Data set of long-term experiments in Forest Experimental Station of the Timiryazev Agricultural Academy since 1862

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Abstract. In the forest experimental station of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy, since 1862, experiments have been carried out to study the methods of planting, the geographical origin of seeds, methods of thinning for forest growth. The measurements available in the dataset are important for forestry. They are the basis for the development of models of growth and productivity of forest stands in the European part of Russia, for the development of methods for mixing tree species and thinning schemes.

1. Introduction
In the middle of the 19th century, the opinion was formed among German foresters that trees and forest stands require long-term observation. The forest research station Baden-Württemberg (Germany), the research station of Lower Saxony in Göttingen (Germany), the Institute for Forest, Snow and Landscape Research (Switzerland) were among the first to be organized. On the oldest forest experimental plots, continuous observations have been carried out since 1848 [1]. From the same time, forest research stations began to be created in other European countries. A large number of long-term experiments have been created in Germany, for example, in Bavaria alone, the network of permanent test plots includes 151 experiments with 934 forest plots on a total area of 181 hectares [2]. To study forest growth in Switzerland, a network of 495 plots currently operates, which are measured every 5–12 years. The total area of the experimental plots is 154 ha. The plots are located in all major types of forests in Switzerland. Many of them have been under surveillance for over 50 years, and 18 sites for over 100 years [3]. Long-term experiments are currently being carried out at 520 sites in the UK [4]. There are 3298 active experiments in Sweden [5].

The organization of experimental forestry in Russia is associated with the creation of experimental plantings in the Lisino educational and experimental forestry (Leningrad region), the experimental forest station of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy (Moscow), Shchelkovo training and experimental forestry (Moscow region) and other facilities. In Lisino educational and experimental forestry, more than 100 permanent sample plots are used to study the dynamics of growth of taxation variable forest stands. For more than 160 years, experience has been carried out in draining forest wetlands and growing forests on them. In the forest experimental station of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy, since 1862, experiments have been carried out to study the methods of planting, the geographical origin of seeds, methods of thinning for forest growth. A series of long-term observations of the growth and yield of forest stands have been accumulated [6, 7]. In Nikolskaya forest station (Shchelkovo
educational and experimental forestry), experimental work began in 1895, and in 1899, 113 test plots were laid in various plantations, including 40 permanent ones.

The results of observations of forest stands over long periods of time made it possible to formulate the basic laws of growth and yield of forest stands, which have found their application in forestry practice and forestry textbooks in many countries of the world. These patterns include the rule of self-thinning of Reinecke stands, numerous tables of growth rates, recommendations for thinning stands, optimal mixing patterns for tree species, etc.

2. Methods and Materials

The materials were data from the measurement of permanent test plots at the experimental forest station of the Russian State Agrarian University – Moscow Timiryazev Agricultural Academy located in the north-west of the city of Moscow. The climate is temperate continental with an average annual temperature of 6.1 °C (for 1987-2016) and average annual precipitation of 700 mm (for 1987-2016). The predominant soils are sod-podzolic [8]. According to the results of the forest inventory in 2009, the area of the forest experimental station is 248.7 ha, including 233.4 ha (93.8%) of the forest-covered land. The area mainly consists of mixed and even-aged forests dominated by pine, larch, birch, oak and linden. In the herbaceous layer prevail Galeobdolon luteum Huds., Aegopodium podagraria L., Geum urbanum L., Stellaria media (L.) Vill., S. holostea L., Luzula pilosa (L.) Willd., Dryopteris carthusiana (Vill.) H.P. Fuchs, Calamagrostis arundinacea (L.) Roth, Lamium album L., Milium effusum L. [9, 10].

The first permanent test plots were laid in 1862 in the process of arrangement of the Petrovsky Forest District by Alfons R. Vargas de Bedemar. Later on, the studies were continued by M K Tursky, N S Nesterov, V P Timofeev and A N Polyakov. From the beginning of the XX century regular measurements were taken with an interval of 5–15 years on the permanent test plots of the experimental forest station. In 2018, A V Lebedev began work on the systematization of long-term observation data. The results of the observation of the stands on the permanent test plots were systematized in the form of the dataset "Stands Growth and Yield Dataset of Permanent Test Plots of the Forest Experimental Station of the Timiryazev Agricultural Academy with 1862" (DOI: 10.13140/RG.2.2.30165.55524/1).

