43, 110), sq. 25 (3, 4)	1
Herb-rich spruce forests	6.3	Square 10 (sites 38, 39), sq. 11 (21)	1
Herb-rich spruce forests	9.0	Square 24 (sites 6, 108)	1
Black alder and birch forests on overmoistened soils and swamps	5.3	Square 24 (sites 62, 111, 112)	1
Decidous forests in river valleys *Grus grus*	3.9	Square 25 (site 10)	2
Lunaria rediviva	9.9	Square 21 (sites 7, 8, 11)	1
Total	**57.6**		**8**
Sofievskoye forestry department			
Western taiga	21.6	Square 36 (sites 6, 7, 14, 17), sq. 47 (1, 2, 4, 11, 12, 14, 21)	1
Decidous forests in river valleys	20.1	Square 153 (sites 10, 11, 13), sq. 154 (2), sq. 158 (3)	1
Decidous forests in river valleys	32.3	Square 135 (sites 6,12), sq. 142 (5), sq. 148 (3, 4, 9)	1
Strix nebulosa	16.7	Square 134 (sites 20, 21), sq. 141 (9-11)	1
Total	**90.7**		**4**
Obolskoye forestry department			
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	5.6	Square 74 (sites 27, 28	1
Total	5.6		1
Ulyanovichskoye forestry department			
Western taiga	8.4	Square 8 (sites 9, 14)	1
Western taiga	28.9	Square 3 (sites 2, 6, 9, 15)	1
Western taiga *Grus grus*	9.0	Square 4 (sites 21, 23)	1
Spruce forests with reach grassy flora	7.9	Square 8 (site 20)	2
Spruce forests with reach grassy flora	16.7	Square 12 (sites 2, 5)	1
Spruce forests with reach grassy flora *Strix nebulosa*	5.0	Square 4 (sites 26, 27), sq. 9 (4)	2
Black alder and birch forests on overmois-	18.1.	Square 7 (sites 16, 23,	3

Biotope Species name	Area, ha	Square/site	Number of specifications
tened soils and swamps *Aquila pomarina* *Dendrocopos leucotos*	And also 9.4 28.9	28, 32), sq. 8 (1, 4, 6, 8, 15, 35), sq. 9 (9, 13) Square 7 (site 16) Square 8 (site 1)	
Black alder and birch forests on overmoistened soils and swamps	10.4	Square 4 (sites 2, 4, 7, 34)	1
Grus grus	29.5	Square 5 (site 13)	1
Glaucidium passerinum	4.6	Square 10 (sites 40, 50)	1
Aquila pomarina	13.1	Square 7 (site 10)	1
Total	311.6		15
Sennenskoye forestry department			
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam *Aquila pomarina* *Muscardinus avellanarius*	38.5. And also 16.1 9.6	Square 17 (sites 7, 16-19, 22) Square 17 (sites 17, 18) Square 17 (site 16)	3
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	8.9	Square 89 (sites 2, 3)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	39.8	Square 82 (sites 18, 19, 22, 23), sq. 83 (15, 16), sq. 85 (2, 11)	1
Allium ursinum	5.5	Square 74 (site 32)	1
Total	**92.7**		**6**
Total in the enterprise	**727.7**		**51**

Table 1.4 – Rare and typical biotopes, habitats of protected plants and animals, which have titles of protection, and area under protection in the territory of SFE “Tolochinsky leskhoz” (among the habitats of protected species are also mentioned those habitats that were put under protection in CY 2016 on the basis of the survey of the NGO "APB-BirdLife Belarus")

Biotope Species name	Area, ha	Square/site	Number of specifications
Volosovskoye forestry department			
Western taiga	6.8	Square 194 (site 8)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	5.8	Square 166 (site 11), sq. 179 (4), sq. 196 (7)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	28.9	Square 18 (sites 1, 2), sq. 20 (3)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	5.8	Square 8 (site 12)	1
Coniferous and birch forests on mires	13.9	Square 193 (site 6), sq. 194 (1)	1
Neckera pennata *Festuca altissima*	23.2	Square 185 (site 3), sq. 186 (1, 3, 6)	2
Neckera pennata *Lathyrus laevigatus*	8.3	Square 142 (site 5), sq. 155 (2)	2
Dendrocopos leucotos	15.8	Square 7 (sites 10, 11)	1
Dendrocopos leucotos	10.8	Square 8 (site 3)	1
Meles meles	26.1	Square 90 (sites 6, 9, 12), sq. 91 (6, 7), sq. 128 (1, 2)	1

Biotope Species name	Area, ha	Square/site	Number of specifications
Meles meles *Glaucidium passerinum* *Dendrocopos leucotos*	49.9	Square 84 (sites 5, 9, 10), sq. 85 (5-8), sq. 89 (3-6), sq. 90 (1, 2, 7, 8, 10) Square 90 (site 10) Square 84 (site 9) Square 90 (site 10)	3
Meles meles *Dendrocopos leucotos* *Dendrocopos leucotos*	61.5	Square 100 (site 5), sq. 101 (6, 8, 9, 10), sq. 107 (2), sq. 108 (1) Square 100 (site 5) Square 107 (site 2)	3
Meles meles *Dendrocopos leucotos*	2.7	Square 100 (site 6)	2
Glaucidium passerinum *Meles meles*	9.5	Square 83 (sites 6, 7), sq. 84 (7, 8) Square 84 (site 8)	2
Dendrocopos leucotos *Meles meles*	14.6	Square 90 (site 11), sq. 127 (2, 3, 5) Square 127 (site a 3, 5)	2
Glaucidium passerinum	15.0	Square 83 (site 5), sq. 84 (1, 2)	1
Glaucidium passerinum	28.5	Square 139 (site 3), sq. 140 (1,5)	1
Bubo bubo	32.3	Square 23 (sites 10-13), sq. 24 (4, 14-20	1
Total	**359.4**		**27**
Kohanovskoye forestry department			
Western taiga	41.2	Square 196 (site 7), sq. 202 (1, 4), sq. 214 (10), sq. 215 (4, 7)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	14.8	Square 227 (site 6), sq. 231 (3, 5, 7)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	36.6	Square 268 (site 5), sq. 273 (3, 6), sq. 274 (1)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	24.5	Square 255 (sites 1, 4)	1
Herb-rich spruce forests	1.2	Square 231 (site 1)	1
Herb-rich spruce forests	13.9	Square 270 (sites 1, 6, 7)	1
Dendrocopos leucotos	11.3	Square 259 (site 4, 5), sq. 260 (1, 2)	1
Dendrocopos leucotos	10.8	Square 271 (sites 2-4)	1
Grus grus	5.1	Square 260 (site 4), sq. 261 (1)	1
Total	**149.4**		**9**
Oboleckoye forestry department			
Western taiga	8.5	Square 225 (sites 3, 10, 11)	1
Herb-rich spruce forests	13.5	Square 231 (site 1), sq. 232 (8)	1
Black alder and birch forests on overmois-	10.9	Square 190 (site 4),	1

Biotope Species name	Area, ha	Square/site	Number of specifications
tened soils and swamps		sq. 191 (1), sq. 225 (4, 9)	
Total	**32.9**		**3**
Ozereckoye forestry department			
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	43.8	Square 177 (sites 8, 9), sq. 178 (2, 7), sq. 182 (3)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	2.9	Square 253 (sites 4, 9)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	1.5	Square 246 (site 21)	1
South taiga and sub-taiga broad-leaved forests with spruce and hornbeam	1.2	Square 250 (site 9)	1
Western taiga	0.5	Square 178 (site 14)	1
Coniferous and birch forests on mires	3.1	Square 250 (site 12), sq. 251 (6), sq. 261 (6), sq. 262 (1)	1
Dendrocopos leucotos	23.0	Square 191 (site 20), sq. 192 (12), sq. 193 (20)	1
Dendrocopos leucotos	18.9	Square 189 (site 22)	1
Neckera pennata	29.2	Square 17 (sites 4-7, 12, 13), sq. 18 (1, 2, 4), sq. 19 (1, 2)	1
Cephalanthera longifolia	11.8	Square 19 (sites 3-6	1
Total	**151.7**		**10**
Slavnovskoye forestry department			
Western taiga	10.0	Square 169 (site 10), sq. 183 (3), sq. 199 (3-5, 7)	1
Western taiga	10.9	Square 185 (sites 5-8)	1
Coniferous and birch forests on mires	24.8	Square 169 (sites 7, 8), sq. 183 (6, 10), sq. 185 (9), sq. 199 (6, 12)	1
Total	**45.7**		**3**
Tolochinskoye forestry department			
Lathyrus laevigatus	4.7	Square 62 (sites 2, 10)	1
Huperzia selago	2.7	Square 62 (site 6)	1
Lunaria rediviva	4.7	Square 53 (site 20), sq. 69 (4)	1
Dendrocopos leucotos *Lunaria rediviva*	3.5	Square 102 (site 5), sq. 103 (7, 17) Square 103 (site 17)	2
Dendrocopos leucotos	7.4	Square 133 (site 4)	1
Dendrocopos leucotos	5.6	Square 69 (site 27), sq. 82 (4)	1
Picoides tridactylus	3.8	Square 91 (sites 9, 10, 14, 15)	1
Picoides tridactylus *Huperzia selago*	8.6	Square 134 (sites 4, 8, 10, 11)	2
Huperzia selago	4.6	Square 132 (sites 1, 5)	1
Huperzia selago	2.7	Square 133 (site 6)	1
Huperzia selago	0.5	Square 134 (site 27)	1

Biotope Species name	Area, ha	Square/site	Number of specifications
Huperzia selago	2.8	Square 121 (sites 2, 9)	1
Huperzia selago *Lunaria rediviva*	5.0	Square 132 (sites 3, 4)	2
Huperzia selago	3.2	Square 82 (sites 13, 14, 23, 30, 33)	1
Huperzia selago	1.3	Square 106 (site 5)	1
Lunaria rediviva	6.6	Square 82 (site 12)	1
Dendrocopos leucotos *Lunaria rediviva*	2.7	Square 103 (site 12)	2
Lunaria rediviva	1.0	Square 119 (site 11)	1
Huperzia selago *Lunaria rediviva*	1.7	Square 120 (site 16)	2
Lunaria rediviva	0.6	Square 120 (site 17)	1
Total	**73.7**		**25**
Total in the enterprise	**812.8**		**77**

Table 1.5 – Total amount of documents of protection and area, which is given under protection

Land user	Number of specifications	Area under protection	
		ha	% of forest fund (out of SPA)
SFE “Klichevsky leskhoz”	46	1026.5	1.2
SFE “Tolochinsky leskhoz”	77	812.8	1.4
SFE “Bogushevsky leskhoz”	51	727.7	0.9
SFE “Gluboksky opytny leskhoz”	82	1218.0	2.8

4. Proposals for improvements to be made to the forest management activities plans were developed. According to item 3 of protective obligations, land user that got documents of protection must “ensure the compliance to special protection regime” of rare and typical biotopes, habitats of wild animal and plants species that is written in the obligations. For protected objects situated in forests, one of the basic protection regimes is the limitation of forest management, including limitations on types of felling. Major felling, felling of reconstruction, renovation and reorganization are mostly prohibited. Established limitations on felling types are proposed to be included in forest management plans of SFE “Klichevsky leskhoz”, SFE “Gluboksky opytny leskhoz”, SFE “Tolochinsky leskhoz”, and SFE “Bogushevsky leskhoz”.

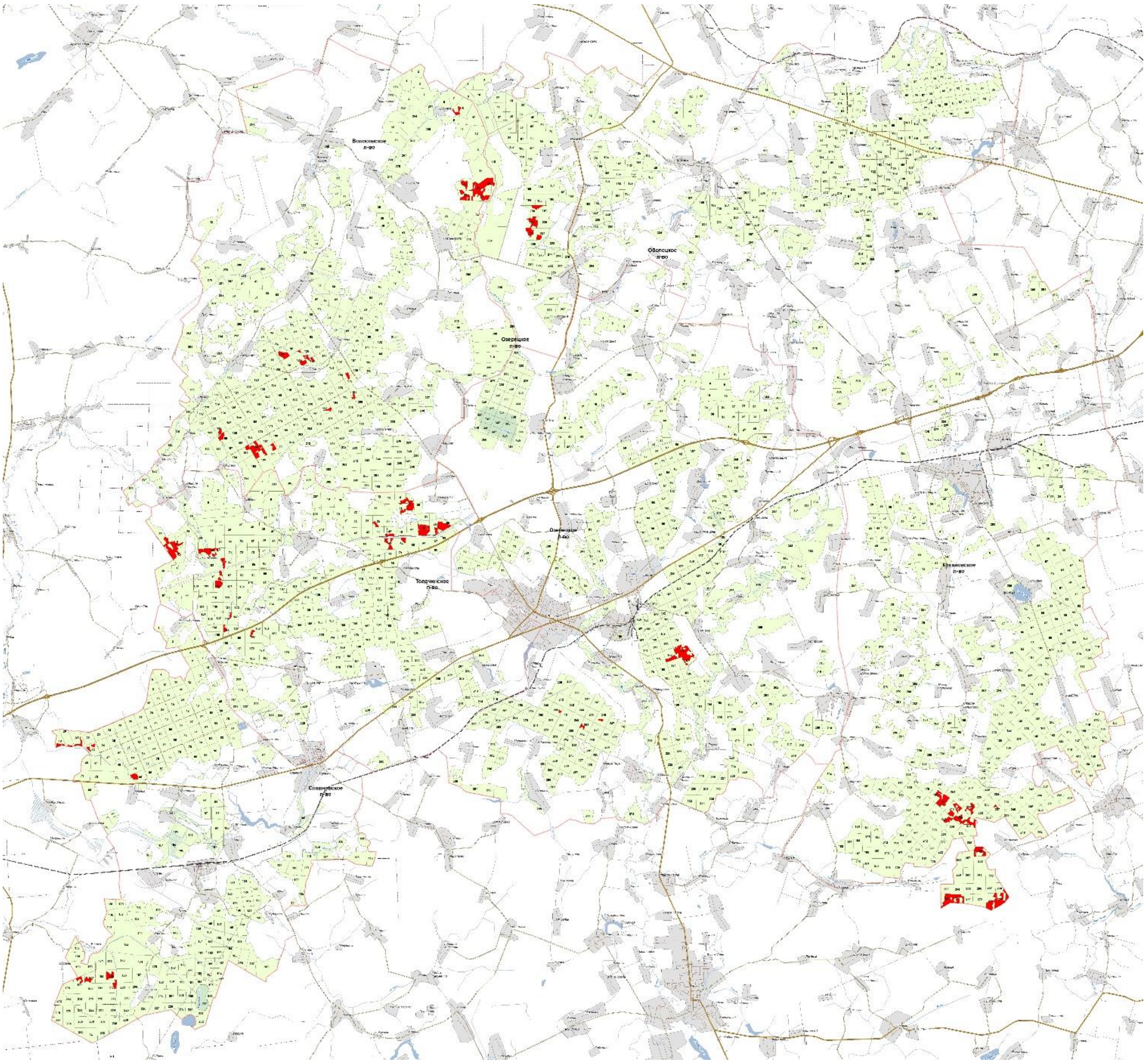

Figure 1.4 – Distridution of designated rare and typical biotops in SFE “Tolochinsky leskhoz”

2. Introduction of changes in the forest management projects of SFE “Klichevsky leskhoz”, “Gluboksky opytny leskhoz”, “Tolochinsky leskhoz”, and “Bogushevsky leskhoz”; preparation and calculation of the size of cutting of the main forest use taking into account the introduced changes and the established regime of the forest use and restrictions

Introduction of changes in the forest management projects of SFE “Bogushevsky leskhoz” for 2017-2016 developed on the basis of forest inventory 2015; SFE “Tolochinsky leskhoz”– for 2018-2025 on the basis of forest inventory 2014; SFE “Gluboksky opytny leskhoz”– for 2018-2026 on the basis of forest inventory 2015; SFE “Klichevsky leskhoz”– for 2018-2023 on the basis of forest inventory 2012.

As the result of work execution, there are some areas of forest fund which are under special protection in the accordance with the requirements of the new Forest Code. In addition, the proposals have been formed in the forest management fieldworks in the form of restrictions on types of cutting or their prohibition on the territory of protected biotopes and habitats and the growth of protected species of flora and fauna. The division of the forest fund of Klichevsky, Gluboksky, Tolochinsky and Bogushevsky Forestry Enterprises was held into the categories of forests according to the new Forest Code; Planning and cartographic materials for forest inventory objects were based on the digital maps of the areas. The project documentation has been developed in terms of the forest management.

SFE “Tolochinsky leskhoz”

The total area of nature protection forests is 1252,7 ha, including (table 2.1):

– forest within the boundaries of specially protected areas – 58,6 ha,

– forest within the borders of habitats of species listed in the Red Book of the Republic of Belarus – 584,8 ha;

– within the boundaries of typical and rare landscapes and biotopes – 609,3 ha.

When determining the size of rated wood cutting, the following requirements must be satisfied: to ensure the continuity and non-depletion of forest use, the relative stability of the size of the harvesting of mature wood, its timely and rational use, to improve the age structure of forests, to preserve and enhance the beneficial natural properties of the forest.

When making changes to the forest management plan for SFE “Tolochinsky leshoz”, there were no changes in the boundaries and area of the SFE, changes in the age of stands, the existing distribution of the forest area by types, and the distribution of forest by species composition was preserved. When changes were made, the territory was redistributed by forest categories and the stands were redistributed by age groups as a result of changing forest categories. Appropriate adjustments have been used to determine the estimated cutting area.

Based on the results of the forest division into the categories according to the new Forest Code (hereinafter referred to as the Code), the nature protection forests are 1.7% of the forestry area, recreational areas - 1.4%, protective forests - 22.5%, operational forests - 74.4%. The rated wood cutting is approved in the volume of 140.3 thousand m^3 of liquid wood, including the groups of species: coniferous - 50.5 thousand m^3, soft-wooded - 89.8 thousand m^3.

The average annual change in volume is 75%, including the next groups of species: caniferous - 46%, soft-wooded - 120%. The final cutting of soft-wooded species exceeds the annual average change of volume of cutting in the household in order to prevent accumulation of volume of mature and overmature plantations of soft-wooded species beyond the optimal norm.

Table 3.8 shows the distribution of plantations for included and excluded from the calculation of volume of final cutting. By the end of the upcoming period, enlargement of the area of mature caniferous plantations that can be used is predicted by 2870 hectares or 130%, hardwooded by 52 ha or 226%, and lessening of soft-wooded species is predicted by 882 ha or 22%. Final cutting for the next period is predicted in the amount of 147.5 thousand m^3 of merchantable wood, including 81.9 thousand m^3 of caniferous, 0.7 thousand m^3 of hard-wooded, 64.9 thousand m^3 of soft-wooded.

Table 2.1 – Distribution of forest of SFE “Tolochinsky leskhoz” by categories

Name of forest district	Total area, ha	Including categories, ha												
		nature protection forests				recreational and health improving forests				protective forests				Commercial forests
		within the boundaries of specially protected areas	within the borders of habitats of species listed in the Red Book of the Republic of Belarus	within the boundaries of typical and rare landscapes and biotopes	total	within the boundaries of cities (urban forests)	within the boundaries of the bands around the cities, other settlements	within the limits of 200 meters around medical, sanatorium and health improving facilities	total	within the boundaries of water protection zones	within the boundaries of 1 and 2 sanitary protection zones of sources and systems of drinking water supply	within 100 meters along the railway lines and the republican highways	total	
Oboletskoe	10138,0	–	–	32,9	32,9	–	99,2	–	99,2	1312,5	–	193,2	1505,7	8500,2
Volosovskoe	11495,0	31,6	384,6	91,7	507,9	–	114,4	20,3	134,7	3517,0	–	–	3517,0	7335,4
Ozeretskoe	12143,0	27,0	111,4	53,0	191,4	–	194,6	–	194,6	2408,6	–	221,8	2630,4	9126,6
Kokhanovskoe	9528,0	–	27,2	122,2	149,4	–	103,9	100,9	204,8	1092,2	0,4	0,9	1093,5	8080,3
Tolochinskoe	7982,0	–	61,6	12,1	73,7	–	74,5	57,4	131,9	2230,1	–	224,0	2454,1	5322,3
Slavnovskoe	8029,0	–		45,7	45,7	–	73,2	–	73,2	2103,4	–	69,7	2173,1	5737,0
Total for the forestry enterprise	**59315,0**	**58,6**	**584,8**	**357,6**	**1001,0**	–	**659,8**	**178,6**	**838,4**	**12663,8**	**0,4**	**709,6**	**13373,8**	**44101,8**
%	100,0	0,1	1,0	0,6	1,7	–	1,1	0,3	1,4	21,4	–	1,2	22,5	74,4

SFE “Gluboksky opytny leskhoz”

The total area of nature protection forests is 8797,3 ha, including (table 2.2):

– forest within the boundaries of specially protected natural territories – 7739,1 ha,

– forest within the limits of habitats, growth of species listed in the Red Data Book of the Republic of Belarus – 341,5 ha,

– forest within the boundaries of typical and rare landscapes and biotopes – 716,7 ha.

When determining the size of rated wood cutting, the following requirements must be satisfied: to ensure the continuity and non-depletion of forest use, the relative stability of the size of the harvesting of mature wood, its timely and rational use, to improve the age structure of forests, to preserve and enhance the beneficial natural properties of the forest.

The calculation of volume of final cutting was conducted by categories of availability of the cutting fund. The final cutting will make 99.7 thousand m^3 of merchantable wood, including:

coniferous - 58.9 thousand m^3;

soft-leaved - 40.8 thousand m^3.

The final cutting of 2015 in the amount of 92.7 thousand m^3 of merchantable wood (coniferous - 49.0 thousand m^3 soft-leaved 43.7 thousand m^3) enlarged by 7.4%, mainly due to the abolition of former protection category "green forest management zone" and lessening of protection category "restricted areas along the banks of rivers, lakes, reservoirs and other water bodies" along the 3-km-wide areas of Berezina River. Now, the width of the sub-category "forests located within the boundaries of water protection zones" is 600 m.

Available cutting fund is 81.1 thousand m^3 of merchantable wood (81.3%), 18.6 thousand m^3 of hard-to-reach wood (18.7%). Hard-to-reach cutting fund is represented mainly by pine woods, birch woods and fern and sedge black alder woods.

For forests located within the boundaries of water protection zones, all kinds of non-final cuttings were planned. For conservation forests, cutting was planned in accordance with the titles of protection. Volume of non-final cuttings will be 17.7 thousand m^3 of merchantable wood (17.7%). With the adopted annual volume of final cuttings, available cutting fund will be used up in 11 years for coniferous, and in 9 years for soft-leaved. Total volume of cut wood is 85% of the average change in the volume of stands.

SFE “Klichevsky leskhoz”

The territory of SFE “Klichevsky leskhoz”is characterized by a large number of protected areas:

- Hydrological reserve of national importance "Ostrova Duleby";
- Landscape reserve of national importance "Svisloch-Berezinsky";
- Hydrological reserves of local importance “Bolshoy Mokh”, “Vankovshchina”, “Gonchanskoe”, “Zvonnitsa”, “Mokroe-1”, “Mokroe-2”, “Poddubie”, “Peschanoe”, “Vyazen”, “Dubrova”, “Zastarie”, “Lozovitsa”, “Lezhaya-Khvoshchev”, “Lutsino-1”, “Orekhovka”, “Sosnovka”, “Unukhalskoe-1”, “Khristy”;
- Natural monument of national importance “Biordovskoe lesonasazhdenie”;
- Hydrological natural monument of local importance “Krinitsa sovkhoza “Dolgovsky”;
- Botanical natural monument of local importance “Dubrava” и “Uchastok dubovo-yasenevogo lesa”.

The established regimes of the above specially protected areas provide protection and create favorable conditions for the preservation of their natural state.

The final cutting was approved in the volume of 213.9 thousand m^3 of merchantable wood, of it by groups of species: coniferous – 114.1 thousand m^3, hard-wooded – 2.4 thousand m^3 , soft-wooded – 97.4 thousand m^3.

Table 2.2 – Distribution of forest of SFE “Gluboksky opytny leskhoz” by categories

Name of forestry	Total area, ha	Forests by categories, ha												
		conservation forests				recreational and health improving forests				protective forests				Commercial forests
		within the boundaries of specially protected areas	within the borders of habitats of species listed in the Red Book of the Republic of Belarus	within the boundaries of typical and rare landscapes and biotopes	total	within the boundaries of cities (urban forests)	within the boundaries of the bands around the cities, other settlements	within the limits of 200 meters around medical, sanatorium and health improving facilities	total	within the boundaries of water protection zones	within the boundaries of 1 and 2 sanitary protection zones of sources and systems of drinking water supply	within 100 meters along the railway lines and the republican highways	total	
Uzrechskoe	8485,6	118,7	126,9	50,6	296,2	–	69,0	–	69,0	1203,8	–	42,2	1246,0	6874,4
Glubokskoe	1076,4	1720,4	56,6	1,0	1778,0	–	333,8	–	333,8	1786,4	–	239,3	2025,7	6938,9
Golubichskoe	10400,0	2373,6	45,1	165,9	2584,6	–	54,1	–	54,1	2279,4	–		2279,4	5482,3
Lipovskoe	9043,0	1292,2	68,4	119,1	1479,7	–	22,9	–	22,9	1705,8	–		1705,8	5834,6
Tumilovichskoe	12447,0	2251,8	47,9	603,4	2903,1	–	181,2	–	181,2	1788,1	–	153,2	1941,3	7421,4
Total for the Forestry Enterprise	**51452,0**	**7756,7**	**344,9**	**940,0**	**9041,6**	**-**	**661,0**	**–**	**661,0**	**8763,5**		**434,7**	**9198,2**	**32551,2**
%	100,0	15,1	0,6	1,8	17,5	–	1,3	–	1,3	17,1	–	0,8	17,9	63,3

Table 2.3 – Distribution of forest of SFE “Klichevsky leskhoz” by categories

Name of forestry	Total area, ha	Forest categories, ha												
		conservation forests				recreational and health improving forests				protective forests				Commercial forests
		within the boundaries of specially protected areas	within habitats of wild plant and animal cpecies listed in the Red Book of the Republic of Belarus	within the boundaries of typical and rare landscapes and biotopes	total	within the boundaries of cities (urban forests)	forests around cities, other settlements	within the limits of 200 meters around medical, sanatorium and health improving facilities	total	within the boundaries of water protection zones	within the boundaries of 1 and 2 sanitary protection zones of sources and systems of drinking water supply	within 100 meters along railway lines and republican highways	total	
Kolbchanskoe	9451,6	1261,0	-	-	1261,0	-	41,6	-	41,6	2872,0	0,2	10,5	2882,7	5266,3
Usakinskoe	14103,7	6850,7	-	76,3	6927,0	-	126,2	-	126,2	1802,1	-	106,9	1909,0	5141,5
Dolgovskoe	17774,4	6804,5	-	60,8	6865,3	-	231,4	-	231,4	2643,8	0,3	127,6	2771,7	7906,0
Potokskoe	8093,3	1001,0	-	19,8	1020,8	-	78,0	12,9	90,9	2242,0	-	127,7	2369,7	4611,9
Virkovskoe	10612,6	2325,7	4,8	198,4	2528,9	-	119,6	-	119,6	2735,1	-	104,4	2839,5	5124,6
Klichevskoe	10833,4	60,0	-	29,4	89,4	-	196,2	-	196,2	2500,1	-	177,6	2677,7	7870,1
Gonchanskoe	12611,6	1253,3	-	227,2	1480,5	-	212,0	-	212,0	1511,0	-	154,8	1665,8	9253,3
Bacevichskoe	7569,0	695,7	14,3	26,7	736,7	-	64,3	-	64,3	1243,1	-	-	1243,1	5524,9
Biordovskoe	9517,9	54,1	60,8	295,5	410,4	-	22,3	-	22,3	3016,0	-	-	3016,0	6069,2
Zapolskoe	8006,2	4412,7	10,8	57,7	4481,2	-	27,5	-	27,5	1269,6	-	21,5	1291,1	2206,4
Total	**108573,7**	**24718,7**	**90,7**	**991,8**	**25801,2**	**-**	**1119,1**	**12,9**	**1132,0**	**21834,8**	**0,5**	**831,0**	**22666,3**	**58974,2**
%	100,0	22,8	0,1	0,9	23,8	-	1,0	-	1,0	20,1	-	0,8	20,9	54,3

According to the methods of cutting, the final cutting is distributed as follows: by volume – continuous cutting – 56.1%, gradual – 43.9%; by area – continuous cutting – 40.8%, gradual – 59.2%. The final cutting was completed in the accessible forest cutting fund, of which 89.5% - commercial forests, 3.8% - environmental forests, 6.7% - protective forests. The period of use of forest cutting fund is 13 years for coniferous, 12 years for soft-wooded forests.

The average change in volume is 67%, including the next groups of species: caniferous - 61%, hard-wooded – 53%, soft-wooded - 76%.

Annual average volume of clear cutting is 2295.5 hectares and 97.4 thousand m^3 of the selected volume. The main place in the clear cutting belongs to forest care cuttings, the annual average designed volume of their conduction is 2260.3 hectares or 94.9 thousand m^3 according to the selected volume.

SFE "Bogushevsky leskhoz"

State Forestry Enterprise «Bogushevsk Forestry Enterprise» of Vitebsk State Experimental Forestry Enterprise is located in south-eastern part of Vitebsk Region on the territory of Syanno and Orsha Districts

According to the geobotanical division into districts of the Republic of Belarus, the forests of the Forestry Enterprise belong to the Surozh-Luchosa complex of forest tracts of the Western Dvina geobotanical area of the subzone of broad-leaved spruce (oak-dark-coniferous) forests.

The dominant forest formations are pine (21%), spruce (20%), oak and ash (3%), birch (33%), gray alder (11%) and black alder (12%) stands.

Table 2.4 shows the distribution of plantations by prevailing species and age groups according to the forest management information in 2015 and also in 2017 (after the forest division into the categories under the new Forest Code). There are some changes in the distribution of plantations by age groups, as a result of changes in forest categories and the allocation of additional areas for conservation forests.

According to the results of forest division into the categories that are fixed in the new Forest Code (here and after referred to as the Code), the conservation forests include 3.8% of the forestry area, recreational and health improving forests - 1.5%, protective forests - 23.9%, commercial forests - 70.8%.

As the result of redesigning, total area included into the calculation of volume of final cutting increased by 260.8 hectares (3.8%).

After redesigning, the cutting area has been approved according to the current age of cuttings in the amount of 152.8 thousand m^3 for cutting, including 41.0 thousand m^3 (26.8%) of coniferous and 111.8 thousand m^3 of soft-wooded (73.2%).

The volume of non-final cuttings will be:

- by area - 29.7%;
- by merchantable reserve - 17.1%.

According to the accessibility the cutting area was distributed as follows:

- available - 143.9 thousand m^3 (94.2%);
- hard-to-reach - 8.9 thousand m^3 (5.8%).

Table 2.4 – Distribution of forest of SFE "Bogushevsky leskhoz" by categories

Name of forestry department	Total area, ha	By category, ha												
		conservation forests				recreational and health improving forests				Protective forests				Com-mercial forests
		within the boundaries of specially protected areas	within the limits of habitats of species listed in the Red Book of the Republic of Belarus	within the boundaries of typical and rare landscapes and biotopes	total	within the boundaries of cities (urban forests)	within zone around the cities, other settlements	within the limits of 200 m zone around medical, sanatorium and health resort facilities	total	within the boundaries of water pro-tection zones	within the boundaries of 1 and 2 sani-tary protection zones of sources and systems of drinking water supply	within 100 meters zone along the railway lines and the republican highways	total	
Sennonskoe	12438,0	1048,4	26,7	82,5	1157,6	-	130,5	-	130,5	2015,6	-	138,1	2153,7	8996,2
Obolskoe	9650,0	-	5,5	5,6	11,1	-	67,8	-	67,8	2313,9	-	108,4	2422,3	7148,8
Bogushevskoe	13589,0	-	32,9	107,9	140,8	-	328,1	25,6	353,7	3857,2	-	258,8	4116,0	8978,5
Sofievskoe	11451,0	-	16,7	90,7	107,4	-	147,3	144,7	292,0	3505,4	-	552,0	4057,4	6994,2
Bourbonskoe	8762,6	-	-	29,8	29,8	-	65,9	-	65,9	758,9	-	327,7	1086,6	7580,3
Ulyanovichyskoe	9781,0	1021,0	98,4	213,2	1332,6	-	92,8	-	92,8	1991,8	-	59,3	2051,1	6304,5
Kokovchinskoe	8803,4	-	13,8	43,8	57,6	-	126,9	-	126,9	1881,3	-	53,6	1934,9	6684,0
Total	**74475,0**	**2069,4**	**194,0**	**573,5**	**2836,9**	**-**	**959,3**	**170,3**	**1129,6**	**16324,1**	**-**	**1497,9**	**17822,6**	**52686,5**
%	100,0	2,8	0,2	0,8	3,8	-	1,3	0,2	1,5	21,9	-	2,0	23,9	70,8

3. Development of principles, methods and program for monitoring the effects of climate change in forest ecosystems; and criteria and indicators for evaluating the effectiveness of measures for adaptation of forestry to climate change

3.1. Specifics of climate changes' impact on Belarusian forest ecosystems

Climatic dangers for Belarusian forests, forest management production and benefit from climate changes are stipulated by stable direct (through damage of forest tree species by windfalls, extreme temperatures, frosts, icing, etc.) or indirect (through changes in ground water level, fires, reproduction of forest pests and stimulation of diseases of tree species) changes of meteorological indicators that lead to changes in composition and structure of living cover, in condition of forest-forming tree species.

