Carbon sequestration in artificial forest stands of the Karachayev-Cherkessian Republic

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Abstract. The work was carried out in order to study the functions of carbon accumulation and oxygen release by biomass of artificial forests of the Karachay-Cherkess Republic. The study was carried out on the territory of the Kuban forestry. Plantings, both pure and mixed in composition, are grown under the same conditions for growing fresh oak forests, aged 48 to 63 years. The research is based on the method of comparison and analysis associated with the concept of multipurpose, rational, sustainable use of forest resources. Carbon stocks were estimated using an analytical method. The volumes of atmospheric carbon and carbon dioxide absorbed by forests, as well as the volume of oxygen released, have been calculated. The calculation results show that the maximum amount of carbon is absorbed by ordinary ash (931.9 t/ha) and English oak (476.7 t/ha). The minimum amount of carbon dioxide (158 t/ha) is absorbed by Siberian elm. This crop also emits the least amount of oxygen – 117.3 t/ha. Using test results can help estimate the amount of carbon dioxide absorbed by plants and the amount of oxygen released.

1. Introduction

Green spaces are a unique creation of nature, the role of which is very multifaceted and multifunctional. Plantations are involved in a number of processes (biological circulation of substances, climate formation and the creation of ideal conditions for people to work and rest). Artificial plantations, parks, fields, meadows, single trees change and improve climatic conditions, giving the environment a comfortable and hygienic quality.

There are a number of studies related to the problem under study. In subtropical forests (Guizhou Plateau), the stand represents the main structural element of the forest, which makes it possible to assess and predict the productivity of the ecosystem and, in turn, the accumulation of carbon. Investigating the change in growth and the influence of the environment on the volume of growth are rare, especially in subtropical forests in karst areas, they are characterized by a complex species composition and play an important role in the global carbon balance. In the course of the study, there were growth patterns for all the dominant species of woody plants in the subtropical karst zone of the Guizhou Plateau. The growth modeling of tree stands was based on the study of various environmental factors. This allows predicting the development of forest and resources, thus ensuring sustainable forest management and planning [1,2], especially in mitigating the use of the greenhouse in a changing climate [3,4]. In the Retezat National Park (Romania's first national park), the study was carried out in the western part of the South Carpathians, including in the Retezat-Godeanu massif and partly in the
Tarku mountain. This was done by increasing the amount of carbon sequestered and fixed in the plantations and following estimation of carbon captured by ecosystems [5].

At the European level, there is an important issue related to the coherence of biodiversity goals in relation to climate goals, as well as the conservation of valuable tree species in accordance with economic goals. This problem can be solved by using forestry expertise, scientific heritage and academia. The aim of the study is to study artificial plantations of various species composition, age and carbon sequestration, as well as to determine the amount of oxygen released by plantations during photosynthesis. Determination of factors influencing the carbon sequestration process.

2. Material and methods

The research was carried out in stands growing in the eastern part of the Karachay-Cherkessia (GPS coordinates: 44.226863, 42.04677 (latitude, longitude), 13 permanent experimental sites were established) under similar conditions of forest vegetation of fresh oak forests (D2).

Before carrying out fieldwork, a detailed survey of the objects on which the laying of test sections was planned was carried out. An assessment of the state of the plantings was carried out on the experimental plots, the optimal size of the plot was determined. The size of the test area depended on the density of forest crops. The optimal number of trees on the test site should have been at least 200. Location of the test site was determined relative to the direction of the rows, the boundaries were drawn in the middle of the aisles.

Short sides were positioned in such a way that they minimally limited the view, so that the test areas could be laid without cutting through the sight. For a greater reference point (when passing through the aisles), the neighboring sides were painted over with chalk. The right angles were broken off with a caliper. Temporary pegs are installed at the corners of the designated test site, which provides a clear view of the boundaries of the site. The distance from the open space or road to the border of the studied territory is set at least the landing height. At the experimental site, after continuous counting of trees, the height of 10 trees of average height was measured. The study was conducted on the basis of the method of comparison and analysis. Carbon reserves were estimated by the analytical method.

The calculation of the amount of deposited carbon was based on the current increase in the amount of phytomass in artificial plantings. Estimation of the amount of oxygen with an annual increase in the amount of phytomass. The total supply of phytomass was calculated using the index of the photosynthesized part of leaves and wood multiplied by the standard ecological index.

3. Results and discussion

The ability of forest stands to absorb carbon dioxide and disengage oxygen establishes their leading role in biosphere, which is expressed in: synthesis of the primary organics from inorganic substances, oxygen production determining atmospheric composition [6,7].

The amount of the carbon is distributed in the following way: stand – 88%, leaves and needle-foliage of conifers – 5%, dead standing trees and wind thrown trees – 6%, other components – 1%.

