THE DISTRIBUTION GEOGRAPHY OF *QUERCUS CASTANEIFOLIA* (C. A. Mey) IN THE GREATER CAUCASUS OF AZERBAIJAN, ITS CONDITION AND REGENERATION

YAHYAYEV, A. B.[1,2*] – SHIRINZADE, I. N.[2] – KURBANOV, E. A.[3] – GOZALOV, S. S.[2] – MELIKOV, A. A.[1] – SHIRALIYEV, SH. M.[1]

[1]*Western Caspian University, Baku AZ 1001, Azerbaijan*
(e-mails: yahyayev-azasu@bk.ru; adilmelikov@gmail.com; shahbaz.shireliyev@mail.ru)

[2]*Azerbaijan Architecture and Construction University, Baku AZ 1073, Azerbaijan*
(e-mails: iradax@yandex.ru; g.sayavush@mail.ru)

[3]*Volga State University of Technology, Yoshkar-Ola 424000, Russia*
(e-mail: kurbanovea@volgatech.net)

[*]*Corresponding author*
e-mail: yahyayev-azasu@bk.ru

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Abstract. The article studies the issues of natural distribution, current state and restoration of chestnut-leaved oak (*Quercus castaneifolia* C.A.Mey) in forest ecosystems of the Greater Caucasus in the territory of Azerbaijan. The research was conducted in the Ismailli district, and according to generally accepted methods, the following were determined: the main characteristics of oak trees; the quality of trees was diagnosed according to the condition index; the number of seedlings of this species was determined according to the "success assessment" scale; work was carried out in the Galynchak forest area of the Ismailli district to promote the natural restoration of this species. As a result of the work, it was revealed that in all areas, mature and overmature trees are common, young and middle-aged trees are absent, and ripening ones are only singly present. The qualitative condition of these trees varies from damaged to poor. The success of natural restoration is assessed as unsatisfactory. In terms of restoration assistance, it was established that at the end of the 5th year the number of seedlings increased by about 2 times, which makes it possible to restore the chestnut-leaved oak and preserve the biodiversity of forest ecosystems in this area.
Keywords: *condition index, number of seedling, quality of tree, promotion of regeneration, relict species*

Introduction

The Republic of Azerbaijan is home to nine wild oak species, one of which, according to forestry and ecological indicators, is the chestnut-leaved oak (*Quercus castaneifolia*, C.A. Mey). Maleev (1935), studying the genus *Quercus* in the Caucasus, indicated that the chestnut-leaved oak was first described and identified as a separate species by Meyer in 1831.

Despite being a relict tree species, chestnut-leaved oak is characterized by intraspecies variability. Bandin (1954) noted in his work that in Azerbaijan one of its representatives is the widespread large-leaved form of chestnut-leaved oak (*Q. castaneifolia* f. *obtusiloba* Freyn), which was described by Freyne. In addition to this form of oak, common in the forests of the Lankaran region, Safarov (1967) gave a description of another form, which was named *Q. castaneifolia* f. *angustifolia* Safarov.

Chestnut-leaved oak is a representative of Tertiary forest mesophilic flora (*Fig. 1*). Badalov (1968) notes in his dissertation that the chestnut-leaved oak is a large tree, reaching a height of up to 35 m, grows quickly and renews well with shoots up to 60 years

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old. It is distinguished by high plasticity and adaptability. Its vertical root system is well developed, providing resistance against drought and wind. Chestnut-leaved oak trees live up to 350 years, are frost-resistant and shade-loving. Amirov (1997) studied the wood productivity of the chestnut-leaved oak in his work and noted that under favorable conditions this species becomes a forest-forming species and is distinguished by high productivity - up to 800 m^3/ha.

Figure 1. *Biological and silvicultural traits of chestnut-leaved oak*

Bandin (1954), characterizing the oak species growing in Azerbaijan, showed that the main natural habitat of the chestnut-leaved oak is the Lankaran forest regions. Here, it is found in both lowland and mountainous areas, with altitudes reaching 1800 m a.s.l. This species is also found in Ismayilli district. Shahnaseri et al. (2023) showed in their works that the chestnut-leaved oak also grows in the south, in the Caspian part of Iran.

Seyfullayev (2017) noted that as a culture, this species is found in the northern regions of Azerbaijan, where 70-80-year old cultures of this species grow. At the same time, he studied the dynamics of radial growth of this species growing in different forestry conditions. Mustafayev (2012) also conducted research in this direction, studying the possibility of creating forestry crops using chestnut-leaved oak and Persian walnut (*Juglans regia*) in different forestry conditions of Talysh.

To assess and manage environmental quality in Azerbaijan, Mamedova and Mamedova (2019) used the indicative and remediative properties of chestnut-leaved oak.

Sasan Babaye et al. (2021) studied the factors affecting the degradation of Hirkan forests of Iran including chestnut-leaved oak. Meanwhile, the ecological capability of the forests was determined using three methods: AHP, GIS-based fuzzy gamma and regression, and weighting factors using the AHP model. As a result, a map of forest degradation in the region was constructed. In another work, Shahnaseri et al. (2023) noted that in the Hyrcanian forests, the integrity and survival of chestnut-leaved oak is threatened by anthropogenic activities. To this end, a joint spatial-statistical modelling was carried out to determine the rate of degradation and determination of chestnut-leaved oak in forest landscape areas of the region.

One of the least studied areas of chestnut-leaved oak distribution in the Greater Caucasus is Ismayili district of Azerbaijan. The available literature is superficial and fragmentary, and does not take into account the changes that have taken place in the last 60-70 years. Since the early 60 s of the last century, chestnut-leaved oak growing areas

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in this district have been gradually selected for settlement, agricultural land, pasture and other purposes. On the other hand, the energy crisis that engulfed the entire Republic in the 1990s led to illegal cutting on a large scale, which continued until early 2010 (Yakhyayev et al., 2015) (*Fig. 2*).