Belarusian territory is located on the border between boreal zone and zone of broad-leaved forests. Spatial redistribution of heat radiation has an effect on the area of distribution of plants. There are borders of distribution of three forest-forming species on the territory of Belarus: Norway spruce (*Picea abies*), European hornbeam (*Carpinus betulus*) and grey alder (*Alnus incana*). This determines the heterogeneity of the composition and typological structure of forests in different parts of Belarus. Researchers (Yurkevich, Geltman 1962, Geltman 1982, Parfenov 1980, Kozharinov 1989) connect it exactly with heat distribution. One of the most unfavorable factors for forest fauna is droughts, frequency and intensity of which increased in the last years (Loginov, Brovka, 2012). Under draughts' influence boreal fauna components weaken and die, borders of taiga and sub-taiga zones move to the North, their area decreases. Hereby, in the last 50 years, under the influence of climate and drainage, the southern border of Norway spruce has already partially moved 20-30 kilometers to the North (Yermokhin, Pugachevsky, 2009).

Data analysis of forest pathology monitoring (Observations …1995-2016) shows that the most mass death of stands occurs as a result of windfalls, droughts and fires. In the last decades, 90% of all dead stands died as a result of these factors, and in the years of extreme intensity of the climatic factors (1992, 2003, 2010), their percentage reached 97,0% (Figure 3.1).

Unfavorable weather conditions of several years of 1990's and of the beginning of 2000's promoted evolution of other species' pests: pine-tree lappet (*Dendrolimus pini*), common pine sawfly (*Diprion pini), Acantholyda stellata*, and in the last years - gypsy moth (*Ocneria dispar*), *Ips acuminatus* and *Ips sexdentatus* (Observation …, 1995-2016). In the result of mass reproduction of pests, during the period 1991-2007 almost 1000 ha of stands died.

In after-drought years, different forest diseases get more active (vascular, necrosis-cancerous, root and stem rots). The most had effects for condition of forests appeared in spruce, oak and ash stands. In 2015-2017, condition of pine forests in the South of Belarus worsened dramatically. About 500 ha of forest plantings die from diseases every year, and there is a stable trend in enlargement of these territories. In recent years, 12233 thnd ha of forest died or was cut down during continuous sanitary felling as a result of activity of *Ips acuminatus* and *Ips sexdentatus* in the southern part of the country. Taking measures for adaptation of forest management will substantially improve condition of plantings and will decrease probability of future mass drying.

In connection with longer arid periods (Loginov, Brovka, 2012), in vegetation period, number of forest and peatbog fires also increases. Though droughts themselves do not lead to fires, but promote more often ignitions and fast spreading of fire. Thus, in climatically extreme 1992, fires went through 27,7 thnd ha of forests and almost half of them died (12,5 thnd ha).

During continuous droughts, fire risk increases on raised bogs, which practically do not burn under normal conditions. During continuous absent of precipitation, level of ground water drops down, peat dries up and probability of specially dangerous peat fires increase, as it was in 2015 (Figure 3.2).

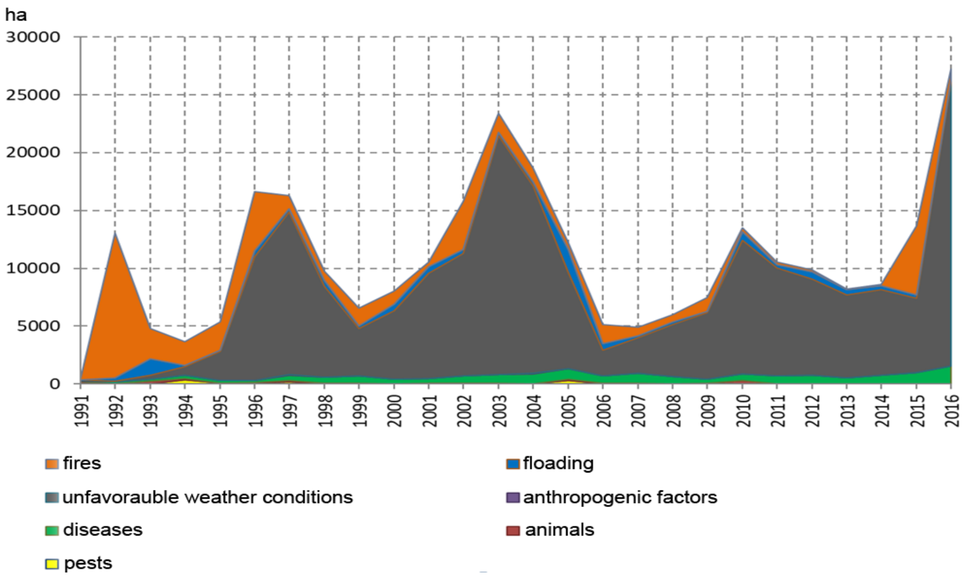

Figure 3.1 – Dynamics of forests' death in Belarus in 1991-2016 (by data of RUE "Bellesozashchita")

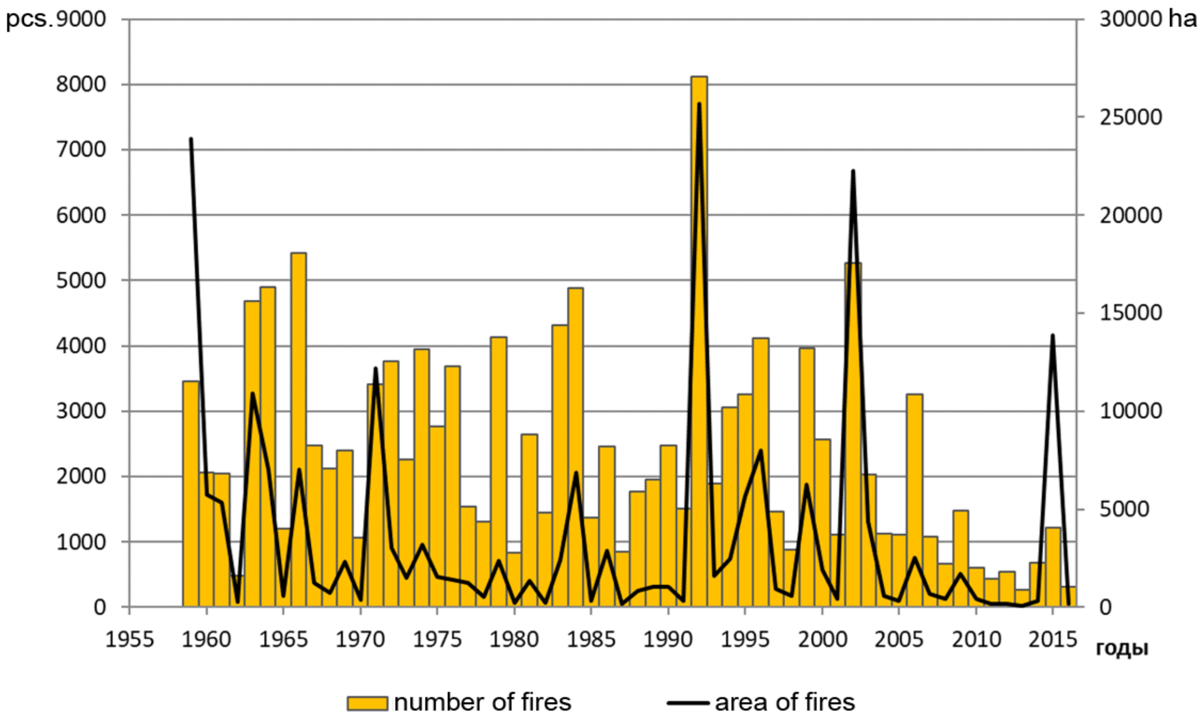

Figure 3.2 – Dynamics of forest fires in Belarus in 1959-2016 (by data of RUE "Bellesozashchita")

In Belarusian forests, local windfall damages rather often take place on over-moistened soils and can appear under wind, much lower than 25 m/s, depending on tree species and structure of canopy. In Belarus, annually at the average about 1900 ha of forest plantings die from windfalls (Observations… 1995-2016). Herewith, hurricanes and squalls are practically unpredictable. 2016 was a record-breaking by damage scale, when on the 12-13 of July, forest stands were destroyed in the result of hurricane on the area of 15,6 thnd ha and with total volume of wood about 5 million m^3.

Hereby, direct effect of climate change together with increasing anthropogenic impact on natural ecosystems can lead to a high variety of forests' reaction: from increase of their productivity to their death.

3.2. Criteria and indicators of forest ecosystems' reaction on climate changes and estimation of effectiveness of measures on adaptation of forest management to climate changes

In terms of necessity to preserve forest ecosystems during climate changes, the main principles of adaptation of forest management to predicted climate change add up to:

- Achievement of higher stability of forests to any scenario of climate dynamics, i.e. preparedness for any changes, either warming, cooling, stabilization or fluctuations of climate;
- Prediction of forest composition on the basis of factual data of forest fund inventory, current forest legislation, regulative technical base of forest management;
- Development and realization of recommendations on composition of future forests, based on zonal and formation-typological methods;
- Inventory of main types of felling (final, clear, incidental) and conditions of harmful and beneficial entomocomplexes and forest diseases, as of a factor, leading to changes in species forest composition;
- Achievement with means of adaptation of the sector to new weather-climatic changes not only through overcoming of negative effects of these changes, but the most full benefit from them;
- Integration of recommendations on adaptation to regulatory base of forest management.

Effectiveness of measures on adaptation of forest management to climate changes is defined on the basis of the next complex criteria:

a) extent (%) of realization of measures on adaptation of forest management to climate changes;
b) achievement of target indicators, on achievement of which, one or another measure on adaptation is directed by established terms;
c) condition of forests or their components under changing climate on a definite area;
d) achievement of advantageous carbon balance in forest ecosystems of the area.

In terms of above-listed criteria of effectiveness of measures on adaptation of forest management to climate changes, indicators, characterizing achievement (implementation) of these criteria, are listed below (Table 3.1).

Application of criteria and indicators of effectiveness can be combined with planned forest management works and also with procedures of forest certification. In the last case, they can be integrated into national standards of sustainable forest management and forest use, according to demands of international forest management certification system.

Estimation of criteria and indicators for a concrete area (usually forestry enterprise) reasonably should be done simultaneously with the forest inventory, i.e. it should be held every 10 years. In case of "forest management" sector, it should be done no less than 1 time in 5 years on the basis of current data of forest fund inventory.

Table 3.1 – Criteria and indicators of forest fund condition, completeness and effectiveness of measures on adaptation of forest fund to climate changes

№ №	Criteria and indicators of effectiveness of measures on adaptation of forest fund to climate changes	
	Criteria	Indicators
I	Degree of implementation of measures on adaptation of forest management to climate changes	I.1. Presence of strategy and plan of sector (or organization) adaptation to climate changes
		I.2. Presence of sections on adaptation of system of forest management and forest use to climate changes in forest management plans of concrete forestry enterprises
		I.3. Presence of educational elements (programmes, courses, etc.) about methods of adaptation of forest management to climate changes in educational and re-educational system of the sector (forestry enterprise)
		I.4. Share (%) of plantings, composition of which correspond to recommended cleaning cuttings and other forest management activities during revision period
		I.5. Share (%) of forest plantations, created according to recommendation from their total area
		I.6. Provision with planting stock (share (%) of total needs for 3 years) of target species of reafforestation and afforestation programme of sector (concrete forestry enterprise)
II	Achievement of target indicators of adaptation measures	II.1. Share of plantings of every age (% for every forest category), composition of which corresponds with recommended
		II.2. Share (%) of forest plantings or natural young stands, transferred to forest-covered area, with recommended structure
		II.3. Preservation of effectiveness of drainage systems or conduction of re-wetting of ineffectively drained bogs (share of drained lands), %
		II.4. Presence of plots and tools of control of forest condition (all types of monitoring and control)
III	Condition of forests and their components under changing climate	III.1. Decrease of burning ability of forests (by number of ignitions and area, damaged by fire during revision period, comparatively to the previous one), %
		III.2. Decrease of area of forest damaged by pests, reproduction of which is stipulated by climatic factors (by area, which emerged during revision period, comparatively to the previous one), %
		III.3. Decrease of area of continuous sanitary felling, necessity of which was caused by effect of climatic factors (by area during revision period, comparatively to the previous one), %
		III.4. Non-admission of decrease of current growth of stands of comparative age categories in main forest types (average during revision period, comparatively to the previous one), %
		III.5. Stable increase (not less than 0,5% in a year) of carbon stock in biomass of forest and swamp systems of the area (by the end of revision period, comparatively to its beginning), %
		III.6. Absence of degradation signs (death or productivity decrease) of forests in the drained forest areas

Table 3.2 – Criteria and indicators of reaction of forest ecosystems to climate changes

№№	Criteria and indicators of reaction of forest ecosystems to climate changes	
	Criteria	Indicators
I	Condition of forest ecosystems	I.1. Dynamics of number and scales (ha) of damage (death) of forests under impact of factors, stipulated by climate changes (fires, windfalls, mass vermin reproduction and evolution of forest diseases, caused by over-moistening).
		I.2. Change of extent of defoliation of tree crowns at monitoring points
		I.3. Share (%) of current tree mortality of prevailing crown layer (I-III Craft classes) at monitoring points, stipulated by certain climatic factors
		I.4. Share (%) of biologically stability-lost stands of different formations from their total area
II	Structure of forest ecosystems	II.1. Change of share of stable (unstable) species in stands (by age categories, % for every category) by the results of forest management (once in 10 years) at observation points of monitoring network (once in 5 years)
		II.2. Change of share of mixed stands and homogenous stands (%) in section of age categories by individual forestry enterprises, regions, country in total by the results of forest inventory (once in 5 years)
		II.3. Preservation of effectiveness of forest drainage systems or conduction of re-wetting in areas of ineffectively drained bogs (share (%) of drained lands)
		II.4. Changes of eco-floristic indexes, stipulated by climate changes, at observation points (once in 5 years)
III	Productivity of forests	III.1. Change of size of current tree-ring width during revision period, comparatively to the previous one and to the standard one, %
		III.2. Change of volume of stands, stipulated by climatic factors (during revision period, comparatively to the previous one), %
		III.3. Change of current growth of stands of comparable age categories in main forest types (average during revision period, comparatively to the previous one)
		III.4. Change of carbon stock in biomass of forest and swamp ecosystems of the area (by the end of revision period, comparatively to its beginning), %
		III.5. Signs of degradation (death or growth category decrease) of forests in the forest drained areas
IV	Growing conditions	IV.1. Dynamics (seasonal and of long-term trends) of temperature regime (by data of meteorological stations)
		IV.2. Dynamics (seasonal and of long-term trends) of precipitation (by data of meteorological stations)
		IV.3. Dynamics (seasonal and of long-term trends) of ground water level by data of measuring in wells at observation points

3.3. Concept and programme of monitoring of effects of climate changes in forest ecosystems

Monitoring of effects of climate changes in forest ecosystems is a system of regular observations over forest ecosystems and forest fund and their estimation, with a purpose of exposure of impact of climate changes on them, determination of effectiveness of adaptation measures, prediction of their changes under the most probable scenarios in the future.

The goal of monitoring of effects of climate changes in forest ecosystems – data provision o for making management, plan and technological decisions on protection, sustainable use of forest resources, ecological security, preservation of biological and landscape diversity, based on estimation of forest systems condition, their dynamics and prediction of their evolution under changing climate conditions.

Tasks of monitoring of effects of climate changes in forest ecosystems:

- Estimation of conditions, dynamics and structure of forest ecosystems and forest fund, by a group of criteria, based on bioindicative, forest management and ecological indicators, materials of official statistic reporting;
- Generalization of data on measures, taken by legal entities, carrying out forest management, on adaptation to climate changes;
- Exposure of climatic factors, which influence condition, dynamics and structure of forest ecosystems and forest fund in total, estimation of character and extend of their revealing;
- Prediction of condition, dynamics and structure of forest ecosystems and forest fund with due regard to the results of monitoring observations and estimations;
- Developing of recommendations on adaptation of forests and forest management to climate changes to make management and plan decisions;
- Accumulation and saving of monitoring results, presentation of them to interested parties.

Principles of functioning of monitoring system of effects of climate changes in forest ecosystems:

- Methodological, procedural and informational integration into National environmental monitoring system (NEMS), compatibility with other forms of monitoring of forests and environment;
- Complexity of maintenance of monitoring and analyses of received data;
- Representativeness (geographical and formation-typological) of monitoring networks;
- Long-term use;
- Orientation on decisions making in the area of stable forest management and forest use, orientation on the users - national forestry enterprises;
- Priority of relatively simple, cheap monitoring methods, using of up-do-date GIS and GPS technologies;
- Multilevel organization of monitoring system, possibility of partial conversion from ground to remote methods of monitoring in the future.

Objects of monitoring of effects of climate changes in forest ecosystems

- Forest ecosystems;
- Forest fund;
- System of activities on adaptation of forests and forest management to climate changes.

Strategy of monitoring of effects of climate changes in forest ecosystems consists of organization and conduction of control over conditions of forest ecosystems, based on analyses of official information about forest conditions (including data about fires in forest fund), measures on adaptation to climate changes, results of ground observations at monitoring networks and remote observations of conditions of forest fund, generalization of results of forest inventory. Its realization consists of two stages and, accordingly, two levels of organization:

1) Laying and periodical observations at PP of monitoring network in forest ecosystems and analyses of data of Earth remote sensing.
2) Collection, generalization and analyses of monitoring data:

- Materials, received at networks of forest monitoring Level 1 and Level 2;
- Materials of hydro-meteorological observations;
- Forest inventory;
- Official inventory data about damage and death of forests, forest fires;
- Remote-sensing data.

Monitoring network of effects of climate changes in forest ecosystems

Components of monitoring network of effects of climate changes in forest ecosystems are represented by *permanent plots (PP)* – they are plots of fixed size and shape, fixed in nature. PP are representative, similar by flora structure sites, where complex of monitoring observations is maintained by special programme (procedure) on a permanent basis.

Observation points are planned in representative plots of forest ecosystems on territories:

- where economic activities are prohibited (usually protection zone of specially protected nature areas);
- situated under strong man impact (recreational zones);
- with traditional forest management.

Subjects of monitoring of effects of climate changes in forest ecosystems:

- Republican Unitary Enterprise "Bellesozashchita"
- Republican Unitary Forest Management Enterprise "Belgosles"
- scientific institution, defined by the Ministry of Forestry of the Republic of Belarus in order, prescribed by legislation.

Users of the information, received during realization of the programme, will be:

- government bodies of the Republic of Belarus: Ministry of Forestry of the Republic of Belarus, Ministry of Natural Resources and Environmental Protection, Administration of the President of the Republic of Belarus;
- state forest management institutions;
- state forest protection institutions;
- scientific organizations, stipulating scientific and procedural maintenance of monitoring of forest ecosystems;
- public ecological organizations.

Order of monitoring of effects of climate changes in forest ecosystems is shown in Table 3.3.

The system for monitoring the effects of climate change in forest ecosystems should be a tool for timely forestry responses to them and use of adaptation measures. However, the existing methods for monitoring forest ecosystems within the framework of the National Environmental Monitoring System in the Republic of Belarus do not meet the needs of assessing their response to climate change. To collect and analyze information, it is necessary to create the one center that can quickly process incoming information, make forecasts of the development of adverse situations in the forests, and provide information to interested parties for making adaptation decisions. A possible organization scheme for such center is shown in Figure 3.3.

Table 3.3 – Program and order of monitoring of effects of climate changes in forest ecosystems

Estimation objects	Observation objects	Observed characteristics	Format of presentation	Frequency of estimation	Organization, making the estimation
Activities on adaptation	Area of held activities	Share (ha, %) of forest management activities, that took into account requirements of adaptation to climate changes in total (individual forestry enterprise, regional division, Ministry of Forestry in total)	Section in plan on organization and maintenance of forest management	Once in 5 years (regional division, Ministry of Forestry) and once in 10 years (forestry enterprise)	"Belgosles"
Forest fund	Area of damages, stipulated by climatic factors	Scale of damages (ha, % from forest-covered lands of forestry enterprise, regional division, Ministry of Forestry): - windfalls; - stipulated by climatic conditions of damaged areas/death of forests because of effect of forest vermin; - fires (ha, %, number of ignitions).	Analytical note (included into annual forest-pathological observe)	Annually	"Bellesozashchita" "Belgosles" (in part of Earth remote sensing data)
Forest ecosystems	PP of forest monitoring (not less than 100)	- structure of forest phytocenosis, - biometrical characteristics, - radial growth, - distribution of forests by damage categories and by living condition, - index of forest stand conditions, - projective coverage of undergrowth, grass-undershrub and moss-lichen levels (total and by species), - characteristic of natural renewal, - dynamics of ground water level.	Analytical note (included into annual observe), tables, diagrams	Annually	"Belgosles"
	PP (not less than 500, including systems of complex monitoring in specially protected nature areas)	- distribution of forests by damage categories and by living condition, - index of forest stand condition, - average defoliation of tree crowns, - radial growth, - projective coverage of undergrowth, grass-undershrub and moss-lichen levels (total and by species), - characteristic of natural renewal, - phytocenotic indexes of moistening, richness, acidity, - dynamics of ground water level (80-100 POP).	Analytical note, tables, diagrams	Annually on 20% of the network (with once in 5 years frequency) Observations over GWL - continuously, for operative control of situation	Institute of Experimental Botany NASB
	Forest cover of model site (not less than 40 model sites with area of 100 sq. km each)	- changes (+/-) of forest-covered area (Earth remote sensing data); - biophysical and biochemical characteristics of vegetation (Earth remote sensing data).	Analytical note (annual report)		Institute of Experimental Botany NASB
	Forest floor in total		Annual forest cadaster		"Belgosles"

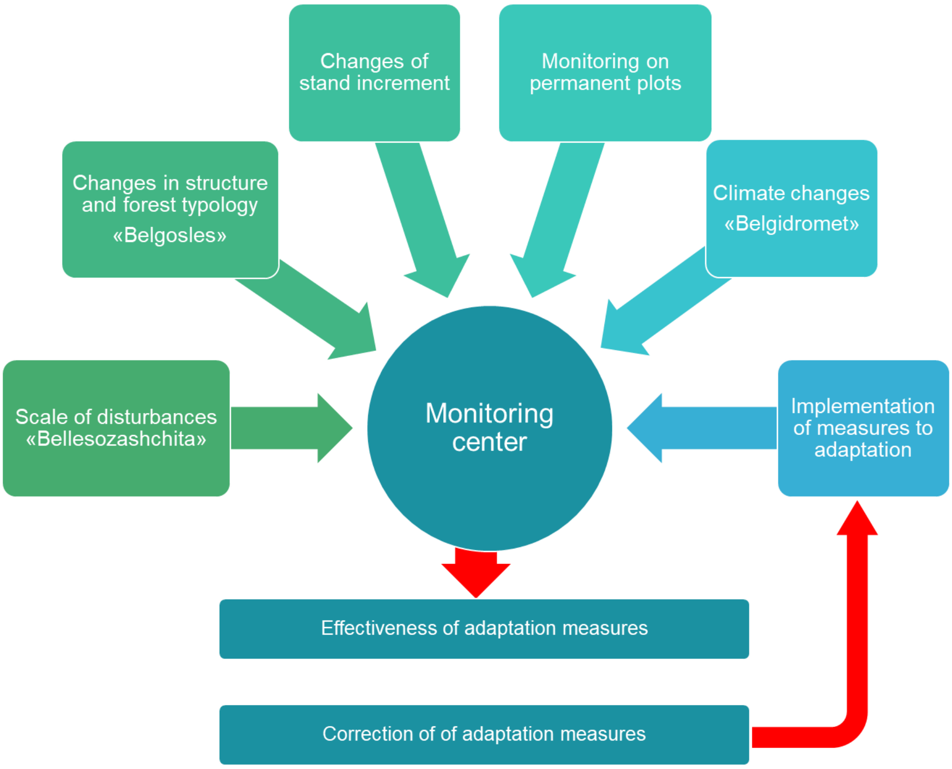

Figure 3.3 – Scheme of a center for monitoring the effects of climate change in forest ecosystems

4. Network of permanent sample plots (PSPs) to monitor forest ecosystems and their dynamics, taking into account climate change and intensive human impact and in case of its absence

According to the Activity, themonitoring network of the effects of climate change in forest ecosystemshas been designed and permanent sample plots (PSPs) have been partially established/adapted according to the concept and the monitoring plan of climate change. The total number of PSPs in the monitoring network accounts for 288 plots (Appendix A),214 of them were created based on forest monitoring plots and 74 – based on the plots of complex ecosystem monitoring in specially protected areas. The scheme of PSPs location is shown in Figure 4.1 and scheme of PSP is shown in Figure 4.2.

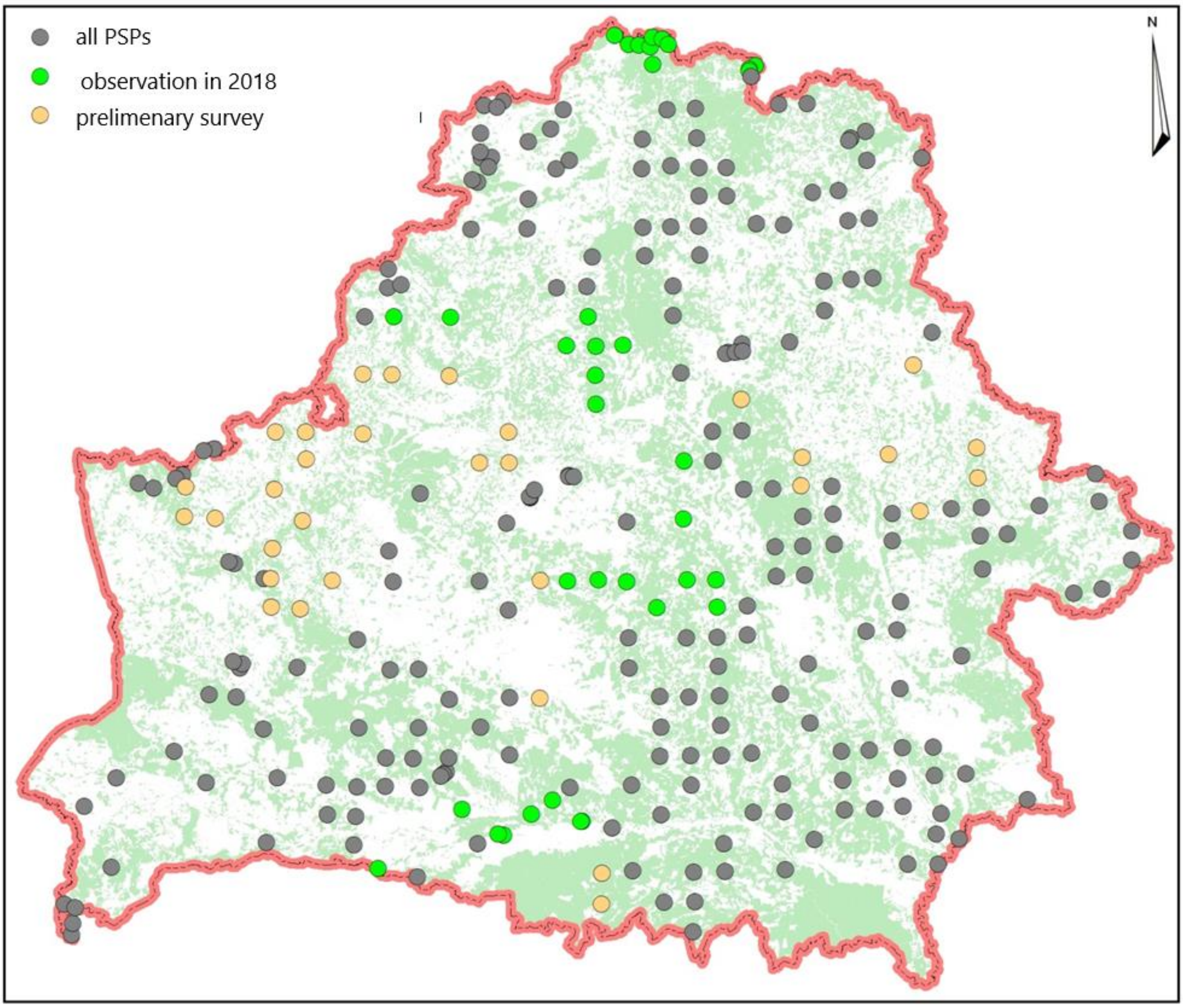

Figure 4.1 – Location of PSPs

PSP consists of five plots (inventory points). The central tree of PSP simultaneously is the central tree of IP 5. Four other IP are laid 25 meters away from the central tree, according to the corners of earth. In the center of every peripheral plot, a central tree is also selected. All central trees of IP (except for IP 5) are marked with the number of given observation point. In every of 5 inventory plots, 6-10 living trees of I-III classes by Craft are selected. Thereby, there are 24-50 trees for estimation in the PSP in total.

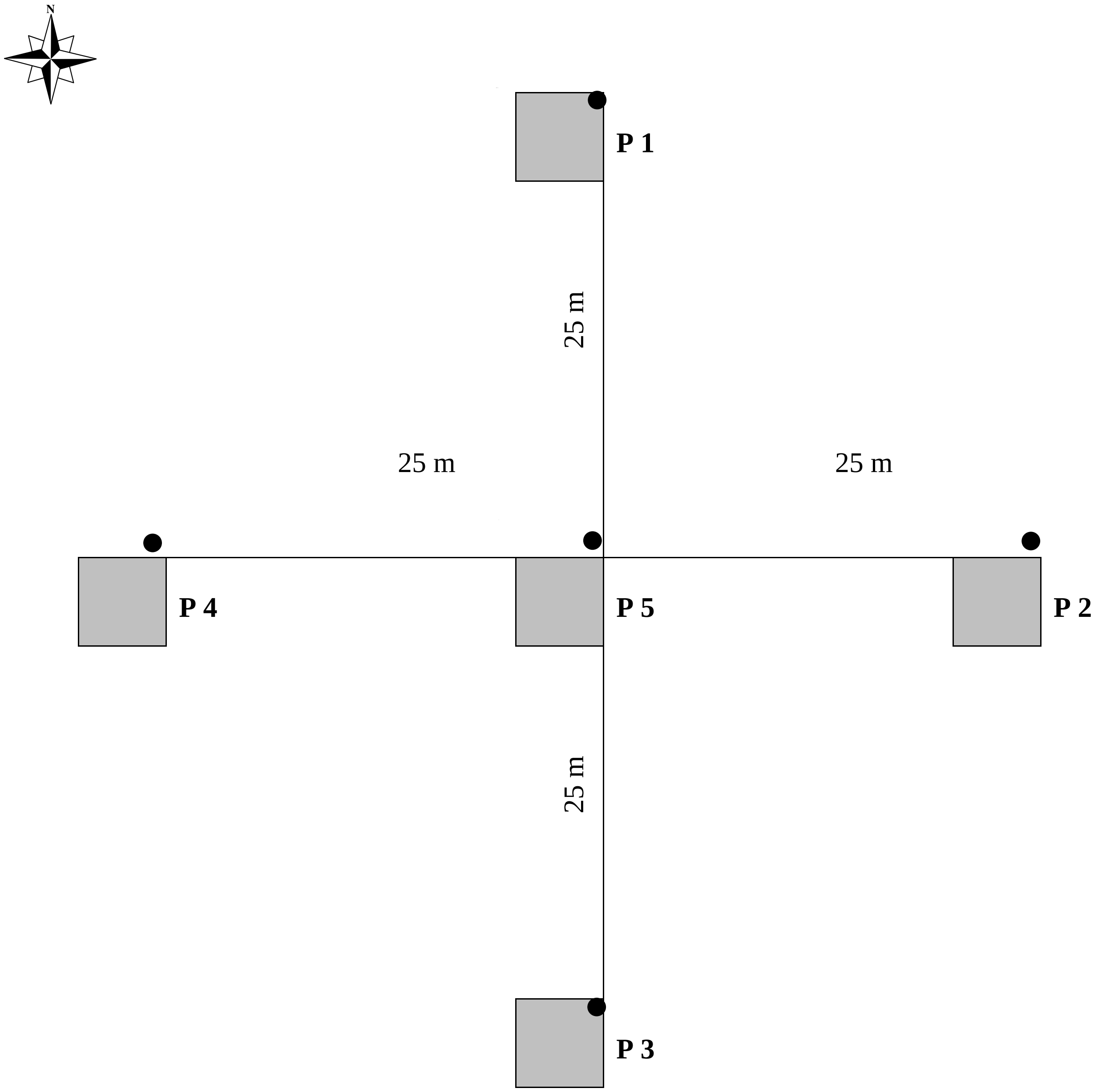

Figure 4.2 – Scheme of location of Inventory points of PSP for the estimation of undergrowth, grass-undershrub and moss-lichen levels

For observation of flora of lower levels (undergrowth, undershrub, moss) as indicator of man impact and regimes of soil environment, description of composition and number of natural regeneration is accomplished at stationary inventory points. Size of every points is 5x5 m. There are 5 points in total, one for every of IP. Points are laid to the north and south from the central tree.

