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CLIMATE CHANGE IMPACT ON THE ABSHERON PENINSULA VEGETATION

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ВЛИЯНИЕ ИЗМЕНЕНИЯ КЛИМАТА НА РАСТИТЕЛЬНОСТЬ АПШЕРОНСКОГО ПОЛУОСТРОВА

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Abstract. Climate change is one of the global problems of modern times, and the increase in the average annual temperature in our country over the past 100 years to 0.4–1.3 °C has affected the structure and function of cultural ecosystems in the Absheron Peninsula. In order to study the impact of climate change on the peninsula, dendrochronological and dendroclimatological studies were conducted, forest assessments were analyzed. The study found that the increase in carbon dioxide in forests due to climate change in the Greater and Lesser Caucasus has affected the growth dynamics, phenology, growth, root system and productivity of plants. The increase in CO_2 in the Greater Caucasus is due to the endemic, rare, endangered tree plants of Azerbaijan *Quercus castaneifolia* C. A. Mey., *Parrotia persica* (DC.) C. A. Mey., *Carpinus betulus* L., *Pinus eldarica* Medw., and others. manifests itself more in species. As a result of warming observed in forests in the northern regions of the Greater Caucasus, an increase in the annual ring remnants of young trees was observed in 2010–2020 compared to 1850. Rapid growth of plants was observed in the early stages of plant growth in areas where the concentration of CO_2 in the atmosphere increased. At the same time, it should be noted that the excessive increase in CO_2 in forests caused drought stress in July and August. Although climate change has affected the physiology and growth of trees in the study, increasing ozone in the area balances it by resisting the positive effects of CO_2.

Аннотация. Изменение климата является одной из глобальных проблем современности, и повышение среднегодовой температуры в нашей стране за последние 100 лет на 0,4–1,3 °C сказалось на структуре и функционировании культурных экосистем Апшеронского полуострова. С целью изучения влияния изменения климата на полуострове были проведены дендрохронологические и дендроклиматологические исследования, проведен анализ лесных оценок. В ходе исследования установлено, что увеличение содержания углекислого газа в лесах вследствие изменения климата на Большом и Малом Кавказе повлияло на динамику роста, фенологию роста, корневую систему и продуктивность растений. Увеличение CO_2 на Большом Кавказе оказывает воздействие на эндемичные, редкие, находящихся под угрозой исчезновения древесные растения Азербайджана и сказывается больше всего на видах: *Quercus castaneifolia* C. A. Mey., *Parrotia persica* (DC.) C. A. Mey., *Carpinus betulus* L., *Pinus eldarica* Medw., и др. В результате потепления, наблюдаемого в лесах северных районов Большого Кавказа, в 2010–2020 гг. по сравнению с 1850 г. наблюдалось увеличение остатков годичных колец молодых деревьев. На ранних стадиях роста растений наблюдался быстрый

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рост растений в районах, где концентрация CO_2 в атмосфере повышена. В то же время следует отметить, что чрезмерное увеличение CO_2 в лесах вызвало засушливый стресс в июле и августе. Хотя изменение климата повлияло на физиологию и рост деревьев в исследовании, увеличение содержания озона в этом районе уравновешивает его, противодействуя положительному воздействию CO_2.

Keywords: climate, parks, tree rings, growth, carbon dioxide, *Pinus eldarica*, *Quercus castaneifolia*.

Ключевые слова: климат, парки, годичные кольца, рост, углекислый газ, *Pinus eldarica, Quercus castaneifolia*.