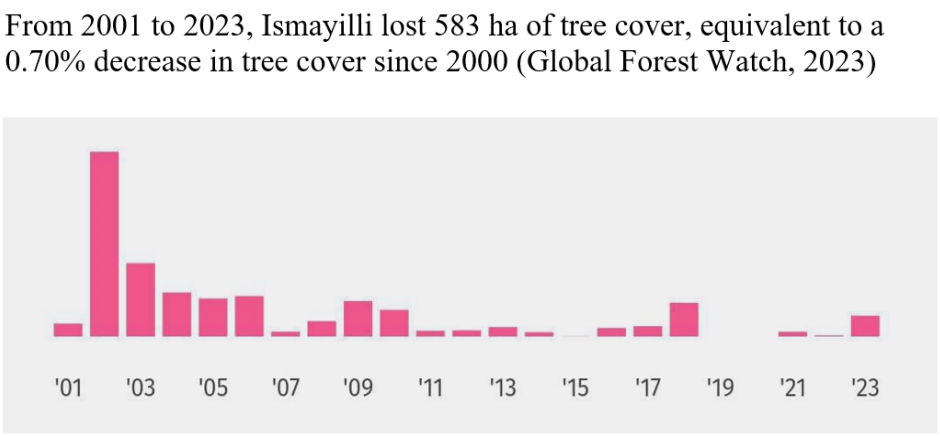

Figure 2. *Dynamics of cutting in Ismayilli district*

As a result, numerous large windows, clearings and glades were formed in the plantings with the participation of chestnut-leaved oak, and part of the tree stands turned into rarely standing trees. Their age and size structure is disrupted. The restoration work carried out was inadequate, and maintenance activities were not implemented in a timely and widespread manner, which resulted in the replacement of chestnut-leaved oak mainly by European hornbeam, common maple and etc. As a result, oak forests turned into low-value and low-density plantings, while the ecological functions performed by them deteriorated (Yakhyayev et al., 2017).

The latest forest stand surveys conducted in 2018-2019 showed that the distribution areas of chestnut-leaved oak in terms of the number of trees and area decreased, and significant changes occurred in the age structure and regeneration process of forest stands. These changes were also observed during our expedition to the region in May-June 2017, 2021 and 2023 (Yakhyayev, 2023).

Azerbaijan is a sparsely forested country interested in increasing the volume of cultivation of hard-wooded broad-leaved species such as chestnut oak. As noted above, this species is a valuable and fast-growing species with high physical and mechanical properties, which is in great demand from the production side. Therefore, in this work, one of the main tasks was not only the restoration of plantations with the participation of chestnut-leaved oak in the marked areas of the Ismayilli region. Also, against the background of climate change (using the example of the growing conditions of the studied areas) in this area will determine the optimal growing conditions for the creation of a chestnut-leaved oak culture in the future.

Based on the above provisions, there was a need to study these issues to preserve the biodiversity and ecological balance of forest ecosystems and develop measures to restore existing plantations with the participation of chestnut-leaved oak, as well as the creation of forest crops of this species in the future and the sustainable development of these plantations in their natural habitat - Ismayilli region.

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The aim of the study was to investigate the distribution, condition and restoration of chestnut-leaved oak in forest ecosystems of the Greater Caucasus of Azerbaijan.

To achieve this, the following tasks were solved:

- Identification of the natural habitat of chestnut-leaved oak in the forest ecosystems of the Greater Caucasus.
- Implementation of an assessment of the condition and natural restoration of chestnut-leaved oak in the forest ecosystems of the Ismayilli region.
- Development of measures to promote the natural restoration of chestnut-leaved oak in the forest ecosystems of the research area.

Materials and methods

Selection of the research area

To conduct research in 2017-2023, an expedition was organized to the Ismayilli, Gabala and Sheki forest regions of the Greater Caucasus. When identifying the areas of natural growth of chestnut-leaved oak, the project plans of forestry enterprises of the studied areas, as well as information from specialists of these institutions, were used. Only in the Ismayilli forest fund, natural distribution of chestnut-leaved oak trees has been identified in five sites. Using a ArcGIS10.2 program, a schematic map of the Ismayilli district was developed indicating their growing areas (*Fig. 3*).

