The results of the analysis the elements of forest management system in the north-taiga forest region of the European part of Russian Federation

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Abstract. The presented article analyzes the elements of the forest management system in the northern taiga forest region of the European part of the Russian Federation, provides basic recommendations. Much attention is paid to the elimination of the dead and the restoration of felled plantations, forest protection and fire-fighting measures. Several scenarios of forest management are presented.

1. Introduction
Analysis of forecasts of climate change for study area showed that old-growth forests are more affected under unfavorable factors, and some climatic indicators in the middle of the 21st century are already moving beyond the norms characteristic of the natural habitat of spruce forests. Thus, the destruction of forests, the main reasons for which FBI «Russian Centre of Forest Health» recognized unfavorable weather conditions, soil, and climatic factors, fires, so directly related to climate change.
A forestry system is a number of forestry activities aimed at increasing the resilience of forests, including taking into account climate change. Sustainable forest management will provide integrated benefits to preservation of the ecological value and sustainability of forests.

2. Methods and Materials
2.1. Methods
The research involved in carrying out a study on the analytical and statistical methods. Analysis and processing of materials by using a database and Microsoft Excel.

The main forestry activities in our study included: forest protection measures (including sanitary cutting in the forest); reforestation; fire protection measures. Scenarios for forestry must be based on measures aimed at reducing lost areas and their reforestation. Three main scenarios were identified: conservative (inertial) implies the volume of forestry activities in which the trend of the last five statistical years is preserved; planned indicator of forestry activities in accordance with the adopted forest plans; optimal indicator implies the timely implementation of measures to eliminate the dead areas and carry out.

2.2. Materials
The official statistical open data were used: Reports on the state and protection of the environment;
Forest Plans; forestry regulations; Annual reviews of the sanitary and forest pathology condition of forests; federal target programs, state programs; Reports agencies of the federal and regional levels of government, data from the Federal State Statistics Service [1-14].

3. Results and Discussion

3.1. Forest protection measures
Forest protection measures are a set of measures aimed at identifying the hotbed of forest pests and diseases, limiting their spread, localizing their hotbed, preventing the emergence of such hotbeds, as well as preventing economic damage to forestry caused by the development of pests, forest diseases and other negative factors of natural and anthropogenic impact. Branches of FBI «Russian Centre of Forest Health» to stands that have lost their biological resistance (or dead plantings) include stands identified in the reporting year, in which, according to their condition, clear sanitary felling is required (the weighted average category of condition is more than 4.50 or stand density after harvesting trees below the critical). The annual area of dead forest stands is presented in table 1.

Table 1. Annual area of dead forest stands, ha.

| Year | Komi Republic | Arkhangelsk region | Murmansk region |
|------|---------------|--------------------|-----------------|
| 2015 | 8204          | 6693               | 344             |
| 2016 | 2387          | 5327               | 9               |
| 2017 | 1200          | 582                | –               |
| 2018 | 1512          | 344                | 0               |
| 2019 | 1212          | 281                | 605             |
| Mean | 2903          | 2645               | 240             |

Scenarios of forestry activities for clear sanitary felling will be assessed through the following indicators (table 2).

Table 2. Scenarios of sanitary and recreational activities in the dead forest areas.

| Scenario   | Region               | Clear sanitary felling, annually |
|------------|----------------------|----------------------------------|
|            |                      | Hectares | % from dead forest stands for year |
| Conservative | Komi Republic     | 301      | 10                                 |
|             | Arkhangelsk region | 1864     | 70                                 |
|             | Murmansk region    | 17       | 7                                  |
| Planned    | Komi Republic      | 558      | 19                                 |
|             | Arkhangelsk region | 2000     | 76                                 |
|             | Murmansk region    | 109      | 45                                 |
| Optimal    | Komi Republic      | 2903     | 100                                |
|             | Arkhangelsk region | 2645     | 100                                |
|             | Murmansk region    | 240      | 100                                |

Based on the results obtained, it is worth noting that under the «planned» scenario, clear sanitary felling will cover less than half of the annually dying forest stands, even though in recent years there has been a decrease in the areas of annual forest destruction. Under the «conservative» scenario of the use of sanitary felling, their area will be about 38 % of the annual average area of forest destruction over the last five years.

In the Komi Republic, a low percentage of sanitary and recreational activities is due to the remoteness and inaccessibility of areas of damaged and dead forest stands.

In the Murmansk region, there is insufficient funding for sanitary and recreational activities and
also the inaccessibility of certain areas.

