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Anthropogenic changes in forest landscapes of Lake Sevan basin under climate change

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ABSTRACT

Statement of the problem. The paper analyzes the spatio-temporal dynamics of forest landscapes in the Lake Sevan basin. This area is one of the most sparsely forested regions of Armenia; moreover, its forests are generally of low productivity and limited industrial significance. A significant part of the forests (12.5 thousand hectares) is of artificial origin, while natural forests (around 3.0 thousand hectares) are mainly concentrated on the steep mountain slopes of the Areguni and Sevan mountain ranges, where oak and juniper communities prevail. Forests regulate climate through carbon storage and sequestration, cool land surfaces via water–energy cycling, sustain biodiversity, secure freshwater resources through hydrological regulation, reduce disaster risks, and contribute directly to livelihoods and public health. In the Lake Sevan basin, these functions should be considered from a multifunctional landscape perspective, because forest degradation affects not only tree cover but also hydrological regulation, soil stability, ecological connectivity, biodiversity, and the ecological condition of the lake.
The relevance. Lake Sevan is the largest freshwater system in Armenia, whose ecosystem stability largely depends on the balance and sustainable use of the basin's natural resources. The study is highly relevant for understanding current ecological transformations and supporting effective forest management and sustainable regional development.
The study aims to analyze and assess the patterns of anthropogenic change in the forest landscapes of the Lake Sevan basin, particularly under current climate change conditions.
The object of the study is the forest landscapes of the Lake Sevan basin.
The subject of the study is forest cover dynamics and the associated ecological risks.
Methods. The research was based on a combination of field observations, spatial analysis, and a review of published and institutional data. A geographical–comparative approach was applied, integrating map interpretation, statistical analysis, and semi-stationary field observations. The study included comparisons of historical and

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contemporary forest maps, assessment of forest cover dynamics, and identification of areas most affected by anthropogenic pressure. Quantitative assessments were complemented by field inspections that verified cartographic and remote sensing data. Additional information was obtained from the State Committee for Forestry, the Cadastre Committee, the Ministry of Environment of the Republic of Armenia, the Gegharkunik Regional Administration, and reports of international environmental organizations.

Results. Historically, the degree of afforestation in the region was considerably higher but has declined markedly due to long-term anthropogenic pressure. Deforestation has continued because of illegal and unregulated logging, together with the loss of flooded forest areas caused by fluctuations in Lake Sevan's water level. These processes threaten the ecological balance of the basin and underline the need for integrated scientific assessment and restoration measures aimed at stabilizing forest and aquatic ecosystems. The analysis demonstrates that current changes in forest distribution result from the combined effects of climatic variability and persistent anthropogenic pressure.

Introduction

According to the Forest Code of the Republic of Armenia adopted in 2005, a forest is defined as *"an interconnected and interacting unity of biodiversity and natural environment components, dominated by tree and shrub vegetation on forest lands or other lands allocated for afforestation, with a minimum area of 0.1 hectares, a minimum width of 10 meters, and a canopy cover of at least 30 percent of the given area, as well as non-forested lands that were previously forest-covered forest lands"* (Forest Code of RA).

Forests are foundational to Earth's life-support systems and human well-being. ScienceDirect-indexed research demonstrates that forests regulate climate through carbon storage and sequestration, cool land surfaces via water–energy cycling, sustain biodiversity that underpins ecosystem functioning, secure freshwater services through hydrological regulation, reduce disaster risks, and contribute directly to livelihoods, food systems, and public health [1]. A forest is not only a source of timber but also provides numerous non-timber products and essential ecosystem services, including climate regulation, soil protection, and water retention. At the same time, the aesthetic, recreational and health values of trees and shrubs are also significant [2]. Simultaneously, Forests contribute to biodiversity conservation, regulation of the water cycle, and the promotion of human well-being by providing recreational, cultural, and health-related services [3, 4, 5, 6, 7].