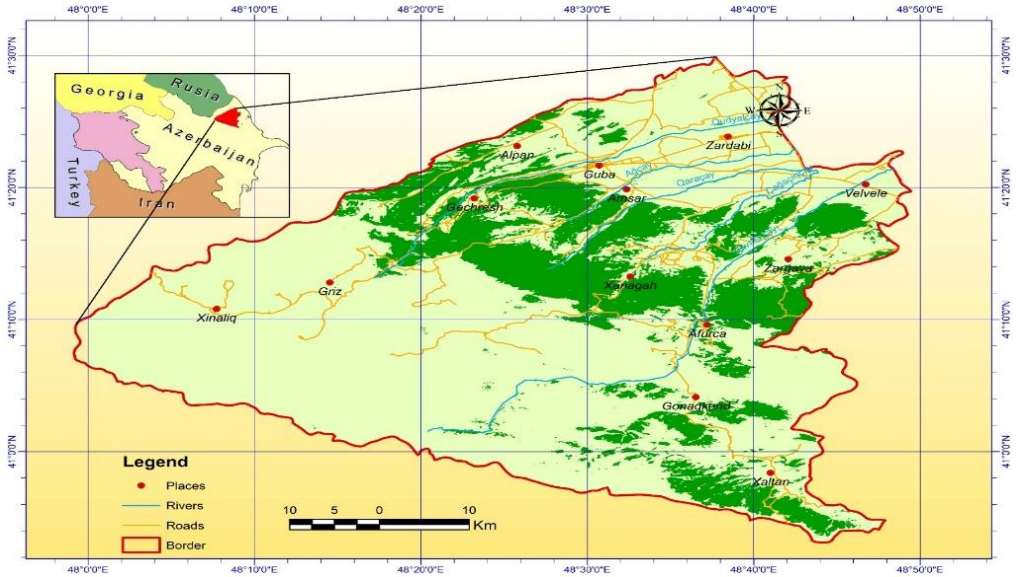

Figure 3. *Schematic map of natural growing areas of chestnut-leaved oak in Ismayilli district*

Geography and natural conditions

Ismayilli district is located at the foot of the Greater Caucasus Mountains in the northwestern part of Azerbaijan. The relief of all areas is characterized by mild slopes with a gradient of up to 6-10^{0}and is located at an altitude of 587-950 m a.s.l. (10). The study area is dominated by mountain-forest brown soils (Mamedov, 2004). Here the average annual temperature fluctuates between 7.6-10.1 ^{0}C, the annual amount of precipitation is 670-777 mm (9).

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Characteristics of planting sites

In field studies, sites and sections were identified based on the distribution of this species in these plantings. Forestry conditions were determined according to the methodological instructions of Asadov (2008). The whole complex of measures was carried out on the plots according to generally accepted methods, including a complete count of trees by species and diameters, height measurements, as well as assessment of regeneration processes of plantings, mainly with the participation of chestnut-leaved oak. The average heights and diameters of trees were determined as the arithmetic mean of data from all measured trees of this species. The age of the trees was determined by counting the wild growings on stump cats and by cores obtained using an incremental drill from 6-8 oak trees (Yakhyayev et al., 2011). The density was determined using a Bitterlich's full-tamer. Stock planting was determined using a standard table of sums of cross-sectional areas and stocks at a density of 1.0 (Baginskiy, 2018). During the research, relatively large areas of chestnut-leaved oak were divided into sections of 0,22-0,62 ha. The general characteristics of the plantings in these areas are given below (*Table 1*).

Table 1. *Characteristics of plantings on experimental sites*

N	Sites and sections	Area ha	Stand composition stand / undergrowth	Density/ piece / ha	Average sizes			Type forest con-dition	Litter, cm
					d, sм	h, м	A, year		
I	Site–AS Sec.-1	0,32	68CO21CM8CH3Al+EH/ 52CO36Кл10CH2Al+EH	0,48 590	60	19	132	D_{2-3}	0-4
	Sec.-2	0,37	44CO26CM14CH12GO4Al/ 50CO28CM17CH5Al+GO	0,51 730	88	22	275	D_{2-3}	2-5
II	Site.-ZS Sec.-1	0,22	30GO25CO 20CH17CM8ME/ 52CM16ME14CO10CH8GO	0,42 580	84	21	224	D_{2-3}	2-5
III	Site-KS Sec.-1	0,26	56CO27GO12CM7CH/ 31CO39CM17GO13CH	0,41 612	68	18	174	D_2	3-5
IV	Site-GS Sec.-1	0,62	36CH34CO17GO13CM/ 32CH28CO25CM15GO	0,50 840	72	21	225	D_3	4-6
	Sec.-2	0,56	42CO38CH14CM6ME/ 36CH28CO26CM10ME	0,51 660	96	26	285	D_3	3-7
V	Site-GRS Sec.-1	0,57	49CO31GO14CH6EH+ME/ 46EH30CH 12CO8GO4ME	0,31 480	72	20	186	D_2, C_2	0-3
	Sec.-2	0,61	43CH28GO17CO10ME2EH/ 36CH32EH14CO13GO5ME	0,33 560	68	19	158	D_2,	0-3

Note: CO – (Quercus castaneifolia (C. A. Mey); CM – (Acer campestre L.); CH - (Carpinus caucasica A. Grossh); Al - (Prunus divaricate Ledeb); OH - (Crataegus orientalis Pall.); GO - (Quercus iberica Stev.); ME - (Ulumus scabra Mill)

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- Ashagybash site (AS), 5.2 ha, altitude 587 m a.s.l, mountain forest brown residual carbonate soils, geographic coordinates: 0261233/4515787, divided into 2 sections consisting of 23 and 16 chestnut-leaved oak trees.
- Zogalli site (ZS), 0.22 ha, altitude 950 m a.s.l, mountain forest brown typical soils, geographic coordinates: 0253917/4512032, one section consisting of 25 trees.
- Kushenchen site (KS), 0.26 ha, altitude 754 m a.s.l., mountain forest brown steppe soils, geographic coordinates: 0255879/4511775, one section consisting of 14 trees.
- Galinchak site (GS) is spread across the southeastern end of the Alazan-Ayrichay valley. In the forest ecosystem, the chestnut-leaved oak participates in the form of an admixture of individual or a group of trees, and is distributed only in the south-eastern part of this area. The site area is 189 ha, with an elevation of 593 m a.s.l., mountain forest brown unsaturated soils, and its geographical coordinates: 0256279/4523561, is divided into two sections, comprising 18 and 23 trees, respectively.
- Gilyan Roadside Site (GRS) is situated in the direction of Gabala for approximately 2 km, with an area of 3.2 ha, an altitude of 695 m a.s.l., mountain forest brown steppe soils, geographical coordinates: 0256279/4523561, is divided into two sections, comprising 14 and 22 trees, respectively.

