Article

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Mediterranean element in the flora of Armenia

Abstract

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The aim of this study was to analyze the representation of Mediterranean species in the broad sense (s.l.) in the flora of Armenia. Despite the significant distance from the Mediterranean basin, species of Ancient Mediterranean origin make up about half of the total flora in Armenia. The article analyzes the growth of Mediterranean species in various altitude zones, ecosystems and floristic regions of Armenia. It shows their greatest association with arid ecosystems, lower and middle mountain belts and floristic regions of Armenia, related to the Armeno-Iranian floristic province.

Key words: Floristic analysis, phyto-geographical elements, Mediterranean element, Caucasus.

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Introduction

Armenia is a country located in the South Caucasus with an area less than 30.000 sq. km^2.. The country's flora is surprisingly rich. This small territory hosts about 3,800 species of vascular plants, which comprises more than half of the entire Caucasus flora (Fayvush 2023). The flora includes a very large number of endemic species - local endemics, endemics of the Caucasus or Southern Transcaucasia, and the Armenian Highlands (Gabrielian & Fayvush 1989; Fayvush 2007; Solomon & al. 2013; Fayvush & Aleksanyan 2020).

Based on the position that allo- and autochthonous trends in the evolution of the Armenian flora were approximately equivalent (Fayvush 1990), it should be recognized that approximately half of the species migrated to the territory of Armenia from other regions, while the second half evolved on the territory of the republic. This does not recognize administrative boundaries, the autochthonous trend should be extended to the Armenian Highlands as a whole and partially to the Caucasus.

Although it is believed that the modern flora of Eurasia is a derivative of the Cretaceous period flora (Krishtofovich 1936), the history of the formation of Armenia's flora can safely begin from the times when both the Greater Caucasus and the Lesser Caucasus were islands and underwater elevations in the ancient Tethys Ocean (that is, from the late

Miocene, approximately 5.5 million years ago). It is well known that at the end of the Cretaceous and the beginning of the Paleogene periods in Central Asia on the eastern shore of Tethys, there already existed a very diverse floristic complex. The reduction of the Tethys was going from east, and this complex moved to the west including its original elements (Kamelin 1988). During this period that the main ecosystems were established in the territory of the Armenian Highlands, which became crucial for the entire Ancient Mediterranean region - shiblyak, arid open forests, semi-deserts, tragacanths, etc. These complexes had a similar coenotic structure, but the floristic composition differed significantly throughout the vast Ancient Mediterranean, and included both local species and migrant species. In this work, we present the results of an analysis of the flora of Armenia, aimed at examine the distribution and association with ecological conditions and ecosystems of plant species belonging to Mediterranean s.l. geographical element. Meaning by Mediterranean s.l. geographical element we mean species that are widespread both throughout the entire territory of the Ancient Mediterranean or in its individual parts.

Material and methods

Study Area

Armenia is a republic in the South Caucasus, neighbouring Georgia, Azerbaijan, Türkiye, and Iran. The total area of Armenia is 29,740 km². It is considerably distant from sea basins—approximately 145 km from the Black Sea and 175 km from the Caspian Sea. It is situated between 38°50’ and 41°18’N latitude and between 43°27’ and 46°37’E longitude (Fig. 1). The distance from north to southeast along the main axis is approximately 400 km. Armenia is a predominantly mountainous country, with an average altitude of 1850 m above sea level, the lowest point being 375 m and the highest 4095 m above sea level (Fayvush 2023).

A wide range of climatic zones are distinguished within Armenia (Fig. 2). This territory shows a pronounced vertical succession of six basic climate types – from dry subtropical up to severe alpine. The average annual temperature ranges from -8°C in high-altitude mountainous regions (2500 m a.s.l. and higher) to 12–14°C in low-traced valleys. In the lowlands the average air temperature in July and August reaches 24–26°C, but in the alpine belt the temperature does not exceed 10°C. January is the coldest month with an average temperature of -6.7°C. The absolute minimum temperature is -42°C. The overall climate is best characterized as dry continental, in some areas with an annual rhythm more or less similar to the Mediterranean climate regime. The average annual precipitation in Armenia is 592 mm. The most arid regions are the Ararat valley and the Meghri region with annual precipitations of 200–250 mm. The highest annual precipitation, 800–1000 mm, is observed in high altitude mountain regions. Major part of the precipitation falls in the spring. Long-lasting snow cover exists in the mountains above 1300 m, where the annual snowfall could attain 2 m. In the northern part of Armenia, humidity comes from the Black Sea in the west, in the southern part from the Caspian Sea in the east, while the central part lies in the rain shadow of mountain ridges and is the driest area (Bagdasaryan 1958; Republic of Armenia 2015). In general terms, the climate is best characterized as dry continental with an annual rhythm more or less similar to the Mediterranean type, especially in lowlands (Fig. 2).