Forest ecosystem multifunctionality, the capacity of forests to simultaneously deliver multiple ecosystem functions and services, is being increasingly affected by pressures stemming from anthropogenic activities and climate change [8]. In this context, forest condition cannot be assessed exclusively through changes in total forest area. Forest composition, structural diversity, spatial connectivity, regeneration capacity and the continuity of ecological processes are also essential indicators of ecosystem integrity. A reduction in these attributes may weaken the capacity of forests to provide several ecosystem services simultaneously, even where nominal forest cover remains relatively stable [9]. Climate change has a strong impact on forests, enhancing their growth but also posing risks to them. Conversely, forests can mitigate climate change, as they have a considerable impact on global surface temperatures through their influence on the land–atmosphere energy exchange and the absorption of vast amounts of CO_2 through photosynthesis [10]. The carbon cycle of forest ecosystems plays an important role in cutting down global environmental pressure, reducing greenhouse effects, and assimilating carbon dioxide [11]. The relationship between forests and climate change is therefore bidirectional. Forests contribute to climate regulation, but climatic warming, increasing evaporative demand, drought, pest outbreaks and altered disturbance regimes may reduce forest productivity and increase tree mortality. These pressures are particularly important in high-mountain and semi-arid environments, where forest regeneration is strongly constrained by temperature, soil moisture and short growing seasons [12]. Under these circumstances, analyzing the spatio-temporal dynamics of forest cover becomes essential for identifying the main trends, vulnerable areas, and combined impacts of climatic and anthropogenic factors. The results of such analyses can inform strategies for sustainable forest management and long-term conservation of the Lake Sevan basin ecosystem.

At present, forest lands in Armenia cover approximately 344.2 thousand hectares, of which 277.1 thousand hectares are forested. Within the Lake Sevan basin, forested territories include recreational zones and the Sevan National Park [13].

Forests perform a wide range of ecological functions, such as climate regulation, water conservation, erosion control and maintenance of mineral balance in the lake ecosystem [14]. I suggest: They stabilize slopes, strengthen the soil through their root systems, reduce surface runoff, and prevent both sheet and gully erosion. [15]. Among these, the water-regulating function of forests is of particular importance [16].

Forested catchments reduce surface runoff and enhance groundwater recharge, resulting in more stable river flow regimes with smaller seasonal fluctuations. When shrub or meadow vegetation is replaced by forest vegetation, the amount of water absorbed and stored water in the basin increases by 2.38 times [17]. Thus, afforestation alone can significantly enhance local water storage capacity without additional hydraulic infrastructure.

From a landscape perspective, the ecological significance of Lake Sevan's forests extends beyond the boundaries of individual forest stands. Their location within river catchments, steep slopes, shoreline zones and ecological corridors determines their contribution to erosion control, water regulation, habitat connectivity and the reduction of sediment and nutrient inputs into the lake. Consequently, forest degradation may generate cumulative effects throughout the basin and intensify existing pressures on the aquatic ecosystem.

The study aims to analyze and assess the patterns of anthropogenic change in the forest landscapes of the Lake Sevan basin, particularly under the current conditions of climate change. Lake Sevan is the largest freshwater system in Armenia, whose ecosystem stability largely depends on the balance and sustainable use of the basin's natural resources. In this context, forested areas play a key role in reducing soil erosion, regulating the hydrological regime, preserving biodiversity, and maintaining local climate stability.

In recent decades, climatic fluctuations and human activities have caused a noticeable reduction in forest cover and changes in its spatial distribution. These alterations disrupt the ecological equilibrium of the basin, increasing the risks to water resources, biodiversity, and soil stability.

This study provides the first comprehensive assessment of anthropogenic transformations in the forested areas of the Lake Sevan basin and their potential link to ongoing climate change. As a result, the main trends in forest cover dynamics have been identified, together with the area most vulnerable to climatic fluctuations and the associated ecological risks. The study also interprets these changes through the concepts of ecosystem multifunctionality, ecological resilience and integrated landscape restoration, thereby linking observed forest dynamics with their broader implications for basin-scale sustainability [8, 9].