Quality condition and natural regeneration of plantings

The vital condition of chestnut-leaved oak trees was determined taking into account the recommendation of Alekseyev (1989) using the condition index. In this case, based on the calculated index, trees were classified as healthy (index 0-0.5); damaged (0.6-1.5); heavily damaged (1.6-2.5); drying out (2.6-3.5); dead wood (3.6 and higher). The types and sizes of fungal and cancerous diseases were studied according to the recommendations of Shevchenko and Tsiliurik (1986). The success of natural restoration of chestnut-leaved oak in the study areas was determined taking into account the recommendations of Mamedov and Asadov (2010). To account for the undergrowth, a continuous count was carried out on sites measuring 1x2 and 2x5 m. In this case, the estimated quantity of undergrowth was distributed according to a scale: good - over 2000 pcs/ha (in terms of large undergrowth); satisfactory - 1000-2000 pcs/ha; unsatisfactory - 500-1000 pcs/ha; poor - less than 500 pcs/ha.

Activities for promotion of natural regeneration

The studies conducted an experiment to promote natural regeneration of the chestnut-leaved oak tree. For this purpose, 5 sections containing 6-8 trees each were allocated on the Galinchak site, which is less exposed to anthropogenic impacts. In each section, 3-4 maturing trees were selected for work to promote natural regeneration. In September 2017, 6-8 plots 1x1 m in size were established in a checkerboard pattern under the canopy of selected trees within a radius of 5-7 m (Aghasizade et al., 2015). In these areas, the forest litter was cleared and the soil was loosened to a depth of 5-8 cm. These plots were naturally seeded with oak acorns within 2 months of their establishment. In the second half of December, in order to protect the sown acorns from rodents and animals, the plots were covered with a mineral soil layer and forest litter 3-5 cm thick (Yakyayev et al., 2021). At the same time, the degree of natural seeding of the plots was visually determined. In unsatisfactory cases, additional artificial sowing of acorns was carried out on the areas.

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Mathematical data processing and analysis

In the work, data processing and analysis was carried out using the EViews program.

Results

The results of the research of plantings of the selected areas can be presented in the following form:

AS site is located in close proximity to the settlement of the same name. It is surrounded on all sides by arable land of agricultural importance and is often used for grazing of livestock. The chestnut-leaved oak trees are mainly distributed in groups of three to five, with a spacing of between 6-12 m between them. This site is divided into two sections.

In the first section, located in the northern exposure, the forest litter is 0-4 mm, the projective covered of vegetation from forest forbs is about 33%.

Here, the most common trees are the chestnut-leaved oak, Georgian oak (*Quercus iberica, Stev.*), Caucasian hornbeam (*Carpinus caucasica, A. Grossh*), alycha (*Prunus divaricate, Ledeb*), common maple, (*Acer campestre, L*), oriental hawthorn (*Crataegus orientalis, Pall.)*. In this section, 23 chestnut-leaved oak trees were described, the main parameters of which varied within the range: diameter 48-64 cm; height 17-20 m; age 136-188 years.

The quality of chestnut-leaved oak trees was assessed according to the condition index from damaged to severely damaged. Among the trees, four were found to be infected with oak tinder (*Inonotus dryadeus, Murr*), 1 tree with cancerous diseases (*Nectria galligena, Bres*), and 1 tree with broken branches at a height of 9.7 m with a diameter of 38 cm (*Fig. 4*).

Figure 4. *Chestnut-leaved oak trees affected by fungal and cancerous diseases*

Natural regeneration of chestnut-leaved oak in this section with 430-550 pcs/ha of undergrowth is assessed as unsatisfactory. The main part of the undergrowth belongs to the small (20-50 cm) category and individual specimens belong to the medium (51-100 cm) category; large categories are absent. Most of the undergrowth specimens are in a state of stress due to anthropogenic and climatic influences.

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In the second section, located in the southern exposure, the forest litter is 2-5 mm, and the projective covered of vegetation from forest forbs is 51%. Here, mainly chestnut-leaved oak, Georgian oak, common maple, Caucasian hornbeam and etc. are found. In this section, 16 trees of the studied species were described. The main parameters of which varied within the following limits: diameter 72-124 cm; height 20-25 m; age 208-328 years.

The quality of chestnut-leaved oak trees according to the condition index is assessed as severely damaged. Among them the following trees were found: 4 trees affected by fungal diseases; 1 tree affected by cankerous diseases.

Natural regeneration of chestnut-leaved oak in this section with 450-575 pcs/ha of undergrowth is assessed as unsatisfactory. The undergrowth consists of small and single specimens of the medium category, while large ones are absent.

ZS and KS sites are located on the outskirts of the settlements of the same names and shrub fence was built around them. The plantings of these sites are distributed on the north-eastern exposure. Here the thickness of the forest litter ranges from 2 to 5 cm, the projective covered consists mainly of forest forbs from 57% to 62%.

These areas are mainly dominated by Georgian oak, chestnut-leaved oak, Caucasian hornbeam, alycha, common maple, mountain elm (*Ulumus scabra, Mill*), oriental hawthorn**.** On the ZS and KS sites, 25 and 14 trees of chestnut-leaved oak were described, the main indicators of which varied within the range: diameter 68-92 cm; height 18-21 m; age 210-284 years.

The quality of trees of the studied species according to the condition index is assessed as severely damaged. No fungal infections were detected here; cancerous diseases were found on the ZS plot - 1, on the KS - 2 trees.

Natural regeneration of chestnut-leaved oak in these areas with 380-446 pcs/ha of undergrowth is assessed as poor. The undergrowth was found to be entirely composed of small trees, which exhibited external signs of anthropogenic-climatic influences.

