The role of mortality coefficients in planning and accounting for greenhouse gas emission reductions

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Abstract. The article presents tables of growth of fir plantations in the southern part of Siberia supplemented by carbon parameters. The dependences of the mortality coefficients on the stock and the number of trunks are considered. The obtained dependences will help determine what determines the relationship between the mortality coefficient and the stock and the number of trunks. Quantitative and qualitative characteristics of fir plantations of the South Siberian mountain forestry region considered in this paper will determine their production potential. The calculated coefficients will significantly reduce the uncertainty of carbon estimates, which will undoubtedly contribute to the development and implementation of forestry planning and practical measures for adaptation and adaptation to climate change. This will undoubtedly contribute to the reduction of greenhouse gas emissions, since the possibility and accuracy of taking into account the possibility of forests to bind and accumulate atmospheric carbon will increase.

1. Introduction

Under the Paris Agreements, the Framework Convention on Climate Change (UNFCCC), adopted at the UN World Conference in 2015, Russia made voluntary commitments to reduce greenhouse gas emissions by 2030 by 30%, subject to the best possible accounting for the ability of forests to bind and accumulate atmospheric carbon [1]. For the rational planning and implementation of practical measures to resist and adapt to climate change, timely and accurate information about the object, in particular about carbon stocks in the forests of Russia, is required. This is the reason for the growing interest of researchers in the study of wood mortality, which makes it possible to approach the assessment of the carbon budget of forests as objectively as possible. The decay of trunks in the plantation is associated with the development of forest ecosystems in general, which means that a thorough study of this process will certainly contribute to the optimal planning of forestry activities, which will be aimed at developing and implementing practical measures necessary to reduce greenhouse gases [2]. Over the past two decades, there has been a decrease in plantation stability for various reasons, which leads to an increase in the stock of decay, which contributes sufficiently to climate change due to changes in carbon fluxes in forests [3].

Mortality of stands is understood to mean the death of trees in the plantation as a result of natural thinning of the stand with age. A natural quantitative decrease in the stand is a change in the number of trees in the stand as a result of the natural withering away of some of them with increasing age [4]. Woody plants die that are weaker in their hereditary properties or due to unfavorable growth conditions (lack of light, nutrients in the soil, heat, lack or excess of moisture, etc.). During the life of woody plants
- from the stage of closed young growth to the onset of natural aging - more than 95% of the forest stand dies due to the struggle for existence. In the period of young growth (before its closure), when there is a formation of woody plants, the decay of trees is characterized by interspecific struggle. In this case, first of all, trees that are weakened, sick, damaged by insect pests and the like die. After trees are closed, decay occurs mainly due to increased competition between them for light, moisture, soil nutrition [5].

The complex relationships between different tree species, the change in their competing interaction under the influence of many factors determine the complex nature of thinning of mixed stands, the consequence of which may be a change in the composition of forests. The intensity of changes in stands is also affected by climate, soil, fauna, and anthropogenic impacts [6].

Particular attention to the problem of calculating the carbon budget in the forests of Russia, as well as the annual organized storage of carbon by the main types of forest ecosystems, has not yet allowed to obtain comparable results. The numerical estimates obtained by different scientists and teams diverge significantly, having a high degree of uncertainty. Despite the difference in the information sources used and the methodological approaches, all regional and global estimates were obtained by calculation and are based on tables that numerically reflect the growth of stands. In the process of work, many tables have been compiled that numerically reflect the process of growth. At the same time, the dynamics of the formation of tree mortality requires a deeper scientific study, which will undoubtedly contribute to the most complete and adequate calculation of the carbon budget of Russian forests.

From all of the above, it follows that the increasing importance of tree mortality, which makes it possible to estimate the carbon budget of forests, together with insufficient knowledge of the features of its formation and assessment, emphasize the relevance of the presented work.

Qualitative and quantitative characteristics of Russian forests, which determine their production potential, are associated with forest conditions, density, type of forest, as well as with the age that will characterize the decline. The conversion factors for the stock of stem wood into the phytomass can significantly reduce the uncertainty of carbon estimates in forests [7].

2. Material and methods
According to the general tables, the growth trends of fir plantations, which take into account mortality, revealed the following indicators: Nmor - the number of trunks of mortality and Motp - stock of mortality. According to the growth progress tables for Siberia, the number of dead trunks was determined.

\[ N_{mor} = N_{i-A} - N_i \] (1)

where Nmor – the number of trunks of mortality, pcs; N_{i-A} – number of trees, pcs; N_i - the number of trunks of the previous period, pcs.

The stock of mortality was calculated by the formula:

\[ M_{mor} = V_i \times N_{mor} \] (2)

where Mmor – stock of mortality, m³/ha, Nmor – the number of trunks of mortality, pcs; Vi – the volume of the middle tree, the data on the directory from the tables of volumes of pine trunks in the bark, m³.

Mortality coefficient by the number of trunks (KmorN), N - number of trunks, pcs:

\[ K_{morN} = \frac{N_{mor}}{N} \] (3)

Mortality rate by reserve (KmorM), M - total reserve, m³/ha.

\[ K_{morM} = \frac{M_{mor}}{M} \] (4)

The analysis was carried out directly on normal (closed) fir plantations, in which the rate of decay is higher than that of modal stands.
3. Results and Discussion

The data of the calculation example were applied to the tables of the course of growth of fir plantations in southern Siberia, which were supplemented by the coefficients of mortality by the number of trunks and by stock (table 1) [9].