Over the years, the measurement method on permanent test plots has not undergone significant changes. The diameters of all trees were measured on a constant trial plot. Diameter distributions are also calculated. The heights were measured for 15-25 trees. For individual species, the quadratic diameter at breast height was calculated. The average height was determined graphically. The average height corresponds to the quadratic diameter. The volume of trees was determined from tables. Most variables are calculated for individual species and for the whole stand.

3. Results and Discussion

There are a total of 258 permanent test plots in the dataset. The dataset contains 1) a table with observations and 2) a table with parameters of permanent test plots, 3) a scheme for allocating permanent test plots and 4) a scheme for placing the forest experimental station in Moscow, 5) a brief description. The table with observations contains variables: permanent test plot index (Plot), year of measurement (Year), age (Age), tree species (Tree species), average height (Height), average diameter (Diameter), number of trees (Number of trees), basal area (Basal area) and growing wood volume (Volume) variables (table 1).

On average, the area of one permanent test plot is 0.1576 ha. The maximum area is 1.5000 ha. The minimum area is 0.0122 ha. Figure 1 shows the distribution of permanent test plots by experiment category. The distribution is conditional, because observations for different experiments can be carried out on the same permanent test plot. The largest number of permanent sample plots belongs to the category of mixed forests (32 %). There are experiments to create mixed stands of pine and linden, larch and pine, larch and linden, pine and birch. There are many permanent test plots for the study of increment thinning (18 %). These experiments were mainly carried out in pine stands. Permanent test
plots for the study of provenance (10%) are the first forestry experiments of this kind in Russia. In these experiments, pine is grown from seeds from different regions of the European part of Russia, Ukraine, Latvia, Poland and Germany [7]. On 15% of the permanent test plots, the goal is to study growth and yield.

Table 1. Description of forest stand variables.

| Variable          | Description                                                                 |
|-------------------|-----------------------------------------------------------------------------|
| Plot              | Permanent test plot index                                                    |
| Year              | Measurement year                                                            |
| Age               | Average age at the time of measurement (years)                               |
| Tree species      | Tree species                                                                 |
| Height            | Average height corresponding to quadratic diameter at breast height (m)        |
| Diameter          | Quadratic diameter at breast height (cm)                                     |
| Number of trees   | Number of trees (trees per ha)                                               |
| Basal area        | Basal area of trees at breast height (m² per ha)                              |
| Volume            | The volume of the trunks of growing trees (m³ per ha)                         |

A visualization of height and age data for selected species is shown in figure 2. The all data cover a wide range of site indexes (SI) from 17 to 45 meters in 100 years. After 100 years for all tree species, growth in height slows down significantly. Pine stands have the largest amount of data. Larch stands have the highest average height. For spruce stands, the maximum observation age is 85 years, since in 1939-1940 all experiments with spruce were closed, because it dried out.

Figure 1. Permanent test plots types.

Figure 3 shows the diameter and age data. The largest diameters in larch stands. The growth in diameter continues throughout the entire observation period of the stands. Figure 4 shows the basal area and age data. The basal area has the maximum values in larch stands. In the stands of pine, birch, oak, growth in the basal area occurs in several stages. In pine stands, the growth curve over the basal area has the first maximum at 30-50 years and the second maximum at 100-130 years. In birch and oak stands, the growth curve of the basal area has up to 5 maximum points.
Figure 2. Height and age data for individual species.

Figure 3. Diameter and age data for individual species.
The measurements available in the dataset are important for forestry. They are the basis for the development of models of growth and productivity of forest stands in the European part of Russia, for the development of methods for mixing tree species and thinning schemes. In Russia, there are no comparable similar forest long-term experiments, as in the Forest Experimental Station of the Timiryazev Agricultural Academy. Similar experiments should be continued to obtain comparable results.

4. Conclusion
Long-term experiments in forestry are promising for the preservation of existing and further development. It will take another 150 years to accumulate a comparable amount of scientific information. Taking into account the ongoing global environmental changes and emerging challenges for sustainable forest management, the network of long-term experiments should be expanded. The current tasks of the development of long-term experiments should be the establishment of a list of recorded variables, as well as the interdisciplinary use of observational data in science and practice.

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