The estimate of the disengaged oxygen and absorbed carbon is based on the element of the biological productivity, which is expressed by the weight units of the absolute dry substance. Inventorial characteristic of the forest crops of the Northern Caucasus is demonstrated in table 1.

The values of dry matter mass are calculated by multiplying the tax indicators of volume and average growth by the value of the conditional wood density. Each of the species has its own values of the conditional wood density. Based on this, the total phytomaps and the growth of the plantation phytomaps are calculated. The phytomaps of the stand include the mass of roots (15-20%) and branches and leaves (20-25%). The investigated artificial plantations are mainly crops of common ash (main tree species). For plantations aged 60 years, the average values of the taxation indicators are characteristic: height 16 m, diameter 20 cm, bonitet 2, density 0.7, average stock per hectare 80 m³/ha.

At the same time, the average increase in timber on the trial plots is 1.3 m³/year. The determination of
the percentage of mass of the stand elements was taken from the detailed methodology of V Tarankova.

### Table 1. Inventorial characteristic of the forest stands.

| No. | Quarter / Stratum | Composition | Age, years | Height, m / Diameter, cm | Growth class / Density | Wood stock per 1 ha, m³ | Annual increment, m³/year |
|-----|-------------------|-------------|------------|--------------------------|------------------------|------------------------|--------------------------|
|     |                   |             |            |                          |                        |                         |                          |
|     |                   | 4 oak       | 18.5/22.6  |                          | 3/0.7                  | 152                    | 2.6                      |
| 1   | 8/4               | 4 ash       | 17.2/20    |                          | 10                     | 80                     | 1.4                      |
|     |                   | 1 apricot   | 16/18      |                          |                         |                         |                          |
|     |                   | 1A          | 16/18      |                          |                         |                         |                          |
|     |                   | 4 oak       | 18/20.3    |                          | 148                    |                         | 2.6                      |
| 2   | 7/18              | 4 ash       | 16.8/18    |                          | 3/0.7                  | 68                     | 1.2                      |
|     |                   | 2 apricot   | 14/16      |                          |                         |                         |                          |
|     |                   | 8 ash       | 18/20      |                          | 180                    |                         | 2.9                      |
| 3   | 9/4               | 2 green ash | 15/18      |                          | 2/0.7                  | 46                     | 0.7                      |
|     |                   | 10 ash      | 18/22      |                          | 1/0.7                  | 170                    | 2.8                      |
| 4   | 13/1              |             |            |                          |                        |                         |                          |
|     |                   | 8 sycamore  | 15/16      |                          | 2/0.9                  | 128                    | 2                        |
|     |                   | maple       | 18.5/24    |                          | 32                     |                         | 0.5                      |
| 5   | 16/32             | 2 ash       | 17.5/18    |                          | 1/0.9                  | 157                    | 3.3                      |
| 6   | 9/18              | 10 ash      | 16/22      |                          | 2/0.6                  | 61                     | 0.9                      |
| 7   | 18/5              | 10 ash      | 19/22      |                          | 1/0.9                  | 299                    | 5.1                      |

| No. | Quarter / Stratum | Composition | Age, years | Height, m / Diameter, cm | Growth class / Density | Wood stock per 1 ha, m³ | Annual increment, m³/year |
|-----|-------------------|-------------|------------|--------------------------|------------------------|------------------------|--------------------------|
|     |                   | 6 oak       | 16/24      |                          | 60                     |                         | 1                        |
| 8   | 8/67              | 2 ash       | 14/20      |                          | 20                     |                         | 0.3                      |
|     |                   | 2 apricot   | 14/20      |                          |                         |                         |                          |
|     |                   | 2 ash       | 18/24      |                          | 214                    |                         | 3.5                      |
| 9   | 8/82              | 7 walnut    | 16/22      |                          | 31                     |                         | 0.5                      |
|     |                   | 1 apricot   | 16/22      |                          |                         |                         |                          |
|     |                   | 9 elm       | 8/14       |                          | 52                     |                         | 1                        |
| 10  | 1/1               | 1 ash       | 10/16      |                          | 5                      |                         | 0.1                      |
|     |                   | 8 ash       | 15/22      |                          | 115                    |                         | 1.9                      |
|     |                   | 2 elm       | 12/16      |                          | 28                     |                         | 0.4                      |
| 11  | 1/25              | 5 sycamore  | 16/20      |                          | 118                    |                         | 1.8                      |
|     |                   | maple       | 16/20      |                          |                         |                         |                          |
| 12  | 3/1               | 2 walnut    | 14/18      |                          | 47                     |                         | 0.8                      |
|     |                   | 1 elm       | 14/18      |                          | 24                     |                         | 0.4                      |
|     |                   | 2 wild pear | 14/18      |                          | 47                     |                         | 0.8                      |
|     |                   | 7 walnut    | 16/22      |                          | 70                     |                         | 1.1                      |
|     |                   | 2 oak       | 14/20      |                          | 20                     |                         | 0.3                      |
|     |                   | 1 black poplar | 14/20    |                          | 10                     |                         | 0.2                      |