Order of description of forest stand. For every tree the next indicators are defined: species, condition category, % of defoliation of crown in total, category of crown damage, % of stem coverage by epiphytic lichens, character and extent of damages of entomological, phytopatological origin, and also of other origin, condition of the top, extent of draining of boughs.

Description of tree condition is conducted basing on pan-European procedure of ecological forest monitoring (Manual…, 2006). Estimation of living condition of trees is conducted based on Sanitary rules for forests of the Republic of Belarus. Some peculiarities of procedures are adopted from north-American technology of forest monitoring (Forest Health Monitoring …, 1997).

Scale of categories of forest condition (Sanitary rules …, 2006):

1 – without signs of weakening;

2 – weakened;

3 – very weakened;

4 – dying;

5 – recent deadwood;

6 – old deadwood.

Index of forest stand condition: parameter, on the basis of which the most important indicator, illustrating current condition of tree community, is calculated – the category of living condition. Calculation of indexes of forest stands condition is made by formula (Forest ecosystems …, 1990):

IC =(100n1 + 70n2 + 40n3 + 5n4) / N,

Where IC – index of forest stand condition, n1 – number of healthy (without signs of weakening) trees, n2 – weakened, n3 – very weakened, n4 – draining, N – total number of trees (including deadwood).

Attribution of plantings to categories of living condition is made, based on modified scale of V.A.Alexeev (Forest ecosystems…, 1990), according to which forest stands of condition index 90-100% are considered "healthy", 80-89% - "healthy with signs of weakening", 70-79% - "weakened", 50-69% - "damaged", 20-49% - hard damaged, less than 20% - "destroyed".

Defoliation (lose of needles or leaves) is stipulated by complex of abiotic and/or biotic factors of diverse origin, which include season peculiarities of insolation and precipitation regimes, air pollution, lack of nutrients, biotic damages, diseases, frosts, droughts, etc.

Defoliation is defined with 5% accuracy. For more accurate and objective estimation of defoliation %, photo-standards should be used. It is especially needed for specialists with a small experience in forest monitoring sphere, and for everyone – in the beginning of estimation season.

By the extent of defoliation, trees are rated by 5 categories of damage:

0 category (undamaged trees) – defoliation 0-10%

1st category (a bit damaged) – defoliation 11-25%

2nd category (medium-damaged) – defoliation 26-60%

3rd category (hardly damaged) – defoliation 61-99%

4th category (drained trees) – defoliation 0-10%

Order of description of lower levels. At stationary inventory points of every IP description of species composition, vitality (by three stages of height) and number (abundance) of young trees, species composition and projective coverage of undergrowth, grass-undershrub and moss levels of forest vegetation, thickness of forest floor is made.

Description of understory. Calculation of number of individuals of every species by stages of height (under 0,5 m, 0,5-1,5 m, higher than 1,5 m) and living condition (trustworthy, untrustworthy, drained) is done. Estimation of natural renewal is done according to scale of estimation of natural renewal of coniferous and hard-leaf species (Practicum…, 1996).

Description of undergrowth. At inventory points, for every met species of undergrowth level, projective coverage is accounted by 1% accuracy with less than 5% coverage and 5% accuracy with higher coverage extent. Average height is calculated with up-to-5-cm accuracy, based on measuring of height of all individuals of tree species on the inventory points.

Description of grass and moss layers. At the inventory points, projective coverage of moss and grass layers is defined by species and in total. Projective coverage is accounted by 1% accuracy with less than 5% coverage and 5% accuracy with higher coverage extent.

Depth of forest litter is defined by 5 measurements (in the corners and in the center of plots) of forest floor. Depending on depth, forest litter is defined by one of 5 categories: 0 – absent, 1 – light (up to 1 cm), 2 – medium (1-3 cm), 3 – thick (4-5 cm), 4 – very thick (more than 5 cm).

Besides, for the PSP in total, erosion (%) of forest floor and grass layer, extent of littering (in points), presence of rare and protected species, listed in the Red Book of the Republic of Belarus are defined.

For estimation of *tree-ring width* and influence of climatic factors on it, 20 trees of I-II Craft classes, selected in boundaries of PSP are used (4 for every IP). Every tree gets a number. At the height of 1,3 m, two cores of wood are taken with borer. Cores are taken up to the center of the tree. During secondary observations, cores are taken of about 10 rings from the same trees. Width of rings and width of earlywood and latewood (for coniferous and hard-leaf species) is measured. Processing of the materials is done according to standard procedures (Yermokhin, Pugachevsky, 2010).

PSPs are located in forest stands of 8 forest formations: pine, spruce, oak, ash, linden, birch, black alder and aspen forests. The most of PSPs are located in pine (70%) and spruce (12%) forest stands that are widely spread over the Belarusian territory (table 4.1, figure 4.3). In total, one plot is located in old ash and linden forests each, as they are especially rare for the Belarusian territory forest formations. At the same time, they are the etalons of natural ecosystems developing almost without human impact.

Table 4.1 – PSPs distribution by forest types

Forest type	Number by forest formations, pcs								**Total**
	Pine	Spruce	Oak	Ash	Linden	Birch	Black alder	Aspen	
Callunosum	1								**1**
Vacciniosum	1								**1**
Pleuroziosum	81	1							**82**
Myrtillosum	26		4			2			**32**
Polytrichosum	3					1			**4**
Pteridiosum	51	1	4			1			**57**
Oxalidosum	18	32	6		1	8	2	3	**70**
Aegopodiosum			5	1		4		4	**14**
Filicosum		1				2	2		**5**
Ledosum	16								**16**
Caricoso-sphagnosum	2								**2**
Sphagnosum	2								**2**
Filipendulosum							2		**2**
Total	**201**	**35**	**19**	**1**	**1**	**18**	**6**	**7**	**288**

According to the Belarusian forest typology, PSPs are located in forest stands of 31 forest type (Table 4.1) and in 13 types of soil conditions (Figure 4.3), taking into account both bog and non- bog stands. The most PSPs are located in *pleuroziosum, myrtillosum, pteridiosum* and *oxalidosum* forest types that are the most wide-spread in Belarusian forests. This will allow to track changes occurred in the same soil conditions, but located in different regions of Belarus.

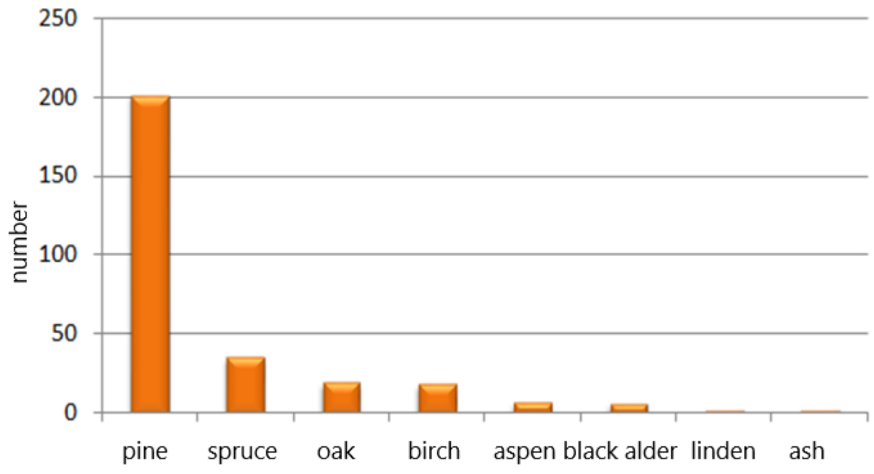

Figure 4.3 – PSPs spreading by forest formations

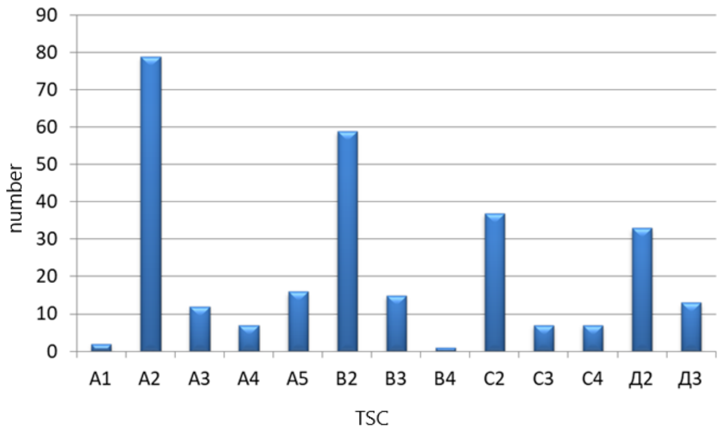

Figure 4.4 – PSPs spreading by type of soil conditions

PSPs are located in forest stands aged not less than 60 years old (except for one). By the age of 60, the species forest structure is stabilised. This allows to see later changes in the lower forest layers as the result of outside factors leading to vegetation transformation. 60-80-yearoldstands (63%) and 80-100-year-oldstands (25%) prevail.

Table 4.2 – Distribution of PSPs by age groups

Forest formation	Age group, years					Total
	40-60	60-80	80-100	100-120	> 120	
Pine		120	57	19	5	201
Spruce		21	11	3		35
Oak		10	3	2	4	19
Ash		1				1
Linden		1				1
Birch		16	2			18
Black alder	1	5				6
Aspen		7				7
Total	1	181	73	24	9	288

During the year of 2018, the first observation cycle has been conducted to 36 PSPs, in 32 PSPs preliminary survey has been conducted (Figure 4.1).

Establishment of wells with automated sensors to measure ground water level has been planned, but wasn't conduced due to the lack of required finances.

State of forest stands

ForeststandsinPSPobserved in 2018 mostly are in a good state: 13 are considered healthy, 18 – healthy with signs of weakness (Figure 4.5). The same state is characteristic for the most of natural stands in the republic. Only two forest stands were considered weak and three – damaged. The last are located in *Heterobasidion annosium*outburst areas. Currently, there are no spatial regularities in changes in the condition of surveyed forest stands on the Belarusian territory, but they may be found during the complete survey.

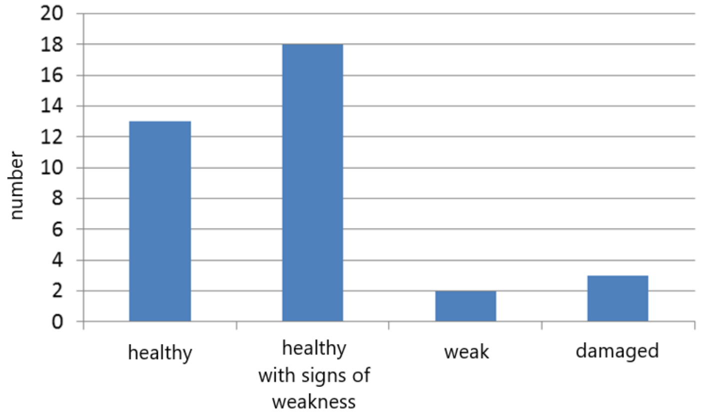

Figure 4.5 – Spreading of surveyed forest stands by condition categories

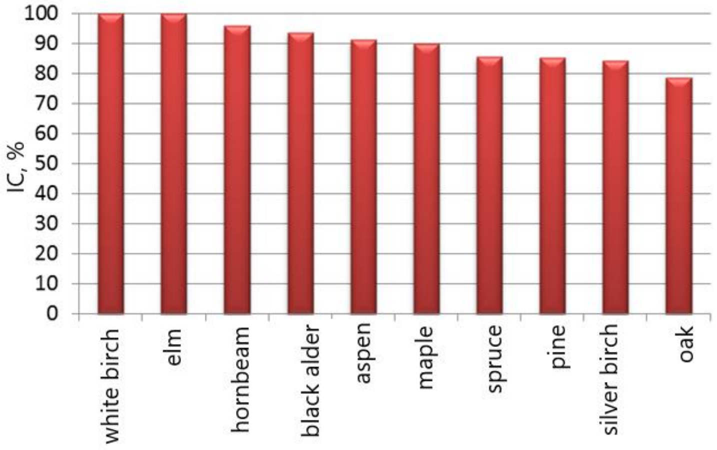

Figure 4.6 – Condition of trees of different species

White birch, elm, hornbeam, black alder and aspenstands are in the best condition (healthy without any sign of weakness). Mostly this is explained by the fact, that they still have not reached their biological old age, and that, on the other hand, they get less damaged by pests and illnesses.

The category "healthy with signs of weakness" includes maple, spruce, pine and silver birch. Eventhoughpine is a pretty stable species, the condition pine and spruce stands is first of all defined by the presence of pests and *Heterobasidion annosum*outburst areas. A bit worse condition of oak stands is explained by the PSPs located in the southern part of the Republic of Belarus, where there is more impact of leaf-eating insects, also there are traces of old previous cuttings in such stands, what led to the damages of the other trees.

The same situation is preserved in canopy defoliation of different species not accounting dead trees (Figure 4.7). The minimal defoliation (up to 10%) is registered in white birch, elm, hornbeam, black alder and aspen stands. The highest defoliation is in oak stands – 17%.

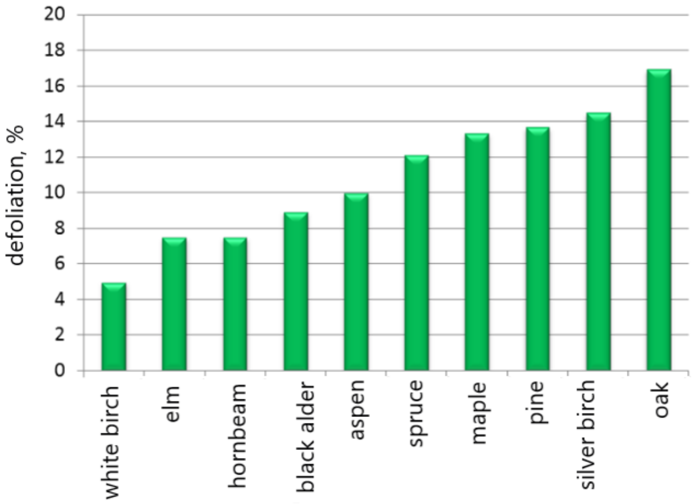

Figure 4.7 – Defoliation of different tree species

Undergrowth condition

Undergrowth structure of the PSPs has the following species: white and silver birch, pine, spruce, oak, maple, elm, hornbeam, linden, ash, aspen. The structure corresponds to the forest type (Table 4.3). In *pleuroziosum* pine stands, pine undergrowth with a significant part of silver birch, aspen and spruce trees prevail. But its number is not so big – only about 1000 pcs/ha. In *pteridiosum* oak stands, undergrowth of oak and silver birch prevail, pine, spruce and aspen undergrowth is more rear, maple undergrowth appears. At the same time its number accounts for almost 1800 pcs/ha. This is enough to form the second layer and the next generation.

Table 4.3 – Average number of undergrowth by forest types

Forest type	Average number of undergrowth by species, pcs/ha										Total
	Pine	Spruce	Oak	Ash	Elm	Maple	Linden	Hornbeam	Birch	Aspen	
Pinetum vacciniosum	900		1400						100		2400
Pinetum pleuroziosum	540	102	33						187	133	996
Pinetum polytrichosum	80										80
Pinetum pteridiosum	420	129	526			23			526	157	1780
Pinetum oxalidosum		50	200						50	600	900
Pinetum ledosum	100	200							1900		2200
Pinetum sphagnosum	1440										1440
Piceetum oxalidosum		608	36			120	16			752	1532
Quercetum pteridiosum			80			240		1600			1920
Quercetum oxalidosum			40	40		920		240			1240
Betuletum pteridiosum		1300	300								1600
Betuletum oxalidosum		200			300	300	900				1700

In the surveyed *vaccinosum* pine forest, there is a bit atypical situation, when oak (1400 pcs/ha) and pine (900 pcs/ha) prevail in undergrowth structure. Suchanumberofoakundergrowth is conditioned by oak appearance in the forest stands nearby. Usually, oakundergrowthcannot form forest stands in *vaccinosum* pine forest.

A lot of undergrowth has been registered in *ledosum* pine forests (2000 pcs/ha). White birch prevails in its structure (1900 pcs/ha). Thisshows some draining of the territory and a tendency of pine stands to be replaced with white birch stands.

Sphagnosum pine stands are pretty stable and, due to boggy, only pine (1440 pcs/ha) can growth here. In *pteridiosum*birch stands, dense spruce (in central and northern regions) and oak (in southern regions) undergrowth is formed, what will lead to the replacement of birch stands with spruce and broadleaved forests. In more fertile *oxalidosum* birch stands, elm, maple and linden appear in the structure of undergrowth. Thisconfirmsthatthere were broadleaved forests here before.

In *pteridiosum* oak stands, dense hornbeam undergrowth (1600 pcs/ha) is formed. It prevents the appearance and the development of the other species undergrowth. There is some maple, oak and ash undergrowth in more fertile *oxalidosum* oak stands.

The best condition is registered in the stands of white and silver birch – average grade is 1,0 – 1,5. Theworstcondition – hornbeamandashstands. Undergrowth condition almost of all species increases together with the height of the undergrowth. This is conditioned by it leaving zone of competition with under-canopy species and lesser ungulate impact. This is especially well seen from leaved species that are the most damaged by ungulates: oak, maple, linden, aspen. Pine undergrowth condition doesn’t depend on its height greatly.

Currently, the structure of ground vegetation corresponds to the forest type (Appendix D). Mostly this is because the most typical plots of the forest type have been selected for PSPs. During survey of PSPs rare flora species were not found.

5. Development of the software for the collection and analysis of monitoring data in forest ecosystems

Automatized system of collection and analyses of monitoring data in forest ecosystems is meant for automatization of collection and analyses of data about monitoring plots and forest inventory plots (sites) and for filling of standard forms (cards) that include numeral and qualitative indices of plantings or other land types of the monitoring plot or site. Photo contours (space or aero photos with contour decryption) are the basis for identification of spatial location and size of the site. The card contains attributive data: general information about the site, taxation characteristic of stands, planned activities and additional information.

Goals of ASCDM creation:

– Better quality of forest fund and forest resources information,

– Decrease of working costs due to automatization of data collection and input,

– Decrease of working costs due to exclusion of paper photos and cards printing, exclusion of the stage of data digitization, transformation and joining.

ASCDM should assure completion of the next tasks:

– Preparation and input of field data about forest fund and forest resources condition during forest monitoring and other forest inventory works to the database;

– Data analyses, which ensure calculation of needed parameters based on survey notes of forest fund and forest resources that were received during forest monitoring and other forest inventory works;

– Data representation, which ensure cartographical and text data mapping of forest fund and forest resources during forest monitoring and other forest inventory works.

There are several information systems of collection and processing of forest monitoring data in the Republic of Belarus as yet. All of them have their own advantages and disadvantages.

Traditional information collection method uses paper basic materials. Principal disadvantage of the method - usage of paper cards and paper printed space and aerial photos, which need additional work to be digitized (scanning and receiving of digital raster photos, their transformation and joining, vectoring of the situation, data input from the cards, etc.), decrease effectiveness and increase costs.

"Lesovichok" is one of the most up-to-date systems of terminal collection of the field data using Android OS. Principal disadvantage – the system does not support spatial identification and storage of data. It is possible to collect only attributive data and to control it, but there is no possibility to make inquiries and plot reports. Usage of usual (exposed) tablet device in field conditions is not convenient, because such devices are very vulnerable to physical impact, have small screen and menu.

There is also technology of *processing of monitoring data* with data input to special forms (field register cards) and their later processing by computer programs, designed for MS DOS OS (nowadays outdated) and it has no spatial characteristic. It is possible to plot some reports. Principal disadvantage of the system – no flexibility, limited number of indexes and inquiries.

The project of the software includes 5 sub-systems. Every sub-system has its own complex of functions

- Input sub-system ensures completion of the following functions:
  - ➢ Conversation of input data to a form, which ensures their representation in the sphere and with services of ASCDM, including secondary data (monitoring data of previous years, characteristic of the plantings etc.);
  - ➢ Geo-referencing of input data to coordinate system used in ASCDM;
  - ➢ Upload and representation of spatial and attributive data in ASCDM;
  - ➢ Editing of vector spatial objects (forest sites);

- Input and editing of attributive data;
- Logical control of accuracy of input data.

Input data of the sub-system:
- Spatial objects of stationary GIS “Forest resources”;
- Attributive information about objects of stationary GIS “Forest resources”.

Output data of the sub-system:
- Spatial objects of GDB ASCDM;
- Attributive data of GDB ASCDM objects.

* Storage and management sub-system ensures completion of the next functions:
    - Organization of spatial vector data storage;
    - Forming of attributive, objective and reference tables;
    - Coordination of vector data, attributive and reference tables;
    - Independence of the data on the physical and logical levels;
    - Informational integrity of the data base, exclusion of redundancy and duplication;
    - Effective completion of data output procedures for its transformation;
    - Reserve copying and restoration of the data base to the portable data mediums.
* Sub-system of the reference data ensures completion of the next functions:
    - Creation and editing of all the classifiers used for coding of GDB objects, libraries of notation conventions and forms used in ASCDM;
    - Import and actualization of regulative-reference data.

    Input data of the sub-system:
    - Codes for the filling of forest inventory cards.

    Output data of the sub-system:
    - Classifiers of spatial and attributive data of GDB ASCDM;
    - Library of notation conventions for spatial objects of GDB ASCDM.
* Sub-system of processing of spatial and attributive data ensures completion of the next tasks:
    - Data output from the GDB ASCDM according to various searching conditions and categories;
    - Data output from the GDB ASCDM on the inquires, which need special processing;
    - Processing and analyses of GDB ASCDM data, based on submitted criteria.

    Input data of the sub-system:
    - Spatial objects of GDB ASCDM;
    - Attributive data of GDB ASCDM objects;
    - Classifiers and libraries of conversational signs for spatial objects.

    Output data of the sub-system:
    - Basic digital map and subject maps, reports;
    - Corrected spatial and attributive data.
* Sub-system of output data preparation and presentation ensures completion of the next functions:
    - Forming of reports on characteristics of stands on monitoring plots in text format;
    - Data export/import to exchange format;
    - Synchronization of spatial and attributive data representation.

    Input data of the system:
    - Basic digital map and subject maps, reports;
    - Spatial and attributive data.

    Output data of the sub-system:

- Reports and tables in digital and (or) paper form;
- Information collections of GDB ASCDM in exchange formats.

ASCDM operation mode

Users interact with ASCDM through visual graphical interface. The interface of the system is understandable and convenient, not overloaded with graphic elements and provides displaying of screen forms. The navigation elements have understandable to user form. Data input and output, results displaying are being done in interactive mode. All the messages, texts of screen forms are written in Russian (except for modules of other producers). The organization of user's graphical interface prevent from user's inaccurate actions. The users can control data input: look through input data; correct input data; clear the data input form.

The interface is meant for stylus usage. The system is operated with a set of screen menu, buttons, icons, etc. The keyboard input mode is mainly used for filling and/or editing of text and numeral fields of screen forms. During input reference books and lists of allowed values are used as much as possible and indices match each other. E.g. the wood volume and determination of quality class are automatically calculated during the input of species, height and age of the trees. According to the result of indices input, accuracy of all the indices of the plot is checked.

The interface of ASCDM consists of the next elements:

- Window of QGIS project;
- Attributive data input (editing) form,

Interaction of these sub-systems helps to complete the next tasks of ASCDM:

– load geographical data base of forest fund and forest resources to the tablet computer;

– open a project in QGIS;

– manage representation of spatial data;

– correct spatial data about forest fund and forest resources;

– manage representation of attributive data about forest fund and forest resources;

– correct attributive data about forest fund and forest resources;

– load geographical data base of forest fund and forest resources from tablet computer;

– manage data base.

Input data for ASCDM is:

- Cartographic support (aerophotomozaic);
- Geographical information about elements of forest fund and forest resources (forestries, forestry enterprises, quarters, sites, forest inventory points);
- Attributive data about elements of forest fund and forest resources (forestries, forestry enterprises, quarters, sites, forest inventory points).

Geographical and attributive data about elements of forest fund and forest resources represents GDB in UTM-35N projection of geodetic coordinate system WGS-84 and consists of spatial classes (layers).

The window of the QGIS project is meant for representation and management of data about forest fund and forest resources. View of the window is shown on the Figure 5.1. List and description of elements of data management are shown in Table 5.1.

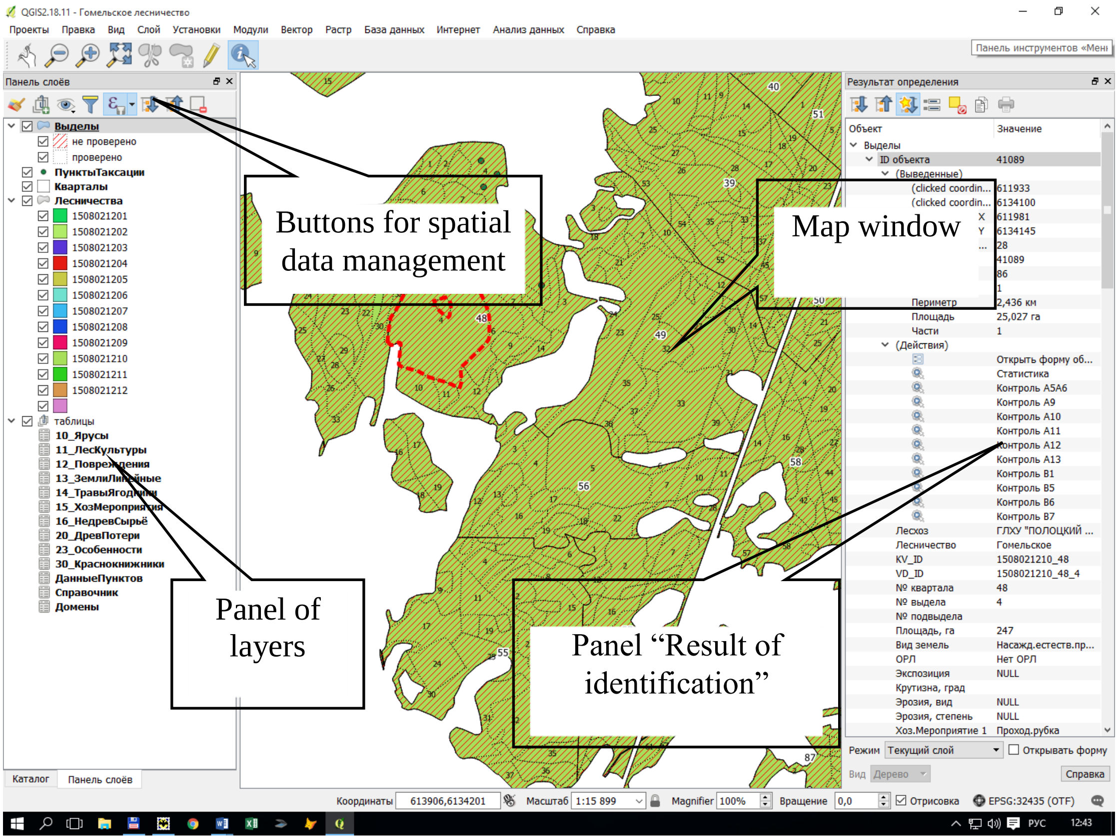

Figure 5.1 – View of window of QGIS project

Table 5.1 – Description of data management elements

№	Name of management elements	Description
1	Panel of layers	Shows the list of spatial classes (layers), turns on/off displaying of layers on map, adds/deletes layers on map
2	Button “Add group”	Adds a group of spatial classes (layers) to the map
3	Button “Layer visibility”	Opens a pop-up menu of operations on layer visibility
4	Button “Expand all”	Expands content of all the layers on the layer panel
5	Button “Minimize all”	Minimize content of all the layers on the layer panel
6	Buttons of spatial data management	Manages spatial data representation on the map
7	Button “Touch navigation”	Turns on navigation with map touching mode
8	Button “Zoom out”	Turns on map zoom out mode
9	Button “Zoom in”	Turns on map zoom in mode
10	Button “Full coverage”	Map scaling shows a full image of all its objects
11	Button “Divide object”	Turns on object dividing mode while edit mode is on
12	Button “Add object”	Turns on object adding mode while edit mode is on
13	Button “Edit mode”	Turns on/off object editing mode
14	Button “Identify object”	Turns on attributive data representation mode (Opens panel “Result of identification”)
15	Panel “Result of identification”	Shows attributive data
16	Button “Expand tree”	Expands full tree of attributive data
17	Button “Minimize tree”	Minimizes full tree of attributive data
18	Button “Open object form”	Opens attributive data input/editing form
19	Button “Clear the result”	Deletes contents of panel “Result of identification”
20	Button “Copy to clipboard”	Copies selected spatial object to clipboard
21	Button “Print web-page”	Outputs attributive data to a printing device
22	Switch “Open form”	Turns on/off mode of attributive data input/editing form automatic opening
23	View of map	Graphical representation of spatial objects

Input (editing) forms of attributive data are meant for representation, input and editing of attributive data about forest fund and forest resources.

Geographical and attributive data about elements of forest fund and forest resources represents GDB in UTM-35N projection of geodetic coordinate system WGS-84 and consists of spatial classes (layers):

- Forestry enterprises;
- Quarters;
- Sites;
- Monitoring points;
- Round plots.

To help the user, there are various notation conventions in the graphic interface of the program (Figures 5.1, 5.2).

Attributive data editing mode turns on with pressing button “Edit mode”.

Editing of attributive data is possible in special forms (Figure 5.3-5.7), so for the editing these forms need to be open.