During the last two centuries, social perception of forest roles has suffered deep changes. New environmental roles, i.e. CO_2 storage and biodiversity, have been added to erosion control and watershed regulation [18]. The trend of anthropogenic change of forests is observed almost on whole territory of Caucasus eco-region, especially in plain areas. Therefore, the decreasing trend of forest area, phytomass amount, also the ecological functions are evident [19]. The Caucasus Ecoregion is rich in forests. The total area of forests covers 18.52 % of the total land area of the Ecoregion and it is considered as the most important for biodiversity conservation [20]. The findings reveal substantial forest decline over the past three decades, accompanied by rapid expansion of agricultural land, settlements, and degraded areas [21]. Improved land use planning, enhanced inter-sectoral coordination, upscaling of participatory forest management particularly in village forests, enhanced performance of institutions mandated to manage forest resources and taking advantages of climate finance opportunities are recommended as means of achieving emission reduction and sustaining the role of forests as carbon sinks [22].

Study area. The Lake Sevan basin, located in the central-eastern part of Armenia, occupies approximately one-sixth of the country's total territory. The lake is surrounded by mountain ranges rising 500 to 1,800 meters above the lake level. The Lake Sevan basin is surrounded by Geghama Mountains (from West), Vardenis Mountains (from South), Areguni Mountains (North-East) and Sevan and East Sevan (East) mountain ranges with elevations up to 3598 m (Vardenis). One of the peculiarities of Lake Sevan basin is the small ratio between the catchment area and the surface area of the Lake (3:1) compared to other major lakes (10:1 in average).

The climate of the basin is temperate continental, characterized by cold winters, relatively warm and sunny summers, and humid, variable conditions during spring and autumn [23]. The Lake Sevan basin is one of the sparsely forested regions of the Republic of Armenia; the current forest cover (12.5 thousand ha) is only 3% of the total forest cover of the republic [24, 25]. Natural forests occupy approximately 3.0 thousand ha, mainly concentrated on the steep slopes of the Areguni and Sevan Mountain ranges where oak (*Quercus spp.*) and juniper (*Juniperus spp.*) communities dominate [26, 27].

The flora of the basin is typical to the highlands of the Transcaucasus Region known with great diversity of plants. Along the shoreline of the lake the greatest artificial woodland of the country is situated, which offers various examples of natural and human affected ecological successions. Aquatic associations (plankton, benthos, ichthyofauna) are qualitatively poor with only a few dominant species, which has simplified studies on ecological relationships (food web, etc.) [28].

The degree of forestation of river basins is very insignificant: in the Pambak and Daranak river

Table 1

Main characteristics of the river catchments in the Lake Sevan basin

River - point	Main characteristics of the river catchments			
	average height, m	average slope, ‰	forest cover, %	plowing, %
r. Dzknaget – p. Tsovagyugh	2220	211	–	15
r. Drakhtik –p. Drakhtik	2270	246	–	35
r. Pambak – p. Pambak	2540	433	15	–
r. Daranak – p. Daranak	2530	341	31	–
r. Masrik – p. Tsovak	2310	158	1	20
r. Karchaghbyur – p, Karchaghbyur	2650	174	–	15
r. Artsvanist – p. Artsvanist	2540	192	–	25
r. Vadenis – p. Vardenik	2680	279	–	25
r. Martuni – p. Geghhovit	2760	285	–	15
r. Argichi – p. Getashen	2470	144	–	10
r. Tsaghkashen – p. Vaghashen	2570	–	–	–
r. Lichk – p. Lichk	2060	87	–	50
r. Bakhtak – p. Tsakqar	2570	123	–	15
r. Shoghvak – p. Dzoragyugh	2650	170	–	35
r. Gavaraget – p. Noratus	2430	133	<1	15

basins it does not exceed 31%, and in the Masrik and Gavaraget river basins it is 1% (Table 1). The average height is from 1900 to 2300 m. The average slope of the river from the remote point is from 87 to 433‰.

Water abstraction and allocation in the Lake Sevan basin is carried out for drinking-household, irrigation, industrial, hydropower generation, fish-farming and watering purposes.

Material and methods

The research was based on a combination of field observations, spatial analysis, and a review of published [29, 30, 31, 32] and institutional data sources. Relevant literature and cartographic materials were analyzed, including works by Khanjyan [13], Vardanyan [26], Grigoryan [27], Olchev et al. [33] and Margaryan et al. [34].