*Eo – oak; Ea – ash; A – apricot; Lo – locust; Ew – walnut, Pr – pear; Ga – ash; Wm – maple; Ew – walnut; Se – elm; Hl – honey locust; Bp – poplar.
Table 2. The volume of carbon and carbon dioxide absorption and oxygen disengagement.

| Quarter/Stratum | Composition    | Age, years | Phytomass Carbon volume | Carbon dioxide absorption | Oxygen disengagement |
|-----------------|----------------|------------|-------------------------|--------------------------|----------------------|
|                 |                |            | current age, t/ha/current increment, t/ha/ year | current age, t/ha / current, t/ha/ year | current age, t/ha / annual increment, t/ha/ year |
| Prigorodnoye forest district of the Kuban leskhoz | 4 oak | 8/4 | 116.2/2 | 131.8/2.3 | 353.2/6.2 | 476.7/8.4 |
|                 | 4 ash |           | 60.3/1.1 | 69/1.2 | 184.9/3.2 | 249.5/4.4 |
|                 | 1 pricot | 57 | 9.2/0.2 | 9.4/0.2 | 25.1/0.4 | 34/0.6 |
|                 | 1A |            | 7.2/0.1 | 8.5/0.1 | 22.7/0.4 | 30.6/0.5 |
|                 | total |            | 192.9/3.4 | 218.7/3.8 | 585.9/10.2 | 790.8/13.9 |
|                 | 4 oak | 7/8 | 113.1/2 | 128.3/2.3 | 344/6 | 464.2/8.1 |
|                 | 4 ash |           | 51.3/0.9 | 58.6/1 | 157.2/2.8 | 212.1/3.7 |
|                 | 2 pricot | 57 | 44.1/0.8 | 45.2/0.8 | 120.5/2.1 | 163.4/2.9 |
|                 | total |            | 208.5/3.7 | 232.1/4.1 | 621.7/10.9 | 839.7/14.7 |
|                 | 8 ash | 9/4 | 135.7/2.2 | 155.1/2.5 | 416/6.7 | 561.2/9.1 |
|                 | 2 green ash | 62 | 33.9/0.5 | 39.3/0.6 | 105.4/1.7 | 142.1/2.3 |
|                 | total |            | 169.6/2.7 | 194.4/3.1 | 521.4/8.4 | 703.3/11.4 |
|                 | 10 ash | 13/1 | 128.2/2.1 | 146.5/2.4 | 392.9/6.4 | 530/8.7 |
| Dzhegutinskoie forest district of the Kuban leskhoz | 8 sycamore maple | 16/32 | 79.6/1.3 | 102.2/1.6 | 275.5/4.4 | 369.6/5.9 |
|                 | 2 ash |           | 24/0.4 | 27.5/0.4 | 73.9/1.2 | 99.6/1.6 |
|                 | total |            | 103.6/1.7 | 129.7/2 | 349.4/5.6 | 469.2/7.5 |
|                 | 10 ash | 9/18 | 118.3/2.5 | 135.3/2.8 | 362.8/7.6 | 489.4/10.2 |
|                 | 18/5 |          | 225.2/3.8 | 257.6/4.4 | 690.8/11.7 | 931.9/15.8 |
| Kholodno-Rodnikovsky forest district of the Kuban leskhoz | 6 oak | 8/67 | 45.9/0.7 | 52/0.8 | 139.4/2.2 | 188.2/3 |
|                 | 2 ash |           | 15/0.2 | 17.2/0.3 | 46.1/0.7 | 62.2/1 |
|                 | 2 apricot | 62 | 18.3/0.3 | 18.8/0.3 | 50.2/0.8 | 68.1/1.1 |
|                 | total |            | 79.2/1.2 | 88/1.4 | 235.7/3.7 | 318.5/5.1 |
|                 | 7 ash | 8/82 | 161.1/2.6 | 184.4/3 | 494.3/8 | 666.8/10.8 |
|                 | 2 walnut | 62 | 40.2/0.6 | 49.8/0.8 | 134/2.2 | 180.2/9 |
|                 | total |            | 28.5/0.5 | 29.2/0.5 | 77.8/1.3 | 105.6/1.7 |
|                 | 1 apricot | 229.8/3.7 | 263.4/4.3 | 706.1/11.5 | 952.4/15.4 |
|                 | 9 elm | 1/1 | 36.8/0.7 | 43.7/0.8 | 117.3/2.3 | 158/3 |
|                 | 1 ash |           | 3.8/0.1 | 4.3/0.1 | 11.5/0.2 | 15.6/0.3 |
|                 | total |            | 40.6/0.8 | 48/0.9 | 128.8/2.5 | 173.6/3.3 |
|                 | 8 ash | 1/25 | 86.6/1.4 | 99.1/1.6 | 265.7/4.3 | 358.4/5.8 |
|                 | 2 elm |           | 19.9/0.3 | 23.5/0.4 | 63.2/1 | 85.1/1.4 |
|                 | total |            | 106.5/1.7 | 122.6/2 | 328.9/5.3 | 443.5/7.2 |
|                 | 7 walnut | 45.9/0.7 | 57/0.9 | 153.4/2.4 | 206.2/3.3 |
|                 | 2 oak | 3/1 | 15.3/0.2 | 17.3/0.3 | 46.5/0.7 | 62.7/1 |
|                 | 1 poplar | 63 | 5/0.1 | 7.4/0.1 | 20/0.3 | 26.7/0.4 |
|                 | total |            | 66.2/1 | 81.7/1.3 | 219.9/3.4 | 295.6/4.7 |
| 5 sycamore maple | 73.5/1.2 | 1/1 | 94.3/1.5 | 254.1/4.1 | 358.4/5.8 |
|                 | 2 walnut | 30.9/0.5 | 38.3/0.6 | 103/1.7 | 138.4/2.2 |
|                 | 1 elm | 8/1 | 17/0.3 | 20.1/0.3 | 54/0.9 | 72.7/1.2 |
|                 | 2 pear |            | 37.5/0.6 | 41.5/0.7 | 111.2/1.8 | 150.3/2.4 |
|                 | total |            | 158.9/2.6 | 194.2/3.1 | 522.3/8.5 | 702.3/11.3 |
By determining the photomaps of each species using the mass of absolutely dry wood through the general equation of photosynthesis, the mass of carbon dioxide, the mass of water and the mass of oxygen released into the atmosphere were determined.