3.2. Reforestation

Reforestation consists of a complex of natural processes, including those caused by special technological and organizational measures, for the formation of young closed forest stands (young stands) of the main forest tree species on lands intended for reforestation. The final stage of reforestation is a survey with the aim of assigning lands intended for reforestation to the lands on which forests are located and preparing an act on changing the documented information of the state forest register.

Reforestation is carried out in a natural, artificial or combined way in order to restore felled, dead, damaged forests, as well as to preserve the useful functions of forests and their biological diversity.

Reforestation areas on forest lands and lands of other categories are shown in table 3.

| Year | Komi Republic | Arkhangelsk region | Murmansk region |
|------|---------------|-------------------|-----------------|
| 2015 | 36719         | 57571             | 1577            |
| 2016 | 35157         | 63526             | 986             |
| 2017 | 45152         | 66661             | 952             |
| 2018 | 44204         | 63770             | 888             |
| 2019 | 55128         | 76985             | 1402            |
| Mean | 43272         | 65703             | 1161            |

The areas of reforestation on the lands of the forest fund are shown in table 4.

| Year | Komi Republic | Arkhangelsk region | Murmansk region |
|------|---------------|-------------------|-----------------|
| 2015 | 36719         | 57567             | 1577            |
| 2016 | 35157         | 63519             | 986             |
| 2017 | 46900         | 66661             | 952             |
| 2018 | 44204         | 63771             | 888             |
| 2019 | 55128         | 78994             | 1402            |
| Mean | 43622         | 66102             | 1161            |

The area of artificial reforestation (table 5) on average for 2015-2019 is 5.9 % of the area of reforestation in the Komi Republic, 6.1 % – in the Arkhangelsk region, 22.8 % – in the Murmansk region.

| Year | Komi Republic | Arkhangelsk region | Murmansk region |
|------|---------------|-------------------|-----------------|
| 2015 | 2430          | 4095              | 562             |
| 2016 | 2574          | 3671              | 212             |
| 2017 | 2416          | 3826              | 75              |
| 2018 | 2489          | 4071              | 210             |
| 2019 | 2908          | 4530              | 264             |
| Mean | 2563          | 4039              | 265             |

Considering that artificial reforestation is carried out in areas where it is impossible to ensure natural reforestation or inappropriate combined reforestation with economically valuable forest tree
species, the optimal scenario would be artificial reforestation in all such areas. Their area depends on seed years, weather, microclimatic, soil and other conditions and is determined by the fact. According to the conservative scenario of carrying out forestry activities of artificial reforestation in the Komi Republic and in the Arkhangelsk region, their area is lower than according to the planned (table 6).

### Table 6. Scenarios of artificial reforestation.

| Scenario | Region          | Artificial reforestation, annually |
|----------|-----------------|-----------------------------------|
|          |                 | Hectares | % from reforestation/year |
| Conservative | Komi Republic | 2563     | 6                      |
|           | Arkhangelsk region | 4039    | 6                      |
|           | Murmansk region  | 265     | 23                     |
| Planned  | Komi Republic  | 2990     | 7                      |
|           | Arkhangelsk region | 6230   | 9                      |
|           | Murmansk region  | 224     | 23                     |
| Optimal  | Komi Republic  | -        | -                      |
|           | Arkhangelsk region | -    | -                      |
|           | Murmansk region  | -        | -                      |

| Total:   | Conservative  | 6867     | 6                      |
|          | Planned       | 9443     | 9                      |
|          | Optimal       | -        | -                      |

Depending on the scenario, the annual volumes of reforestation of the dead stands that are felled by the clear sanitary felling can range from 2.2 to 5.8 thousand hectares (table 7).

### Table 7. Volumes of reforestation work in areas that emerged from clear sanitary felling of dead forest stands according to various scenarios.

| Scenario | Region          | Reforestation, % Sanitary cutting from dead forest stands for year | Hectares |
|----------|-----------------|----------------------------------------------------------|----------|
| Conservative | Komi Republic | 10                                      | 301      |
|           | Arkhangelsk region | 70                               | 1864     |
|           | Murmansk region  | 7                                       | 17       |
| Planned  | Komi Republic  | 19                                      | 558      |
|           | Arkhangelsk region | 76                             | 2000     |
|           | Murmansk region  | 45                                      | 109      |
| Optimal  | Komi Republic  | 100                                     | 2903     |
|           | Arkhangelsk region | 100                          | 2645     |
|           | Murmansk region  | 100                                     | 240      |

| Total:   | Conservative  | 38                                    | 2182     |
|          | Planned       | 46                                    | 2667     |
|          | Optimal       | 100                                   | 5788     |

The Strategy for the Development of the Forestry Complex of the Russian Federation until 2030 states that, starting in 2011, the clear cut area exceeds the area where reforestation is being carried out. In recent years, the accumulated area of unregulated felling amounted to about 0.5 million hectares.