GS site is spread across the southeastern end of the Alazan-Ayrichay valley. In the forest ecosystem, the chestnut-leaved oak participates as a forest-forming species. The thickness of the forest litter is 3-7 cm. Here, forb and dead-cover forest types are common; in humid forest conditions, fern cover is sometimes found. This site is divided into two sections.

In both sections, the stands consist of chestnut-leaved and Georgian oak, Caucasian hornbeam, common maple, mountain elm, oriental hawthorn, etc. Here, 18 and 23 trees of chestnut-leaved oak were described, respectively, the main indicators of which varied within the range: diameter 52-122 cm, height 18-26 m, age 158-312 years.

According to the condition index, the quality of trees of the studied species in the sections is assessed as severely damaged. Fruiting bodies of the oak tinder were found in the tree trunks: in the first section on 2 trees, in the second section on 3 trees. Here the trees are also affected by cancerous diseases, which were found in 2 and 1 trees respectively. In addition, in the first section, two trees with diameters of 56 and 48 cm had broken trunks at heights of 6.2 m and 3.4 m, respectively. Cross-sectional analysis of the broken parts of the trees revealed that more than half of the diameters were covered by stem rot (*Fig. 5*). In the second section, one tree with a diameter of 122 cm and a height of 26 m was felled. When the tree fell, rot was found in the broken part with a diameter of about 1/3 of the cross-sectional area.

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Figure 5. *Trunks of broken and fallen chestnut-leaved oak trees affected by fungal diseases*

In this area, the natural regeneration of chestnut-leaved oak with 660-840 pcs/ha is assessed as unsatisfactory (при нормальных условиях 1200-1500 pcs/ha). The undergrowth consists of small and partially medium category plants.

GRS site is located on the right side of the central highway and adjoins the residential area. In addition to the chestnut-leaved oak, the area is home to Georgian oak, Caucasian hornbeam, oriental hawthorn, mountain elm and etc. The thickness of the forest litter is 0-3 cm. This site is mainly dominated by dead-cover and partly forb forest types. The description of chestnut-leaved oak trees in the amount of 14 and 22 pieces was carried out in 2 sections respectively, the main indicators of which were: diameter 68-76 cm, height 19-20 m, age 204-236 years.

According to the condition index, the chestnut-leaved oak trees in the sections are assessed as severely damaged. In each section, 2 fruiting bodies of oak tinder were found in the tree trunks. In the first section, 2 trees are affected by cancerous diseases.

In this area, the natural regeneration of this species with 284-366 pcs/ha of undergrowth, consisting of a small category, is also assessed as poor.

It should be noted that due to the identical geographical coordinates as the GS site, the GRS site is not indicated on the Schematic Map.

The results of the experiment conducted to promote the regeneration of chestnut-leaved oak in the GS site are presented below.

In the spring (May 20-21, 2018), primary observations of emerging shoots were carried out on all sown areas. At the end of the vegetation period (02-04.XI) of the same year, their numbers by species, the participation of chestnut-leaved oak in the composition, its preservation and current growth in height were determined, the results of which are presented in *Table 2*.

At the end of May 2018, it was found that 2.0-4.1 pieces of shoots of chestnut-leaved oak appeared on each created site, the total number of shoots was 2.34-3.12 thousand pieces/ha. At the end of the first year, the preservation of chestnut-leaved oak shoots in these areas was 61-80%, with a height growth of 10.9-12.5 cm.

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Table 2. *Dynamics of the number, preservation and growth in height of seedlings of chestnut-leaved oak*

No. of sections	Forestry conditions	Wood species	Number of seedlings per 1 ha, ths. pcs.						
			when counting in Spring 05-06 / VI	1st year		3rd year		5th year	
				Preservation	height, cm	Preservation	height, cm	Preservation	height, cm
№1	Oak grove forb-fresh	Oak/Cl Oak/G Hornbeam Others Total	2,82 1,61 3,67 0,86 8,91	2,27 1,38 3,03 0,72 7,40	11,8 ± 0,3 10,2±0,3 14,3±0,4 13,0±0,4	2,02 1,03 1,23 0,41 4,69	42,4±0,5 39,8±1,2 50,2±1,3 47,1±1,5	1,88 0,89 0,51 0,23 3,51	91,5±1,6 85,8±2,3 108,6±5,2 94,0±4,1
№2	Oak grove dead-cover-fresh	Oak/Cl Hornbeam Others Total	2,34 5,76 1,45 8,20	1,67 4,12 1,14 4,23	10,9±0,4 13,1±0,5 12,9±0,4	1,29 2,21 0,98 3,06	41,5±0,8 48,9±1,6 39,3±1,2	1,03 0,95 0,71 2,69	82,5±2,3 98,6±4,1 84,1±3,1
№3	Oak grove forb-fresh	Oak/Cl Oak/G Hornbeam Others Total	2,41 2,12 4,47 1,39 10,4	1,58 1,63 2,74 1,08 7,03	12,5±0,4 10,6±0,2 15,1±0,6 14,2±0,5	0,92 1,08 1,67 0,73 4,40	46,0±1,3 41,2±1,4 57,4±1,8 49,1±1,5	0,83 0,55 1,07 0,51 2,96	83,6±2,1 78,9±2,6 96,2±4,7 89,9±4,4
№4	Oak grove dead-cover-fresh	Oak/Cl Hornbeam Others Total	3,12 4,36 2,18 9,66	2,03 3,09 1,52 6,64	11,6±0,3 14,6±0,5 13,8±0,4	1,26 1,71 0,78 4,17	45,3±1,3 54,0±1,5 40,1±1,7	0,94 1,14 0,62 2,70	86,2±2,8 100,2±4,9 79,8±4,4
№5	Oak grove forb- humid	Oak/Cl Maple Others Total	2,43 4,57 2,08 9,08	1,48 3,12 1,32 5,82	12,4±0,3 15,9±0,4 14,3±0,5	1,03 1,77 0,76 3,56	42,5±1,7 44,6±1,6 46,7±1,6	0,85 1,06 0,68 2,59	80,2±2,4 85,4±3,2 91,1±3,4