The determined values of carbon absorption and oxygen evolution through the equations of photosynthesis are the conversion factors for determining the indicators in general for specific stands of the current growth of wood, expressed in units of weight of absolutely dry matter.

Calculation of the mass of carbon in the studied plantations consists in dividing the photomaps into individual elements. To do this, it is necessary to determine the stock of photomaps of each of the components of the composition (by species) by multiplying by the value of the average growth and summing up the data [8-10].

The dynamic of carbon-retention and oxygen-disengagement functions of forest stands photomaps is determined by the age of stands (table 2).

The main share of carbon is about 88% in the plantation, only 5% in foliage, 1% in arid, backward, thickets and soil cover. The carbon stocks in table 2 were determined by the total photomaps stock of all plantations on the test plots. By the stock of photomaps through a conversion factor (0.5 for wood, 0.45 for leaves), the volume of carbon in the plantations under study was determined. So, its maximum content is observed in plantations with a predominance of ordinary ash 263.4 t/year, the minimum – in crops of stocky elm – 48 t/ha.

When calculating the amount of released oxygen, only woody growth was taken into account. Multiplying the annual dry weight gain by a production factor of 1.4. The maximum amount of oxygen released by pure crops of common ash is 931.9 t/ha, the minimum culture of elm is 173.6 t/ha.

Based on the data obtained, it can be said with confidence that the carbon content and oxygen evolution largely depend on the growing conditions, the composition of the plantations under study, and the state of the soil. Soil conditions play a very important role; therefore, the studied artificial plantations of the main types of ash and oak grow on fertile gray forest soils, and elm crops – on salt licks.

4. Conclusion

As a result of the study of artificial forest plantations, it was found that retention is provided by the absorption of CO₂ (carbon monoxide) and the release of O₂ (oxygen). In the experimental plots, the plantings of ordinary ash (931.9 t/ha at the age of 59 years) and plantations of pedunculate oak were absorbed for the greatest amount of bound carbon and released O₂.

The maximum rate of absorbed CO₂ (carbon monoxide) and released O₂ (oxygen) is observed in oak at the age of 57 years and is 476.7 t/ha and 353.2 t/ha, respectively. The minimum values of absorbed CO₂ (carbon monoxide) and released O₂ (oxygen) were recorded during sowing of Siberian elm: 158 t/ha and 117.3 t/ha, respectively. Also on the carbon sequestration in composition, as was previously accepted, changing the growing conditions (natural and climatic), the composition of the plantings and, of course, the type of soil.

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