In accordance with the objectives of the study, a geographical–comparative approach was applied, integrating map interpretation, statistical analysis, and semi-stationary field observations. The research involved the comparison of historical and contemporary forest maps, the evaluation of forest cover dynamics, and the identification of areas most affected by anthropogenic pressure. Quantitative assessments were complemented by qualitative field inspections, which allowed for the verification of remote and cartographic data in situ.

Additional information was obtained from the State Committee for Forestry, the Cadastre Committee, and the Ministry of Environment of the Republic of Armenia, as well as from the Gegharkunik Regional Administration. These datasets included official statistics, forest management plans, and legal documents regulating forest use and protection within the Lake Sevan basin. Reports and guidelines from international environmental organizations were also examined to provide a broader contextual framework for assessing forest dynamics under climate change.

Furthermore, international and national policy frameworks were reviewed to ensure that the study aligns with current forest management and restoration strategies. These included the FAO State of the World's Forests [35], the IPCC Sixth Assessment Report [36], the UNECE/FAO Regional Analysis on Forest Landscape Restoration in the Caucasus and Central Asia [37], the UNEP Frontiers Report [38], and the National Forest Program of Armenia 2021–2030 [39]. Together, these references offer a comparative perspective that situates the Lake Sevan basin within the broader context of global forest change and restoration policies.

The interpretation of the results followed a landscape-based analytical framework. The observed changes were considered in relation to five interconnected dimensions: forest extent, forest origin and composition, spatial location within the basin, exposure to climatic and anthropogenic pressures, and capacity to maintain ecosystem services. This framework made it possible to distinguish between simple changes in forest area and broader processes of forest landscape degradation [8, 9, 40].

Table 2

Main agroclimatic indicators of Gegharkunik region by altitudinal zones [43]

Climatic indicators		Altitude above sea level (m)				
		1800	2000	2200	2500	3000
Average air Temperature, C°	July	17-19	14-16	13-15	11-13	9-10
	absolute maximum	33-35	31-33	29-30	26-29	22-25
	absolute minimum	-32 – -39	-32 – -41	-32 – -42		
	annual sum of days above 10 C°	1900-2300	1500-1900	1200-1500	900-1100	300
	Number of days above 10 C°	140-155	110-140	100-120	70-90	25-35
	Number of days above 5 C°	195-205	175-190	165-180	145-155	95-105
Frost-free period on the soil surface	Beginning	26/05	05/06	15/06	25/06	
	End	29/09	18/09	05/09	24/08	
	duration	126	105	82	60	
Number of precipitations, mm	annual	600-650	450-500	550-600	650-750	800-900
	growing season	400-450	300-350	350-400	400-450	500-550
Annual evaporation deficit, mm		500	450	400	300	250
Humidification coefficient		0,25-0,45	0,35-0,55	0,45-0,70	0,75-0,95	
Maximum number of days with snow, days		30-35	15-35	10-20		
Number of days with stable snow cover, days		94-111	94-112	118-135	160-165	207-216
Effective moisture reserves in the 0-50 cm soil layer, mm	during autumn sowing	50-60	50-75			
	during spring sowing	33-90	100-110			

However, the study does not provide a statistical attribution of forest-cover change to individual climatic and anthropogenic drivers. The relationships identified should therefore be interpreted as spatially and historically supported associations rather than as direct causal estimates.

Results and Discussion

The formation and distribution of forest landscapes in the Lake Sevan basin are closely linked to the specific climatic conditions of the region (table 2).

Studies indicate a clear warming trend, with a gradual increase in mean annual air temperature [41, 42]. This trend has significant implications for forest productivity, spatial distribution and future reforestation strategies. However, the effects of warming should be interpreted together with precipitation variability, soil moisture, slope exposure, altitude and forest composition. Higher temperatures may extend the growing season at some elevations, but they may also increase evapotranspiration and water stress, particularly in the lower and drier parts of the basin. Consequently, climatic warming may produce contrasting effects depending on local environmental conditions and the ecological requirements of individual tree species [10, 36]. The basin receives between 400 and 450 mm of precipitation during the growing season and between 800 and 900 mm annually. The humidity coefficient varies from 0.25 to 0.95, while the annual evaporation deficit ranges from 250 to 500 mm.