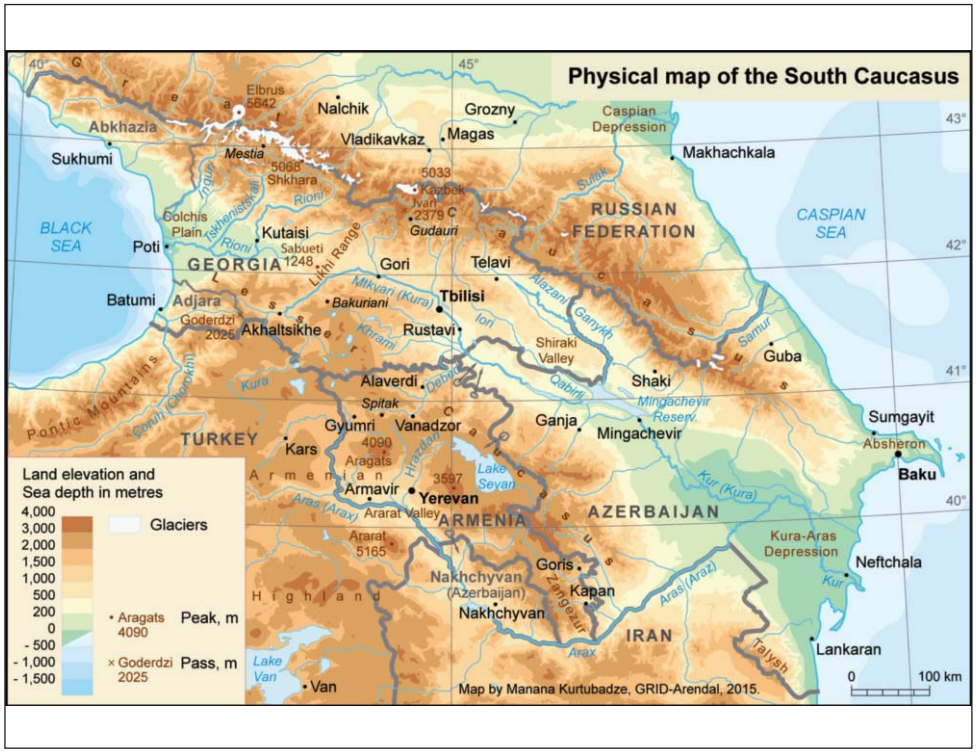

Fig. 1. Location of Armenia in the Caucasian Ecoregion.

The diversity of landscapes and orography is a significant determinant of Armenia's diverse vegetation. The lower mountain belt (375–1300 m) is covered by semi-desert formations, gypsophilous or halophilous vegetation. There are salt marsh areas as well as the South Caucasian sand desert. The middle and upper mountain belts (1300–2200 m) are characterised by various kinds of steppe and forest vegetation, meadow-steppes, shrub steppes and thorny cushion (tragacanth) vegetation. The altitudinal span of the forest belt varies from 500 to 2000 m depending on the region and may approach 2400 m when open park-like tree stands are included. The subalpine and alpine belts (2200–4095 m) are covered by meadows and carpets (Magakyan 1941; Takhtadjan 1941; Fayvush 2006; Fayvush & Aleksanyan 2016; Fayvush 2023).

Armenia lies at the intersection of two biodiversity hotspots (Caucasian and Irano-Anatolian; Mittermeier & al. 2011) and two phytogeographical subkingdoms: Boreal (Euro-Siberian) and Ancient Mediterranean (Takhtadjan 1986).