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In the created sites, the number of 3-year-old seedlings of chestnut-leaved oak varied within the range of 0.92 - 2.02 thousand pieces/ha, their participation in the composition of sections No. 1 and No. 2 increased by 11.5% and 13.6%, respectively, in sections No. 3 and No. 4 decreased slightly. There was an increasing trend in section No.5. The preservation of 3-year-old chestnut-leaved oak undergrowth varied from 58% in section No. 3 to 89% in section No. 1. At the same time, its current height growth was 41.5-46.0 cm.

At the end of the 5th year, the total number of seedlings on the established sites amounted to 2.59-3.51 thousand pcs/ha, including 0.83-1.88 thousand pcs/ha of chestnut-leaved oak. In the composition of the undergrowth, its participation was: 2.8-5.4 units, current growth - 80.2-91.5 cm, preservation - 74-93%.

On the created sites, for five years, eight agrotechnical tendings were carried out for the seedlings (1st year - 2 tendings, 2nd year - 2 tendings, 3rd year - 2 tendings, 4th year - 1 tending, 5th year - 1 tending). During which weeding around the site at a distance of 1 m, partial loosening of the soil, cutting down secondary tree species that suppressed the chestnut-leaved oak and watering of the sites were carried out. The sites were watered 15 times (1st year – 4 times, 2nd year – 4 times, 3rd year – 3 times, 4th year – 2 times, 5th year – 2 times).

The general dynamics of the regeneration work carried out can be presented as follows. During the first three years, seedlings of chestnut-leaved oak gradually increase in height. Starting from the fourth year, there is a higher growth in height, which remains in the following three to four years.

Discussion

During the study of the plantings, AS site was found to have been subjected to anthropogenic impact for a considerable period of time, as a result of which many paths 2-3 m wide had formed throughout the entire territory, on which the regeneration processes had completely stopped. Due to the absence of young and middle-aged trees in this plantings, the age and size structure of chestnut-leaved oak trees is disrupted, which are graphically presented for all areas in *Fig. 6*. The undergrowth is in a similar condition, i.e. the main part belongs to the small category, medium ones are found singly, and large ones are absent (*Fig. 7*).

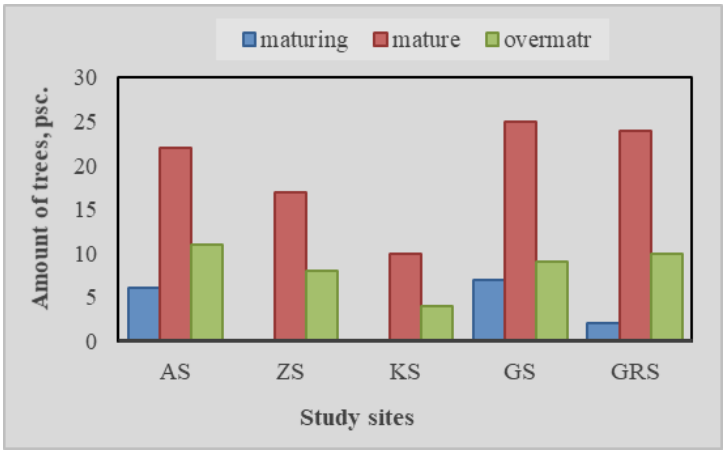

Figure 6. *Age structure of chestnut oak trees in the research planting*

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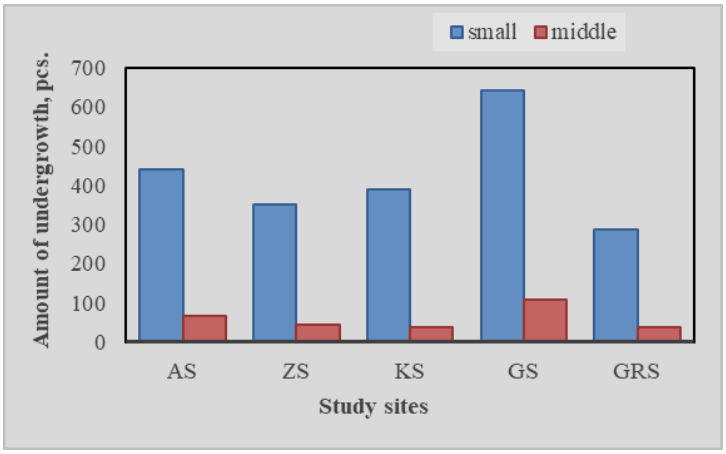

Figure 7. *Structure of chestnut oak undergrowth in a research planting*

On the site, the quality of trees and undergrowth of chestnut-leaved oak according to the index of condition is assessed from damaged to severely damaged, associated mainly with anthropogenic and climatic factors. Hosseini et al. (2015) also came to the same conclusion when studying the spatial structures of trees at different stages of their life. The changes in the plantings of chestnut-leaved oak were associated with anthropogenic impacts and age factors.