Research shows that forest landscapes have little or no influence on regional ice conditions [44].

Historically, forest cover in the basin was much greater, as demonstrated by archaeological, pollen, and palaeoecological evidence [31, 32]. During different historical periods, the coastal zones of Lake Sevan were densely populated, and deforestation was mainly driven by anthropogenic pressure. Similar long-term reductions in forest cover have also been recorded in other parts of Armenia, such as the Tavush region, where continuous human impact combined with progressive climatic aridification has reduced forested area to about 51 % of its former extent [45].

These historical trajectories demonstrate that present-day forest patterns are the result of interacting social and ecological processes. Current forest vulnerability is therefore partly inherited from previous periods of intensive resource use, which reduced stand density, simplified forest structure and weakened natural regeneration. Climate change may act as an additional pressure on forests that are already structurally degraded and fragmented.

According to Grigoryan [2], the Sevan basin is considered the poorest in terms of forest mass (Fig. 1). The eastern oak (*Quercus spp.*) is the

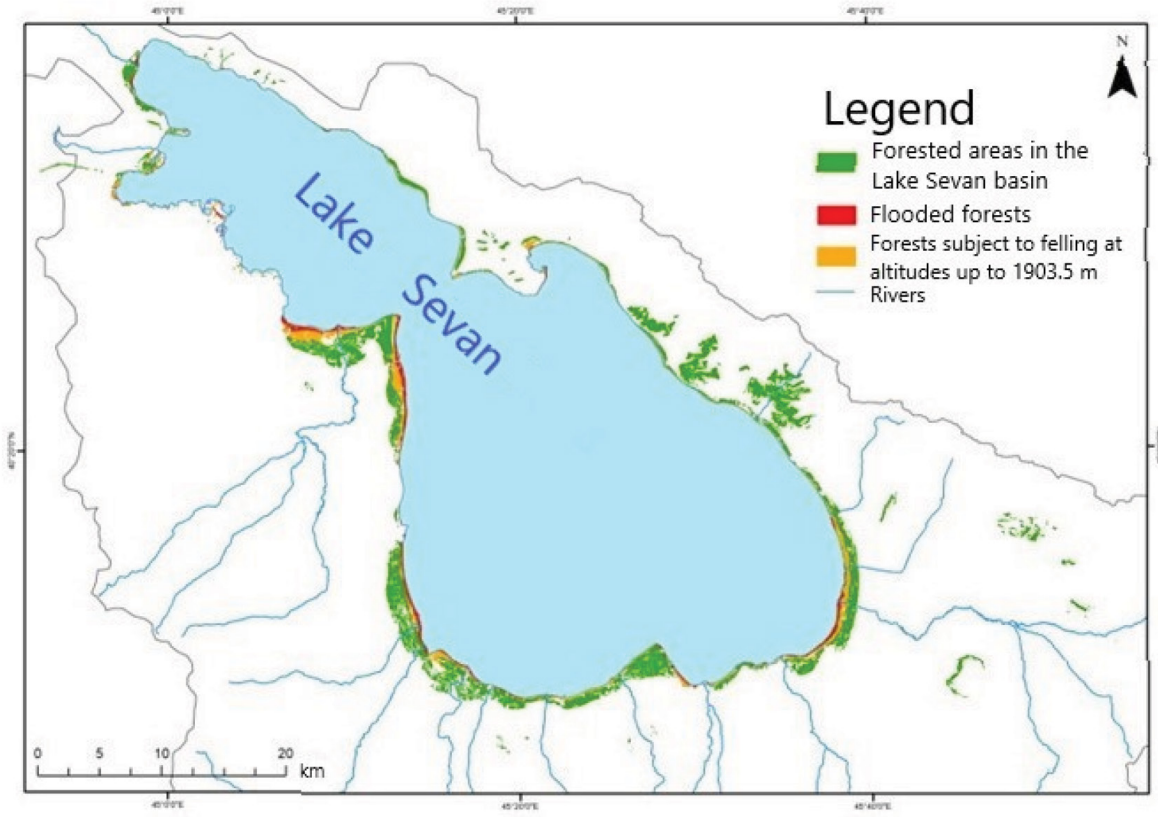

Fig. 1. Forested areas in the Lake Sevan basin (current situation) [14, 32]

most widespread species, valued for its durable and high-quality wood. Caucasian pine (Pinus caucasica) predominates in the low-growing forests on the former lakebed and is widely used in green-construction projects. Other species, such as broad-leaved maple (*Acer platanoides*), birch (Betula spp.), and elliptic-leaved willow (*Salix spp.*) are also present, although some provide low-value timber with limited industrial use.