On the basis of numerous literature and herbarium data, as well as long-term observations in nature, we adjusted the floristic zoning of Armenia by Takhtajan (1954). In this

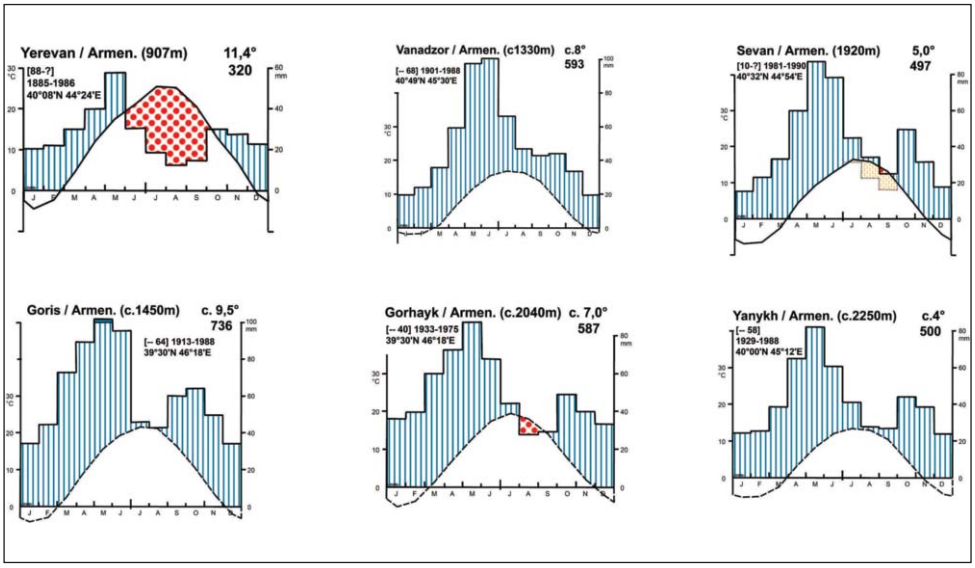

Fig. 2. Climatic diagrammes of some meteostations of Armenia (Fayvush 2023).

work, we use this updated scheme to indicate the distribution of plant species throughout the republic (Tamanyan & Fayvush 2009) (Fig. 3).

It should be noted that according to our previous studies, the Shirak, Aparan, Yerevan, Darelegis, and Meghri floristic regions belong to the arid Armeno-Iranian floristic province (Ancient Mediterranean subkingdom), while the rest belong to the more mesophilic Caucasian province (Boreal subkingdom; Tamanyan & Fayvush 2009; Fayvush & al. 2023).

Methods

The flora of Armenia includes approximately 3800 species of vascular plants (Republica of Armenia 2014), of which about 50% are distributed mainly in the Ancient Mediterranean region (Saghatelyan 2006; Fayvush & al. 2023). Investigating species of the flora of Armenia for the determination of geographical elements, we used the scheme of N. Portenier (2000), adapted by us for the conditions of the South Caucasus (Fayvush & Adamyan 2015).

The analysis included 463 distinct species of vascular plants distributed in the Ancient Mediterranean region, for which we had accurate data on their distribution and confinement to altitudinal zones and specific ecosystems. This represents approximately 25% of all species whose main range lies in the Ancient Mediterranean region. In addition, we included in the analysis another 99 species with a somewhat wider range – Euro-Ancient Mediterranean and Euro-Mediterranean.

Based on the objectives of this study, we did not include in the analysis species with a very wide range – polychoric and Holarctic, as well as species whose main range lies in the Greater Caucasus, as this area belongs to the Boreal subkingdom of Takhtajan (1986).