During the research of the plantings in the ZS and KS sites, disturbances in the age and size structure of oak trees and undergrowth were also identified. In the territory of these areas, especially in the homestead plots of the local population, single old-aged (220 years and above) chestnut-leaved oak trees were found. This confirms that this species was previously widespread in the territories of the indicated areas, but decreased over time, under the influence of anthropogenic impact. Here the quality of trees and undergrowth of chestnut-leaved oak varied from damaged to severely damaged. Our results are consistent with the data of Sefidi et al. (2022) who, using the calculation of the structural diversity index, identified various types of anthropogenic changes affecting the structure and composition of oak forests in the South Azerbaijan region. With this, the authors compared the structures of oak and oak-hornbeam plantings from the point of view of the consequences of degradation in this region.

In the GS site, high-aged trees of chestnut-leaved oak are found in a scattered form, which is mainly due to anthropogenic impacts in the past and ongoing changes in the forestry conditions of this region. As a result, the chestnut-leaved oak shifted its border from the south-east to the north-west, i.e. to the more humid part of this area. The age and size structure of trees and undergrowth of this species is also disrupted here, mainly due to the unsystematic cutting of forests in these areas about 30-50 years ago.

The qualitative condition of trees and undergrowth of chestnut-leaved oak in this area varies from damaged to severely damaged, mainly due to anthropogenic and climatic factors.

Our results and conclusions are consistent with the data obtained by Taleshi et al. (2019), who also linked the ongoing changes in the Hyrcanian forests of Northern Iran mainly to climatic factors, since climatically suitable habitats for most species tend to shift and shrink in the future. Under climate change scenarios, shifts in tree boundaries are expected along both the east-west gradient and the altitudinal gradient.

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The plantings of the GRS site are also subject to anthropogenic impacts in the form of frequent visits by people, grazing by livestock, their use for economic needs, etc. As a result, the plantings of this area turned mainly into rarely standing trees. Large windows have formed here, mostly without litter. Small number of small-category undergrowth is found only under the canopy of trees of this species. It was found that the age and size structures of trees and undergrowth of the studied species were also disturbed in the area. The qualitative condition of trees and undergrowth is assessed as severely damaged, mainly due to anthropogenic and climatic factors. Similar conclusions were reached by Yousefzadeh et al. (2022) characterizing *Gleditsia caspica* common in the Hyrcanian forests, where many of its habitats have been destroyed in the last half century due to anthropogenic impacts. In their work, they mapped the past geographic distribution and assessed suitable areas and potential risks for remaining populations of this species in the face of future climate change.

As can be seen, in all plantings of the studied areas, the changes occurring are a consequence of the long-term influence of anthropogenic factors, among which the main place is occupied by unsystematic cutting. In addition, climatic factors in the form of precipitation and evaporation during the warm season (May-September) also play an important role in these changes. Characterizing these factors, the following can be noted.

In the Republic, forest ecosystems were twice subjected to strong impacts of anthropogenic factors. In the first period after the Second World War, for the restoration of the national economy in the regions, including in Azerbaijan, intensive cutting of the main forests was permitted, which continued until the 1970s of the last century. In most cases the cutting rules were not followed especially in mountainous areas and available sizes (d = 20-50 cm) were unsystematically cut down for felling and transporting timber, while large trees were left. This was evidenced by the presence of decomposed stumps with diameters of 20-50 cm in the field (Yakhyaev, 2004).

In the second, the impact of anthropogenic factors in the form of unsystematic cutting was associated with an energy crisis that lasted for about 20 years. At the same time, available sizes of mainly hard-wooded species, including oak trees, were also cut down en masse for firewood, especially in nearby areas and with a road network.

The unsystematic cutting in this area in the past led to disruptions in the age and size structure of the plantings in the form of the absence of young, middle and partially maturing (140-180 age) chestnut-leaved oak trees. The disruption of the age and size structure of the young generation of chestnut-leaved oak over the past 60 years is associated with ongoing changes in forestry conditions and climate in this region (Mamedova and Mamedova, 2019; Shahnaseri et al., 2023).

As a result of the unsystematic cutting carried out in the past, the density of forest stands in this region has decreased from low density to rarely standing trees. As a result, the conditions for natural regeneration, emergence of shoots, and rooting of seedlings worsened. Under these conditions, the habitat of the studied species is more quickly occupied by seedlings of relatively resistant and fast-growing species, such as Caucasian hornbeam, field maple, etc. They compete with the chestnut-leaved oak and in most cases displace it. It should be noted here that in the studied plantings the number and age of seed trees of chestnut-leaved oak do not allow for abundant seeding of these areas. All these factors negatively affect the regeneration process of this species (Hosseini et al., 2010a).

One of the main climate elements influencing the distribution of chestnut-leaved oak in this region is the amount and seasonal distribution of precipitation. The annual amount

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of atmospheric precipitation in the study area is 670-777 mm (10), in the foothills and plains this amount decreases to 370-520 mm (Safarov and Olisayev, 1991). On the other hand, according to the Methodological Cabinet of the Hydrometeorological Center of the Republic (10), in the plains and foothills of the southeastern part of the Greater Caucasus (study area) about 33% of precipitation falls in the warm season, i.e. in the vegetation period, and 67% in the cold season. This means that in the oak plantings of this region during the warm season there is about 300-350 mm of precipitation with 400-600 mm of evaporation (Mamedov, 2004) and an average air temperature of 18-22^{0}C (8, 9). Under these conditions, the emergence of shoots and the growth of small undergrowths is hampered due to the lack of water in the soil, especially during the vegetation period, and in most cases they die. The continuation of these climatic conditions in the study area over the past several decades has led to disturbances in the age and size structure of the chestnut-leaved oak undergrowth (Sasan Babaye et al., 2021).