The forests of the Lake Sevan basin are currently under strong anthropogenic pressure, including recreational overuse, grazing, and unregulated logging, which have severely degraded the forest fund of the Sevan National Park [**25, 31**]. Table 3 presents the number of tree and shrub species in Armenia and within the Sevan basin [**2**], confirming its comparatively low floristic diversity.

The cumulative character of these pressures is particularly relevant. Grazing can limit seedling establishment, logging can simplify stand structure, recreational use can compact soils, and fragmentation can reduce ecological connectivity. When these processes occur simultaneously, they may lower forest resilience and increase the time required for natural recovery following drought, pest outbreaks or other disturbances [46].

Widespread illegal logging peaked during the 1990s, particularly in the Martuni and Gavar sectors of the national park, where about 500 hectares of forest were lost. This uncontrolled exploitation significantly reduced stand density and hindered the natural regeneration capacity of forest ecosystems.

In addition, the forests are increasingly affected by insect pests, mainly belonging to the class Insecta (arthropods), which attack roots, leaves, fruits, and seeds. In recent years, extensive pine dieback has been observed, causing the drying of large forest tracts. Since aerial chemical control measures have proven ineffective and ecologically harmful, alternative restoration strategies are recommended.

Restoration planning should not be based solely on the identification of fast-growing or drought-tolerant species. It should also consider ecological suitability, provenance, genetic diversity, potential invasiveness, compatibility

Table 3

Number of tree and shrub species in Armenia by forest massif [2]

Forests	Number of species	Including			From whom		
		trees	shrubs	wraps	evergreens	conifers	deciduous species
Sevan Basin	82	26	56	–	2	5	75
Armenia	262	110	146	6	6	7	249

with local habitats and the future climatic conditions expected at different elevations and slope exposures. Priority should be given to native species and to the reinforcement of natural regeneration wherever ecological conditions make this possible [12].

We propose the use of more climate-resilient tree species in new afforestation programs, such as poplar (Populus deltoides), ash (Fraxinus excelsior), birch (Betula spp.), and high-mountain maple (Acer ibericum); and among shrubs, viburnum (Viburnum lantana), currant (Ribes orientalis), gooseberry (Ribes uva-crispa), and Caucasian honeysuckle (Lonicera iberica). Special attention should be given to the restoration of native juniper (Juniperus polycarpos) and oak (Quercus macranthera) forests, which formerly dominated the slopes of the Sevan range. Junipers prefer arid, south-facing slopes, whereas oaks thrive on the moister, north-facing ones. In many places, former oak forests have degenerated into shrublands, with 6–9 shoots emerging from a single stump as a result of intensive felling during the 1990s. Implementing stump-shoot thinning and selective restoration [**47**] could help recover a healthy forest structure. The main part of the activities carried out to combat forest diseases and damage falls on aerial chemical control, which in many cases is destructive for the existence of some forest animal species.

A diversified restoration strategy would increase structural and functional heterogeneity and reduce dependence on uniform plantations. Mixed stands containing species with complementary ecological traits are generally better positioned to maintain multiple ecosystem functions under changing environmental conditions than simplified, even-aged plantations. Restoration should therefore combine assisted natural regeneration, selective thinning, enrichment planting and the protection of regenerating stands from excessive grazing [8, 12].

The Lake Sevan basin forests are characterized by low productivity and limited industrial importance [26]. The maximum forest cover occurred in the mid-1980s, when plantations established during the 1960s–1970s matured and were incorporated into the forest belt, reaching about 14.5 thousand ha.