Introduction

The Earth’s climate is a complex, multi-component system that has undergone many changes throughout history. One of the main reasons for the global variability in the atmosphere in the twentieth century is the influence of anthropogenic factors in the environment. Assessing climate change in ecosystems is one of the global challenges of our time, when it is not possible for humans to influence climate change on Earth. It should be noted that cultural ecosystems cover the world's largest surface carbon pool. The Absheron Peninsula is a large industrial city, where climate change has affected vegetation. The peninsula, which has a dry subtropical climate, has been enriched by vegetation over the past 20 years as a result of climate change, and now has characteristics similar to the subtropical climate zone. Climate change is one of the most discussed topics in our country. According to a recent assessment by the Intergovernmental Panel on Climate Change (http://www.ipcc.ch/), the average global temperature has risen by 0.8–1.2 °C over the past 100 years. For this purpose, employees of the Laboratory of Dendrochronology of the Institute of Dendrology of Azerbaijan NAS conducted dendrochronological studies to analyze the impact of climate change on the vegetation of the Absheron Peninsula. The effect of climatic factors on vegetation has been studied on a scientific basis. As a result of the research, it was found that the last 20 years have seen an increase in carbon dioxide in the Absheron Peninsula as a result of climate change, which has affected the growth dynamics, phenology, growth, root system, productivity and physiology of plants [1–4].

Materials and methods

Pinus eldarica Medw., *Quercus castaneifolia* C. A. Mey. and others, widespread in the cultural ecosystems of the Absheron Peninsula, were studied in the study. The study of the impact of climate change on plant species has shown that the factors influencing the potential growth of trees in the historical development of the species during these years have been different in different years. For this purpose, samples were taken from plant specimens in the form of pens and discs. Using SUUNTO and MAKITA devices, it was dried and transferred to laboratory conditions to collect chronological data from samples 0.5–1.6 meters high, 4–5 mm in diameter and 10–50 cm long.

Using TSAPwin and ARISTAN programs, the width of the annual rings was measured with a binocular microscope to the nearest 0.01 mm, and registration coding was performed on the samples. Information on changes in the rings of plants every 10 years was collected. The impact of climate change on vegetation, data quality results and annual ring series were assessed by the

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Crossdating method according to the COFECHA program. Samples taken from the trunks of the studied species along the radius were crosswise, false and missing rings were found.

Based on the annual rings of the samples, data on climate change in the past were calculated graphically using Lintab 6 and Resistograph denrochronological equipment.

The Gleichlaigkeit (GLK) method was used to determine the similarity between the positive (upper) and negative (lower) tendencies of the annual rings. Radial growth, the number of distance intervals between the rings was determined. Based on the COFECHA program, the correlation coefficient of the series was measured with 99% accuracy. When the correlation coefficient falls below 0.3281, this threshold is considered a critical level. 3051C Plant Photosynthesis Meter equipment was used to determine CO_2, air temperature and humidity in the cultural ecosystems of the Absheron Peninsula [5].

The temperature and amount of precipitation in the country are given on the basis of statistical data of the Statistical Committee of the Republic of Azerbaijan, the Ministry of Ecology and Natural Resources.

Results and discussions

As a result of research conducted in the Absheron Peninsula, it was found that the impact of anthropogenic factors has led to an increase in the thermal effect in the area, which has affected the growth, phenology and dynamics of plants. The increase in temperature in the Absheron Peninsula was caused by toxic wastes, transport pollutants and other anthropogenic factors discharged into the environment from quarries, cement-gypsum plants, especially petrochemical enterprises located around the peninsula [6].

The composition of the thermal effect of these anthropogenic and toxic wastes consists of carbon, methane, nitric oxide, nitrogen 1 oxide and chlorine-fluorine gas compounds, which play an important role in climate change on the peninsula. As a result, because of recent climate change in Absheron, many new ornamental plants imported from the Mediterranean countries are adapting more quickly to the climate of the peninsula. On the other hand, as a result of the privatization of lands in the deserts of the peninsula, the demand for water for planting greenery has increased significantly, and unusable areas have been restored. As a result, the climate of the Absheron Peninsula changed from dry subtropical to weak subtropical. Because of increasing population demand on the peninsula, a decrease in water in the Caspian Sea was observed on the peninsula. It should be noted that in 2002-2020, as a result of climate change in the Absheron Peninsula, the thermal effect increased, drought stress occurred in some areas, led to the degradation of natural vegetation [7].