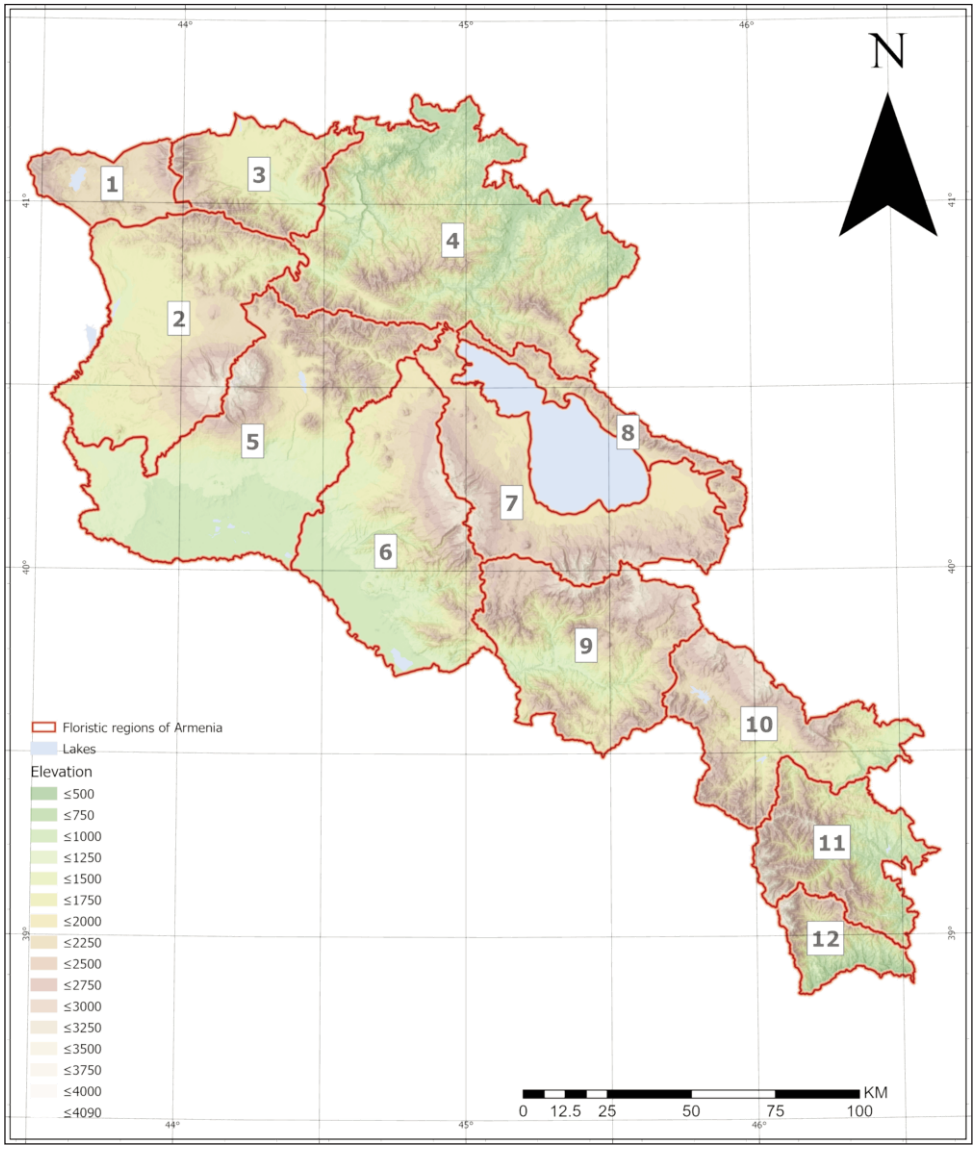

Fig. 3. Floristic regions of Armenia (Tamanyan & Fayvush 2009): 1) Upper Akhuryan; 2) Shirak; 3) Lori; 4) Idjevan; 5) Aparan; 6) Yerevan; 7) Sevan; 8) Areguni; 9) Darelegis; 10) North Zangezur; 11) South Zangezur; 12) Meghri.

To determine the altitudinal confinement of the studied species, literary data were used (primarily “Flora of Armenia” 1954–2009), data from the herbarium of the Institute of Botany after the name A. Takhtajan of the National Academy of Sciences of the Republic of Armenia (ERE) and the results of our own observations in nature for more than 40 years.

To assess the distribution of plant species in different habitats, we used the EUNIS habitat classification system (Fayvush & Aleksanyan 2016), the new version of this classification can be found on the website https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification-1.

Results and discussion

The analysis of 562 species of Armenia's flora (Electronic Supplementary File 1, Table S1), which in their distribution are directly related to the Ancient Mediterranean subkingdom (Takhtajan 1986), showed that among the studied taxa, the largest part consists of species growing exclusively on the Armenian Highlands (Armenian geographical element) (Table 1).

Due to the fact that Armenia is predominantly a mountainous country with well-expressed altitudinal zonation of vegetation, in our analysis of the studied species, we primarily examined their distribution in altitudinal zones (Table 2). It should be noted that many species grow in more than one altitudinal zone. Because of this, the sum of species across zones is greater than the number of studied species.