Most forests in the basin are artificial plantations created after the artificial lowering of the lake level in the mid-20th century. Extensive afforestation campaigns were implemented in the 1960s on newly exposed soils [32], using mainly poplar, willow, and pine species. Additional thickets of sea buckthorn (*Hippophae rhamnoides*) and yellow acacia (*Caragana arborescens*) also developed naturally. Since 2002, a general rising trend has been observed, resulting in the flooding of coastal forest stands and significant ecological impacts. Continuous inundation has created water-logged zones, leading to tree mortality and deterioration of water quality. Consequently, since 2005, clean-up operations have been periodically conducted in submerged forest areas to mitigate these effects.

The flooding of artificial shoreline plantations illustrates a complex management trade-off. The recovery of the lake's water level can contribute to aquatic ecosystem restoration, while simultaneously causing the loss of terrestrial forest stands established on formerly exposed lakebed. These areas should therefore not be interpreted only as forest loss, but as transition zones in which aquatic restoration, water quality, dead biomass removal, shoreline habitat development and landscape connectivity need to be managed jointly [37, 40, 48].

Studies predict that if the lake level reaches 1903.5 m, approximately 4 thousand hectares of forest would be inundated, requiring additional clearing and further disrupting the ecological balance of the basin. To date, about 1.6 thousand hectares of flooded forests have already been removed. Overall, due to the combined effects of illegal logging (since the 1990s) and state-authorized clearing of flooded forests (since the mid-2000s), the total forest area of the Lake Sevan basin has declined by around 2 thousand ha compared with its maximum in the 1980s, now covering approximately 12.5 thousand ha (Fig. 1). If the state clearing program continues up to the target water level of 1903.5 m, an additional 2.4 thousand ha may be lost in the coming years, further reducing the already fragile forest ecosystem of the basin.

From a Forest Landscape Restoration perspective, the objective should not be to maximize tree cover uniformly throughout the basin. Restoration priorities should vary according to landscape position and ecological function. On steep slopes and in river catchments, priority should be given to soil protection, erosion control and hydrological regulation. In degraded natural forests, management should promote regeneration, structural complexity and native species recovery. In shoreline areas affected by rising water levels, interventions should be coordinated with aquatic restoration objectives. Around settlements and recreational zones, restoration should also incorporate social use, fire prevention, environmental education and community participation [37, 40].

This differentiated approach would help reconcile forest conservation with water management, biodiversity protection and local development. It would also strengthen the capacity of the Lake Sevan landscape to absorb disturbance, reorganize and continue delivering

essential ecosystem services under future climatic and socioeconomic change [9, 46].

Conclusion

The study of the spatio-temporal dynamics of forest cover in the Lake Sevan basin demonstrates that changes in forest distribution result from the combined effects of climatic variability and long-term anthropogenic pressure. The identified patterns reveal significant spatial heterogeneity, with particularly vulnerable zones located along the steep slopes and coastal areas of the basin. These findings highlight the critical role of forests in maintaining ecosystem stability, supporting soil protection, water regulation, and biodiversity conservation in this fragile high-mountain environment. Over the past decades, deforestation driven by unregulated and illegal logging, as well as by the clearance of flooded forests, has led to a substantial reduction in forested area. However, forest degradation in the basin involves more than a decline in total area. It also includes the simplification of stand structure, limited natural regeneration, fragmentation, declining connectivity and the weakening of ecosystem functions.

To prevent further degradation and restore the ecological balance of the basin–especially under current climate change conditions–integrated restoration programs should be implemented [12, 37]. These programs should combine reforestation with native and climate-adapted species, continuous monitoring, and community-based participation and environmental education. Restoration should be planned at the landscape scale and adapted to the ecological functions of different parts of the basin rather than applying a uniform afforestation model [37, 40]. It is recommended that new forest plantations prioritize poplar (*Populus deltoides*), ash (*Fraxinus excelsior*), birch (Betula spp.), and high-mountain maple (Acer ibericum), while shrub species such as viburnum (*Viburnum lantana*), currant (*Ribes orientalis*), and Caucasian honeysuckle (*Lonicera iberica*) can enhance structural diversity and ecological resilience. In addition, stump-shoot restoration in degraded oak stands (*Quercus macranthera*) on the northern slopes of the Sevan range is essential to re-establish a healthy and self-sustaining forest structure. Nevertheless, species selection should be preceded by site-specific assessment and should prioritize native provenance, ecological compatibility and genetic diversity. Assisted natural regeneration should be preferred where viable, while planting should be concentrated in areas where natural recovery is unlikely [12].