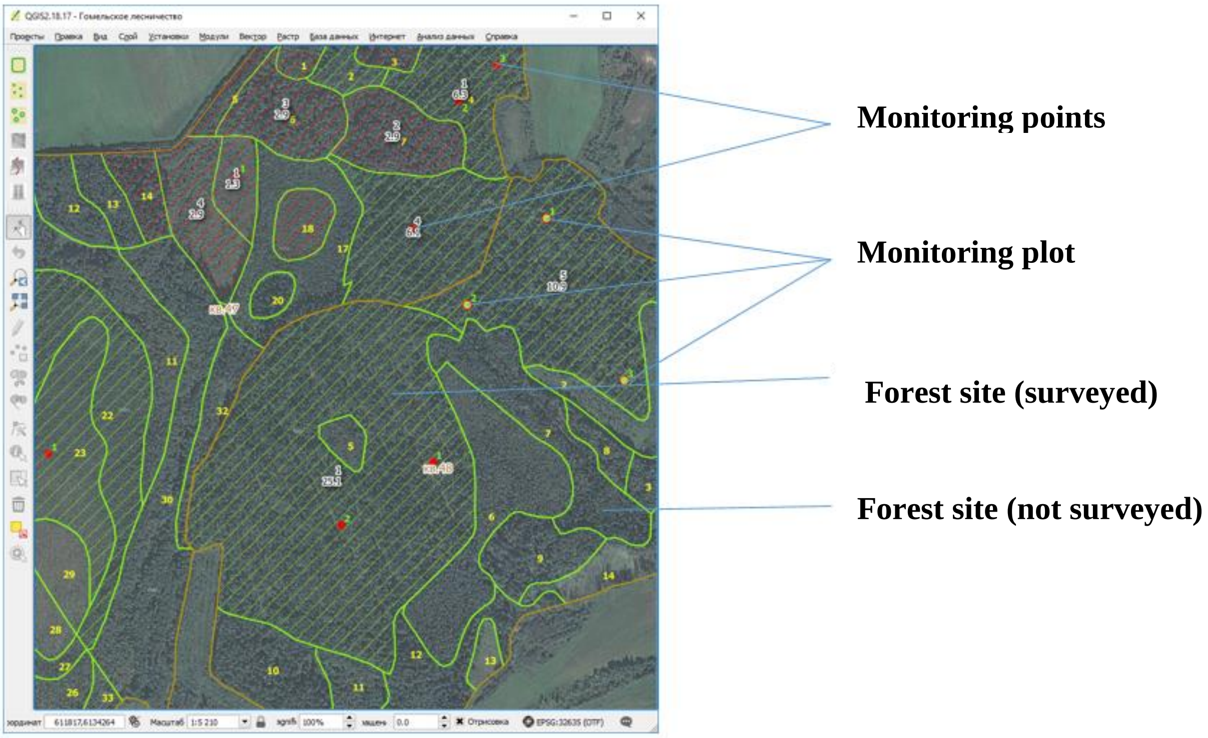

Figure 5.2 - Spatial location of monitoring points and plots with aerophotoplan displaying

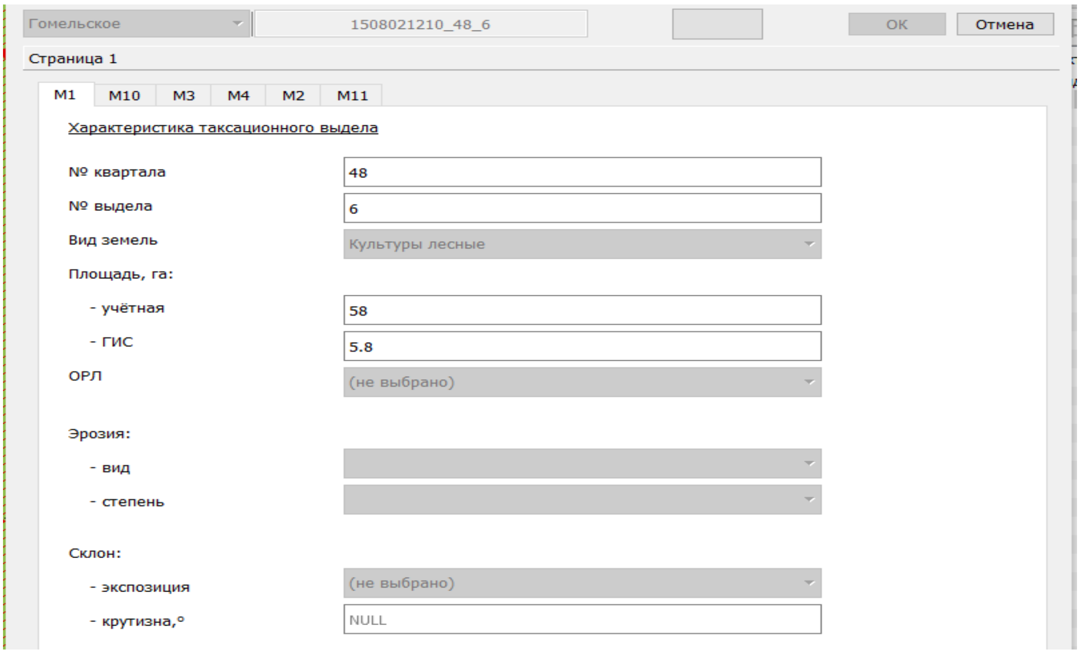

Figure 5.1 – Form "Characteristics of the site"

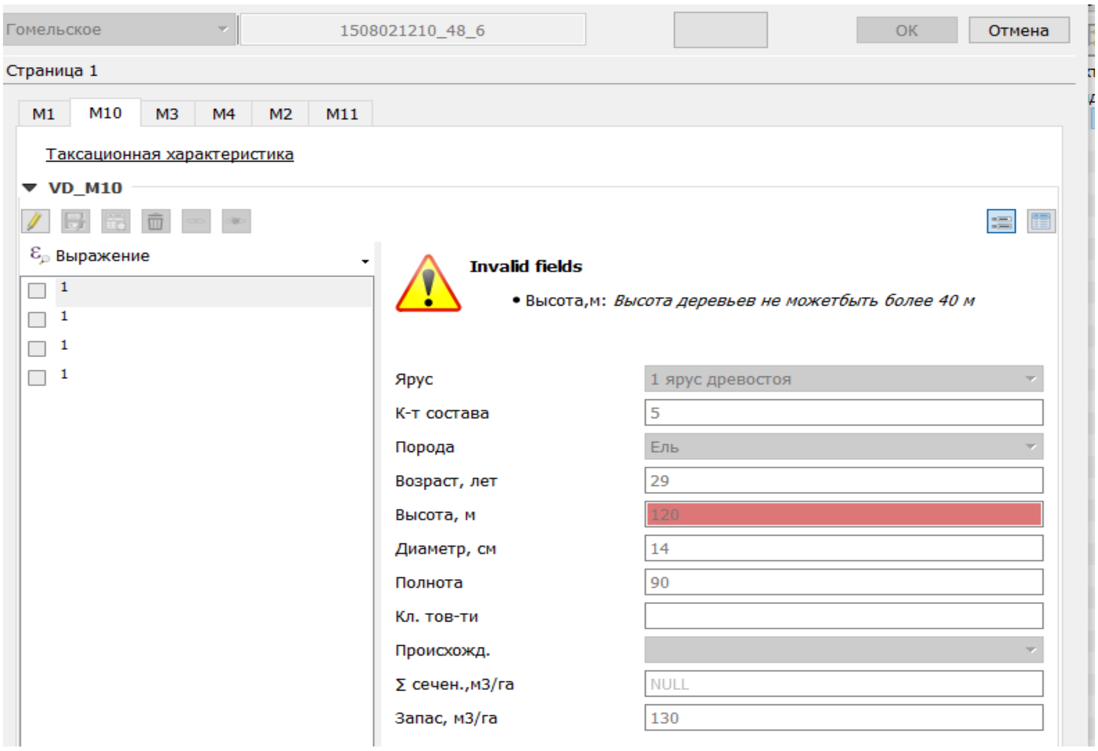

Figure 5.2 – Form "Characteristic of stands"

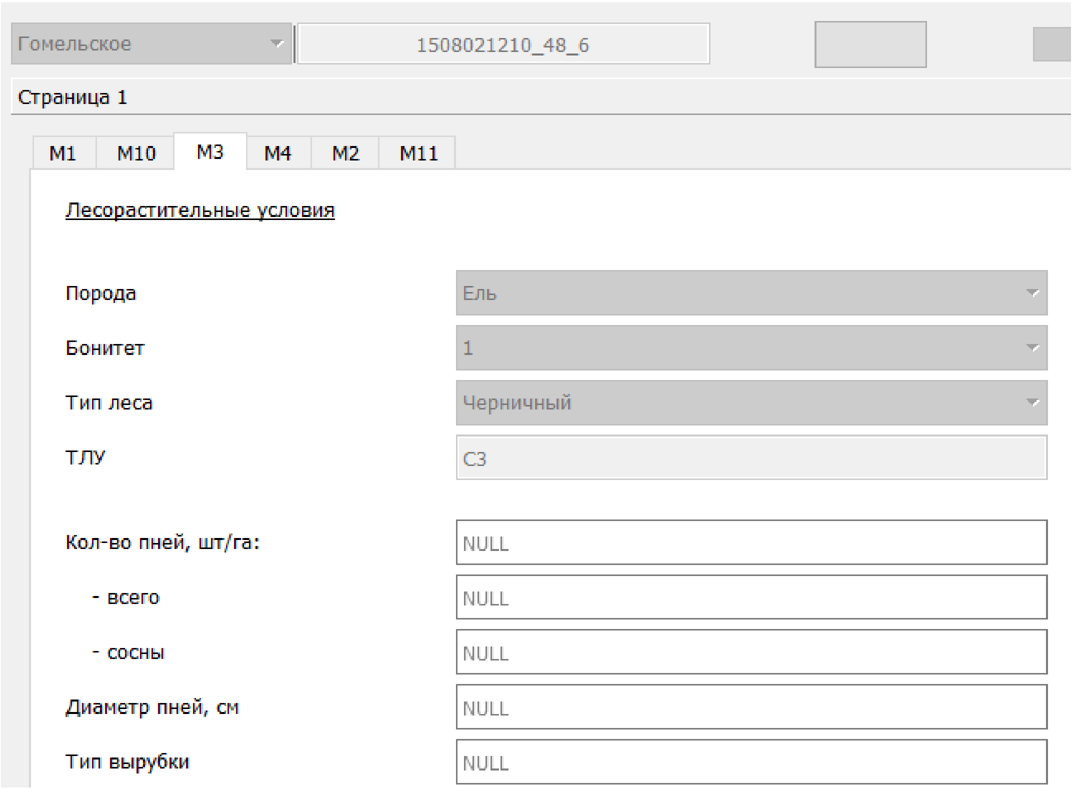

Figure 5.3 – Form "Forest growing conditions"

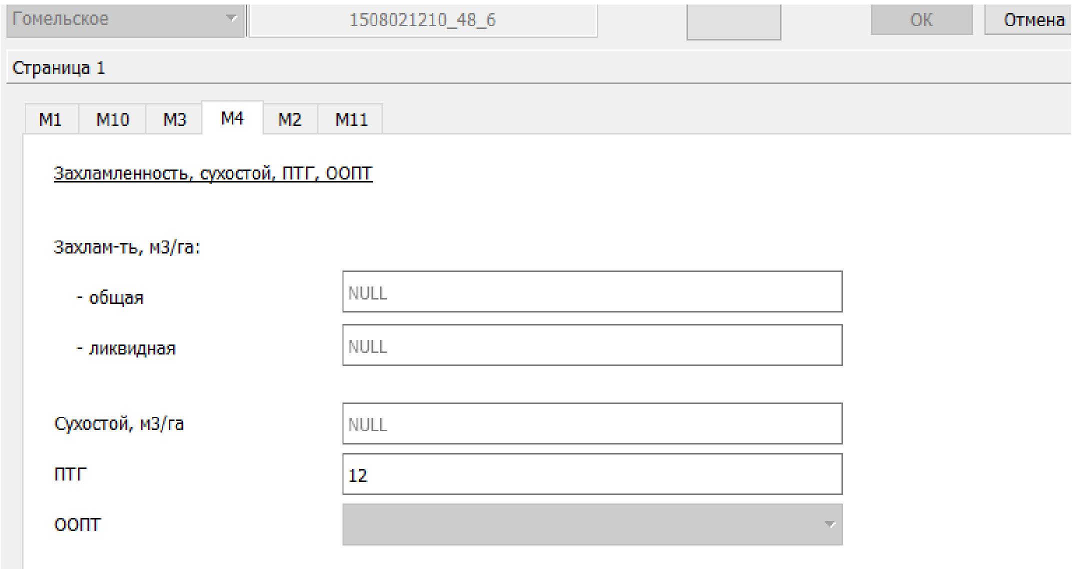

Figure 5.4 – Form "Litter, deadwood, soil type, SPA”

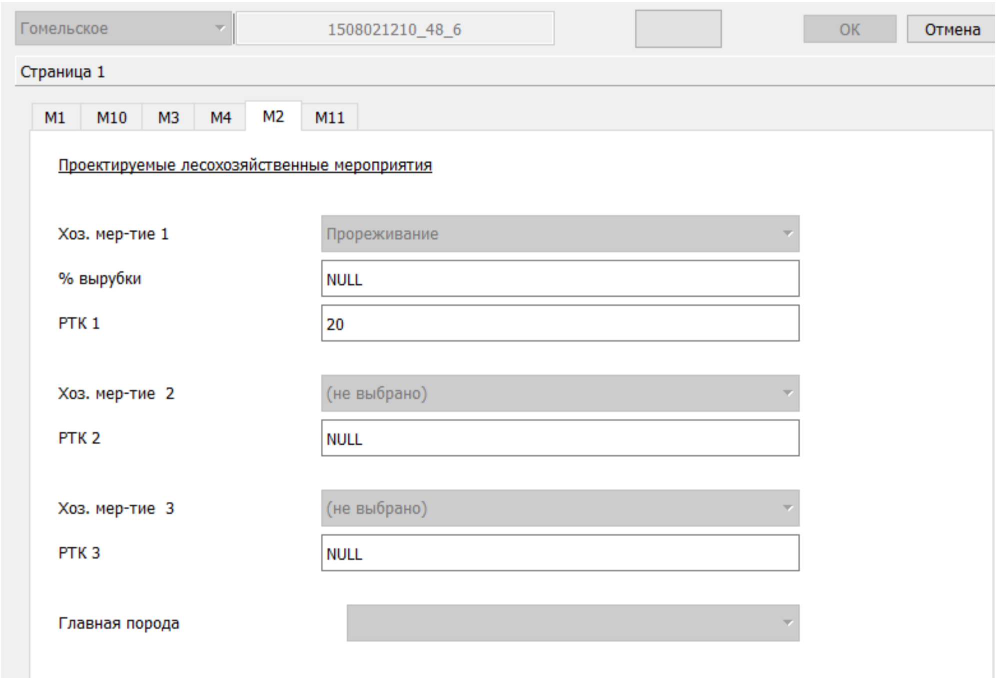

Figure 5.5 – Form "Planned forest management activities"

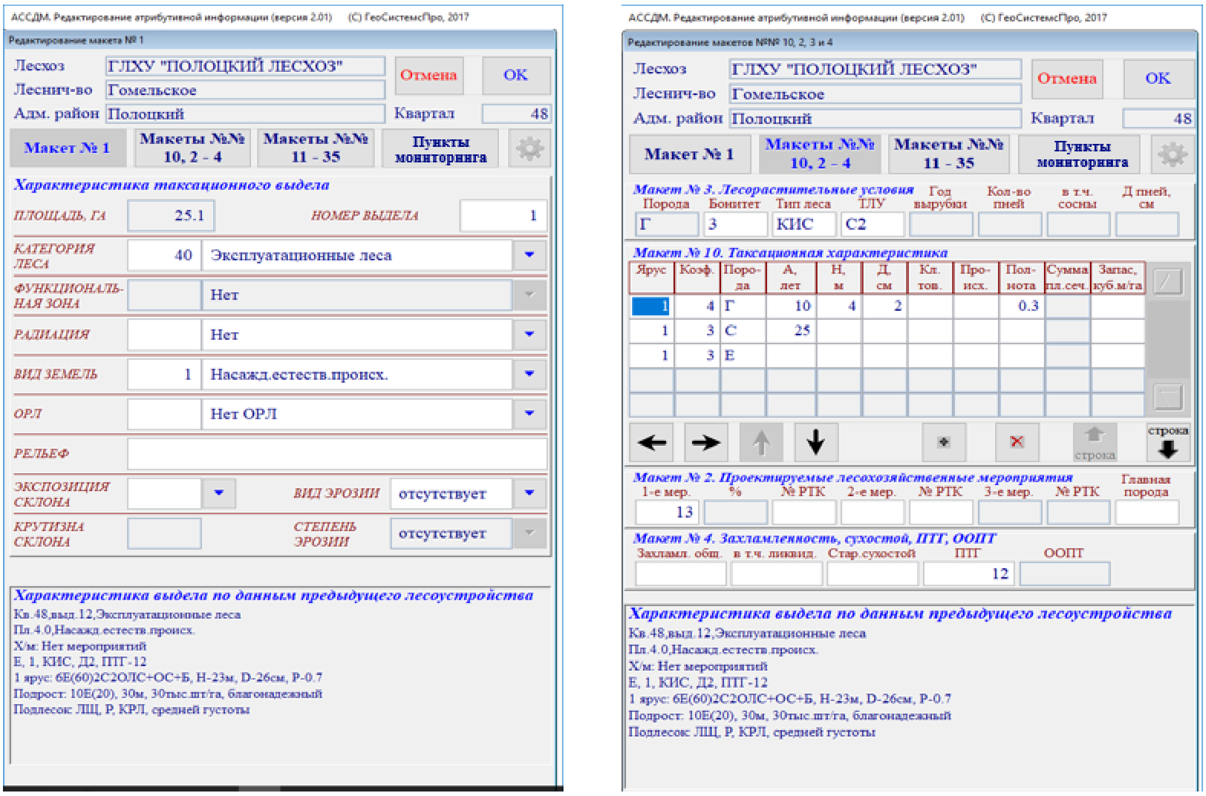

Figure 5.8 – Input of monitoring data to digital record card

Collected information will be represented by vector (coordinates) and attributive data, surrounding spatial location and attributive characteristics of the plot. Automatized system represents integration of hardware and software devices, which ensure input, control, editing and representation of spatial and attributive data that characterizes the monitoring plot.

After the conversion of received information, it can be uploaded to software used in interested organizations.

Trial testing of ASCDM

In the result of the trial testing, found errors and calculation inaccuracies have been corrected, and requirements have been worked out. Taking this into account, approval tests have been made.

During the tests, the following has been done:

– Checkout of the results of trial testing and error and requirements removal;

– Estimation of ASCDM's completeness and quality, according to the requirements, submitted in preliminary specifications;

– Estimation of completeness and quality of documentation, submitted for the tests.

During approval tests the following has been confirmed:

– If structure and compound of GDB ASCDM corresponds with submitted documentation for the system;

– system work ability during completion of tests in full, ability to prevent set up of restricted combinations of values and codes and codes and to notify the operator about data input errors;

– ability of ASCDM to maintain logical and physical integrity of database, to reflect all the changes in condition of the existing objects and to create new ones;

– ability of ASCDM to calculate saved in GDB ASCDM characteristics of monitoring plot properly;

– informativity and convenient data representation in GDB ASCDM, which does not obstruct the use of the system;

– accurate presentation and interpretation of reference books, tables, domains and lists of legitimate values in GDB ASCDM, which does not obstruct the use of the system.

Deployment of the software

Loading of GDB about forest fund and forest resources to the tablet computer is conducted in laboratory conditions. Preparation and uploading of the fragment of central GDB about forest fund and forest resources is conducted with the means of GIS application ArcGIS by the specialist in geographical information systems.

For specialists, we designed a detailed User manual, where all main working points are described.

For users, we designed a Training program on the use of ASCDM. It lasts for 12 hours and will be taught before the field works in RUC "Les".

Program of the seminars includes learning of the structure and compound of GDB about forest fund and forest resources, basic functions of QGIS software, ASCDM working process in QGIS sphere, working skills with Arc GIS for Desktop, which are enough to upload the project to the tablet computer and later transfer data back to the system after the end of the field works and are enough for quality to be controlled by ASCDM services. In the course of the seminars, questions about management, storage, creation, editing and verification of spatial and attributive data in the frames of ASCDM operation are being explained.

Seminar №	Topic	Hours	Notes
1	Introduction to ASCDM. Main definitions, components and principles of ASCDM. Introduction to GIS.	1	Lecture
	Learning of the structure and compound of GDB about forest fund and forest resources, specifics and differences of stationary and mobile GDB.	1	Lecture
2	Learning of the interface, program settings and functions of QGIS, specifics of QGIS usage on table computer and potential of expansion of QGIS basic functions.	2	Practical lesson

Seminar №	Topic	Hours	Notes
	Learning of the working project of ASCDM in QGIS: data of mobile GDB, layer compounds, settings, user forms, programming scripts of data verification.	1	Practical lesson
3	Working process of ASCDM operation on the tablet computer: order of operations for representation, checkout, editing and creation of new spatial and attributive data.	3	Practical lesson
4	Working process of ASCDM in stationary GIS. Structure and purpose of software complex ArcGIS. Functional purpose of modules, included to ArcGIS.	2	Practical lesson
5	Order of data actualization in GDB of stationary GIS basing on data, collected on tablet computers. Updating of mobile GDB and QGIS working project by the up-to-date information of the stationary GDB. Definition of distributed GDB and its replication.	2	Practical lesson

Seminar 1

ASCDM: goals and tasks of the system, sphere of use, structure of the system, functions of program modules, means and methods of data exchange between components of the system.

Introduction to GIS: GIS definition, principles of construction and functioning of nowadays GIS, GIS software.

GDB about forest fund and forest resources: logical and physical structure, coordinate system. GDB of stationary GIS, mobile GDB as part of stationary GDB in borders of working area. Aerophotomozaic and its use.

Seminar 2

Introduction to QGIS as the most popular free up-to-date GIS. QGIS interface: main elements and components. Basic instruments of QGIS. Operation of QGIS settings and working projects. Setting of QGIS interface for usage on tablet computer in field conditions. Setting of GPS. Definition of modules and user functions of QGIS using programming language Python.

ASCDM project in QGIS. Compound of mobile project data, its location on tablet computer. Settings of the project in general and of its separate layers, operation of settings. Connection of external user forms for the output of attributive data and programming scripts of data processing during their creation, editing and verification. Symbolizing of layers.

Seminar 3

Looking through site’s attributive data, forest inventory card and connected additional information. Editing of data: using of input fields, drop-down menus, nested tables (models). Data control. Starting of programming scripts (actions). Informational messages while script processing.

Creation of a new site (sub-site). Editing instruments, topological editing. Fill-out of attributive form (taxation card and models of additional data).

Creation of points and fill-out of attributive data in the layers of forest inventory points and plots. Calculation of characteristics of the stands basing on data from forest inventory points and plots.

Data saving. Exit from the project with saving of the changes.

Seminar 4

ArcGIS for Desktop: up-to-date proprietary GIS. Main components: ArcMap, ArcCatalog, ArcToolBox.

ASCDM working process in ArcGIS for Desktop, working with stationary version of GDB. Editing instruments ArcMap, instruments ArcCatalog, sets of instruments ArcToolBox. Topology in ArcGIS.

Seminar 5

Basics of multiuser GDB ArcGIS. Default version and branch versions. Historical versions. General order of versions corresponding.

Basics of distributed GDB ArcGIS. Creation of replicas and their synchronization with mother GDB.

Causes of collisions during synchronization of versions/replicas and methods of their solving.

Preparation of the project for the tablet computer in the sphere of stationary GIS.

Transfer of data, collected in ASCDM and GDB of stationary GIS.

Prospects of system improvement

During system development, results and experience received by operators is being used. Convenience of system operation is provided with correlation of user accessible instruments of data input, processing, storage and output, system settings and functional elements with extension type and user's level of competence.

Received software will allow fast analyses of forest resources on the territory of the country. Also, working costs of forest monitoring will decrease due to automatization of spatial and attributive data collection, exclusion of many stages of laboratory material processing.

ASCDM will allow better interaction between forest complex and management of nature protection resources, will allow receiving of fast and qualitative estimation of forest resources and make fast decisions in the sphere of forest management.

6. Analysis of the change in forest area and dynamics of the biological diversity of the forest ecosystems of the Republic of Belarus

Natural age and species structure of forests, first of all, are defined by soil conditions (fertility, humidity, acidity, etc.) and climatic factors. Besides, human activity impact on forest ecosystems has been increasing during the whole human history, which led to significant changes in forest structure, forest appearance and disappearance on the land. Thus, the survey of forest fund land transformation in the post-war period is impossible without assessment of changes in the environment during this period

6.1. Climate change impact on vegetation growth

Climate changes are accompanied by numerous extreme weather and climate factors (draughts, floods, rainstorms, strong winds, hurricanes, extreme heat, frosts, abnormal winter temperatures, etc.) and have a negative impact on the condition of forest ecosystems and forestry. These are the extreme weather factors that lead to lessening of trees growth, stands weakening and decrease of their stability against pests. Stands with valuable species are being replaced by small-leaved stands. Stands productivity is also decreasing.

Two periods when drastic climate change took place are registered in the Belarusian territory. The most significant is an increase of annual average temperatures since the beginning of 1990s (Figure 1.1). Global warming is observed not only in Belarus but all over the world. Compared to 1960-1990, the annual average temperature has increased by more than 1°C.

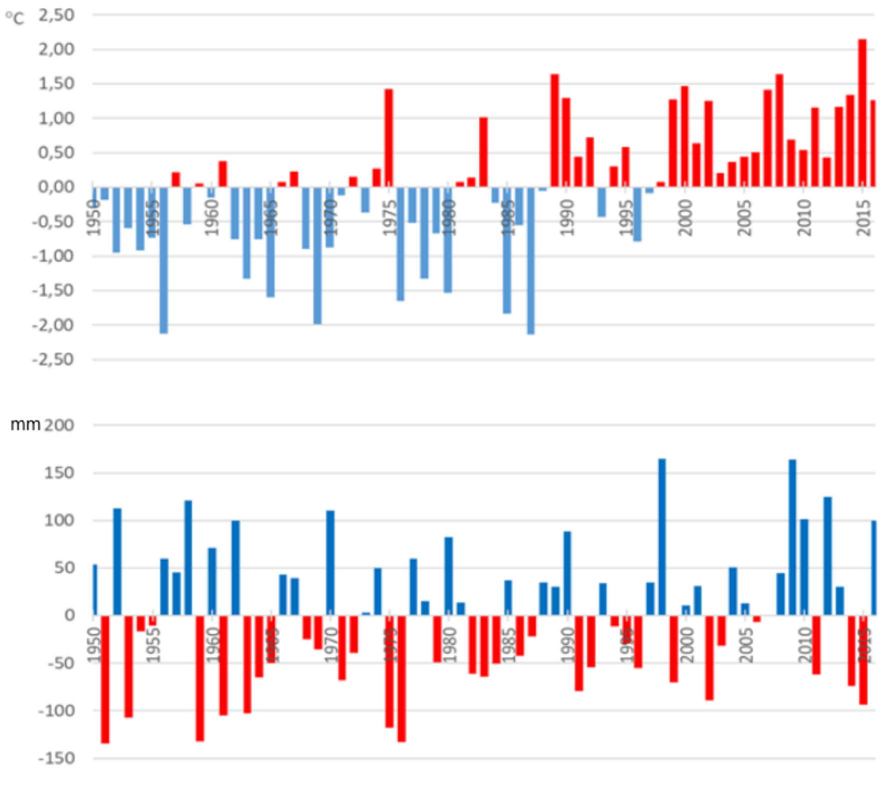

Figure 6.1 – Deviations of annual average temperature and total precipitation amount from average long-registered numbers in the Belarusian territory in 1950-2016

Climate change, first of all, had an impact on winter, late-autumn and early-spring months, which led to longer vegetation season. On the other hand, milder winters and the absence of snow cover led to water lack of plants at the beginning of the vegetation season (Puhacheuski et al, 2011) and more frequent spring frosts. Light increase of summer months temperature with the same precipitation amount led to more intensive and longer summer draughts (Loginov, Brovka, 2012).

The second period of significant climate changes in Belarus is often underestimated. Firstly, these changes took place more than 70 years ago, secondly, meteorological stations of that time made it impossible to assess the changes in the whole Belarusian territory. It was the annual average precipitation amount change that took place. In 1940 in the southern Belarus it accounted for 700 mm, but since mid-1940s it accounted only for 600 mm and remains the same till now (Figure 6.2). It is this climate change that began changes in formation and type structure of bog and over-moistened Belarusian forests.

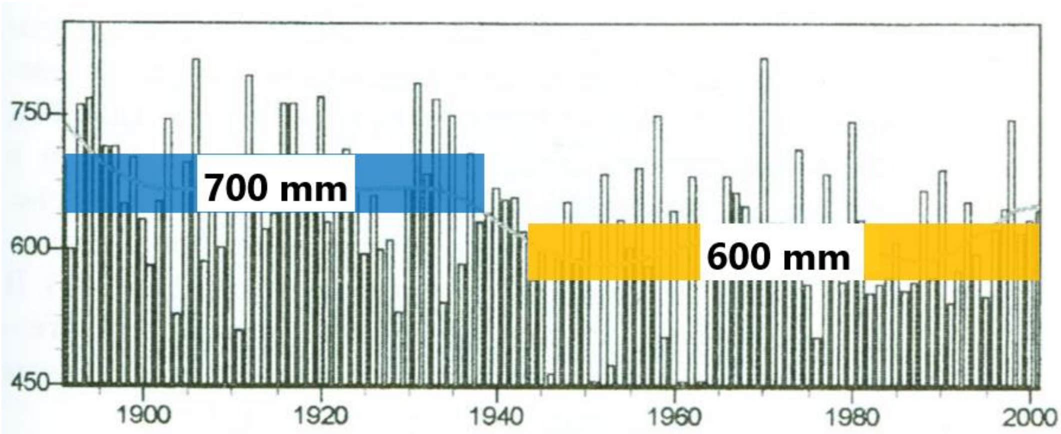

Figure 6.2 – Change in annual precipitation amount in the southern part of Belarus (Loginov et al, 2003)

Expectations of both Belarusian and foreign specialist say that by 2050 annual precipitation amount will not significantly change (Loginov, Brovka, 2012). At the same time, the annual average temperatures are expected to increase by 1.0-1.5 °C.

6.2. Changes in land use

During the post-war period, significant changes in land use in Belarus took place due to several reasons.

First of all, drastic decrease of population in the post-war period and urbanization led to mass afforestation and lessening of agricultural lands area. Such tendencies remain even now (Figures 1.3, 1.4, 1.5).

Since 1991, the Belarusian population is decreasing, in general, but rural population is decreasing several times faster. In 1991 it accounted for about 3.8 million people, but in 2018 – only 2.1 million people. This tendency is registered in all regions (Figure 1.4).

Alongside with rural population decrease, agricultural land area decreases and forest land area increases (Figure 1.5). Compared to 1990, forest- and bush-covered land area increased by 2,191.1 thousand hectares (22.9%). And the structure and condition of the first forest generation in the former agricultural lands significantly differ from forests that continuously grow in forest lands.