According to statistics provided by the Ministry of Ecology and Natural Resources, the average annual temperature in the Absheron Peninsula in 2002 was 14.8 °C, while in 2020, the temperature reached 15.7 °C, which reflects 1 °C rise. Maximum average monthly temperature was 27.3 °C, unchanged by years. The minimum temperature on the peninsula rose from 1.4 °C in 2002 to 6 °C in 2020.

During this period, temperature changes also affected the vegetation of the Absheron Peninsula. Thus, as a result of monitoring and expeditions in the areas for the new publication of the flora of Absheron, it was found that the temperature rise was observed mostly in the non-landscape areas of Baku, and least in the Dendrological Park. This temperature increase is unevenly distributed depending on the area.

Over the past 18 years, the maximum average monthly temperature on the peninsula (2006, 2012, 2014, 2018, 2020) was higher than the climatic norm, and the minimum average monthly

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temperature (2002, 2003, 2006, 2008, 2012) was observed in the following years. The average multi-year temperature indicators for 2002–2020 are given for the city (Table 1).

Table 1

THE AVERAGE MULTI-YEAR TEMPERATURE INDICATORS FOR 2002-2020 YEARS

2002	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
1961-1990 average multi-year temperature - 12.3																		
Medium annual temperature																		
12.3	12.2	13.8	13.2	13.2	12.9	13.0	13.1	14.4	12.1	13.3	13.4	13.4	13.6	13.0	13.5	15.0	14.4	14.4
Medium annual temperature average multiplicity difference																		
0.0	-0.1	1.5	0.9	0.9	0.6	0.7	0.8	2.1	0.2	1.0	1.1	1.1	1.3	0.7	1,2	2.7	2.1	2.1
Average monthly temperature																		
26.2	24.7	25.4	24.9	26.9	25.5	25.4	24.5	26.2	26.7	27.0	25.7	28.5	24.7	24.7	26.6	28.4	25.4	29.7
Minimum (lowest) average monthly temperature																		
2.2	2.1	3.2	1.4	1,2	0.3	-3.7	0.3	3.3	1.3	0.9	3.6	2.9	2.6	2.4	1.5	3.6	3.4	-1.9
In the city of Baku																		
In 1961-1990 average multiyear temperature -14.7																		
Medium annual temperature																		
14.8	14.0	14.9	15.4	14.8	15.1	14.9	14.9	16.3	14.4	15.7	15.6	15.5	15.6	15.2	15.5	16.0	15.6	15.7
Medium annual temperature average multiplicity difference																		
0.1	-0.7	0.2	0.7	0.1	0.4	0.2	0.2	0.2	0.3	1.0	0.9	0.8	0.9	0.5	0.8	1.3	0.9	1.0
Maximum (highest) average monthly temperature																		
27.3	26.4	27.6	27.0	28.0	27.7	27.6	26.8	29.3	28.8	28.0	26.3	29.0	27.6	28.8	27.6	29.6	34.7	27.3
Minimum (lowest) average monthly temperature																		
1.4	3.0	5.6	3.4	2.0	4.4	0.4	3.9	4.6	3.4	0.8	5.5	4.0	4.9	4.5	7.5	4.7	-1.5	6.0

According to information provided by Ministry of Ecology and Natural Resources, as can be seen from the table, the temperature in the Absheron Peninsula has partially changed since 2002–2020.

In addition, the amount of precipitation on the peninsula for 2002-2020 was analyzed. Thus, in the Absheron peninsula in 2002 it was 420.2 mm, in 2020 it was 310.3 mm. During these years, the periods with the highest rainfall were observed in 2002, 2010, 2011, 2016, and the least in 2005, 2009, 2018, and 2019. The maximum average monthly precipitation was observed in 2002, 2011,

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2016, 2017, and the minimum precipitation was observed in 2004, 2006, 2007, 2010, 2015, 2016, 2017, 2019, 2020. The amount of precipitation on the peninsula was also analyzed, and the results are given in Table 2.