Table 1. South Siberian mountain forestry region (III), Altai-Tuvino-Sayan mountain taiga forestry region (9). Forest type - mixed herb. III class boniteta.

| Age, years | Average height, m | Average diameter, cm | The sum of the cross-sectional areas, m²/ha | The number of trunks per 1 ha, pcs | Species number 0.001 | Total stock, m³/ha | Stock change, m³/ha | Average | Current | Number of trunks, pcs | Mortality stock, m³ | Mortality coefficient |
|------------|-------------------|----------------------|--------------------------------------------|----------------------------------|-----------------------|-------------------|------------------|--------|--------|-----------------------|--------------------|---------------------|
| 30         | 7.3               | 7.4                  | 12.7                                       | 2955                             | 563                   | 52                | 1.7              | -      | -      | -                     | -                  | -                   |
| 40         | 11                | 13.1                 | 15.4                                       | 1140                             | 522                   | 88                | 2.2              | 3.6    | 2170   | 163                   | 1.904              | 1.849               |
| 50         | 14.3              | 16.6                 | 17                                         | 785                              | 503                   | 122               | 2.4              | 3.4    | 520    | 79                    | 0.662              | 0.644               |
| 60         | 16                | 19                   | 17.6                                       | 620                              | 496                   | 140               | 2.3              | 1.8    | 235    | 55                    | 0.379              | 0.396               |
| 70         | 17.3              | 20.5                 | 18.2                                       | 550                              | 492                   | 155               | 2.2              | 1.5    | 120    | 31                    | 0.218              | 0.201               |
| 80         | 18.1              | 21.6                 | 18.4                                       | 500                              | 489                   | 163               | 2                | 0.8    | 95     | 25                    | 0.190              | 0.152               |
| 90         | 18.9              | 22.7                 | 18.5                                       | 455                              | 488                   | 170               | 1.9              | 0.7    | 65     | 26                    | 0.143              | 0.154               |
| 100        | 19.4              | 23.4                 | 18.8                                       | 435                              | 486                   | 177               | 1.8              | 0.7    | 45     | 18                    | 0.103              | 0.102               |
| 110        | 20                | 24.1                 | 18.8                                       | 410                              | 485                   | 182               | 1.7              | 0.5    | 35     | 14                    | 0.085              | 0.077               |
| 120        | 20.3              | 24.6                 | 19                                         | 400                              | 484                   | 187               | 1.6              | 0.5    | 20     | 8                     | 0.050              | 0.043               |
| 130        | 20.8              | 25                   | 19.3                                       | 390                              | 483                   | 194               | 1.5              | 0.7    | 20     | 9                     | 0.051              | 0.045               |
| 140        | 21.1              | 25.4                 | 19.4                                       | 380                              | 482                   | 197               | 1.4              | 0.3    | 15     | 7                     | 0.039              | 0.033               |
| 150        | 21.3              | 25.7                 | 19.4                                       | 375                              | 482                   | 198               | 1.3              | 0.1    | 15     | 7                     | 0.040              | 0.033               |
| 160        | 21.6              | 26                   | 19.4                                       | 365                              | 481                   | 202               | 1.3              | 0.4    | 10     | 4                     | 0.027              | 0.021               |

The dependence of the number of mortality trunks on age according to the growth tables is shown in figure 1.

![Graphs](image)

a) Dependence of the number of trunks of mortality on age

b) Dependence of the stock of mortality on age

Figure 1. Dependence of the number of trunks of mortality (A) and stock (B) on age according to the growth tables of the South Siberian Mountain Forestry Region (III), Altai-Tuvino-Sayan Mountain Taiga Forestry Region (9). The forest type is multi-grassy. III class boniteta.
Further, according to the growth progress tables, charts are presented of the dependences of the mortality coefficients by the number of trunks and stock by age (figure 2).

![Dependence of the coefficient of mortality in the number of trunks on age](image1)

![Dependence of the mortality coefficient on the stock on age](image2)

Figure 2. Dependence of mortality coefficients by the number of trunks (A) and stock (B) on age according to the growth tables of the South Siberian Mountain Forestry Region (III), Altai-Tuvin-Sayan Mountain-Taiga Forestry Region (9). The forest type is forbs. III class boniteta.

4. Conclusion

The data on the dependence of the number of mortality and reserve trunks on age show a significant mortality at the age of 30 to 50 years, then the number of muzzle decreases with age. The presented dependences show that a significant decline in the stand at the age of 30 to 50 years does not depend on the bonitet or type of forest, but is due to age-related competition. The obtained dependences showed that the relationship between the mortality coefficient both in reserve and in the number of trunks is determined by the initial density, in the case of forest type, pine grass is expressed in the initial period. Old-age stands are characterized by higher mortality. Quantitative and qualitative characteristics of fir plantations of the South Siberian mountain forestry region make it possible to determine their production potential. The calculated coefficients will significantly reduce the uncertainty of carbon estimates, which will undoubtedly contribute to the development and implementation of forestry planning and practical measures for adaptation and adaptation to climate change. To some extent, this will contribute to a reduction in greenhouse gas emissions, since the possibility and accuracy of taking into account the possibility of forests to bind and accumulate atmospheric carbon will increase.

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