As we can see, the middle mountain belt is the richest in species of the ancient Mediterranean flora. This is most likely due to the fact that this belt hosts the greatest diversity of ecosystems – it is here that steppe and forest ecosystems, woodlands, and tragacanth habitats reach their greatest variety. Intrazonal habitats (such as wetlands and petrophilous habitats) are also well represented. Fewer species are found in the lower mountain belt, where deserts and semi-deserts are more prominent. The fewest species are recorded in the alpine belt, likely due to the smaller areas covered by alpine vegetation and the predominance of Caucasian and boreal plant species in this region (Fayvush & Ghukasyan 2023).

Table 1. Geographical elements (according to Fayvush & Adamyan 2015) of investigated species and subspecies.

Geographical element	**Number of taxa**
Ancient Mediterranean (taxa distributed in the whole area of Ancient Mediterranea)	55
East Ancient Mediterranean (taxa distributed only in the East part of Ancient Mediterranea – from Turkey to East border)	68
Mediterranean (taxa distributed in Mediterranean basin with small irraditions or disjunctions)	14
East Mediterranean	10
Armeno-Iranian	91
Armeno-Atropatenian	46
Iranian	12
Atropatenian	18
Armenian	149
Total Ancient Mediterranean	463
Euro-Ancient Mediterranean	79
Euro-Mediterranean	20

Table 2. Confinement of Ancient Mediterranean taxa to altitudinal zones of Armenia.

Geographical elements	**Altitudinal zones** (number of taxa)				
	Lower (375 – 1300 m a.s.l.)	Medium (1300 – 1800 m a.s.l)	Upper (1800 – 2200 m a.s.l.)	Subalpine (2200-2700 m a.s.l.)	Alpine (2700 – 4095 m a.s.l.)
Ancient Mediterranean	49	44	26	11	4
East Ancient Mediterranean	57	54	26	6	3
Mediterranean	9	12	5	4	3
East Mediterranean	5	8	7	5	2
Armeno-Iranian	52	76	46	30	14
Armeno-Atropatenian	24	40	27	16	6
Iranian	9	8	6	1	0
Atropatenian	8	10	7	6	5
Armenian	46	96	71	41	23
Total (Ancient Mediterranean s.l.)	**259**	**348**	**221**	**120**	**60**
Euro-Ancient Mediterranean	62	73	40	21	8
Euro-Mediterranean	13	16	10	7	3
Total	***75***	***89***	***50***	***28***	***11***

Table 3 illustrates the representation of ancient Mediterranean species in the major ecosystems of Armenia. The first noticeable trend is that most of the studied species are found in grassland ecosystems, with the highest number concentrated in mountain steppes (E1.2). A similar, if not larger, number of species occurs in Armenia's semi-deserts (categories E1.3 and E1.4). A significant number of species have also been recorded in mountain hay meadows (E2.3). Among forest vegetation, oak forests (G1.A1) stand out, as they are found in northern, central, and southern Armenia, in contrast to beech forests (G1.6H), which are only present in northern Armenia. Among shrub ecosystems, the richest in ancient Mediterranean species are the arid woodlands (F5.3 – Pseudomaquis). In petrophilous ecosystems, ancient Mediterranean species are better represented in scree habitats than on rocks, particularly on calcareous and ultrabasic screes of warm exposures (H2.6). Very few species are associated with aquatic and wetland ecosystems (categories C and D). However, it is worth noting that salt marshes (D6.2) host typical Mediterranean species such as *Microcnemum coralloides* (Loscos et J. Pardo) Buen*, Frankenia hirsuta* L., *Merendera sobolifera* Fisch. et C. A. Mey., *Sphaerophysa salsula* (Pall.) DC., and *Iris spuria* subsp. *musulmanica* (Fomin) Takht.

Species with a very broad Euro-Ancient Mediterranean range type are best represented in both mountain steppes (E1.2) and calcareous and ultra-basic screes of warm exposures (E2.3), meaning that most of them prefer calcareous substrates. The same can be said for Euro-Mediterranean species. A relatively small number of Euro-Ancient Mediterranean and Euro-Mediterranean species are found in Armenia's forests (slightly more in oak forests), and surprisingly, none have been recorded in Grecian juniper (*Juniperus excelsa* M. Bieb.) woods (G3.93). Interestingly, very few ancient Mediterranean species are found in agricultural lands (Category I), with Euro-Ancient Mediterranean species preferring bare tilled, fallow, or recently abandoned arable land (I1.5).