The study analyzed the air quality of the peninsula for 2005–2020. The average annual NO_2 concentration of nitrogen dioxide in the peninsula was 19 mcg/m^3 in 2005 and 56 mcg/m^3 in 2020 in Baku. The average annual concentration of sulfur dioxide (SO_2) in cities was 50 mcg/m^3 in 2005 and 28 mcg/m^3 in 2020. The average annual concentration of carbon monoxide (CO) in cities was higher in 2015, 2017, 2018, and 2019. As a result of the study, it was found that the number of moisture-loving plants in the Absheron Peninsula has decreased over the past 18 years due to rising temperatures, and the number of windy days, changing the boundaries of landscapes, lowering the boundaries of humid zones and partially changing the boundaries of thermal zones (eco.gov.az).

Table 2

THE AMOUNT OF PRECIPITATION MM ACCORDING TO THE INFORMATION PROVIDED BY MINISTRY OF ECOLOGY AND NATURAL RESOURCES
(date of last update: June 4, 2021, in the city of Baku

2002	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Average for 1961-1990 perennial precipitation quantity - 234.7																		
Average annual precipitation quantity																		
420.2	372.2	342.1	257.1	242.2	273.6	325.4	251.0	402.7	545.5	346.3	381.0	285.2	340.8	477.6	352.6	232.1	277.3	310.3
The difference between average annual precipitation and average annual precipitation																		
185.5	122.5	107.4	-22.4	7.5	38.9	90.7	21.3	168.0	310.8	111.6	146.6	50.5	106.1	242.9	117.9	-2.6	42.6	75.6
Maximum (highest) average monthly precipitation quantity																		
184.0	67.7	65.1	78.0	125.2	66.2	97.2	57.4	88.5	140.4	70.3	69.9	70.4	70.6	138.1	118.9	62.1	80.1	126.1
Minimum (lowest) average monthly precipitation																		
0.0	2.0	0.0	0.4	0.0	0.0	4.0	0.4	0.0	0.7	0.0	5.2	0.7	0.0	0.0	0.0	0.3	0.0	0.3

This has affected the vegetation of Absheron, as well as the introduction and acclimatization of plants, growth dynamics and productivity, public health, tourism and resort recreation. Thus, as a result of climate change on the peninsula, in some areas of the peninsula, on the contrary, the sensitivity of the temperature reaction has led to their weakening, reduced growth and degradation of areas. However, although climate change has affected the physiology and growth of trees in parks and gardens in the area, the increase in ozone in the area has counteracted and balanced the positive effects of CO_2. In some highlands of the peninsula, such as Yasamal and Saray, excessive CO_2 levels are associated with the onset of drought. In addition, in drought areas, for example, around the airport highway, in Garadagh, Gobustan, on the roadsides, the increase in temperature has led to water shortages and stress. As a result of these anthropogenic factors, an increase in CO_2 levels and nitrogen (N) precipitation was observed in some areas of the Absheron Peninsula.

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As a result of climate change, new taxa, diversity, shape variability, phytocenoses (formation, association, macro and micro groupings, biotypes), new distribution areas enriching the flora and vegetation of Absheron were discovered.

Physalis peruviana L., *P. angulata* L. are new to the flora of Azerbaijan. Azollaceae family, *Azolla* L. genus, *Azolla caroliniana* species is new for the whole Caucasus. Their new distribution areas have been discovered in the wetlands around Siyazan and Sumgayit. *Silybum marianum* f. *alba* species was discovered for the first time in Absheron Peninsula for Caucasian flora. Such findings include changes in the shape of the *Celosia* genus of the Amaranthaceae family. The flora of plants in these ecosystems is currently dominated by xerophytes, xeromesophytes, mesoxerophytes, halophytes, psammophytes. Mesophyte, hydrophytic plants have decreased in number. As a result of recent research, 2821 higher spore, bare-seeded and flowering plant species belonging to 5 phyla, 61 class, 4 order, 193 family, 983 genera were found in Absheron flora, which is evidence of 30% increase in species richness compared to 2002.