The current forestry management system in the Lake Sevan basin requires substantial institutional and financial reform. Limited state funding forces management bodies to focus on short-term exploitation rather than on long-term forest recovery. A transition towards sustainable, ecosystem-based forest management, in accordance with the Forest Code of Armenia and international restoration principles [12, 35, 37], is therefore urgently needed. Such a transition requires coordination between forestry, water management, protected-area administration, agriculture and local authorities, because the main pressures and ecological effects extend across sectoral and administrative boundaries.

Finally, forest conservation and restoration should be recognized as a national and regional priority, aligned with Armenia's commitments under global environmental frameworks. Strengthening forest resilience in the Lake Sevan basin would not only protect forest resources but also contribute to water security, erosion control, biodiversity conservation and adaptation to climate change [9, 46, 48]. The basin could therefore become a model for integrated Forest Landscape Restoration in other mountain regions of the South Caucasus [37, 40].

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Антропогенні зміни в лісових ландшафтах басейну озера Севан під впливом зміни клімату

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АНОТАЦІЯ

У статті аналізується просторово-часова динаміка лісових ландшафтів у басейні озера Севан. Цей район є одним із найменш заліснених регіонів Вірменії; його ліси характеризуються низькою продуктивністю та обмеженим промисловим значенням. Значна частина лісів (12,5 тис. га) має штучне походження, тоді як природні ліси (близько 3,0 тис. га) зосереджені переважно на крутих схилах хребтів Арегуні та Севан, де переважають дубові та ялівцеві угруповання. Ліси регулюють клімат шляхом накопичення та секвестрації вуглецю, підтримують біорізноманіття, забезпечують гідрологічне регулювання, стабільність ґрунтів, зменшують ризики природних небезпек і сприяють добробуту населення. У басейні озера Севан деградація лісів впливає не лише на деревний покрив, а й на гідрологічне регулювання, стабільність ґрунтів, екологічні зв›язки, біорізноманіття та екологічний стан озера. Мета дослідження – проаналізувати та оцінити закономірності антропогенних змін у лісових ландшафтах басейну озера Севан в умовах сучасної зміни клімату. Об›єктом дослідження є лісові ландшафти басейну озера Севан, предметом – динаміка лісового покриву та пов'язані з нею екологічні ризики. Дослідження базувалося на поєднанні польових спостережень, просторового аналізу та опрацювання опублікованих і відомчих джерел. Застосовано географічно-порівняльний підхід, що поєднав картографічний і статистичний аналіз, порівняння історичних та сучасних лісових карт, оцінку динаміки лісового покриву й визначення територій, найбільш уражених антропогенним тиском. Польові обстеження дали змогу перевірити результати дистанційних і картографічних досліджень. Додаткові дані отримано від Державного комітету лісового господарства, Кадастрового комітету, Міністерства навколишнього середовища Республіки Вірменія, Гегаркунікської регіональної адміністрації та міжнародних екологічних організацій. Встановлено, що історично рівень заліснення регіону був значно вищим, однак істотно знизився під впливом тривалого антропогенного тиску. Вирубування лісів триває через незаконні та нерегульовані рубки, а також втрату затоплених лісових ділянок унаслідок коливань рівня води в озері. Ці процеси загрожують екологічній рівновазі басейну та підтверджують, що сучасні зміни у розподілі лісів є результатом поєднаного впливу кліматичної мінливості й довготривалого антропогенного навантаження, що потребує комплексних заходів із відновлення та збереження лісових і водних екосистем.

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Вірменія, басейн озера Севан, динаміка лісу, просторово-часові моделі, антропогенні зміни, льодові явища, вирубка лісів, екологічний баланс, відновлення лісового ландшафту, екосистемні послуги, екологічна стійкість.