Table 3. Distribution of Ancient Mediterranean Plant Taxa Across Main Ecosystems.

Habitats	**Geographical elements**											
	Ancient Mediterranean s.str.	East Ancient Mediterranean	Mediterranean	East Mediterranean	Armeno-Iranian	Armeno-Atropatenian	Iranian	Atropatenian	Armenian	**Total**	Euro-Ancient Mediterranean	Euro-Mediterranean
C3.2		1							4	**5**		
D4.1	5	6	1	1	10	1	1		7	**32**	13	4
D6.2	3	2				1			1	**7**		
E1.2	26	36	9	6	53	31	6	4	65	**236**	29	8
E1.3	23	34	1	1	27	16	8	7	20	**137**	20	2
E1.4	23	34	1	1	27	16	8	7	14	**131**	20	2
E1.6	1									**1**		
E1.C									1	**1**		
E2.3	11	11	3	5	23	14	3	1	33	**104**	29	7
E4.3	1	1	1		7	3			16	**29**	3	3
E4.4	1	1	1		6	2			19	**30**	3	3
E5.4	4	6	1	1	4	3		1	9	**29**	8	1
E5.5					1	1			2	**4**		
F2.3	5	5	1	3	5	1	2		10	**32**	7	2
F3.1									1	**1**		
F3.2									4	**4**		
F5.1	2	2			1	3			3	**11**		
F5.3	10	8	1		12	3	2	1	20	**57**	14	
F7.4									3	**3**		
G1.6H	4	2	1	1	3	1	1		7	**20**	6	3
G1.A1	5	4	2	3	7	5	1	3	17	**47**	12	5
G3.93	2	2			1	3			4	**12**		
H2.3	1	1		1	3	3		3	11	**23**	2	1
H2.4	1	1			3	1			6	**12**	1	1
H2.5	4	4	2		6	3			5	**24**	1	1
H2.6	4	8			15	4	3	1	8	**43**	2	2
H3.1	1	3		1	4	3		2	11	**25**	1	1
H3.2	2	4			2	3		2	9	**22**	1	2
H5.3	3	2			4		1		3	**13**		1
I1.22											5	
I1.3	4	4	2		1					**11**	5	
I1.5	3	5							1	**9**	12	1
I2.2	1									**1**		

C3.2 - Water-fringing reedbeds and tall helophytes other than canes

D4.1 - Rich fens, including eutrophic tall-herb fens and calcareous flushes and soaks

D6.2 - Inland saline or brackish species-poor helophyte beds normally without free-standing water

E1.2 - Perennial calcareous grassland and basic steppes

E1.3 - Mediterranean xeric grassland

E1.4 - Mediterranean tall-grass and wormwood – *Artemisia* - steppes
E1.6 - Subnitrophilous annual grassland
E1.C - Dry mediterranean lands with unpalatable non-vernal herbaceous vegetation
E2.3 - Mountain hay meadows
E4.3 - Acid alpine and subalpine grassland
E4.4 - Calcareous alpine and sub-alpine grassland
E5.4 - Moist or wet tall-herb and fern fringes and meadows
E5.5 - Subalpine moist or wet tall-herb and fern stands
F2.3 - Subalpine deciduous scrub
F3.1 - Temperate thickets and scrub
F3.2 - Submediterranean deciduous thickets and brushes
F5.1 - Arborescent matorral
F5.3 - Pseudomaquis
F7.4 - Hedgehog-heaths
G1.6H - Caucasian beech forests
G1.A1 - Oak - ash - hornbeam woodland on eutrophic and mesotrophic soils
G3.93 - Grecian juniper - *Juniperus excelsa* - woods
H2.3 - Temperate-montane acid siliceous screes
H2.4 - Temperate-montane calcareous and ultra-basic screes
H2.5 - Acid siliceous screes of warm exposures
H2.6 - Calcareous and ultra-basic screes of warm exposures
H3.1 - Acid siliceous inland cliffs
H3.2 - Basic and ultra-basic inland cliffs
H5.3 - Sparsely- or unvegetated habitats on mineral substrates not resulting from recent ice activity
I1.22 - Small-scale market gardens and horticulture, including allotments
I1.3 - Arable land with unmixed crops grown by low-intensity agricultural methods
I1.5 - Bare tilled, fallow or recently abandoned arable land
I2.2 - Small-scale ornamental and domestic garden areas