Taking into account the data on the area of reforestation, the scenarios of reforestation of clear
cutting areas are shown in Table 8. In this case, the planned scenario (one hundred percent recovery) coincides with the optimal one. If the trend of the average clear cutting area over the last 5 years of statistics persists, it will be necessary to restore forests by 133.8 thousand hectares annually.

Table 8. Scenarios of reforestation in clear cutting areas.

| Scenario    | Region         | Hectares | % from clear cutting |
|-------------|----------------|----------|----------------------|
| Conservative| Komi Republic  | 43622    | 76                   |
|             | Arkhangelsk region | 66102   | 88                   |
|             | Murmansk region  | 1161     | 69                   |
| Planned     | Komi Republic  | 57029    | 100                  |
|             | Arkhangelsk region | 75103   | 100                  |
|             | Murmansk region  | 1685     | 100                  |
| Optimal     | Komi Republic  | 57029    | 100                  |
|             | Arkhangelsk region | 75103   | 100                  |
|             | Murmansk region  | 1685     | 100                  |

Total:

Conservative: 110884, 83%

Planned, Optimal: 133817, 100%

3.3. Fire protection measures

According to available data by forest fires, the situation has been relatively favorable in recent years. Since 2009, the most unfavorable year in the Arkhangelsk region (76.5 thousand hectares were covered by forest fires) and Komi Republic (50.9 thousand hectares) in 2011, in the Murmansk region (11.2 thousand hectares) in 2018.

The European North turned out to be abnormally hot in 2011. According to the Russian Meteorological Center in the North-Western Federal District, the average air temperature for 121 years of observation (from 1891 to 2011) in 2011 was 2 rank.

In recent years there were also relatively few burned-out forest stands. At the same time, in the forest fire control zone for the available statistical period (2017-2020) in the North-West Federal District, forest fires in the control zone were recorded only in 2017 (30 units on the area of 5150 hectares).

In previous years (from 1992 to 2015), the volume of burnt and damaged standing forest in middle-aged, ripening, mature and over matured forest stands, including the number of young growth of natural and artificial origin over the age of 10 years, reached an annual maximum of 8.3 million m$^3$ in the Komi Republic, 2.8 million m$^3$ in the Arkhangelsk region and 0.2 million m$^3$ in the Murmansk region with average values of 0.6 million m$^3$, 0.4 million m$^3$ and 0.03 million m$^3$, respectively.

Thus, in recent years, the volume of burned forests on the considered areas of forest lands in Komi Republic. In Arkhangelsk region has significantly decreased, despite the fact that, in general, climate change contributes to an increase in temperature anomalies.

4. Conclusion

The results of the analysis of the elements of the forest management system showed that the areas of clear sanitary felling according to the conservative and planned scenarios are insufficient and cover less than half of the annual average area of forest destruction over the last 5 statistical years. Despite the fact that the areas of reforestation have been growing in recent years, the incomplete development of dead stands will not allow fully implementing the program for the restoration of felled and dead stands by 100%. Therefore, more attention should be paid to forest protection measures.
If the trend of the average clear cut area over the last 5 years of statistics continues, it will be necessary to restore forests by 133.8 thousand hectares annually. At the same time, the area of artificial reforestation remains approximately at the same level. It depends on the area of the reforestation fund, where it is impossible to provide natural reforestation or inappropriate combined reforestation with economically valuable forest tree species and is determined by the fact. According to the conservative scenario, the area of artificial reforestation is lower than the planned one.

Despite the fact that climate change leads to an increase in the fire hazard, the situation in the European North has been relatively favorable in recent years. Fire protection measures, timely extinguishing of forest fires, preventive measures, purchase of new equipment, monitoring, etc. contribute to the reduction of fires.

Over matured spruce forests are especially susceptible to windfalls, therefore, the exploitation of such areas before they decay will allow avoiding economic losses in forest management. At the same time, it is necessary to take care of the reforestation of the harvested areas in accordance with the forestry intensification program.

Adaptation to winds, which is one of the main causes of plant destruction from unfavorable weather conditions, is a number of forestry activities: selection of the direction of the cutting area perpendicular to the direction of the current winds; the use of narrow-strips cutting, which reduces the wind load on the forest wall; observance of terms of adjoining cutting areas; conservation of biodiversity, which contributes to the resilience of forests; the creation of mixed forest crops or the formation of mixed plantings. Selective cutting in weakened stands can contribute to their further disturbance and susceptibility to windfalls.

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