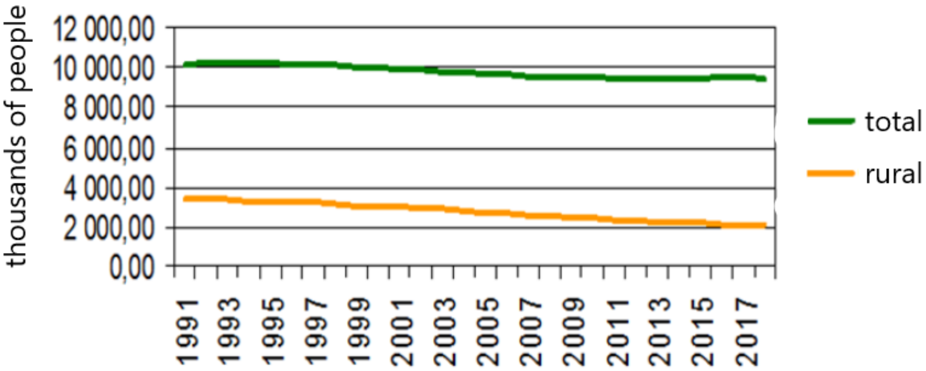

Figure 6.3 – Dynamics of Belarusian population in 1991-2018

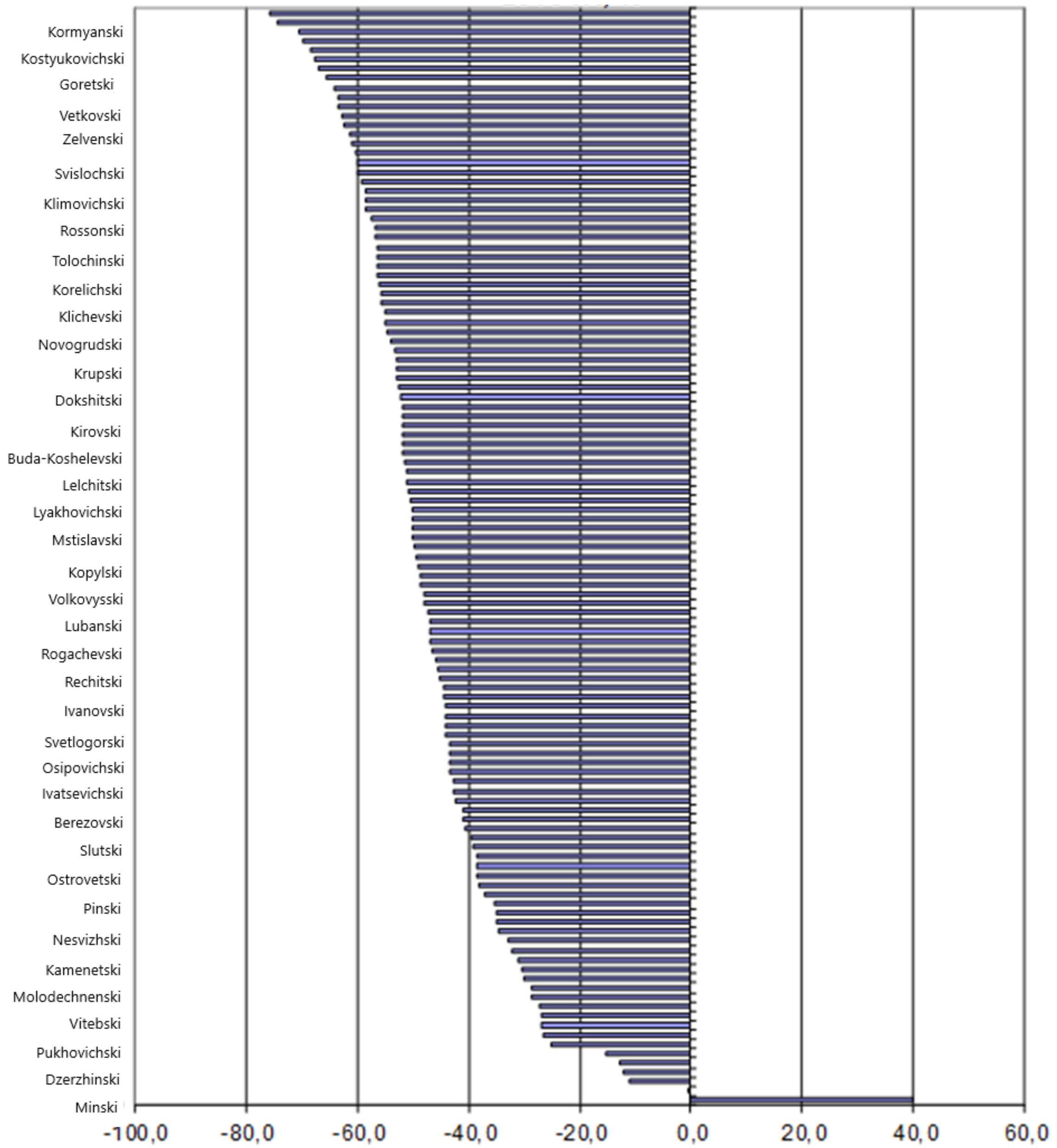

Figure 6.4 – Changes in rural population by regions in 1991-2018

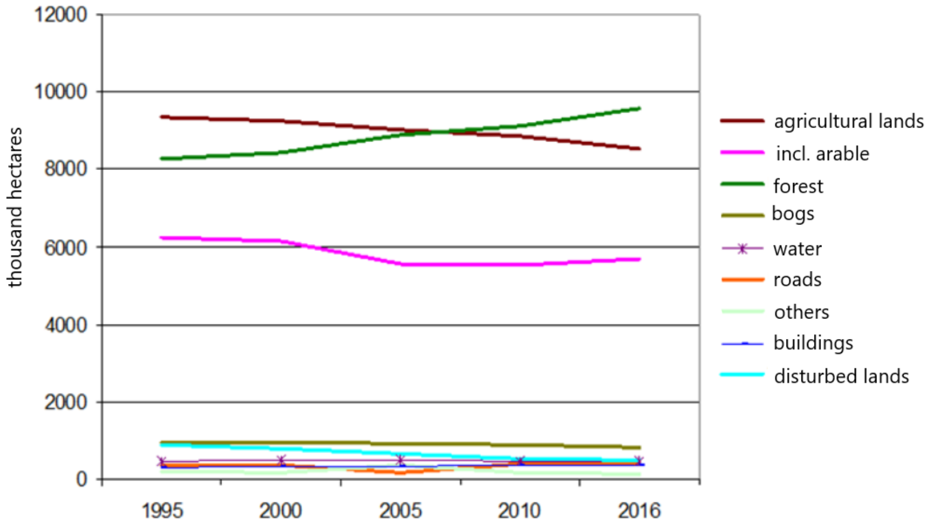

Figure 6.5 – Dynamics of land fund structure in 1995-2016

Intensive development of industrial production in Belarus, building of large factories and processing complexes, development of roads led to the maximum polluting emissions in 1980 (Table 6.1).

Table 6.1 – Dynamics of man-made emissions in the Republic of Belarus in 1988-2017

units	Volume of emissions by years								
	1988	1989	1990	1995	2000	2005	2010	2015	2017
	Emissions from stationary sources								
Thousand tons	1327	1249	1173.3	528.3	388.3	403.7	377	458	453
% by 1990	113.1	106.5	100.0	45.0	33.1	34.4	32.1	39.0	38.6
	Emissions from mobile sources								
Thousand tons	2103	2145	2229.5	1692.5	952.8	1013.9	942	801	787
% by 1990	94.3	96.2	100.0	75.9	42.7	45.5	42.3	35.9	35.3
	Anthropogenic emissions in total								
Thousand tons	3430	3394	3402.8	2220.8	1341.1	1417.6	1 319	1 259	1 241
% by 1990	100.8	99.7	100.0	65.3	39.4	41.7	38.8	37.0	36.5

Besides, at the beginning of production boom, when emissions were insignificant, they favourably influenced forest stands. This is related to entrance of micro- and macroelements required for plants in the ecosystems. After the production achieved its maximum capacity, emissions became critical for stands survival. As a result, growth and condition of trees decreased (Puhacheuski et al, 2001).

One of the most significant factors of environment transformation in Belarus in the 20th century is mass land drainage in 1950-1980. It had impact almost on the whole territory of the country, but the most drained territories are in Polyessye districts (Figure 6.6).

Canal length (except for straightened rivers) in most Polyessye districts accounts for more than 0.75 km/km^2. In five districts (Lyuban, Soligorsk, Luninyets, Drogichin and Kobrin districts) it is over 1.25 km/km^2. Changes in hydrological regime have led to transformations not only of drained agricultural lands, but also to significant changes of forest ecosystems in these regions.

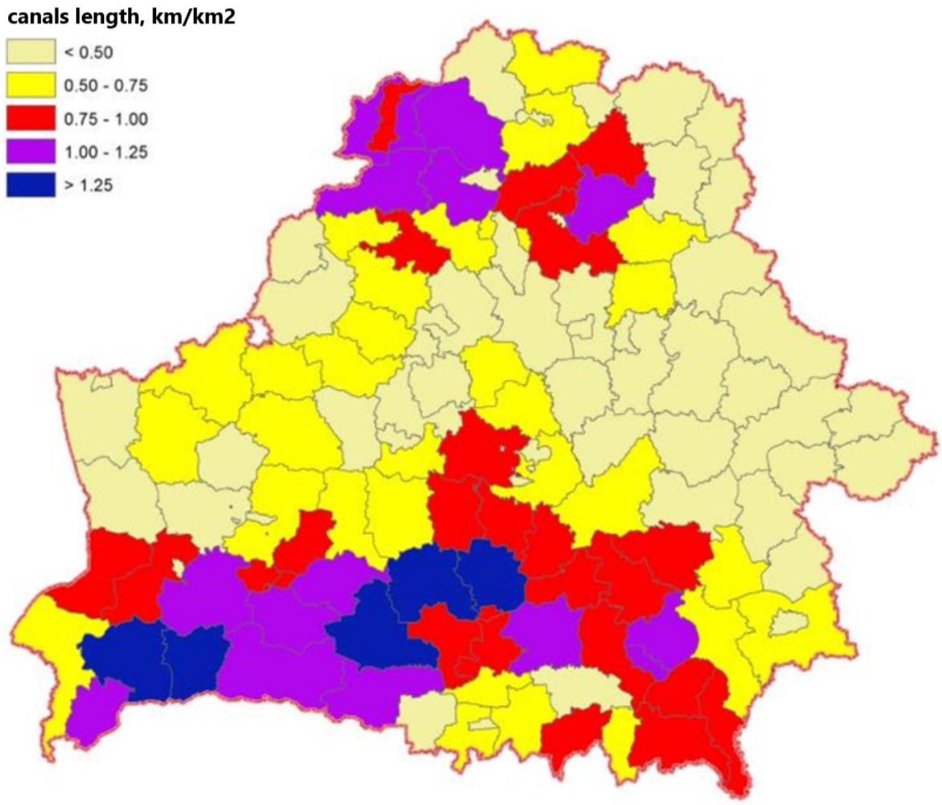

Figure 6.6 – Length of drainage canals in the territory of forestry enterprises

6.3. Changes in the forest-covered lands area of Belarus

More or less reliable estimates of forest-covered area in Belarus appeared only after the country got its present-day borders. This allows to use statistical materials for assessment. If the materials have any flaws, these flaws are insignificant. Estimates of forest-covered area in Belarus given in the pre-war sources are mostly expert opinions based on small data. So, the assessment of forest-covered area in Belarus has been conducted during the period of work and is based on topographic maps of 1930s. Thus, it became possible to make reliable estimates of changes in forest cover of Belarus during the last 80 years.

Forest-covered area was calculated by the geographical method, using GIS software. The basis was topographical maps of the General Staff of the Red Army in scales 1:50000, 1:100000 and 1:200000, prepared and published in 1927-1936, and in 1937-1940. Thus, the data are not older than of the years 1937-1940, as the topographical maps were refined (in Poland and neighboring countries maps were prepared and edited only by using aerial photography data).

Vectorization was conducted manually, the data were entered to shp-file, and at the end the areas of the indicated plots were calculated and data were exported to the aggregated table. After vectorization and areas calculation, the data were aggregated into the table by administrative districts. Data on total land area, forest land area, forest and bush-covered land area were taken from the Land Resources Register, data on total forest fund, forest lands and forest-covered area was taken from the Forest Cadastre. The aggregated data on changes in forest-covered area by regions are shown in Table 6.2.

On January 1, 2016, the total forest-covered area accounted for 9.1 million hectares or 43.7% of the total area of the Republic of Belarus, forest stock is 0.95 ha/capita. The most forest-covered districts in 2016: Rossony District (73.5%), Narovlya District (70.2%), Lyelchitsy District (68.5%), Gorodok District (66.6%), Krasnopolye District (61.8%), Klichev District (61.6%), Polotsk District (61.4%). The least forest-covered districts are: Nyesvizh District (12.9%), Mstislavl District (17.6%), Zelva District (18.4%), Berestovitsa District (18.9%). The most forest-covered areas are located in the north of Belarus, in the Berezina river basin and in Polyessye region. The least forest-covered areas are located in Predpolyessye region and in the east of Belarus – in regions with the most developed agriculture. The largest increase of forest-covered area (compared to 1937) was registered in Vitebsk region and in some districts of Gomel and Mogilev regions that were affected by Chernobyl disaster. The decrease of forest-covered area in absolute terms in some regions is related to the development of agricultural activity, changes in settlement system and mass drainage in 1960-1970.

Table 6.2 – Changes in forest-covered area in 1929-1939 and 2016

Regions	Total area of the region, ha	Area in vector layer	Forest area in 2016, ha	Forest area in 1930s, ha	Forest-covered area in 2016, %	Proportion in 1930s, %	Increase since 1937, %
Total in Belarus (except for Minsk city)	20,725,569	20,582,378	9,046,738	6,378,031	43.7	31.0	40.9
Brest Region	3,278,644	3,269,856	1,270,793	1,041,965	37.6	30.7	22.3
Vitebsk Region	4,005,134	3,989,216	1,932,550	1,112,720	46.3	26.3	76.3
Gomel Region	4,036,951	3,926,288	2,027,774	1,375,904	48.9	33.5	46.0
Grodno Region	2,512,698	2,499,169	931,825	734,965	35.4	28.1	26.0
Minsk Region	3,985,380	3,999,680	1,622,295	1,341,567	38.7	32.3	19.8
Mogilev Region	2,906,762	2,898,169	1,256,984	888,250	42.3	30.1	40.8
Total in BSSR in the borders of 1937	12,652,429	12,540,893	5,947,504	4,096,383	47.0	32.4	45.2
Total in Western Belarus in the borders of 1937	7,846,379	7,814,351	2,970,260	2,343,538	37.9	29.9	26.7

In 1937, the forest-covered area in the current borders of the Republic of Belarus accounted for 6.4 million hectares or 31.0% from the total country area (Figure 2.1), the forest stock varies from 0.68 ha/capita to 0.76 ha/capita depending on the population estimation method. Therefore, the forest-covered area has increased by 40.9% compared to 1937. The most forest-covered districts in 1937 were: Zhitkovichi District (57.9%), Yelsk District (55.5%), Gantsevichi District (52.7%), Klichev District (52.3%), Lelchitsy District (50.1%). The least forest-covered districts were: Kamenets District (8.0%), Chashniki District (8.5%), Nyesvizh District (11.1%), Shklov and Mstislavl Districts (13.0%). The most forest-covered districts were located in Polyessye region and in the Berezina river basin. The least forest-covered districts were located in the east of Belarus and Pribuzhye region.

According to the research, in 1920-1930 forest-covered area of the Europe was about 31% (Yalava states it to be 28.7%, forest-covered area of the USSR European part – 29%) (Orlov,1931), i.e. the percentage of forest-covered area in Belarus is almost the same as the average European percentage of forest-covered area of that time.

V.F. Baginskiy (Baginskiy, Yesimchik, 1996) noted that the percentage of forest-covered area in Belarus in 1917 was 22%, due to intensive reforestation activities the situation got better and by 1939 it was 26.7%. But the author does not mention either sources of the data or the methods of calculation. Besides, it is unclear if the number means the forest-covered area in the borders of BSSR before November 2, 1939 (official joining of Western Belarus to the USSR) or in the current borders of the Republic of Belarus.

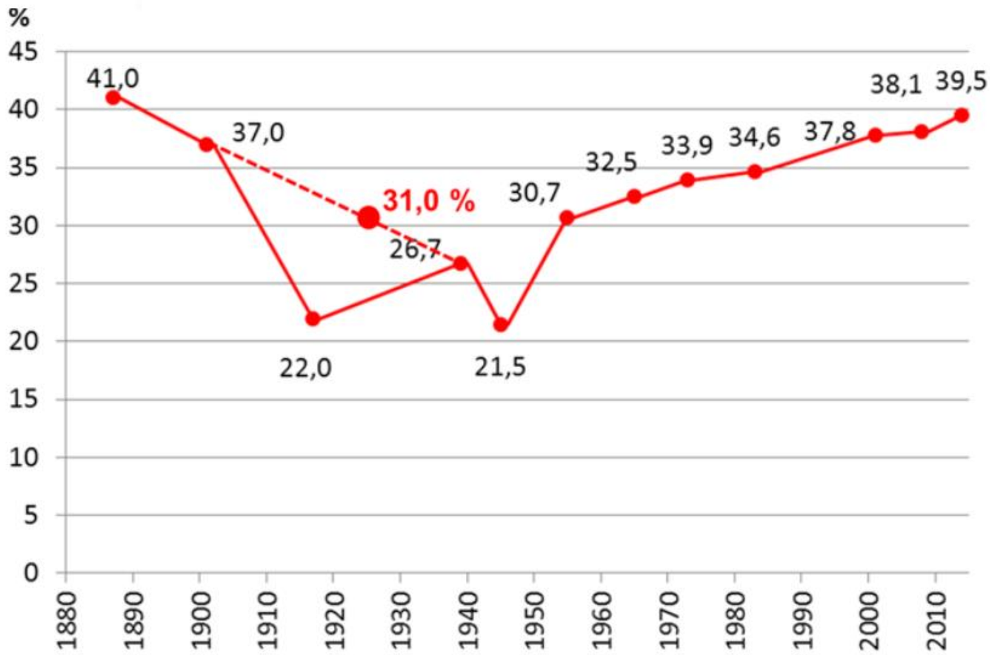

Figure 6.7 – Dynamics of forest-covered area in Belarus (Baginskiy, Yesimchik, 1996, refined by topographical maps)

Thus, the corrected dynamics of forest-covered area percentage shows that the area was continuously decreasing from 41.0% at the end of the 19th century down to its minimum in the post-war years (21.5%). No dounbt that it was stipulated by intensive cuttings during both World Wars and mismanagement in the Revolution period. Only in the post-war period the forest-covered area began to increase. In the first post-war years it was stipulated by a great decrease of Belarusian population and natural afforestation of agricultural lands. Then, forest managers took part in the process using artificial afforestation methods in lands not used before.

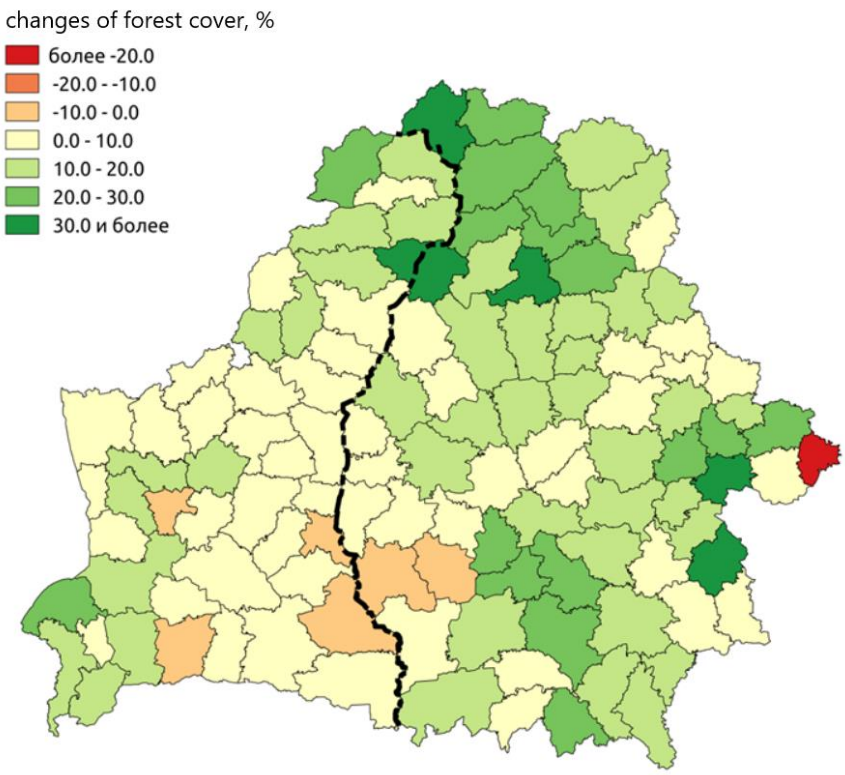

Figure 6.8 – Changes in forest-covered area in Belarus in 1930s-2016

At the same time, it should be noted that not all Belarusian districts went through the increase of forest-covered area (Figure 6.8). In Lyuban district, Soligorsk district, Drogichin district, Zelva district and Kletsk dDistrict forest-covered area decreased by 0.1-10.0%. First of all, it is related to intensive agriculture development in the districts and mass bog drainage. This has led to a significant transformation of forest ecosystems in the periphery of forest-bog massifs and the decrease of their stability.

6.4. Changes in typological and species structure of the forests

The increase of forest-covered area in Belarus caused by afforestation of agricultural lands and bogs as well as climate change and mass drainage has led to changes in typological and species structure of the forests. Besides, a change in age structure of forest stands is another reason for changes in typological forest structure.

In 1978-2018 proportion of pine forests decreased by more than 7% of the total forest area: from 57.6% to 50.2%, oak – from 4.0% to 3.5%. But at the same time the total forest area increased by more than 15%.

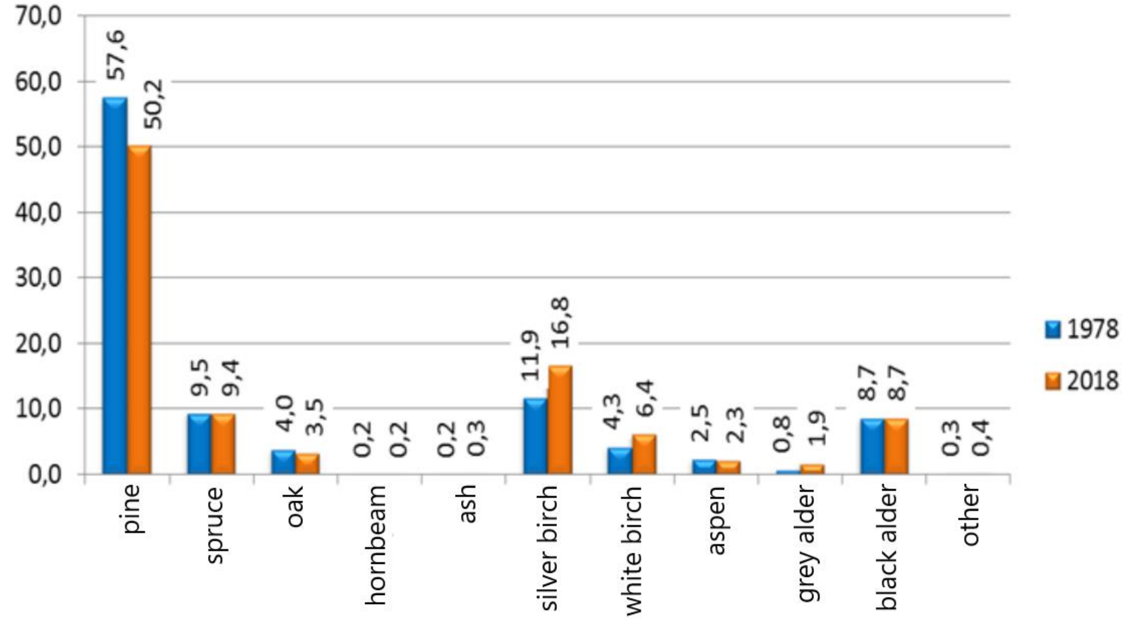

Figure 6.9 – Changes in species structure of the Belarusian forests

At the same time the proportion of birch and grey alder forests has increased. These changes clearly reflect the process of natural afforestation of agricultural lands. It is birch, and grey alder in the north, that are pioneer species to be first to conquer open spaces. Currently, the proportion of hornbeam, ash, aspen, etc. forests altogether accounts for more than 4% of forest territory.

Black alder forests should also be mentioned as their area accounts for 8.7% of total forest area. This proportion hasn't changed for more than 40 years. Increase of black alder area, first of all, is stipulated by afforestation of floodplains and swamps where hay mowing stopped.

In the typological structure of forests, the proportion of the most infertile upland forests, such as *cladinosum*, *callunosum*, *vacciniosum* and *pleuroziosum* forest types (Figure 6.10) decreased. The proportion of *callunosum* forest type decreased from 12% to 2%. At the same time the proportion of the most fertile forest types such as *pteridiosum*, *oxalidosum*, *vacciniosum* and *filicosum* increased. These changes mostly reflect changes in the age structure of the forests: in the young growth on former agricultural lands in the post-war period, the ground vegetation is very poor. Only after 60 years it stabilizes, young growth and the second layer of forest stands appear. This allows to identify the forest type more clearly. Besides, by that time forest environment appears and fallen trees, leaves and needles in a certain way increase the ground fertility.

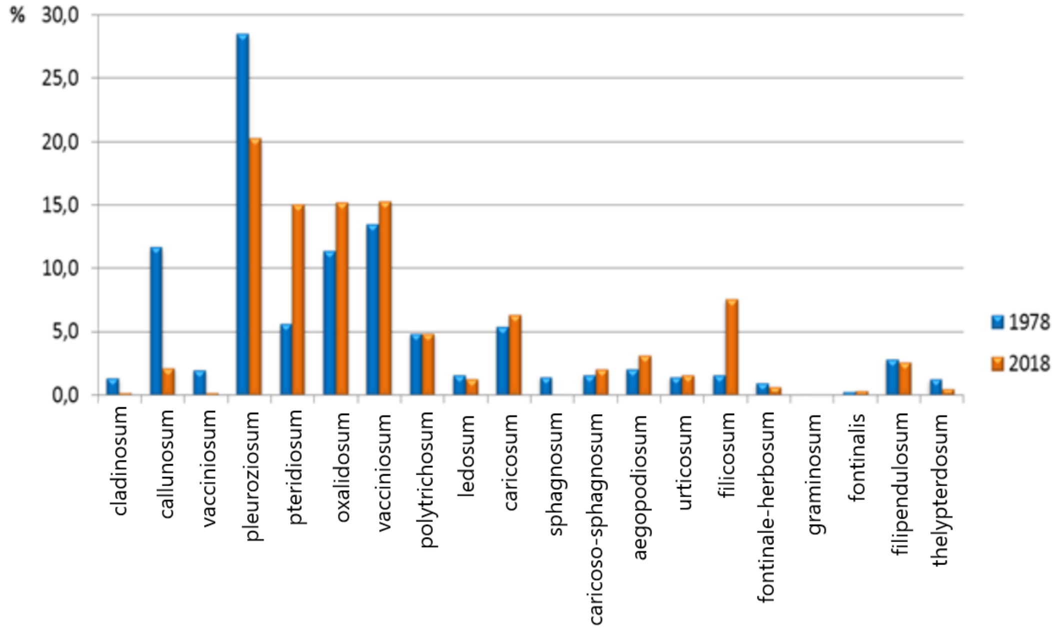

Figure 6.10 – Change in typological structure of Belarusian forests

Bog afforestation reflects almost complete disappearance of *sphagnosum* forest type and their replacement by *caricoso-sphagnosum* forest type. At the same time, the proportion of bog forest types, such as *thelypteridosum*, *filipendulosum*, *fontinale-herbosum* forest types, decreased and the proportion of *filicosum* forest type drastically increased. Such changes are clearly related to mass drainage, as the forest inventory showed that most post-drainage forests are *filicosum* forest type forests.

The similar changes take place in protected territories. Surveys conducted in Berezinski Biosphere Reserve have shown that about 16% of current forest ecosystems are located in areas used to be agriculture lands during different periods of time: from 5 to 90 years ago (Yermokhin et al, 2017). This made it possible to track the dynamics of plant communities from the beginning of natural restoration successions to the formation of native forest stands. The following tendencies are noted in forest and bog-forest ecosystems:

- transformation of white birch forests in transitional bogs to pine forests;
- upland bog afforestation with pine forests, transitional bog afforestation with white birch forests. This process began long before the climate change and was registered in 1976-1993;
- stable enough condition of black alder forests in lowland bogs – in some areas they are replaced by white birch forests and, on the contrary, in some areas black alder becomes a dominating species in white birch forests.

It was proved that forest stands naturally appeared on non-forest-covered lands stand with higher diversity than forest plantings created on the same land category. The older trees are, the lesser number of forest formations is, as tree and bush species of short lifespan are no longer there (Salix, aspen, grey alder, birch).

Species structure of forest plantings created both in the pre-war and post-war periods, both in former agricultural lands and cutting sites didn’t change much. In all cases pine forests dominate – from 87.7% to 100%. At the same time, when natural afforestation takes place on such lands, pine dominates only in 30-50% of cases. It was noted that in more than 50% of cases forest management was in conflict with natural successions.

6.5. Transformation of areal borders of main forest species

Forests in Belarus has a complex species and typological structure. This is due to the fact that Belarus is in the zone of change of two large botanical and geographical boundaries - the Eurasian boreal coniferous forest and European nemoral broad-leaved forest. On the territory of Belarus there are borders of the distribution of three forest-forming species - the southern border of the European spruce (*Picea abies* L. Karst.), the southern border of the gray alder (*Alnus incana* (L.) Moench), and the north-eastern border of the common hornbeam (*Carpinus betulus* L.)

In conditions of global warming, lessening of areal borders of boreal species (spruce and grey alder) and enlargement of areal borders of immoral species (hornbeam) are expected. Last survey has shown that in the recent 60 years the areal border of European spruce has moved to the north by 20-30 km in some plots (Figure 6.11). This is related to climate change, influence of drainage and forest cuttings (Yermokhin, Puhacheuski, 2009).

The assessment of areal borders has shown that in the current situation the western part of hornbeam areal border should be marked 10-20 km to south-west compared to the marks by Heltman (1982). At the same time, it should be marked 10-20 km to the north in the central part of Belarus (Uzda, Dzerzhinsk, Osipovichi and Klichev districts). Currently there are several hectares of hornbeam stands here. In the central and eastern parts, hornbeam areal border hasn't changed much. But along the border, at the 10-km distance from it, under favourable conditions hornbeam appears as young growth or second-layer trees. In case of first-layer cutting, hornbeam will be able to dominate here under current climatic conditions.

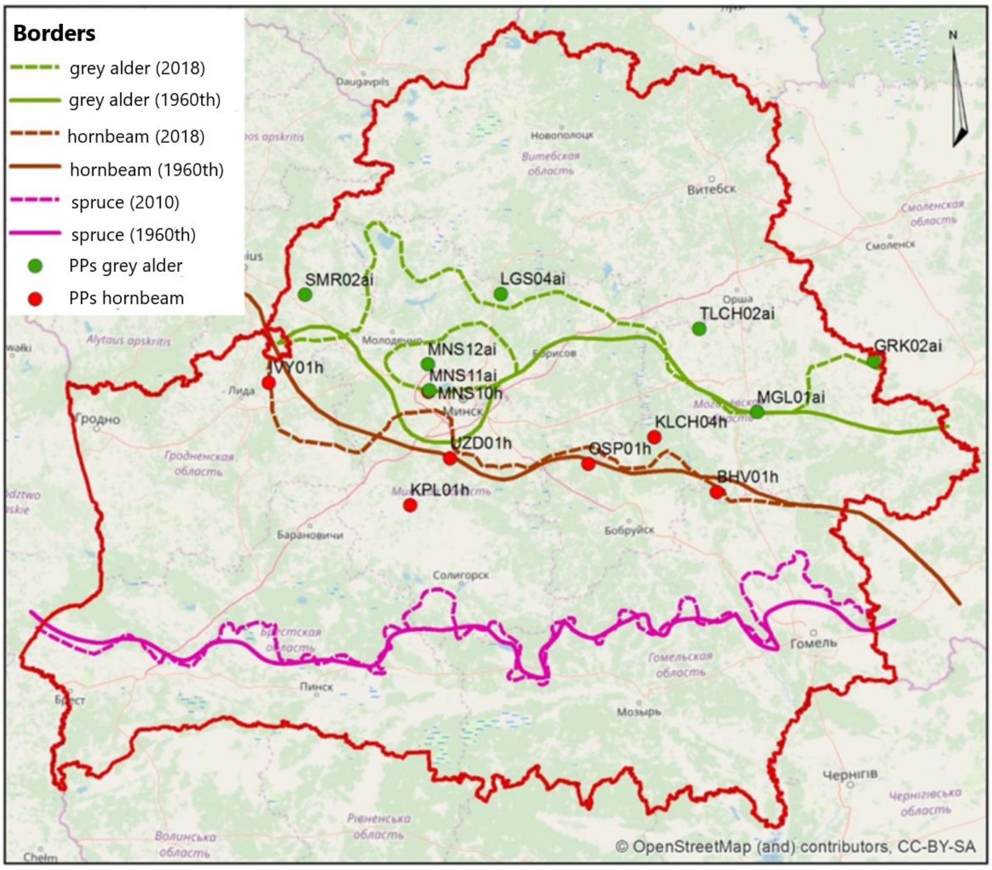

Figure 6.11 – Changes in areal borders of spruce, hornbeam and grey alder forests in the Belarusian territory

Far more significant changes occurred to the areal borders of grey alder. In fact, its border is 100 km to the north in the central part of Belarus and 50 km to the north in the eastern part, compared to 1960s, and rounds Minsk hill from the north. Such change of grey alder areal completely corresponds to natural successions, climatic fluctuations and changes in agricultural management. And it seems that climatic change wasn't the last factor to play the great role in the process, as since 1990s the annual temperatures are often 0.5-1.0°C higher than average long-period temperatures, and at the same time precipitation remains the same, so all these factors led to more frequent draughts.

Alongside with areal border changes, periodical large-scale forest death is a result of climate change (see Chapter 3).

6.6. Dynamics of vascular plant diversity in forest fund in 1945-1962 and 2001-2017

In order to assess biological diversity of plants, data on the most representative and well-surveyed organisms were taken into account – there are big fundamental researches on vascular plants in the middle of the 20th century (Flora of the BSSR, 1949, 1949a, 1959, 1955, 1959), in 1930-1950 and at the end of 1990s – the beginning of 2000s (the Identification guide for higher plants …, 1999; Flora of Belarus …, 2009, 2013, 2017; Red Book …, 2015).