It should also be noted that at least three species (*Silybum marianum* (L.) Gaertn., *Clematis vitalba* L., *Cirsium incanum* (S. G. Gmel.) Fisch ex M. Bieb.) of Mediterranean, Euro-Mediterranean or Ancient Mediterranean origin appeared on the territory of Armenia in the 20th century. They are currently considered invasive alien species in Armenia and are confined mainly to disturbed habitats.

Table 4 shows the occurrence of Ancient Mediterranean species across various floristic regions of Armenia. As we can see, the largest number of these species is found in the Darelegis, Yerevan, and Meghri floristic regions. This is not surprising, as the flora of the Darelegis region is directly linked to the ancient Tethys Ocean – according to geologists, this area was already an island during the Paleogene (Derkur & Sonnenschein 1990). It later served as a refugium where many Tertiary relic species survived. The Yerevan and Meghri floristic regions are areas with the most pronounced arid climate, to which Ancient Mediterranean species are particularly well adapted.

Table 4. Distribution of Ancient Mediterranean Plant Species Taxa Across the Floristic Regions of Armenia (Tamanyan & Fayvush 2009).

Geographical elements	**Floristic regions of Armenia**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Ancient Mediterranean s.str.	13	31	23	34	32	45	27	21	43	35	38	46
East Ancient Mediterranean	13	27	18	23	32	64	26	24	50	29	27	47
Mediterranean	4	5	4	7	6	7	6	4	6	5	8	9
East Mediterranean	4	3	4	5	7	1	6	6	6	6	5	6
Armeno-Iranian	29	43	23	30	56	71	49	41	75	64	53	59
Armeno-Atropatenian	15	18	12	14	24	31	19	20	31	12	19	21
Iranian	0	4	1	2	6	9	4	3	9	6	4	8
Atropatenian	0	0	0	1	2	5	2	2	6	3	7	12
Armenian	26	50	29	41	55	67	50	38	78	41	39	35
Total (Ancient Mediterranean s.l.)	104	181	114	157	220	300	189	159	304	201	200	243
Euro-Ancient Mediterranean	39	43	47	64	55	58	46	46	59	62	67	59
Euro-Mediterranean	8	9	14	16	13	9	13	11	9	16	15	9

1 – Upper Akhuryan, 2 – Shirak, 3 – Lori, 4 – Idjevan, 5 – Aparan, 6 – Yerevan, 7 – Sevan, 8 – Areguni, 9 – Darelegis, 10 – North Zangezur, 11 – South Zangezur, 12 – Meghri

Conclusion

The flora of Armenia represents a complex and multifaceted structure, in which species of Ancient Mediterranean and Holarctic distribution are present in approximately equal proportions. Additionally, it includes species whose origins are directly linked to the territory of the republic, the Ancient Mediterranean, and the Caucasus. It has been shown that most species of Ancient Mediterranean origin in Armenia grow in the middle and lower mountain belts, where the climate, in terms of seasonal patterns, is most similar to that of the Mediterranean. These species are best represented in steppes, semi-deserts, and, in general, in ecosystems developing on calcareous substrates. According to the floristic division of the Earth by A. Takhtajan (1986), the boundary between the Caucasian and Armeno-Iranian provinces passes through the territory of Armenia, thus separating the Boreal and Ancient Mediterranean subkingdoms. Naturally, this boundary is not a geometric line but rather a broad corridor, within which species with predominantly “northern” and “southern” distributions are represented in varying proportions. The conducted analysis confirms our earlier assumption that the Yerevan, Darelegis, Meghri, and Shirak floristic regions should be attributed to the Armeno-Iranian province of the Ancient Mediterranean subkingdom, while all other regions belong to the Caucasian province of the Boreal subkingdom. At the same time, two floristic regions—Sevan and Areguni—occupy an intermediate position, where Caucasian and Armeno-Iranian species are represented in nearly equal proportions.

Acknowledgements

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