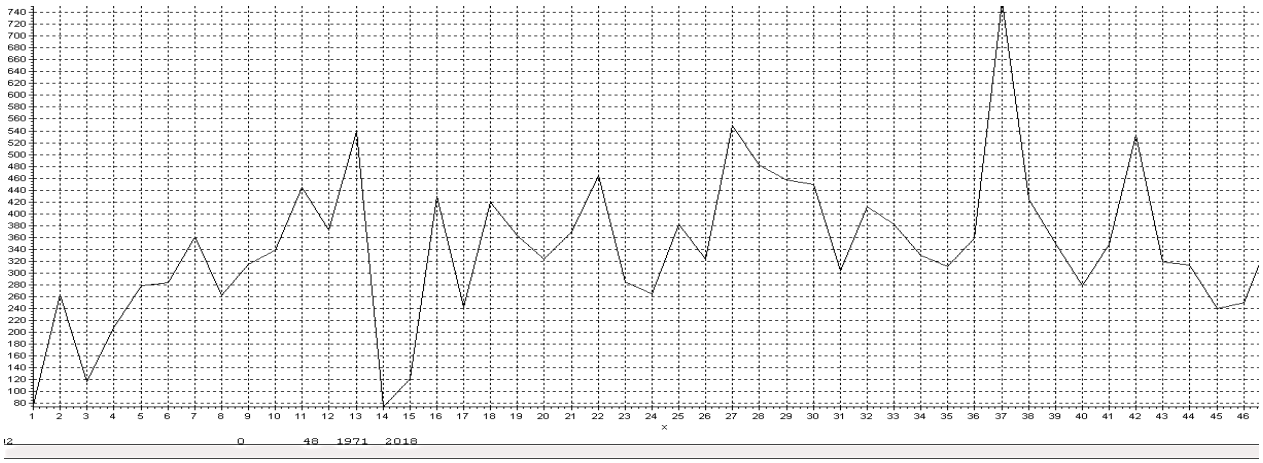

Figure 1. The mechanism of influence of climate change on the dynamic development of the species *Pinus eldarica* Medw.

In recent years, as a result of climate change in the flora of Absheron: trees, shrubs, shrubs, semi-shrubs, semi-shrubs, lianas, perennial grasses with geophytes, annual, annual-biennial grasses are widely found. In recent years, we have conducted dendrochronological and dendroclimatological research to study these and other problems caused by climate change on the peninsula. During the last twenty years of research on the Azerbaijani pine species *Pinus eldarica* on the Absheron Peninsula, it was found that the ring widths of the species have increased significantly as a result of climate change. The mechanism of the impact of climate change on the dynamic development of the species Pinus eldarica as a result of the increase in CO_2 from 1971 to 2018 is shown in the diagram below (Figure 2).

This is explained by the fact that the increase in CO_2 observed in tree ring widths is due to an increase in biomass. This is due to the rapid growth of plants due to the increase in CO_2 concentrations in the atmosphere, and the accelerated growth has led to an increase in underground root mass and cambium activity, which has led to changes in tree-ring width [7].

The small increase in temperature observed in the peninsula led to the process of photosynthesis in these species [8], and the excess temperature led to an increase in density and anomalous decrease in temperature sensitivity.

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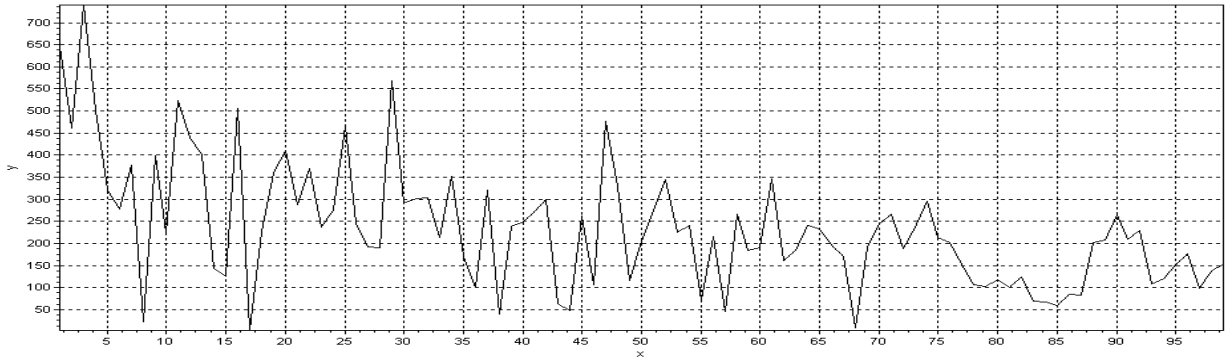