According to the data from the five-volume edition "Flora of the BSSR" (1945-1956), 1,785 species were analysed, and later confirmed by findings. But for the later analyses of biological diversity dynamics stipulated by forest management activities, only 906 plant species growing in forests, forest edges, clearings, bushes and bogs were taken into account. And on the other hand, species that grow only in forest plantings (412 species), on meadows (146 species), in water and near it (84 species), in ruderal habitats (134 species), on sands, open slopes and buildings (64 species), taxonomy doubtful species and hybrids (39 species) are indicated in Table 6.3.

According to the data of last decades from the Identifyer for higher plants in Belarus (1999); three volumes of Flora of Belarus (2009, 2013, 2017), the Red Book of the Republic of Belarus (2015) and Internet resource "Belarusian plants" (http://gbs.bas-net.by/plantae), 2,250 species are registered in Belarus. For the future detailed analysis of biological diversity dynamics stipulated by peculiarities of forest management, 1,101 species growing in forests, forest edges, clearings, bushes and bogs were taken into account. The species growing only in forest plantings (446 species), on meadows (136 species), in water and near it (132 species), in ruderal habitats (385 species), on sands, open slopes and buildings (18 species), taxonomy doubtful species and hybrids (30 species) are mentioned in Table 6.3.

Table 6.3 – Total number of species analysed in 1930-1950 and 1990-2010

Species categories	Number of species analysed	
	1930-1950	1990-2010
Included in the latest analysis, total	906	1101
Species growing in:		
Forest	545	719
Forest edge and bush	222	260
bog	139	122
Excluded from the later analysis, total	879	1147
Species growing in:		
Meadow	146	136
Water and near water	84	132
Ruderal habitats	134	385
introduced species growing only in parks, gardens etc.	412	446
Sands, open slopes, buildings	64	18
Doubtful, hard-to-analyse hybrids	39	30
Total	1,785	2,250

In five-volume book "Flora of the BSSR" (1949, 1949a, 1950, 1955, 1959), 545 vascular plant species of 275 genera of 92 families were considered forest species. From them, 108 species are usual for leaved forests (41- broadleaved forests), 178 – coniferous forests (128 – pine forests), 59 – black alder and other bog forest stands (31 – alder forests).

From the total number of forest species in 1930-1950, 278 species also grew at the forest edge and in bushes, 19 – on clearings, 44 – on bogs. In total 500 species of vascular plants grew at forest edges and in bushes. 198 species were registered on bogs, 139 of them were originally bog species

In 1930-1950 only 23 introduced species were found, they were mostly trees: *Pinus mugo, Pinus nigra subsp. pallasiana, Pinus nigra, Pinus banksiana, Pinus murrayana, Pinus rigida, Pinus strobus, Pinus sibirica, Pinus cembra, Larix sibirica, Larix decidua*. But all of them are growing in forest plantings. Recently such species as *Sambucus racemosa, Amelanchier ovalis* are found in forests, at forest edges and in bushes. Only such grasses as Be*llis perennis, Vinca minor, Vinca herbacea, Bryonia alb*a are considered "sometimes growing wild near a settlement". 32 species of introduced vascular plants were found, this is 3.5% of the total number of analysed flora species. 50 years after the last fundamental survey of the Belarusian flora, its species structure has changed significantly. At the same time forest, forest-edge and bush, bog fractions of flora have changed significantly as well.

Reasons for such changes are both objective (agriculture, climate change, land transformation) and subjective – related to more fundamental and detailed survey of forest plants, changes in taxonomy of a range of families and genera, when instead of 1 species, there are 2-3 and more previously unidentified species are found.

Among 1,101 species of analysed flora, 720 species of 330 genera of 79 families are considered forest species. Among them 420 grow at forest edges and in bushes, 102 – on clearings, 120 – in bogs. Also, there are 260 more plant species of 147 genera that grow at forest edges and in bushes, and 123 species of 65 genera growing in bogs (Table A2). Altogether, 680 species were found at forest edges and in bushes, 256 – in bogs.

Total increase of species number since the 1st survey period (1930-1950s) until the 2nd (1990-2010s) is 121.5%, number of genera – 109.3%.

At the same time the number of introduced species increased by 78.3% (from 23 to 41), and the number of brought species increased almost by 3 times (from 32 to 94). 42 of them are aggressive invasive species, whose reproduction leads to transformation of phytocenosyses and disappearance of native species. The proportion of such species in the surveyed flora fraction reached 3.8%, , the total proportion of invasive species reached 8.5%, and in 1930-1950s it was only 3.5%.

The number of vascular plants listed in the Red Book of the Republic of Belarus (Red Book …, 2015) is 13.8% (152 species) of the total number in analysed types of habitats. This is 80.4% of all protected vascular plants.

A significant increase of brought species, including invasive species, in the flora of forests, bogs, forest edges and bushes is caused by the following reasons:

-significant increase of forest-covered area of the country (from 25 to almost 40%), as well as due to afforestation of previously non-forest lands and introduction of non-forest species to the structure of new forest ecosystems, especially pine and small-leaved forests;

-drainage of great bog areas, forests and nearby lands, which led to decrease of forest phytocenosis stability against invasion of meadow and ruderal species;

- use of introduced tree and bush species that are actively invasive (*Querqus rubra*, *Acer negundo, Robinia pseudoacacia, Amelanchier spicata, Lupinus polyphyllus* etc.) for reforestation and afforestation;

- expansion of a range of introduced species from nearby regions of Poland, Ukraine and Lithuania (*Prunus serotina, Asclepias syriaca, Xanthium albinum,* etc.);

- adaptation of many not-native plant species to Belarusian climatic conditions and to competition with native species;

-general climate warming during global climate change.

In most cases, forest management doesn't lead to natural flora degradation. In the total number of surveyed plant species listed in the "Black list" of the Red Book that vanished during the surveying period, only 11 grew in the surveyed habitats: 3 of them growing in forest (*Aposeris foetida, Gladiolus palustris u Cephalanthera grandiflora*), 4 – at forest edge and in bushes (*Botrychium lanceolatum, Linum flavum, Cypripedium guttatum, Orobanche caryophyllacea*), 4 – in bogs (*Sonchus palustris, Montia lamprosperma, Carex rhynchophysa, Nasturtium officinale*).

At the same time, forest species dominate among vascular species listed in the Red Book of the Republic of Belarus that need protection (Table 6.4). Among the protected animal species, those that live in forest, bog, forest-edge and bush habitats dominate too (Table 6.5).

On the one hand it shows that used forest management does not fully meet the requirements for rare species habitats, and on the other hand, it increases the responsibility of forestry enterprises for 226 plant and animal species protected by the nature protection legislation of the Republic of Belarus.

Table 6.4 – Distribution of protected vascular plants by type of growing conditions and categories of national nature protection significance (according to the Red Book ..., 2015)

Type of habitat	Number of species by the category of national nature protection significance				Species in total
	1	2	3	4	
Forest	29	30	26	24	109
Bog	10	7	8	2	27
Forest edge and bushes	6	6	4	2	18
Total	45	43	38	28	154

Table 6.5 –Distribution of protected animal species (except for fish) by habitats (according to Red Book ..., 2015a)

Type of habitat	Mammals	Birds	Amphibians and reptiles	Insects	Other land invertebrates	Species in total
Forest	10	17	2	28	1	58
Bog	-	15	-	15	-	30
Forest edge and bush	4	4	-	16	-	24
Meadow	2	9	-	13	-	24
Floodplain and near-water	3	10	2	5	1	21
Man-made	1	3	-	1	-	5
Sand	-	2	-		-	2
Water	-	10	-	9	7	26
Total	20	70	4	87	9	190

6.7. Key factors of transformation of Belarusian forest cover

Changes in age and species structure of Belarusian forests in the post-war period were going on in different ways, which was caused by numerous outside factors. The main changes can be divided into the following groups:

- drastic enlargement of forest-covered area;
- decrease of broadleaved and pine forests proportion on one hand, and increase of birch and grey alder forests proportion, on the other hand;
- decrease of the most infertile upland forest types proportion: *cladinosum, callunosum, vacciniosum, pleuroziosum* and increase of more fertile forest types proportion: *pteridiosum, oxalidosum, myrtillosum*;
- almost complete disappearance of *sphagnosum* forest type and its transformation into *caricoso-sphagnosum* forest type;
- appearance of pine forests in open raised bogs and white birch in transitional bogs;

- decrease of the proportion of forest types related to bogs: *thelypteridosum*, *filipendulosum*, *fontinale-herbosum*, and drastic increase of *filicosum* forest type proportion (most post-drainage forests);

- transition of continuous diversion of forest-making species to the north: European spruce, common hornbeam and grey alder;

- periodical large-scale forest death from unfavourable climatic conditions or bark beetle attacks;

- drastic increase of number of introduced and brought plant species in forest ecosystems;

-drastic increase of introduced species number.

There are several **key factors** in these processes. These factors often enhance each other. There are both relatively natural and purely human factors:

1) changes in land use (lessening of used agricultural lands) have led to drastic enlargement of forest-covered territory and bog afforestation with tree and shrub vegetation;

2) stable decrease of precipitation by 20% in 1940s and mass drainage in 1950-1970 conducted after these climate changes have led to fast bog afforestation with tree and shrub vegetation, decrease of bog forest types proportion, appearance of unstable post-drainage forest types and active appearance of meadow and weedy-ruderal species in forest ecosystems;

3) forest management (first of all, cuttings, reforestation and afforestation) has led to simplicity of age, species, and spatial forest structure, decrease of broadleaved and pine forests proportion, increase of birch and grey alder forests proportion; introduction of invasive species to forests (while forest plantings creation);

4) climate warming since 1990s and related longevity and intensity of summer draughts, longer vegetation season have led to changes in the borders of species diversion, forest stands weakening and often pest outbursts that lead to mass forest death.

Other factors that influence forest ecosystems and lead to their transformation but locally include the following:

- forest and peat fires;
- recreational burden of forest ecosystems;
- pollution by industrial emissions;
- hunting farms (larger number of ungulates);
- flooding of single areas because of beaver activity or drainage systems;
- development of communication routes, enlargement/ lessening of locality areas.

The task of forest management in such conditions is pretty clear: to preserve/restore hydrological regime and adapt forest structure to the circumstances in place. Therefore, there will be only one uncontrolled factor – climate change, which, unfortunately, humanity cannot control.

7. Development of a system of measures to prevent degradation of forest lands

High share of drained wetlands in Belarus and forest lands with high water table promote the formation of waterlogged lands. Such lands are characterized by essential change of the hydrological regime towards the increase in the ground water level (GWL). Increase in the area of such lands is caused by a variety of reasons of anthropogenic and natural character. Waterlogging of forest lands is followed by a number of negative consequences. They are decrease of forest stand growth rate, forest stands dieback, transformation of lands in less productive ones, degradation of landscapes.

This document provides a set of measures for differential approach to waterlogged woodlands for their return to normal economic cycle, for the increase in efficiency of the use of such lands and maximization of output of forest products.

It was supposed that polder sites would not only maintain normal water table on farm-lands, but also correctly regulate hydrological regime on woodlands. However it doesn't take place and reasonable recommendations for appropriate nature protection actions weren't devel-oped.

The category of the disturbed lands in the form of cut-over peatlands has close connec-tion with draining melioration. The insufficient use of cut-over peatlands is caused by complexity and considerable cost of their drainage and development as well as the lack of appropriate responsibility for their timely transfer to further use. In this regard the performance of complex of actions for prevention of degradation of such lands by local reclamation is relevant. The part of the present Recommendations is dedicated to the question.

Separate provisions on prevention of degradation of woodlands because of recreational load are also stated in the Recommendations.

7.1. General provisions of the System of Actions for Prevention of Forest Lands Degradation

Degradation of lands on the territory of Belarus in its various forms is caused both by environment and anthropogenic influences. Those influences is closely connected with features of functional use of the lands and protection of land resources.

Hydrological regime of lands drained for agricultural use has been significantly changing in the last 20-25 years due to raising of the ground water level. Formed waterlogged lands often characterized by a sharp change in the hydrological regime, which cause subsequent forest stands dieback.

Waterlogged woodlands are subject to recovery with preservation of their nature protec-tion functions, according to requirements of improvement of the environment, with obligatory respect for the principle of effective use of forest lands.

The problem of recovery of forest ecosystems disturbed by waterlogging as a result of human activity has to be solved after their inventory. On the basis of the received data the possi-bility of land rehabilitation on waterlogged area is determined. The ways of their further use are listed below:

– forestry (restoration of forest stands);

– water management (creation of fire ponds and reservoirs of other types);

– nature protection (with preservation of the high but stable water table; for example, preservation of the wild cranberry population which formed on waterlogged area);

– recreational use (complex changes of the water regime of waterlogged territory with creation of reservoirs and recreation areas on it).

The choice of the directions of the use of waterlogged woodlands is made on the basis of objective comparative assessment of possible directions of rehabilitation of a concrete object. The use of waterlogged woodlands in forestry should be preferred choice. Only in a case of irre-versible consequences of waterlogging the respective sites of forest lands can be transferred in accordance with the established procedure to other types of forest lands.

The area of more than 1.0 million hectares is subject to various extent of technogenic transformation (mining, transport use, drainage construction, etc.) in the Republic of Belarus. For the purposes of restoration of damaged after construction works and extraction of non-ore miner-als (peat, sand, gravel, crushed stone, clay, etc.) lands a complex of works on reclamation and on bringing the land sites to a safe state is performed. The reclamation is performed for worked out quarries, cut-over peatlands and burrows.

Reclamation (restoration) is carried out consistently in stages. Lands after technical recultivation, which means preliminary preparation of disturbed territories, are usually transfer to the forest lands. The forestry reclamation approach provides creation of forest plantations on this category of lands. The features of afforestation technique depend on recultivated quarry compo-nent (quarry floor, face, and bench) and conditions on quarry and cut-over peatland (flooding degree, residual thickness of peat layer and extent of its decomposition).

Natural complexes of national parks recreational zones as well as green zone forests are exposed to significant anthropogenic and recreational influence, which endanger them. Estab-lishment of the regime of protection and restriction of use of natural resources on the territories mentioned not always and not fully guarantees protection of the ecosystems against existing threats. The system of actions for increase in recreational potential of forests has to include and use widely:

– biological methods of increase in forest stability (introduction of soil-improving trees and bushes into forest ecosystems, the use of useful plants and animals for pest control and forest protection);

– preventive actions aimed at the increase in viability of trees and decrease in the number of pests and diseases (annual pest inspections and phytopathological assessments of forest stands and development of measures for control on pests and diseases; performance of actions for pre-vention of pollution and improving of forest sanitary state; temporary exception of woodlands (for 5-10 years) out of recreational exploitation for recovery of their protective functions);

– forest management and silvicultural actions for increasing of recreational potential of forests (formation of mixed forests with complex structure in order to raise the resistance to recreational loads; fellings for formation and improvement of stand spatial structure and esthetic qualities of landscape; selective sanitary fellings; amenity plantations).

The monitoring of forests state in Belarus is performed in compliance with the document "Requirements for Monitoring of the Forests of the Republic of Belarus". In order to prevent degradation of forest lands and to develop timely actions for their rehabilitation the regular assessments of woodlands situated on the areas characterized by at least one features listed below is recommended. Those features are great risks of wind and water erosive processes on farmlands adjacent to the forest, waterlogging of reclaimed lands, functioning of polder systems as well as recreational forest exploitation. The decision making system for restoration of disturbed lands was developed. The system takes into consideration the state of forest lands. They could be temporary waterlogged, waterlogged, submerged, disturbed as a result of extraction of peat or non-ore minerals as well as recreational impact. The system suggests the set of actions on woodland rehabilitation. The actions is focused on prevention of forest degradation, the recovery of tree stands and their environmental functions.

7.2. Actions for reclamation of waterlogged forest lands

The waterlogged forests are classified by the nature of violations of the hydrological regime, the reasons of waterlogging, duration of waterlogging, features of the processes on the waterlogged areas.

According to the nature of violations of the hydrological regime natural character and anthropogenic origin of waterlogging is distinguished.

The natural reasons of sharp increase in the GWL are as follows:

– rainfall peaks;

– beaver dams on drainage channels near reservoirs, along water flows, on hollows and lowerings;

– subsidence of soil;

– deterioration of old-age and overripe forests and associated with it reducing the evaporation of water.

The reasons of sharp increase in the GWL of anthropogenic origin are as follows:

– arrangement of artificial water reservoirs (ponds, fish-breeding farms);

– systematic pumping of water from polder systems to woodlands or to the water intakes incapable to pass the pumped-out amount of water;

– construction of linear objects (automobile and railroads, oil pipelines, gas pipelines, the power transmission line and other linear communications);

– destruction of drainage networks;

– pumping of water from wells of water intakes;

– destruction of the existing surface water flows during the elimination of technogenic accidents on oil and gas pipelines;

– incorrect design of linear constructions and appropriate drainage networks (the unapproved building of roads and dams, reconstruction of only some parts of the drainage system, etc.);

– re-wetting worked out peatlands and degraded peat bogs– clear cut or selective felling of old-age and overripe forests and associated with it reducing the evaporation of water.

According to features of waterlogging processes waterlogged areas are divided into three groups:

–developing waterlogged area (the area is still extending on adjacent territories);

– stabilized waterlogged area (area is not increasing);

– reconstructed or liquidated waterlogged area (GWL has been stabilized for a definite purpose or brought to the initial state).

The legal entities engaged in forest management are recommended to survey their forest lands periodically for identification of areas with developing woodlands waterlogging. For this, the technical state of water flows, forest roads including those going along the water flows is assessed.

The criteria of the choice of the direction of rehabilitation of the waterlogged forest lands are subdivided into the main and auxiliary ones.

The main criteria are:

– duration of waterlogging process (age of waterlogging process);

– geomorphological conditions of waterlogged and adjacent territories;

– existence and state of the drainage network.

The auxiliary criteria are:

– area of waterlogged territory;

– reversibility of consequences of waterlogging;

– location, distance from settlements, availability;

– consequences of waterlogging for adjacent territories;

– existence of beaver’s activity;

– existence of rare and endangered species on waterlogged area;

– estimated costs of rehabilitation actions.

The criterion «age of waterlogging process» characterizes complexity of rehabilitation process. The lower the «age of waterlogging process» is, the simpler is to carry out its rehabilita-tion and restoration of the former LGW and to provide conditions for successful recovery of woody vegetation.

Depending on intensity of waterlogging process and its properties damaged areas should be subdivided according to table 7.1.

The criterion «existence and state of the drainage network» is important for waterlogged stands where drainage network was established for stands adjacent to the agricultural drained lands. The criterion allows to narrow the choice of possible directions of rehabilitation.

The additional criterion «area of waterlogged territory» allows identifying the features of processes on waterlogged area. In most cases, the higher the «age of waterlogging process», the more space is occupied by it. Significant amount of engineering constructions and essential volumes of expenses are required for rehabilitation of big waterlogged areas.

Table 7.1 – The characteristics of waterlogged areas

Stage of waterlogging process	State of a forest stand	Age of waterlogging process, years
Initial	formation of dieback sites in the lowered places of the center	1-5
Development	dieback of submerged part of stand, oppression of waterlogged part of stand	5-10(20)
Intensive spread to adjacent territories	fen formation on submerged sites, increasing of the areas of waterlogging and submergence, stand dieback on the border of waterlogging and submergence	10(20)-40(50)
Stabilization	Dieback of stand on submerged and waterlogged area, further expansion of waterlogging is not observed, in the middle of submerged area raised bog is formed, at the edges of the area fen is formed.	More than 50

The possible reversibility of consequences of waterlogging in most cases is determined by the age of the process. At the age of over 50 years, when raised bog is forming, consequences of flooding are, as a rule, irreversible. Rehabilitation of such waterlogged woodlands is econom-ically and ecologically inexpedient.

The waterlogged areas up to 3 hectares in sites with high fire danger can be reclaimed with the establishment of fire ponds. Waterlogged areas that occupy more than 3 hectares and situated near settlements are expedient to reconstruct into recreation areas.

Consequences of waterlogging development for adjacent territories are determined by relief. The waterlogging process inside low-lying basins makes the minimum impact on adjacent territories. The waterlogging processes on low flat territories have the tendency to gradual occu-pying of adjacent territories.

The criterion «existence of beaver's activity» focuses on the need of planning of actions not only for decrease in the GWL, but also on the change of the number of the beaver (its catch-ing, shooting, resettlement).

As a rule in waterlogged area the decrease in biological diversity and disappearing of rare plant species is observed. In some cases, the formation of specific floristic complexes that include rare or endangered plant species from the Red List and provide the habitats for rare animal species occurs in areas with the old-age waterlogging processes.

The presumable costs of reclamation actions on waterlogged areas depend on their sizes, the direction and complexity of works on its rehabilitation.

The choice of the direction of rehabilitation of waterlogged forest lands

The choice of the direction of rehabilitation of waterlogged forest lands and scheduling of appropriate actions are determined by the results of inspection of such areas. The choice of the direction of rehabilitation is made on the basis of the criteria of the choice listed in section 2.2.

The forestry use of damaged land has to be considered the main direction. Only in a case of impossibility of recovery of the former LGW or irreversible consequences of waterlogging process owing to its age other directions of rehabilitation can be applied.

The water management direction of rehabilitation of waterlogged forest lands with crea-tion of fire ponds is rational decision for some cases. The terms of such cases are waterlogging of lowerings of a rather small size (up to 1-3 hectares) and location of waterlogged area among coniferous stands. Creation of reservoirs of more than 3 hectares on waterlogged forest lands is rational in places of intensive hunting, aimed at ensuring services in hunting.

The nature protection direction of rehabilitation of waterlogged forest lands with preservation of the stabilized water regime is possible in the terms listed below. They are the age of waterlogging process over 40-50 years or more; formation of raised or intermediate bog on waterlogged area; appearing of populations of rare and endangered species on such areas. In the case of LGW decrease the conditions for growth of forest plantations stay unfavorable, but fire danger become significantly higher.

Recreational direction of rehabilitation of waterlogged forest lands is expedient on the sites adjacent to large settlements where the anthropogenic load on forests is rather high. In this case creation of reservoirs and recreation areas around them is recommended. These actions will allow reducing anthropogenic load on forests.

Prior to works on lowering of LGW and recovery of surface water flows according to the Recommendations on Norms of Drainage…, 1967 on areas where waterlogging process for-mation is caused by beavers activity it is necessary to perform a number of actions according to the Instruction for Development of Projects…, 2000.

Work order on recovery of the natural hydrological regime and rehabilitation waterlogged forest lands for forestry use

The legal entities engaged in forest management are carrying out activities on recovery of the natural hydrological regime and reclaiming waterlogged forest lands for forestry use in the order stated below.

The preliminary survey of waterlogged forest lands on the criteria, provided in section 7.2, is made.

If it is necessary (waterlogged forest lands is situated in difficult geomorphological states; waterlogging process is caused by actions of departments which are not related to the Ministry of Forestry) the engineering design documentation is ordered, its approval are carried out. The complex of works and actions is carried out according to developed project of land reclamation.

The features of recovery of former GWL which depend both on the cause of waterlog-ging and on the processes happening on waterlogged area have to be taken into account during the development of the project of forest land rehabilitation.

If the cause of waterlogging is violation of a water drain by linear communications, you can restore the former GWL by installing culverts through linear communications. It is also pos-sible to build channels for discharging water into the nearest culverts, if terrain conditions allow it. In both cases, the work must be carried out on special projects.

If the cause of waterlogging process is functioning of solid waste landfill or burial ground, organizations operating these constructions have to construct engineering systems, sur-rounding these sites, for preventing hit of drains from these sites to woodland.

If the functioning of drainage network failed, the department that manages this network has to restore the hydrotechnical construction.

The natural waterways destroyed during the elimination of technogenic accidents have to be restored. In case of impossibility of restoration of a water flow through the same canal, a by-pass around the place of technogenic accident has to be built.

The optimum GWL for the main forest forming species is shown in table 7.2. The values in the table characterize the middle of the vegetative period and applicable for forest stands situ-ated along the waterlogged lands. In the case of clear cut or selective felling of old-age and over-ripe wet wood, the drainage of the area has to be provided.

The reclaiming of lowering of soil for forestry is possible if the lowering have a moderate character and the relief of adjacent areas allows constructing the channels for dumping of water. In other cases water management rehabilitation of waterlogged area has to be carried out.

The waterlogged forest lands, which are formed as a result of draining network failure owing to processes of their aging, could be rehabilitated with accounting of actions for restora-tion of drainage systems.

On the waterlogged forest lands where beavers activity are observed, first of all measures are their resettlement or sharp decrease in the number (according to the Recommendations on Norms of Drainage… and the Instruction for Development of Projects. Further actions is recovery of the former GWL.

Table 7.2 – The optimum LGW values for the main forest forming species

Tree species	Type of soil	Optimal LGW, cm (below soil surface)
Birch (*Betula pendula*)	mineral	79
	Peat	40-60
Black alder (*Alnus glutinosa*)	Peat	68
Scotch pine (*Pinus sylvestris*)	mineral	85
	Peat	50-60
European spruce (*Picea abies*)	mineral	40-70
	Peat	30-60

7.3. System of actions for forest land restoration

Afforestation on the worked out peatlands should be conducted with account of the waterlogging processes, which are divided into three groups according to the character of forming mires. They are fens, intermediate bog or raised bog.

The worked out peatlands should be also divided according to the residual thickness of peat layer into three categories: the mineralized soils, the areas with a peat layer up to 0.5 m and deep-peat soils (depth of peat of 0.5 m and more). Afforestation on the worked out peatlands should be conducted with account of the residual thickness of peat layer, especially in its upper part as zone of forest trees root growth.

The criterion of fertility of soils on worked out peat lands is the extent of decomposition of peat in upper (0.3-0.5 m) layer of soil which is determined organoleptically. More fertile soil should be considered as peat with average extent of decomposition (26-35%). The indicators of such soil are portion of soil could be pressed through in a fist, water is wrung out with effort, peat smears a hand palm when grinding. High extent of decomposition of peat (more than 35%) is characterized by follow organoleptic properties: portion of soil is pressed through at compres-sion by fingers and their prints are noticeable.

The forest plantations of the spruce, the pine, the Black alder and the birch for wood obtaining should be established on the worked out peatlands with high extent of peat decomposi-tion. The forest plantations of the pine or the birch with an environment protective function should be established on the worked out peatlands with low extent of peat decomposition.

The drained milling type worked out peatlands are classified by the hydrological regime into (counting of the LGW from the day surface of the site): flooded fields (the LGW from Spring to Fall is from +50 cm and higher to +20 cm); waterlogged ones (from +30 cm to -10 cm); low ones (from +10 cm to - 50 cm); average ones (from -50 cm to -100 cm); high ones (from -100 cm to -200 cm and lower).

The flooded, waterlogged and fields in the lowlands are not suitable for creation of forest plantations. Exception is the establishment of forest plantations of Black alder on fen mires in some cases.

Creation of forest plantations on worked out peatlands

The choice of technological processes of creation of forest plantations (table 7.3) should be made with considering the prevailing conditions and size of the area, the used woody species and technical and economic opportunities for mechanization of the main operations.

The applied ways of processing of the soil under forest plantations on the developed peat fields are united in three groups: continuous processing, creation of micro elevation and cutting of furrows. On the fields, which are out of agricultural use (the previous cultivation of cultivated and grain crops), planting can be made without processing of the soil.

Table 7.3 – The recommended technological processes of forest plantations on the drained worked out peatlands

Techno-logical process	Types of Mire	Category of area	Planting design	Technological operations and requirements to them		
				way of processing of soil	way of forest plantation establishment	other procedures (weeding, addition, processing of soil, etc.)
techno-logical process-1	fen, intermediate	high fields, mineral soil with weak or average turf development	2.0-3.0 m x 0.75-0.5 m 4 rows of pine +4 rows of birch	cutting of furrows up to 15 cm in depth with V-blade plows of the P101-70 type	mechanized or manual planting	extermination of weeds with KLB-1.7 cultivator
techno-logical process-2	fen, intermediate	average fields in 2-3 years after extraction (thickness of peat layer is 0.1 m and more)	2.5-3.0 m x 0.5-0.75 m 7-8 rows of pine +2-3 rows of birch*; 7-8 rows of spruce +2-3 rows of birch*; 5 rows of spruce +5 rows of alder**	mechanized planting (MLU-1, etc.) with simultaneous processing of the soil or planting manually in the furrows cut with a plow of the PKL-70 type		agrotechnical care is taken if it is necessary with KLB-1.7 cultivator
techno-logical process-3	fen, intermediate	average fields, well developed turf (thickness of peat layer is 0.3 m and more)	2.5-3.0 m x 0.75-1.5 m 7 rows of spruce +3 rows of birch*; 5 rows of spruce +5 rows of alder**; pure alder plantations**	continuous processing of the soil with a plow of PLN-4.35 (PBN-3-45) and disking with BDN-3 harrow	mechanized or manual planting	agrotechnical care is taken if it is necessary to exterminate weeds with KLB-1.7 cultivator
techno-logical process-4	fen, intermediate	low fields (thickness of peat layer is 0.3 m and more)	3.0 m x1.0 m pure alder plantations**	ploughing of shafts (layers) with a plow of PKLN-500A (PKL-70)	manual planting	care isn't taken
Notes: * - in case of natural regeneration of the birch; ** - autumn planting of the Black alder and the spruce is allowed on low and average fields						

It is expedient to carry out creation of forest plantations on the developed peat fields in the first three years after being out of production, till formation of a powerful grass cover.

On high and partially average fields with unturfed and weakly-turfed soils the automated or mechanized planting of seedlings of the pine without processing of the soil is made. Manual planting is allowed.

On areas with average and high-turfed soils its preliminary processing by cutting of fur-rows to 15 cm in depth is made by forest two-dump plows of the PKL-70 type. Distance between centers of furrows is 2.5-3.0 m. The subsequent planting of coniferous and deciduous species is made at the bottom of plow furrows.

On the sites with weak and average turfed soils (peat is mixed with sand) creation of for-est plantations of the pine, the spruce and the birch is made by planting of seedlings with simul-taneous processing of the soil. Technological operations are carried out by a forest planting au-tomated vehicle with the removable device of a plow type for processing of the drained soils.

On average fields with high level of the LGW (30-50 cm – spring) it is necessary to create the spruce cultures and the Black alder culture with large-sized planting material (25-30 and 50-70 cm) along with processing of the soil. Saplings are planted previously by their cut root system. When planted by large-sized planting material, care of cultures, as a rule, is not taken.

On average and low fields where there are lowered sites (the LGW is 10-30 cm), on which production of forest plantations is accompanied by probability of their death from adverse weather states or because of unsatisfactory work of the drainage network, it is necessary to hold actions for assistance to natural renewal, by creation of micro elevations with V-blade plows.

Processing of the soil (irrespective of options) is recommended a year (late Fall) before Spring planting of forest plantations.

7.4. Recultivation of lands disturbed as a result of extraction of non-metallic minerals

Quarries are subject to flattening after termination of extraction of construction materials and other materials (sand, gravel, clay, limestone). Sometimes a fertile layer of soil is placed to the slopes and bottom in order of reclamation.

There are the following locations of quarry developments: at the bottom; lower, average and top parts of slopes as well as on the quarry brow. The bottoms may be flat or wavy. Slopes by a bias distinguish up into 4 groups (up to 5°, 6-12°, 13-40° and more than 40°). Usually flat-tened sand quarries have slopes up to 5°; in gravel ones slopes can be on certain sites up to 12°; and clay and cretaceous ones have slopes up to 40°.

The technique of forest plantations creation on former quarries depends on mineralogical and mechanical structures of soil mixtures, presence of humus and toxic compounds in soils and LGW.

Sand quarries in the flood-free part are afforestated with the Scotch pine. Processing of the soil at the bottoms and flattened slopes with the steepness up to 5° is carried out by making small furrows with the PKL-70 plow across slopes or is not performed. Planting is carried out with forest planting machines on the untreated soil and in furrows. Extermination of weeds in young forest plantations on former sand quarries is not necessary. If survival rate of seedlings in plantation less than 90%, then the replacement of died seedling is needed. Density of plantations in such case is not less than 7 thousand seedlings per ha.

If forest plantations in quarries show low growth rate and the needles of the pine turn yel-low, then it is necessary to use nitrogen fertilizers in the Spring in the amount of 60-90 kg of ac-tive ingredient per 1 ha.

Quarries which were used for extraction of gravel or gravel and sand mixtures have steep-ness of slopes up to 5° or from 5° to 12°. The former quarries are afforestated with the pine similar to sand ones in the case of steepness of slopes up to 5°. On slopes with steepness from 6° to 12° processing of the soil is made by making deep furrows across slopes or their terracing with V-blade plows with layer capsizing down a slope (usually two layers). Distance between furrows and terrac-es is 2-3 m. Planting of seedlings is made manually or with forest planting machines at the bottom of furrows or the next layer from a furrow every 0,7-1,0 m. Extermination of weeds in young forest plantations on former gravel quarries is not necessary. If survival rate of seedlings in plantation less than 90%, then the replacement of died seedling is needed. If forest plantations in quarries show low growth rate, then it is necessary to use fertilizers.