In the work of Monika Konatowska et al. (2024) all oak stands in Poland were analyzed and the hypothesis regarding the differences between *Quercus robur* and *Q. petraea* stands in terms of soil type, annual total precipitation, average annual air temperature and the length of the vegetation period was tested. The results of the research showed that an increase in air temperature by 1^{0}C may worsen the growth of *Q. robur* and slightly improve the growth of *Q. petraea*.

On this basis, the authors pointed out the possibility of expanding the geographic range of sessile oaks to the east and northeast in conditions of climate change, provided that appropriate humidity conditions are maintained.

The data obtained by Polish researchers once again confirms that changes in the growing conditions of oak stands lead to changes in the growth, structure, and renewal process of these stands, resulting in the displacement of oak stands to more suitable habitats.

In the work, Camarero et al. (2024) studied partially pruned oak forests common in Spain under conditions of ongoing aridization in southern Europe. In their studies, the authors compared the trends of basal area increment (BAI) and the responses of growth indices to climate variables and the drought index of previously pruned oak stands (*Quercus faginea, Q. humilis*) located in the north and east of Spain. As a result, they found that pruning is an appropriate management tool for maintaining strong old oak stands in drier climates.

The research methods indicated in this work are new for the conservation of old-growth trees of chestnut-leaved oak in this area and deserve attention for future use.

In all study areas, the quality of trees and undergrowth of chestnut-leaved oak according to the condition index is assessed from damaged to severely damaged. This is due to anthropogenic impacts in the form of unsystematic cutting, and climatic impacts in the form of insufficient soil water regime, especially during the vegetation period. As a result, chestnut-leaved oak trees become vulnerable and sensitive to biological impacts. This is facilitated by fast-growing and sprouting trees of other species of this plantings, which are more prone to biological diseases and the spread of disease.

The damaged condition of the undergrowth of the chestnut-leaved oak is explained by strong competition from fast-growing species for soil and solar nutrition. As a result, the sparse oak undergrowth falls into a stressful state and eventually passes into mortality. On the other hand, in rarely standing trees and low-density plantings, the upper soil horizons dry out during the vegetation period, which contributes to the mortality of the young generation of the studied species (Yakhyayev, 2007).

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Summing up, it can be noted that in this region the influence of anthropogenic-climatic and biological factors on the distribution of chestnut-leaved oak led to the above-mentioned changes.

The experiment to promote the regeneration of chestnut-leaved oak was dictated by the insufficient number of small and almost complete absence of medium and large specimens of undergrowth in all the studied areas of the Ismayilli region.

During the experiment, a large attrition of seedlings was found in the created sites at the end of the first year, which is explained by the unfavorable conditions of the open area of the section and the destruction of some seeds and shoots by rodents and other animals, a decrease in the moisture content of the upper soil horizon (up to 2-3 times), especially during the vegetation period. These facts are consistent with the data obtained and the explanations shown in the work of Yakhyayev et al. (2021).

At the end of the first year in sections No. 2 and No. 3, the remaining small number of shoots of chestnut-leaved oak with 2.6 pcs./sites is explained by the insufficient number of replacement trees in these areas. In section No. 5, the decrease in the number of shoots of the studied species with a attrition of about 40% in some areas was influenced by humid forestry conditions with dense shading covers of tall grass with the participation of ferns, which deprive the shoots of light and dry out the upper soil horizon. Similar explanations for the remaining insufficient amounts of undergrowth of chestnut-leaved oak in humid growing conditions are given in the work of Mustafayev (2012).

The success of the regeneration of chestnut-leaved oak at the end of the fifth year in the GS site of the Ismayilli district with a number of undergrowth of 0.83-1.88 thousand pieces/ha is assessed as satisfactory. Since, compared to the initial number of 0.48-0.84 thousand pieces/ha of undergrowth of this species in the field, this is almost 2 times more. However, for sustainable regeneration of chestnut-leaved oak and preservation of biodiversity and ecological balance in the forest ecosystem of this region, it is recommended to increase work to promote natural regeneration with created sites, additional artificial sowing of them, protective measures of sown sites, etc.

Conclusion

As a result of the studies conducted, the following conclusions can be noted:

- It was revealed that in the forest ecosystems of the Greater Caucasus of Azerbaijan, naturally growing chestnut-leaved oak with single specimens is found in Gabala and Sheki regions; only in Ismayilli region, in five sites, plantings with the participation of the studied species were found.
- It was found that chestnut-leaved oak trees are mostly of mature and overmature age, while young and middle-aged trees are absent in the plantings of the selected sites, and maturing trees are found only sporadically. The quality condition of trees of this species according to the index of condition varies from damaged to severely damaged.
- It was established that the success of natural regeneration of chestnut-leaved oak in all selected areas is assessed as unsatisfactory due to the insufficient number of seedlings of small categories and the almost absence of medium and large categories.
- It was determined that with the work carried out on the GS site of the Ismayilli district to promote the natural regeneration of chestnut-leaved oak at the end of the 5th year, the number of seedlings increased by about 2 times, i.e. from 0.48-0.84

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thousand pcs/ha to 0.83-1.88 thousand pcs/ha.

- It was revealed that in order to expand the distribution areas of chestnut-leaved oak in the Greater Caucasus region of Azerbaijan, it is necessary to identify places with optimal growing conditions in order to create a culture of this species.

Recommendations

For natural restoration of chestnut-leaved oak and expansion of its distribution areas, preservation of biodiversity and ecological balance in the forest ecosystem of Ismayilli district it is recommended: in low-density plantations to increase work to promote natural restoration; in sparse stands, large windows and clearings to create plantations of chestnut-leaved oak with mixed species. And also, against the background of climate change in the Greater Caucasus region of Azerbaijan to identify places with optimal growing conditions in order to create a culture of chestnut-leaved oak.

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