Figure 2. Mechanism of influence of climate change on the dynamical development of the plant species *Quercus castaneifolia* C. A. Mey. over the years

Atmospheric carbon dioxide also influenced the radial growth of plants in the Absheron Peninsula. The overall change in the radial growth index was observed in approximately 61% of both young and old trees. It was found that in 2010–2020, the annual ring remnants of young trees developed more strongly than in 1900–1996. As a result, growth is well observed in the early developmental stages of some tree species, and at the same developmental stage, more growth reactions were found in the areas as a result of increased CO_2 concentrations in the atmosphere. Dendrochronological analysis of tree samples taken from trees 25–30 m high on the peninsula revealed that plant growth has been more intensive in the last decade [9–12].

This rapid growth on the peninsula indicates an unprecedented ecological change in recent centuries. The increase in temperature observed in the areas was reflected both in the growth interval and in the width of the ring. At the same time, the increase in temperature in some areas of the peninsula has played an important role in the growth of species. The increase in CO_2 in the dendrological park is more evident in species *Quercus castaneifolia* C. A. Mey. in 1960, 1967, 1969, 1994, 2006, 2016, under the influence of climatic factors that led to poor development, and in 1964, 1970, 1979, 1985, 1987, 2000, 2002, 2012 to relatively high development dynamics (Table 3).

Table 3

CONCENTRATIONS OF GASES IN CITIES

	2005	*2010*	*2015*	*2017*	*2018*	*2019*	*2020*
Average annual concentration of nitrogen dioxide (NO_2) in cities, mcg/m ^{3}							
Baku	19	90	60	60	70	70	56
Sumgayit	80	90	90	90	80	70	x
Average annual concentration of sulfur dioxide (SO_2) in cities, mcg/m ^{3}							
Baku	50	14	14	26	32	33	28
Sumgayit	2	23	27	27	28	26	x
Average annual concentration of carbon monoxide (CO) in cities, mcg/m ^{3}							
Baku	x	x	2300	2000	2200	2300	x

As a result of research, it was found that the warming observed on the peninsula has a greater impact on drought stress in the same areas, resulting in the drying of some plants in the area, the spread of new species of pests. These pathogenic insects can result in mass destruction of trees. For example, the recent spread of Eldar pine can cause the mass extinction of pinecones and tar cancer.

In addition, a dendroclimatological study of oak species in the Dendrological Park found that radial growth was limited by an increase in humidity in the spring. Growth is more common in weak dry soils in spring and August-September.

In the study, increasing CO_2 concentrations and temperature rises on the peninsula have a significant impact on tree growth. Tree ring analysis in different areas with reduced crop yields found that although the effect of climate change on plant growth changed ring width in similar areas for some time in different trees, then their ring width had completely different characteristics. It can be concluded that the gases emitting heat from stationary sources into the country's atmosphere in the Republic affect the territories in different directions, creating global climate change [13].

Conclusion

Although climate change in the Absheron Peninsula has affected growth, temperature sensitivity has led to an anomalous decline.

At the same time, the observed climate change had a positive effect on the reduction of solar radiation in the areas and the process of photosynthesis.

Dendroclimatological analysis of older specimens on the peninsula compared favorable years with unfavorable years for trees in the area, and the impact of climatic factors on plants on its historical period and years was analyzed on a scientific basis based on wide and narrow ring patterns.

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