Clay and cretaceous quarries on the bottom can have high LGW and be submerged. Their bottoms are subject to afforestation with depth of ground waters during vegetation season lower than 20 cm below surface. In flat not flooded bottoms processing of the soil is made with ploughing of layers with V-blade and two-blade plows. Planting of seedlings is made in layers with forest planting machines or manually. Seedlings are planted manually without processing of the soil on hilly bottoms. Mechanized way of planting is possible after alignment with bulldoz-ers. Planting of seedlings is possible to carry out on not flooded hillocks. For planting on poor soil mixtures the birch and the pine are used, on more fertile soils the Black alder and the spruce are used. The plant-ing material are usual seedlings or large-sized seedlings. Silvicultural care of plantations is not con-ducted. When the pine and the spruce plantations is overgrowing with osier-beds, then the willow have to be removed from the third year after planting.

The technology of processing of the soils on slopes depends on their steepness. On slopes up to 5° it is carried out by overall or partial plowing of the soil, loosening, making fur-rows. Across slopes with the steepness from 6 to 12° their deep loosening is carried out, making furrows and ter-racing is also carried out. On the slopes with bigger steepness the terracing of slopes is made or plantations are created without processing of the soil. On gentle slopes plant-ing is carried out with forest planting machines, on steep ones planting is carried out manually in poles of 30x30 cm.

Selection of tree species is carried out depending on height of a slope and fertility of the soil mixture. In the lower part on poor soil mixtures (20-40% of carbonates, more than 50% of gravel) the pine in mix with the birch (7 rows of pine + 3 rows of birch) have to be planted. Plantations of the spruce in mix with the pine have to be planted on more fertile soil mixtures. Oak and poplar plantations have to be planted on clay soils.

The pine in mix with the birch are planted on middle and high parts of slopes as well as on brows of slopes, especially southern expositions. Silvicultural care of plantations is not con-ducted.

7.5. Actions for decrease in recreational load and prevention of digression of forests

Forestry institutions in recreational forests have to carry out the tasks aimed at:

- increase in sanitary and recreational functions of forests, as well as improving of these es-thetic advantages and sustainability for creating of favorable conditions for mass rest of the people;
- strengthening of measures for protection of the most valuable forest landscapes, relic for-mations, nature sanctuaries and sites having great protective or cultural and historical value;
- preservation of biodiversity of forest ecosystems;
- carrying out actions for prevention of digression of forest stands as a result of recrea-tional influence.

Expedient form of forestry in recreational forests is development of the landscape plan-ning project, organizational, silvicultural and nature protection actions on the basis of recrea-tional forest management.

Five stages of a degree of recreational forest digression are distinguished on the basis of the state of vegetation of the lower tiers and degree of surface cover trampling. The stages of forest di-gression described below.:

The 1st stage. Soil cover is undisturbed. Not more than 5% of undergrowth and under-brush are damaged. Ground cover consists only of typical forest species. The footpath network is absent.

The 2nd stage. Footpaths occupy no more than 8% of the land surface. Meadow and weed species is a part of a live ground cover.

The 3rd stage. The live ground cover, typical for such soil conditions, remains approxi-mately on 50-60% land area. The rest of the area is occupied by groups of meadow and weed species and footpaths. The forest stand thinning up to 10% is observed.

The 4th stage. 40% of the forest area is trampled. The forest stand thinning up to 50% is observed. Meadow type sod is forming intensively.

The 5th stage. Trampled up to 70% of the forest area. 80-90% of the area is under strengthened recreational influence. Typical forest species have remained only on 5-10% of the territory.

Periodically complex assessments of recreational capacity of city and suburban forests on the basis of the technique considering traditional approaches is one of the most effective in-struments for optimiza-tion of recreational forest exploitation. Such assessments allow tracing a state of the forest in time and evaluating the possibilities of its use for resting of both on stand level and in its separate parts. The analysis of the obtained results allows estimating the pro-spects of recreational use of the forest and finding the causes of forest digression. Moreover monitoring makes possible the accurate planning of measures to re-duce the revealed shortcom-ings as well as predict the changes in forest stand after the planned actions. Regular observa-tions of a state of city and suburban forests will allow revealing dynamic tendencies in them as well as evaluating the need of holding adequate silvicultural actions.

The increase in recreational capacity and formation of sustainable recreational forest landscapes is provided with the rational architectural and planning organization of the territory as well as creation of plantations with a complex structure and high level of plant species diver-sity.

In the places with the highest concentration of visitors and the lowered resistance of for-est ecosystems the artificial glade complexes are created. They are characterized by certain sizes and forms, dense structure, constructing of protective borders and open spaces (glades, lawns, roads and tracks) and consist of mixed plantings of woody and shrubby species. Glades are created in order to stabilize the parking places of tourists the organization and equipment of sports and children's playgrounds and massively visited beaches.

It is necessary to maintain the density of a forest stand in spite of sanitary fellings or ini-tial stages of its digression. The replacement of the cut down trees is recommended to make, where it is possible and expedient, by planting of large-sized seedlings of tree species. They could be placed individually or in groups depending on the state of a forest stand.

It is necessary to use biological methods for the increase in stability of the recreational forests. Main of them is listed below:

- Introduction to forest communities of soil-improving tree and shrubby species;
- Resettlement of useful species of ants for protection of the forest against pests;
- Biotechnical actions for attraction of birds for protection of the forest against pests.

Preventive actions against the decrease in sustainability of forest stands and for minimization of pest and diseases damages [4] include:

a) creation of mixed and complex on structure plantations of the woody and shrubby species tolerant to pest and diseases;

b) timely removal from stands of dead and seriously damaged by pest and diseases trees;

c) pollution abatement of the forest, especially with household and organic garbage;

d) an exception of recreational load on sites, where forest stand needs rest and repair, for 5-10 years. During the time on such sites the silvicultural measures are held;

e) annual entomological and phytopathologic inspections of stands with development of measures for pest and diseases control.

The measures for improvement of soil fertility by the use of peat or sawdust as mulch and introduction of perennial lupine are held on the most valuable for the recreational purposes sites of stands (in wet conditions).

Selective sanitary and formation fellings and landscapeplantations belong to actions for the increase the recreational capacity of the stand.

8. Development of the system of activities for preservation of plants of natural origin and biological diversity during reforestation, afforestation and forest use

The territory of Belarus experienced intensive human impact and nature ecosystem transformation. This negatively influenced the condition of nature resources. Forest management activities (cuttings, reforestation and afforestation), first of all, aim at creation of productive forest stands but almost do not take into account necessity to preserve elements of biological and landscape diversity, peculiarities of natural successions. Often cuttings do not satisfy strategies of tree species, and thus, stands stability against unfavourable factors decrease and costs of their future restoration increase. At the same time forest communities have a capacity of high stability. They are stable systems that can regulate themselves and restore in natural way. This is important when considering more and more extreme climate factors taking place in last decades that lead to mass death of forest stands.

Poor natural reforestation assistance increases forest growing timeframes by 10 and more years, especially in pine and spruce forests. Forest plantings were created in clear sanitary cutting sites conducted in places where spruce, oak and pine stands had died as the result of unfavourable climatic factors. Forest plantings were created using previously cut down species. Ten years after forest plantings creation, the analysis of forest stands structure has shown that 10% of them are naturally replaced, mostly by non-valuable species or bogs.

Thus, it is necessary to change and improve technologies of wood harvesting and afforestation in order to create stands, which will be more stable against unfavourable climate factors, whose structure will be closer to natural stands structure, and preserve biological diversity of natural ecosystems.

The analysis of assigned and conducted final cuttings, reforestation technologies, structure of created forest plantings and preservation of biological diversity during final cuttings has been conducted during the project implementation.

The system of activities for optimization of reforestation and afforestation has been developed based on the conducted survey. The system aims at better quality of forest stands, increase in stability and biological diversity of forest ecosystems with taking into account the peculiarities of natural successions.

8.1. Short analysis of reforestation and afforestation practices

The analysis of preservation of biological diversity elements during various final cuttings in SFE “Pinskiyleshoz”, “Stolinskiyleshoz”, “Luninecckiyleshoz”, “Petrikovskiyleshoz”, “Mozyrskiyleshoz”, “Narovlyanskiyleshoz” and “Zhitkovichskiyleshoz” has shown a certain pattern for the whole territory of the Republic of Belarus.

Artificial reforestation is dominating in the cutting sites in all of non-bog types of forest (Figure 8.1). Cutting sites left for natural reforestation account for 4% in *pleuroziosum* forest types up to 58% in *oxalidosum* forest types. In over-moistened forest types, cutting sites are left for natural reforestation. *Filicosum* and *polytrichosum* forest types are the exception – here, oak, black alder or pure pine forest plantings are created in some cases.

Low proportion of selected final cuttings leads to use of forest plantings for reforestation in non-bog forests, which increases costs and complexity of afforestation process. This especially applies to *pleuroziosum*, *callunosum*, *cladinosum* and *pteridiosum* forest types, where natural reforestation assistance measures usually bring good results.

Reforestation method, first of all, depends on natural reforestation of main species and soil and hydrological regime of the site. Percentage of sites with different conditions during reforestation is shown in Figure 8.2. Pure forest plantings mostly have been created in TSC A2 (68%), mixed forest plantings of two and more species have been created in TSC D2(42%), A2 (30%), B2 (16%). At the examined cutting sites partial forest plantings have been created only in TSC B3, natural reforestation assistance measures have been mainly planned in TSC A2(45%) and C2(31%).

Cutting sites have been left for natural reforestation almost in all forest types, but most of them are in TSC A2(30%), D2 (22%) and B3 (14%).

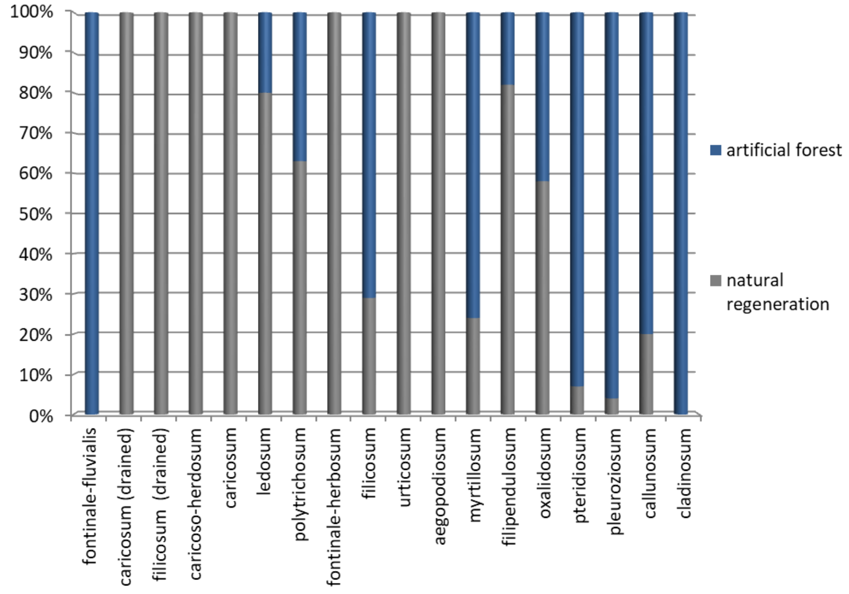

Figure 8.6 – Correlation of natural and artificial reforestation in clear sanitary cutting sites in the scale of forest types

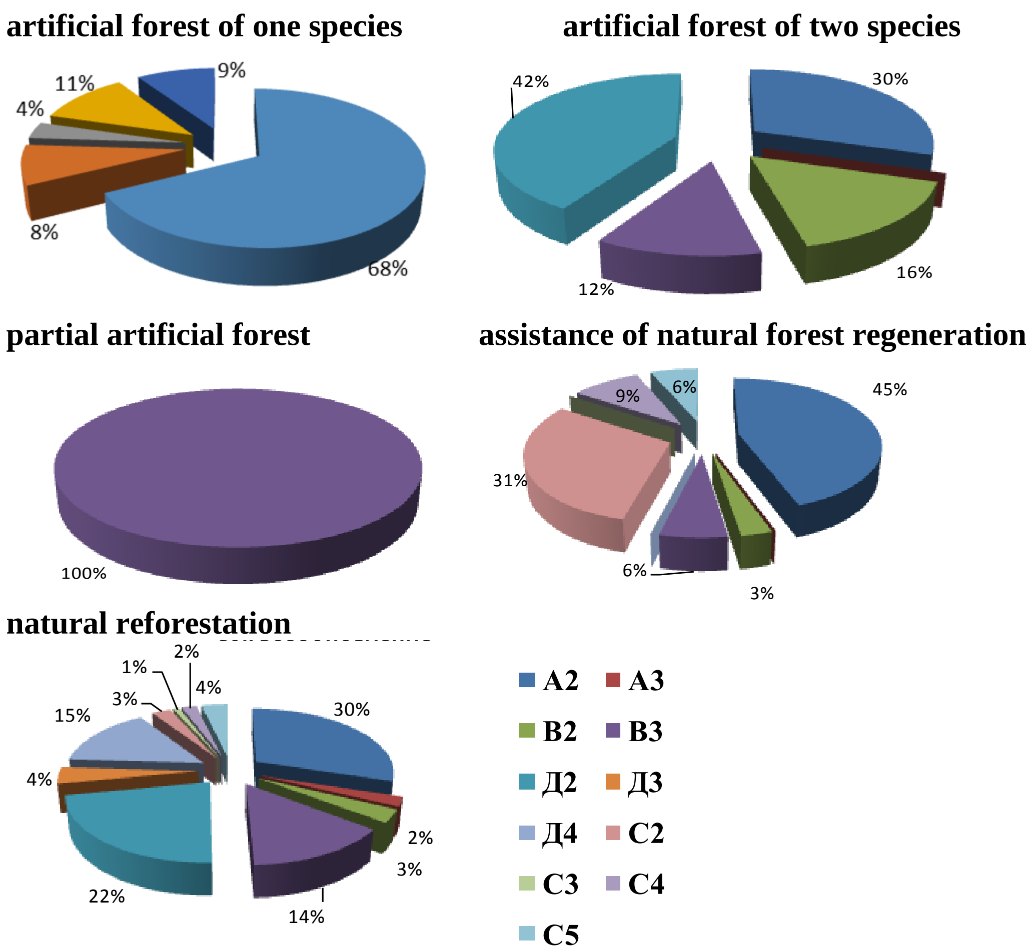

Figure 8.7 – Proportion of various growing conditions during reforestation

Recommendations on optimization of reforestation and afforestation have been proposed based on the conducted survey. They aim to increase quality of forest stands, stability and biological diversity of forest ecosystems with taking into account the peculiarities of natural successions.

8.2. Reforestation and afforestation optimization activities

Reforestation and afforestation planning, selection of technologies for creation of forest plantings, their structure, density and plants location are conducted according to the forest region division. There are 3 geobotanical/forest subzones and 7 regions:

I) Oak and dark coniferous forests (broadleaved and spruce forests) with Zapadno-Dinskiy, Oshmyansko-Minskiy and Orshano-Mogilevskiy districts, located in the northern part of Belarus, from the south bordered by the areal of hornbeam.

II) Hornbeam, oak and dark coniferous forests (spruce and hornbeam oak forests) with Berezinsko-Podpolyesskiy and Nyomansko-Podpolesskiy areas, located in the central part of Belarus between areal borders of hornbeam and Norway spruce;

III) Broadleaved and pine forests (hornbeam oak forests) with Bugsko-Polyesskiy and Polyessko-Pridnyeprovskiy areas, located to the south from Norway spruce areal.

Species recommended for reforestation and afforestation as of the geobotanical region division.

1) In Zapadno-Dvinskiy area of oak and dark coniferous forest zone, the species for forest plantings are: Scots pine, Norway spruce, European ash and Black alder; English oak can be the main species on rich well-drained soils (further there are only simple names of species)
2) In Oshmyansko-Minskiy and Orshano-Mogilevskiy districts of oak and dark coniferous forest subzone and hornbeam, oak and dark coniferous forest subzone, the main species for forest plantings are: spruce, pine, oak, ash and Black alder.
3) In broadleaved and pine forest subzone the main species for forest plantings are: pine, oak, ash and black alder.

As secondary or sometimes main species the following are used: Norway maple, small-leaved linden, silver birch, white birch, elms.

While planning reforestation and afforestation activities, the share of forest plantings with broadleaved species in their structure (at least 2 species) must account for at least 15% of the whole area of created plantings in the territory of a forest management enterprise in all geobotanical subzones.

Invasive shrub and tree species are not allowed to be used for reforestation and afforestation (Table 8.1). Usage of other introduced species is allowed only if they are proved to be non-invasive and if their spreading is controlled.

Forest plantings are not allowed to be created in flood-meadows considered to be rare biotopes to be protected according to the nature protection legislation (TCP 17.12-06-2014 (02120) “Rules of definition and protection of typical and rare biotopes, typical and rare natural landscapes”): “4.7 Hydrophilic high-grass ecotone meadows along watercourses and on the periphery of forest massifs”, “4.8 Flood-meadows with *Cnidiondubii* species”, “4.9 Boreal flood-meadows”.

Selection of reforestation method

The reforestation method is selected depending on the natural reforestation of the main species according to the Rules on reforestation in effect.

Natural reforestation should be in preference when selecting the method of reforestation in case if it is conducted with seeds of main species in the specified timeframes and in such forest site conditions that ensure its successive growth. Forest crops must be created if needed.

Table 8.1 – List of invasive shrub and tree species

Common name	Latin name
Trees	
Northern red oak	*Quercus rubra* L.
Ash-leaved maple	*Acer negundo* L.
Black locust	*Robinia pseudoacacia* L.
Silver poplar	*Populus alba* L.S.L. (Incl. P. x canadensis Schmith)
Black cherry	*Padus serotina* (Ehrh.) Borkh.
Bushes	
Sorbaronia mitschurinii	*Sorbaronia mitschurinii* (A.K. Skvortsov et Maitul.) Sennikov
Red elderberry	*Sambucus racemosa* L.
Black elder	*Sambucus nigra* L.
Scotch broom	*Sarothamnus scoparius* (L.) Koch
Low juneberry	*Amelanchier spicata* (Lam.) K. Koch
Common sea buckthorn	*Hippophae rhamnoides* L.
False spirea	*Sorbaria sorbifolia* (L.) A. Braun
Siberian dogwood	*Swida alba* (L.) Opiz

Areas should be left for natural reforestation or for creation of forest crops of silver birch with the following corridor reconstruction cuttings in sites where pine and spruce stands died from *Heterobasidionannosum* or pests and in reforestation sites to prevent forest illnesses if needed.

Categories of forest sites

Based on forest management assessment of forest fund, it is recommended to define **six** categories of forest sites (not five as it is now):

a) glades, clearings, fire sites and cutting sites with rotten, burned or removed stumps, areas with small number of stumps;
b) not-restored clearings and sparse forest with number of stumps up to 500 pcs/ha and more, where low stumps (not more than 5 cm from roots) were left after final cutting;
c) non-restored clearings with a number of stumps more than 500 psc/ha, where preliminary stumps reduction has not been conducted (cutting, crushing, etc.);
d) areas with unsatisfactory natural afforestation with main species or reforested with softwood species, areas with corridor reconstruction cuttings conducted;
e) excavated peatlands and drained lands;

areas previously used for agricultural purposes, wastelands and areas damaged with mining of non-metallic minerals, where reclamation has been conducted.

Types of forest plantings

Type of forest plantings is selected according to TSC, geobotanical region and the category of the forest site. The recommended structure of forest plantings is shown in Table 8.2.

Usually, forest plantings are mixed (at least two valuable species) in all TSC except for the following cases:

- in pure conditions A_0, A_1 only pine and birch can survive, and that is why forest plantings of these two species should be created here;
- in sites of pine stands died from *Heterobasidionannosum* and sites of “E” category, pure birch plantings should be created are reconstructed later;
- mixed pine and spruce plantings are recommended for B_2 conditions (*pteridiosum* pine forests and *pleuroziosum* spruce forests). The structure of the stands is completed with natural reforestation of birch and, sometimes, aspen. This will allow to increase stands stability against un-

favourable factors and at the same time expand the biological diversity of animals, plants and fungus;

Table 8.2 – Recommended structure of forest stands

TSC, type of forest reforestation site	Structure of forest plantings by geobotanical subzones (P – pine, S – Spruce, O – oak, A – ash, B -birch, Br – broadleaved		
	Oak and dark coniferous forests	Hornbeam, oak and dark coniferous forests	Broadleaved and pine forests
A_0, A_1; a, b, c	(8-10) P (2-0) B	(8-10) P (2-0) B	(8-10) P (2-0) B
A_2; a, b, c	(7-8) P (3-2) B	(7-8) P (3-2) B	(7-8) P (3-2) B
B_2; a, b, c	(6-7) S (4-3) P (7-8) P (3-2) S	(6-7) S (4-3) P (7-8) P (3-2) S	(7-8) P (3-2) B, O
A_3; a, b, c	(7-10) P (3-0) S	(7-10) P (3-0) S	10 P
B_3; a, b, c	(5-7) P (5-3) S	(5-7) P (5-3) S	10 P
$A_{4;}$ a, b, c	(7-8) P (3-2) S, B	(7-8) P (3-2) S, B	(7-8) P (3-2) B
$B_{4;}$ a, b, c	(7-8) S (3-2) P, B, O	(7-8) S (3-2) P, B, O	(7-8) P (3-2) B, S, O
$C_{2;}$ a, b, c	(5-7) S (5-3) Br	(4-6) S (6-4) Br	(7-8) O (3-2) P
$C_{3;}$ a, b, c	(6-10) O (4-0) S, Br	(6-10) O (4-0) S, Br	(6-10) O (4-0) Br
D_2, $D_{3;}$ a, b, c	(6-10) O (4-0) Br	(6-10) O (4-0) Br	(6-10) O (4-0) Br
C_4, $D_{4;}$ a, b, c	(5-10) O, A (3-0) S	(5-10) O, A (2-0) S	(5-10) O, A

- pure pine plantings are recommended to be created in A_3 conditions. Here is a good natural re-forestation of birch and later, mixed stands are formed. It is reasonable to introduce up to 3 pieces of spruce to the plantings inoak and dark coniferous and hornbeam, oak and dark coniferous forest subzones. In B_3 conditions the proportion of spruce can be increased up to 5 pieces and pine-spruce and spruce-pine forest stands can be created. In broadleaved and pine forest subzone, mixed stands with pine dominating are formed due to natural reforestation of small-leaved species;
- it is reasonable to leave clearings in $A_{4,}$ B_4 conditions for natural afforestation or create mixed forest plantings of pine and spruce. In B_4 conditions spruce is preferred, because especially in these conditions it has the greater stability against unfavourable factors. At the same time, it is better not to create pure spruce plantings, or other way this it is going to lead to mass windfalls;
- in oak and dark coniferous and hornbeam, oak and dark coniferous forest subzones in TSC C2-3, not to create pure spruce stands and aim at creation of mixed spruce (5-7 pieces), pine and broadleaved (oak, maple, linden) stands with different mixing schemes.
- in all geobotanical subzones in TSC D2-3, not to create pure spruce stands and aim at creation of mixed stands of native species with the spruce as the secondary species in oak and dark coniferous and hornbeam, oak and dark coniferous forest subzones;
- in C4, D4 conditions, mixed common oak and ash stands are preferred. In oak and dark coniferous and hornbeam, oak and dark coniferous forest subzones up to 3 pieces of spruce is allowed in the structure of stands

Tillage

Tillage is conducted a year before or in the year of forest planting. The main requirement is the maximum available preservation of forest environment outside the planting site.

Tillage is conducted in stripes at all the forest sites of all “a” and “b” categories, and after partial stump uprooting in “C” and “D”.

Boardless tillage should be preferred for forest plantings, which ensures the best growth of the plants. But after stripes mineralization withthe milling cutter, grass vegetation develops better, which leads to the need of early maintenance activities (firstly – in the end of May – June, secondly – July – the beginning of August).

Afforestation

The main afforestation methods on former agricultural lands are forest plantings creation and assisted natural reforestation.

Tillage for forest plantings is conducted partially the year before or in the year of forest planting. Tillage is conducted with ploughs at 5-10 cm depth in order to remove sod and weeds and preserve as much fertile soil as possible. At the same time heaps are mangled with roller machines in order to slow down the growth of weeds.

Agricultural lands are left for natural afforestation or the combined afforestation method is used (with creation of birch plantings) in order to prevent forest illnesses and pest reproduction. This will correspond to natural successions and will allow to prepare the soil for the future creation of coniferous and broadleaved forest plantings during the reconstruction.

Large seedling should be used for forest plantings creation in order to ensure their fast exit from competition zone with grass and undershrub species.

Agrotechnical care of forest plantings is conducted annually until their transfer to forest-covered lands category with cultivation between rows 1-2 times a year or with other methods of control of intensively developing ground vegetation (e.g. moving).

First of all, agrotechnical care should be conducted in TSC D2, D3, C2, C3, B2, B3. In TSC A2, A3 agrotechnical maintenance can be conducted basing on the preliminary site examination, because in poor TSC tree species are less inhibited by grass and shrub species.

During afforestation of sand pits and similar objects, preliminary cultivation should be conducted for even distribution of fertile soil layer. It is the only way to increase the survival rate of plantings and ensure their successful growth.

Reconstruction of low productivity forest stands

Sites in need of reconstruction with artificial reforestation methods:

1) Low productivity young growth and middle-age stands, which do not satisfy TSC and aim of forest management by their structure, density, expected maturity according to the age and performed functions;

2) Young growth of softwood species that are an intermediate stage in the technology of growing of broadleaved and coniferous species. In this case, reconstruction is conducted with corridor and group methods according to normative documents.

8.3. Activities for optimization of forest cuttings and cutting technologies

Prevalence of clear cuttings over other cutting types (more than 70% of all cuttings) leads to reduction of genetic, biological and landscape diversity of forests, creates favourable conditions for invasion of unwelcome invasive species (Figure 8.3). Problems with forest reproduction, species structure and quality of forests appear. AlsoBesides, stripe-gradual cuttings become more and more popular among selective cuttings. Their technology is very close to the previously used narrow-stripe cutting technology.

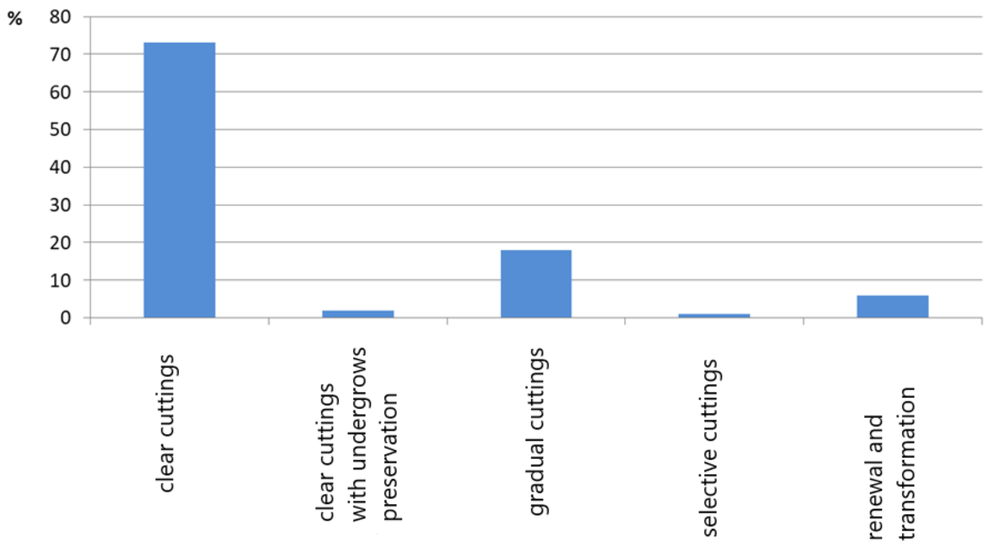

Figure 8.8 – Different types of final and renewal/reconstruction cuttings in modeling forestry enterprises

Results of forest cutting sites survey in SFE “Pinskiyleshoz”, “Stolinskiyleshoz”, “Luninecckiyleshoz”, “Petrikovskiyleshoz”, “Mozyrskiyleshoz”, “Narovlyanskiyleshoz” and “Zhitkovichskiyleshoz” have shown that as a result of clear final cuttings ground vegetation is often destroyed – only in 60% of cutting sites it is destroyed on the area less than 10%. In some sites (10%) in non-bog forest types ground vegetation is destroyed on more than 50% of the area. At the same time, successful restoration of the cover is registered on more than 60% of sites, including those where forest plantings have been done.

At most cutting sites cutting felling debris are gathered to banks (44%) or piles (28%) for rotting. In 10% of sites leftovers were processed into wood chips to be used as fuel.

Only in 12% of examined cutting sites more than 10 trees of first canopy layer per hectare are left in order to preserve biological diversity. Besides, there were no big trees (trunk diameter more than 40 cm) registered in the examined cutting sites. At the same time the second layer trees are often preserved. Only in 10% of cutting sites, coarse woody debris, which are a required substrate for the growth of a range of entomofauna species, have been registered.

Thus, it is obvious that the existing forest management practices must be modified in order to preserve biological and landscape diversity. The proportion of selected final cuttings (even-gradual and selective) should increase. Single big trees and trees with hollows, ground vegetation, young growth and shrubs should be preserved. As a result, not only afforestation timeframes will shorten and single biological diversity elements will be preserved, but at the same time forest stability against unfavourable factors will increase, which is especially important during climate changes.

Recommended target species

1) In Zapadno-Dvinskiy area of oak and dark coniferous forest subzone, the target species usually are: Scots pine, Norway spruce, European ash and Black alder; English oak can be the target species on rich well-drained soils (further there are only simple names of species)
2) In Oshmyansko-Minskiy and Orshano-Mogilevskiy districts of oak and dark coniferous forest subzone and hornbeam, oak and dark coniferous forest subzone, the main target species are spruce, pine, oak, ash and Black alder.
3) In broadleaved and pine forest subzone the target species are pine, oak, ash and black alder.

As secondary or sometimes main species the following are used: Norway maple, small-leaved linden, silver birch, white birch, Scots elm, European white elm.

During cuttings of all types (final and intermediate), activities on preservation of biodiversity, non-available for cutting trees and shrubs, sites of grass species listed in the Red Book of the Republic of Belarus and mentioned in the forest management documents and their annexes must be planned.

Cutting of species listed in the Red Book of the Republic of Belarus is prohibited, e.g.: sessile oak, European silver fir, dwarf birch, swamp willow, yellow azalea, *Cotoneaster melanocarpus*, blackthorn, German greenweed, pine trees with *Viscum austriacum* and European ivy. These species can be cut down only if they are in bad sanitary or emergency state.

Full cycle of forest management activities, including further reforestation, should be planned for all the cutting cycle during the planning of forest cuttings.

The following must be defined before the cutting:

- target species composition by the end of I, II, III age categories;
- target species composition by the time of final cutting (if assigned);
- type of final cutting;
- timeframes and measures for reforestation;
- target species of reforestation.

If trees were in mass damaged by root and trunk illnesses or pests, main species should be changed or other species should be introduced to the structure (more than 50%) after the clear sanitary cutting. These activities should take into account soil conditions and geobotanical zoning in order to decrease a chance of the same damages in the future.

During all the cutting stages the best is to aim at the creation of multi-age mixed stands regardless of the protection category of the forest, as it is done during maintenance cuttings. During maintenance cuttings, young spruce trees damaged in the lower part of trunk (by animals or as the result of forest management activities) must be removed, as their trunks will already have been rotten vastly by the time of final cutting.

Forest management directions in basic TSC taking into account natural successions

TSC A_0, A_1 – in such conditions natural successions of forest stands correlate with fires. Naturally, pure pine or mixed birch and pine stands (that by the age of 100 years also transform into pure pine stands) are formed here.

Maintenance cuttings. It is recommended to maintain a high proportion (up to 3-4 pieces) of silver birch in 50-60-year-old stands in order to prevent appearance of *Heterobasidionannosum*. Later they can be transformed into pure pine stands (up to 1 piece of birch) with assisted natural reforestation methods (burning of cutting leftovers). Reliable young growth of pine must be formed here by the time of final cutting.

Final cuttings – clear cuttings with preservation of young growth and/or natural reforestation assistance, even-gradual with 2-3 cutting stages.

Clearing of the cutting site – burning of cutting leftovers, their gathering into piles or banks. Reforestation – preliminary (pine, silver birch) or concomitant. Forest plantings are created only in case of unsuccessful natural afforestation in two years.

Clear sanitary cutting sites in places of *Heterobasidionannosum* and pest outburst are left for natural reforestation or new forest plantings of birch are created leaving the survived pine trees.

TSC A_2 - in such conditions natural successions of forest stands correlate with fire factor. Naturally, pure pine or mixed birch and pine stands with spruce attendance (that by the age of 100 years also transform into pure pine stands) are formed here.

Maintenance cuttings. It is recommended to maintain a high proportion (up to 3-4 pieces) of silver birch in 50-60-year-old stands in order to prevent appearance of *Heterobasidionannosum*. Later they can be transformed to pure pine stands with appearance of birch or spruce (up to 2 pieces) with assisted natural reforestation methods (partial burning of cutting leftovers). Reliable young growth of pine must be formed here by the time of final cutting.

Final cuttings – clear cuttings with preservation of young growth and/or natural reforestation assistance, even-gradual with 2-3 cutting stages.

Clearing of the cutting site – burning of cutting leftovers, their gathering into piles or banks. Reforestation – preliminary (pine, silver birch) or concomitant. Forest plantings are created only in case of unsuccessful natural afforestation in two years.

Clear sanitary cutting sites in places of *Heterobasidionannosum* and pest outburst are left for natural reforestation or new forest plantings of birch are created leaving the survived pine trees.

TSC B_2 – in such conditions natural successions go in different ways depending on presence of seed trees, a seed year, a fire impact. Usually, mixed birch, spruce and pine stands with aspen and oak are formed here at the first succession stage (especially in broadleaved and pine forest subzone). Species proportion can vary and in different periods of time one of them can be dominant. If there are no ground fires, pine-spruce, spruce-pine or oak-pine stands are formed here after 100-200 years.

Maintenance cuttings. It is recommended to maintain a high proportion (up to 3-4 pieces) of softwood species in 40-50-year-old stands in order to prevent appearance of *Heterobasidionannosum*. Later they can be transformed to mixed pine-spruce, spruce-pine or oak-pine stands with appearance of softwood species (up to 2 pieces).

Final cuttings – clear cuttings with preservation of young growth, even-gradual with 2 cutting stages, group-selective, voluntary-selective. Usually it is irrational to leave the second layer of spruce for future growth in forests with a high density of ungulates, as the most of trees will already have been rottenvastly by the time of final cutting.

Clearing of the cutting site – burning of cutting leftovers, their gathering into piles or banks. Reforestation – preliminary (pine, spruce, oak) or concomitant. Forest plantings are created mixed (pine, spruce, oak) and only in case of unsuccessful natural afforestation in two years.

Clear sanitary cutting sites in places of *Heterobasidionannosum* and pest outburst are left for natural reforestation or new forest plantings of birch are created leaving the survived pine trees.

TSC A_3, B_3 – in such conditions natural successions go in different ways depending on presence of seed trees, a seed year. Usually, mixed birch, spruce and pine stands with appearance of aspen are formed here at the first succession stage, in broadleaved and pine forest subzone spruce is replaced with oak. Species proportion can vary and in different periods of time one of them can be dominant. If there are no ground fires, pine-spruce, spruce-pine or oak-pine stands are formed here after 100-200 years.

Maintenance cuttings must aim at preservation of mixed structure with coniferous and broadleaved species dominating. Proportion of softwood species should accounts for 20-30%.

Final cuttings - clear cuttings with preservation of young growth, even-gradual with 2 cutting stages, group-selective, voluntary-selective. Usually it is irrational to leave the second layer of spruce for future growth in forests with a high density of ungulates, as the most of trees will already have been rottenvastly by the time of final cutting.

Clearing of the cutting site – gathering of cutting leftovers into piles or banks. Reforestation – preliminary (pine, spruce, oak) or concomitant. Forest plantings are created mixed (pine, spruce, oak) and only in case of unsuccessful natural afforestation in two years.

TSC A_4, B_4 - in such conditions natural successions go in different ways. Usually, mixed birch-pine (A_4) or mixed softwood, spruce and pine (B_4) are formed here at the first succession stage, in broadleaved and pine forest subzone spruce can be replaced with oak (B_4). Species proportion can vary and in different periods of time one of them can be dominant. Pure pine (A_4), or multi-age pine-spruce, spruce-pine or oak-pine stands (B_4) are formed here after 100-200 years.

Maintenance cuttings must aim at preservation of mixed structure with coniferous (A_4, B_4) and hardwood (B_4) species dominating. Proportion of softwood species should account for 20-30%.

Final cuttings - clear cuttings with preservation of young growth, group-selective, voluntary-selective.

Clearing of the cutting site – gathering of cutting leftovers into piles or banks. Reforestation – preliminary (pine, spruce, oak) or concomitant. Forest plantings are created mixed (pine, spruce, oak) and only in extraordinary cases.

TSC C_2, C_3, D_2, D_3 (*oxalidosum* and *aegopodiosum* forest types) – in such conditions natural successions go in several ways depending on the previous reforestation and structure of the nearest forest stands. In most cases softwood stands are formed here at the first succession stage. By the age of 40-50 years old, reliable spruce and/or hardwood young growth is formed under their canopy. By the age of 100-150 years old, as the softwood canopy disintegrates, species of the second layer come up to the first layer. At this stage, softwood and spruce stands are formed in oak and dark coniferous and hornbeam, oak and dark coniferous forest subzones, softwood and hardwood stands are formed in broadleaved and pine forest subzone. Later, pine stands disintegrate and softwood, spruce and hardwood stands are formed less than in 200 years both in oak and dark coniferous and hornbeam, oak and dark coniferous forest subzones.

Maintenance cuttings. It is recommended to maintain mixed structure of stands with at least 4 tree species with spruce and oak dominating. In softwood stands, reconstruction cuttings are needed in order to decrease the number of cuttings and increase the proportion of spruce and hardwood species. By the age of final cutting, proportion of spruce must not overcome 5 pieces.

Final cuttings - clear cuttings with preservation of young growth, even-gradual with 2-3 cutting stages, group-selective, voluntary-selective. Usually it is irrational to leave the second layer of spruce for future growth in forests with a high density of ungulates, as the most of trees will already have been rottenvastly by the time of final cutting.

Clearing of the cutting site – gathering of cutting leftovers into piles or banks. Reforestation – concomitant with softwood species, creation of softwood plantings if there is a danger of excessive shrub growth. In 20-30 years after the cutting, corridor reconstruction is conducted with spruce, oak, maple, elm, linden, ash plantings.

Clear sanitary cutting sites in places of mass death of spruce are left for natural reforestation or new forest plantings of softwood species are created.

Thinning

During all maintenance cuttings, some part of died and weak trees is left in order to improve the sanitary condition of the stands. The following trees are not to be cut: available for habitation of various forest fauna species the oldest single trees (including those left after final cuttings) and seed trees, single trees that rise over the forest canopy, trees with hollows, dead trees with trunk diameter more than average in the stands 3-4 pcs/ha and trees with bird and animal nests.

During all cutting types some part of dead and fallen trees that do not obstruct the growth of left stands must be preserved – this allows to preserve some insect species that are natural enemies of pests.

Seed trees left after final cutting and single trees left from the previous stands are to be preserved until their natural death.

In order to maintain the diversity of useful and rare microflora and invertebrates, logs with diameter of 24 cm and more and length up to 2 m (if there is such wood) can be left in cutting sites after cuttings in the volume of 5 m^3/ha;

Technologies of maintenance cutting must ensure preservation of plant and animal habitation environment found in the forest site. During maintenance cuttings, undergrowth, bushes and ground vegetation must be preserved in the best possible way.

Recommended target age structure is shown in Table 8.3.

Renewal and transformation

Renewal and transformation cuttings are conducted in mature and over-mature stands in case of beginning of stands disintegration and lack of prospects for successful natural reforestation.

The main goal of renewal and transformation cutting is to form mostly multi-age mixed stands in a complex form and, likely, of seed origin, to ensure stability of forest-covered lands and their condition, to prevent natural disintegration of stands as a result of their aging.

The main task of renewal and transformation cutting is to create long-lasting stable forest stands that continuously and effectively perform water-protective, protective, sanitary and other functions and preserve biological diversity.

Table 8.3 - Recommended target age structure of stands during thinning

Forest type	Stands structure by geobotanical zones		
	Oak and dark coniferous forests	Hornbeam, oak and dark coniferous forests	Broadleaved and pine forests
Pine forests			
cladinosum, callunosum, ledosum	8 P2 B	8 P2 B	8 P2 B
vacciniosum	8 P2(S, SW)	8 P2 SW	8 P2 SW
pleuroziosum	(7-8) P (3-2) S, SW	(7-8) P (3-2) S, SW	(7-8) P (3-2) HW, SW
myrtillosum	(7-8) P (3-2) S, SW	(7-8) P (3-2) S, HW, SW	(7-8) P (3-2) HW, SW
polytrichosum	(7-8) P (3-2) S, SW	(7-8) P (3-2) S, HW, SW	(7-8) P (3-2) HW, SW
pteridiosum, oxalidosum	(6-7) P (4-3) S, HW, SW	(6-7) P (4-3) S, HW, SW	(6-7) P (4-3) HW, SW
Spruce forests			
vacciniosum	(6-7) S (4-3) C, SW	(6-7) S (4-3) P, SW	(6-7) S (4-3) P, SW
pleuroziosum, myrtillosum, polytrichosum, fontinale-herbosum, caricosum	(7-8) S (3-2) P, SW	(7-8) S (3-2) P, SW	(7-8) S (3-2) P, HW, SW
pteridiosum	(6-7) S (3-1) P, SW	(5-6) S (5-4) P, HW, SW	(3-4) S (7-6) P, HW, SW
oxalidosum, aegopodiosum, urticosum, filicosum	(5-6) S (5-4) HW, SW	(5-6) S (5-4) HW, SW	(3-4) S (7-6) HW, SW
Oak forests			
pteridiosum, myrtillosum	(7-8) O (3-2) S, SW	(7-8) O (3-2) Con, SW	(7-8) O (3-2) C, SW
oxalidosum, aegopodiosum, urticosum, filicosum	(6-7) O (4-3) S, HW	(6-7) O (4-3) S, HW	(6-7) O (4-3) HW
fontinalis	(7-8) O (3-2) S, HW, SW	(7-8) O (3-2) S, HW, SW	(7-8) O (3-2) HW, SW
Birch forests			
callunosum, vacciniosum, polytrichosum, pleuroziosum, ledosum	(7-8) B (3-2) Con	(7-8) B (3-2) Con	(7-8) B (3-2) P
pteridiosum, myrtillosum	(7-9) B (3-1) Con, HW	(7-9) B (3-1) Con, HW	(7-9) B (3-1) P, HW
oxalidosum, aegopodiosum, urticosum, filicosum	(7-9) B (3-1) S, HW	(7-9) B (3-1) S, HW	(7-9) B (3-1) HW
Aspen forests			
vacciniosum, polytrichosum, pleuroziosum	(6-7) Asp (4-3) Con	(6-7) Asp (4-3) Con	(6-7) Asp (4-3) P
pteridiosum, myrtillosum	(6-7) Asp (4-3) Con, O	(6-7) Asp (4-3) Con, O	(6-7) Asp (4-3) P, O
oxalidosum, aegopodiosum, urticosum, filicosum, fontinale-herbosum	(6-7) Asp (4-3) Con, HW	(6-7) Asp (4-3) Con, HW	(6-7) Asp (4-3) HW
Black alder forests			
oxalidosum, aegopodiosum, urticosum, filicosum, fontinalis	(6-7) BA (4-3) S, HW	(6-7) BA (4-3) S, HW	(6-7) BA (4-3) HW

Forest type	Stands structure by geobotanical zones		
	Oak and dark coniferous forests	Hornbeam, oak and dark coniferous forests	Broadleaved and pine forests
iridosum, filipendulosum, caricosum	(7-10) BA (3-0) A	(7-10) BA (3-0) A	(7-10) BA (3-0) A
Grey alder forests			
oxalidosum, filipendulosum	(8-9) GA (2-1) S, HW, SW	(8-9) GA (2-1) S, HW, SW	(8-9) GA (2-1) HW, SW
aegopodiosum, filicosum, graminosum	(6-8) GA (4-2) S, HW, SW	(6-8) GA (4-2) S, HW, SW	(6-8) GA (4-2) HW, SW

*P – pine, B – birch, S – spruce, O – oak, A – ash, Asp – aspen, BA – black alder, GA – grey alder, Con – coniferous, SW – softwood, HW – hardwood

Renewal and transformation cuttings are assigned and conducted according to the Rules of cutting with the following amendments:

- renewal and transformation cuttings are assigned only in over-aged stands or stands influenced by unfavourable factors that has lost or are losing biological stability (growth) and functions;
- after the last stage of renewal cutting, density of the first layer (the eldest trees) must be not less than 0.3.

Final cuttings

Age of final cutting should be defined not lower than it is defined by normative documents, taking into account structure of stands and TSC, e.g. cutting age of *ledosum* and *caricoso-sphagnosum* pine stands and *caricoso-sphagnosum* spruce stands can be increased up to 140 years and more.

Taking into account target functions of forests and forest-growing conditions, clear and selective final cuttings are conducted in forest stands.

In exploitation forests all types of final cutting are conducted.

In recreational and sanitary forests final cuttings are not conducted, in protected and protective forests only selective final cuttings are conducted.

During selection of cutting sites and final cuttings, the following must be preserved:

- seed trees and groups of trees;
- big dominating trees of the first layer not less than 5 spc/ha of broadleaved and coniferous species, not less than 10 spc/ha of softwood species;
- single trees and tree groups of broadleaved species;
- single large-scale (more than the average diameter of stands) dead (up to 5 psc/ha) and/or dead-top trees;
- big trees with hollows, big (more than the average diameter of stands) 4-7m high stumps (5-7 psc/ha);
- small (up to 0,2 ha) and not valuable for agriculture areas of forest stands (in bogged lowlands, etc.);
- big fallen trees (diameter more than 24 cm) of different rotting stage in form of logs or undamaged trunks of non-useful wood in volume of $20 m^3$/ha.

In a 50-meter-stripe at the edge of a forest, only selective final cuttings can be conducted or a stripe of at least 30-meter width is left undamaged.

9. Development and implementation of special monitoring of the results of forestry activities on forest growth of high productivity, sustainability and biodiversity during land use planning

9.1. Aanalysis of the current forest management results of monitoring in typical forest management projects

Forest management in the Republic of Belarus is carried out according to a forest plan, which is developed for 10 years (revision period) by a forest management organization and is subject to ecological expertise in the Ministry of Natural Resources and Environmental Protection. Forest plans are designed according to “Instructions for organizing and maintenance of forest inventory works, content of forest management documentation and supervision of implementation of forest management plans”, approved by the Ministry of Forestry.

The goal of a forest management plan is to ensure forest management stable development, plan forest management based of rational organizing and, first of all, effective use of forest lands, form the best species and age forest structure, increase forest productivity, stability and value. Herewith, the main principles of forest plans are stability, inexhaustibility and high yield of forest use together with preservation and strengthening of environment-making, water-protective, protective, sanitary, recreational and other forest functions.

Volume of wood cut during final cuttings is planned within scientifically calculated volume based on age and species forest structure so that inexhaustibility of forest use is ensured. Selective cuttings are planned in stands, which require maintenance works (area and volume of harvested wood).

In addition to wood harvesting, the resources and their possible utilization as secondary forest use are listed (wild mushrooms, berries, medicinal and technical raw materials, juices, honey, etc.).

As the forest plan is developed for 10 years, it certainly contains the assessment (monitoring) of forest management activities carried out during the previous revision period. This allows to refine planned activities in order to increase their efficiency in the long term. But it should be stated that currently not enough attention is paid to monitoring of changes in forest productivity, stability and biological diversity.

At the same time, within the framework of voluntary international forest certification, forestry enterprises have to show results of monitoring of various indices that represent forest management. And the forest plan is the document, where the results of long-term monitoring of productivity, stability and biological diversity can be represented. This will allow to timely track the efficiency of forest management activities for biological diversity and forest ecosystem stability preservation, increase their productivity.

The monitoring of various forest management indices is mentioned in the several parts of the forest plan. There is a list of parts/tables showing various aspects of monitoring of forest productivity, stability and biological diversity as well as the analysis of missing data below.

Forest productivity.

Assessment of forest productivity is described in more detail in chapter 2 “Characteristics of forest fund” and in chapter 3 “Management analysis” of the forest plan. It includes the following:

- stands distribution by bonitet class (part 2.4). There is an area of forest-covered lands by bonitet class and dominant species, the average bonitet class of the main species. As the bonitet class is defined by soil conditions and is stable enough at the specific plot, there is no comparison to the previous stage of forest inventory;
- stands distribution by density (part 2.4). There is an area of forest-covered lands by density and dominant species, the average density of the main species. The data represent forest productivity indirectly only, as low-density forest stands have less wood stock than high-density stands;
- stands distribution by age categories, density and bonitet class (part 2.4). There is an area of forest-covered lands by density, bonitet class, species groups and age categories. Like in the previous two tables, the data represent forest productivity indirectly only;

- wood stock by dominant species (part 2.4). There is total wood stock, wood stock in mature and over-mature forest stands by dominant species during two stages of forest management. The data represent only general change of wood stock related, first of all, to changes in forest stands age structure and changes in forest-covered land area;
- dynamics of average forest stands attributes (part 2.5). The data represent changes in average forest stands attributes (age, bonitet class, wood stock per 1 ha, growth per 1 ha) by species during two stages of forest management. Like in the previous table, it represents only general change in wood stock related, first of all, to changes in forest stands age structure and changes in forest-covered land area;
- total supply of phytomass and carbon accumulation in forest stands (part 2.6). The data represent general change of total phytomass stock (t/ha), carbon accumulation (t/ha) by dominant species during two stages of forest management. It represents only general change in wood stock related, first of all, to changes in forest stands age structure and changes in forest-covered land area;
- assessment of forest fund (=stock) condition (part 3.9). There is only an average density and productivity of forest stands during two stages of forest management.

In the above-mentioned typical forms, current stock of forest stands and average indices of forest-covered lands is analysed quite well. And changes in stands productivity (m3/ha) should be based not only on the volume analyses by tree species, but also by age categories. This will allow to assess changes in stands productivity independently from changes in age structure of forest (it changes significantly in 10 years). Besides, change of the average forest stands volume by age categories and species allows to estimate the effectiveness of implemented forest management activities (selective cuttings, sanitary activities) and correct them for the future revision period.

Forest stability.

Assessment of forest stability is described in detail in chapter 2 "Characteristics of forest fund" and in chapter 3 "Management analysis" of the forest plan. It includes the following:

- stands distribution by biological stability categories (part 2.6). There is an area of forest-covered lands by biological stability categories and dominant species. The text part analyses the change of stands biological stability indices using the data of the previous and current forest management: how the current situation has changed and what has caused the improvement (degradation). There is an area of failed stands, windfalls and fire sites specified only for the moment of forest management;
- forest plantings condition (part 3.2). The data allow to assess the condition of forest plantings (including unclosed ones) of different ages and types (including those grown for pulpwood, large wood, created during reconstruction as well as under the forest canopy). Forest plantings condition represents not only the efficiency of forest management activities, but also their stability against outside impact;
- causes of unsatisfactory forest plantings condition (part 3.2). There is the analysis of unsatisfactory forest plantings condition by the following causes: violation of agricultural machinery, incompatibility with the type of soil conditions, pests and illnesses, untimely maintenance, fire damages, unfavourable climatic factors, etc.;
- data on forest fires during the previous revision period (part 3.3). There is the analysis (area and number) of forest fires by every year during the previous revision period by types (crown fire, ground fire, underground fire);
- distribution of forestry enterprise territory by fire danger categories (part 4.4). There is the area of forests by fire danger categories for every forestry enterprise and the average rate of fire danger. The data represent the stability of forest stands against fires;
- sanitary condition of forests and activities carried out to protect them from pests and illnesses (part 3.4). There is the analysis of forest sanitary condition, outbursts of needle and leaf eating pests and illnesses during the last 3 years, assessment of the efficiency of forest management activities conducted;

- assessment of forest maintenance activities effectiveness (part 3.9). There is the analysis of forest fund condition assessment at the beginning and at the end of the previous forest plan implementation, advantages and disadvantages of forest management, forest management effectiveness impact on the general condition of forest fund.

In the above-mentioned typical forms, the average indices of forest condition and stability are analysed in detail. But of the best index showing the change of forest stability against outside impact is the forest death during the revision period by year and cause. This allows to estimate timing of unfavourable outside impact, define the main factors leading to the decrease of forest stability and assess the activities conducted to increase forest stability, correct them for the future revision period.

Biological diversity.

Assessment of forest biological diversity is described in detail in chapter 2 “Characteristics of forest fund”, in chapter 3 “Management analysis” and in chapter 4 “Planned forest management activities and forest use for the future revision period” of forest plan. It includes the following:

- stands distribution by dominant species and age categories (part 2.2). There is the area of forest-covered lands by age categories and dominant species of the current and previous forest management. This allows to analyse formation changes in forest structure;
- stands distribution by forest types (part 2.3). There is the area of forest-covered lands by dominant species and forest types according to the data of the current forest management;
- stands distribution by type of soil conditions (part 2.3). There is the area of forest-covered lands by dominant species and type of soil conditions according to the data of the current forest management;
- bog forest distribution by bog types and dominant species (part 2.3). There is the area of forest-covered lands by dominant species and type of soil conditions, non-forest-covered lands according to the current forest management data;
- characteristics of natural reforestation on non-forest-covered lands (part 2.7). There is the area of plots with natural reforestation on different land types (fire sites, failed stands, clearings, glades) by dominant species. The area and structure of stands of natural origin, their peculiarities in comparison with the indices of artificial forests (structure, productivity, etc.) are analysed;
- characteristics of young growth under the canopy of pre-mature, mature and over-mature stands (part 2.7). The area of plots with young growth is analysed by forest types;
- analyses of hardwood stands reproduction during the previous revision period (part 3.2). There are the areas of forest plots and their changes (included in forest fund, cut down, forest plantings created) for hardwood stands of seed origin;
- forest distribution by categories (part 4.1). There are forest areas in the scale of categories (nature-protective, recreational, protective, exploitational, etc.) and sub-categories. As the new Forest Code was adopted in 2015, now it is impossible to compare materials of the current and previous forest management;
- forest distribution by its ecological, economic and social significance (part 4.1). As the same forest plot can perform several functions at the same time (nature-protective, recreational, protective, exploitational), the table contains data that allow to estimate multifunctionality of forests, including their biological diversity;
- specially protected areas. There is a list of specially protected nature areas by categories (reserves of republican significance, reserves of local significance, nature monuments of republican significance, nature monuments of local significance), their names, area and location (the map and the list of forest areas/sites). But the changes during the revision period are not represented, which makes it impossible to assess the changes in the biological diversity of the area;
- habitats of wild plant and animal species listed in the Red Book of the Republic of Belarus and transferred into protection of forestry enterprises (part 4.1). There is a list of protected wild plant and animal habitats, their names and protected plots. But the changes during the revision

period are not represented, which makes it impossible to assess the changes in the biological diversity of the area;
- typical and rare landscapes and biotopes transferred into protection of forestry enterprises (part 4.1). There is a list of plots containing typical and rare landscapes and biotopes transferred into protection of forestry enterprises, their names and protected sites. But the changes during the revision period are not represented, which makes it impossible to assess the changes in the biological diversity of the area;
- forest plots of restricted use (part 4.1) There are areas of forest plots with restricted forest use: forest plots around capercaillie mating-places, genetical reserves, riverside forest stripes, flood plain forest plots, forest plots on steep slopes, etc. As the new Forest Code was adopted in 2015, now it is impossible to compare materials of the current and previous forest management.

In the above-mentioned typical forms, the biological diversity of the forest fund territory (dominating tree species, forest structures (in the inventory description), typological and age structure of forest, forest reproduction, protected plant and animal species, rare and typical biotopes, specially protected areas, etc.) is analysed quite well. But the monitoring of some aspects of the efficiency of forest management activities for biological diversity preservation is not represented in the typical forms. In particular, it is the dynamics of forest distribution by categories and subcategories, dynamics of number of protected wild plant and animal species habitats, areas of rare and typical biotopes, areas and number of specially protected areas. Introduction of these indices will allow to assess the efficiency of management activities for preservation and increase of biological diversity in the forest fund territory, correct them for the future revision period.

9.2. Monitoring of the results of forest management activities for growing of productive, stable and biologically diverse forests

Based on the analysis of missing data and possibilities to get this information during planning of forest management, new forms (tables) were designed and added to the typical form of the explanatory note. Data to be listed in these forms allow to objectively assess the efficiency of management activities for the preservation and increase of biological diversity, productivity and stability of forests.

The designed forms (tables) and data on their place in the explanatory note are listed below.

Table 9.1 – Dynamics of forest stands death during the previous forest plan implementation (part 2.6, Table 2.6.1 in the explanatory note for of the forest management plan)

Cause	Area by years, ha									
	20__	20__	20__	20__	20__	20__	20__	20__	20__	Total
Fires										
Unfavourable weather conditions										
including:										
Windfalls										
Snowfalls										
Floods										
Illnesses										
Pests										
Damage from wild animals										
Human impact										
Total										
% from forest lands										

Here is the analysis of forest stands death and the main causes of unfavourable impact to the forest.

Table 9.2 – Distribution of forest-covered lands and wood stock of forest stands by age categories and dominant species (part 2.2, Table 2.2.2 in the explanatory form for of the forest management plan)

Age category	Forest management						Changes in %%(+ -)		
	Current	Previous	Current	Previous	Current	Previous	Area, ha	Total stock, thousand m^3	Average supply in 1 ha
	Area, ha		Total supply, thousand m^3		Average supply in 1 ha, m^3				
Main species - Pine									
1							+/-	+/-	+/-
2							+/-	+/-	+/-
3							+/-	+/-	+/-
4							+/-	+/-	+/-
5							+/-	+/-	+/-
6							+/-	+/-	+/-
7							+/-	+/-	+/-
8							+/-	+/-	+/-
Total							+/-	+/-	+/-
Main species - Spruce									
1							+/-	+/-	+/-
2							+/-	+/-	+/-
3							+/-	+/-	+/-
4							+/-	+/-	+/-
5							+/-	+/-	+/-
6							+/-	+/-	+/-
7							+/-	+/-	+/-
8							+/-	+/-	+/-
Total							+/-	+/-	+/-
Main species - Larch									
1							+/-	+/-	+/-
2							+/-	+/-	+/-
3							+/-	+/-	+/-
4							+/-	+/-	+/-

Age category	Forest management						Changes in %%(+ -)		
	Current	Previous	Current	Previous	Current	Previous	Area, ha	Total stock, thousand m^3	Average supply in 1 ha
	Area, ha		Total supply, thousand m^3		Average supply in 1 ha, m^3				
5							+/-	+/-	+/-
6							+/-	+/-	+/-
7							+/-	+/-	+/-
8							+/-	+/-	+/-
Total							+/-	+/-	+/-
Main species - Oak									
1							+/-	+/-	+/-
2							+/-	+/-	+/-
3							+/-	+/-	+/-
4							+/-	+/-	+/-
5							+/-	+/-	+/-
6							+/-	+/-	+/-
7							+/-	+/-	+/-
8							+/-	+/-	+/-
Total							+/-	+/-	+/-
Main species - Hornbeam									
1							+/-	+/-	+/-
2							+/-	+/-	+/-
3							+/-	+/-	+/-
4							+/-	+/-	+/-
5							+/-	+/-	+/-
6							+/-	+/-	+/-
7							+/-	+/-	+/-
8							+/-	+/-	+/-
Total							+/-	+/-	+/-
Main species - Ash									
1							+/-	+/-	+/-
2							+/-	+/-	+/-
3							+/-	+/-	+/-
4							+/-	+/-	+/-

Age category	Forest management						Changes in %%(+ -)		
	Current	Previous	Current	Previous	Current	Previous	Area, ha	Total stock, thousand m^3	Average sup-ply in 1 ha
	Area, ha		Total supply, thousand m^3		Average supply in 1 ha, m^3				
5							+/-	+/-	+/-
6							+/-	+/-	+/-
…	…	…	…	…	…	…	…	…	…
etc.									
Total in the forestry enterprise									
1							+/-	+/-	+/-
2							+/-	+/-	+/-
3							+/-	+/-	+/-
4							+/-	+/-	+/-
5							+/-	+/-	+/-
6							+/-	+/-	+/-
7							+/-	+/-	+/-
8							+/-	+/-	+/-
9							+/-	+/-	+/-
Total							+/-	+/-	+/-

Table 9.3 – Dynamics of specially protected areas
(part 4.1, table 4.1.2.2 in the explanatory note of the forest management plan)

SPA category	Area according to forest management data, ha			Area according to forest management data, pcs		
	Current	Previous	Change, +/-	Current	Previous	Change, +/-
Nature monuments of republican significance						
Nature monuments of local significance						
Reserves of republican significance						
Reserves of local significance						
Total						

Table 9.4 – Dynamics of the habitats of protected wild plant and animal species listed in the Red Book of the Republic of Belarus and transferred into protection of forestry enterprises
(part 4.1, Table 4.1.2.4 in the explanatory note of the forest management plan)

Species	Number according to the forest management data, places		
	Current	Previous	Change, +/-
Plants			
…			
…			
Total			
Animals			
…			
…			
Total			

Table 9.5 – Dynamics of typical and rare landscapes and biotopes transferred into protection of forestry enterprises
(part 4.1, Table 4.1.2.6 in the explanatory note of the forest management plan)

Number of categories and subcategories of rare and typical landscapes and biotopes	Area according to forest management data, ha		
	Current	Previous	Change, +/-
Rare and typical landscapes			
…			
Total			
Rare and typical biotopes			
…			
Total			
Total			

CONCLUSION

The problems of conservation, reproduction and use of the flora and fauna, natural landscapes and their resources require decision-making at the transboundary level and coordinated action across regions and continents. It is only through cooperation between countries that it is possible to develop and implement measures to manage large transboundary natural complexes, maintain migratory species, and preserve rare and endangered species of animals and plants and their habitats.

Belarusian Forestry Development Project is based on the experience of the World Bank in the forest sector of Belarus since the mid-1990s, including the first Forestry Development Project, the first and second stages of the program "Forest Law Enforcement and Governance in the Eastern Region of the European Neighborhood and Partnership Instrument" (ENPI) FLEG) (2008 - 2012, 2012-2017) and a note prepared in 2013 on forestry.

In the framework of the Belarusian Forestry Development Project GEF/The World Bank TF0A1173, Project Activity 3.1.7 "Monitoring research into changes in the forest fund in response to climate change, human impacts and forest activity and the development of recommendations for the preservation of plants of natural origin and biological diversity during reforestation, afforestation and forest use":

- a procedure for changing the forestry management plans using pilot forestry enterprises as an example (SFE "Klichevsky leskhoz", SFE "Gluboksky opytny leskhoz", SFE "Tolochinsky leskhoz", and SFE "Bogushevsky leskhoz"), based on the analysis and identification of areas in the forest fund that require the establishment of a special protection regime based on the new Forest Codex of the Republic of Belarus has been developed;
- principles, methods and a program for monitoring the effects of climate change in forest ecosystems, criteria and indicators for assessing the effectiveness of measures to adapt forestry to climate change has been developed;
- the software to collect and analyze monitoring data in forest ecosystems and to ensure its integration into forest management practices has been developed;
- the project and the network of observation points for the state of ecosystems and their dynamics caused by climate changes, as well as the effectiveness of measures to adapt to such changes have been developed;
- transformation of the forest fund lands and the dynamics of the biological diversity of the forest ecosystem of Belarus for the post-war period has been analysed;
- the system of measures to prevent the degradation of forest lands and the conservation of biological diversity has been developed;
- the system of activities for preservation of plants of natural origin and biological diversity during reforestation, afforestation and forest use has been developed;
- special monitoring of the results of forestry activities on forest growth of high productivity, sustainability and biodiversity during land use planning has been developed and implemented.

Thus, hydrological regime management in drained forest lands, former peat pits and near drained agricultural lands must be one of the priorities of main forest management directions. The other main direction is to create forest stands of complex species and age structure, increase broad-leaved species proportion, and take into account natural successions during forest management planning. All these together will allow increasing forests stability against changing natural and human factors.

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