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AI-BASED SPATIAL ANALYSIS OF FOREST RESOURCES IN THE KARABAKH ECONOMIC REGION IN AZERBAIJAN

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Abstract: *The primary aim of this study is to assess the spatial distribution of forest resources in the Karabakh Economic Region using AI-assisted geospatial analysis and to evaluate the implications of identified spatial disparities for sustainable regional development and forest resource management. The paper investigates the spatial distribution of forest resources in the Karabakh Economic Region of Azerbaijan using AI-based geospatial analysis. The study highlights significant regional disparities in forest coverage, with the total forest area in the region amounting to 139,495.34 hectares, of which 34,616 hectares (24.82%) were directly studied. The overall forest coverage in the region is 13.96%, which is 1.46-2.46 percentage points higher than the national average. The analysis reveals that districts such as Aghdara (43.47%), Khojavand (25.79%), and Khojali (22.78%) have substantial forest resources, while districts like Aghjabadi, Aghdam, Barda, Fuzuli, and Tartar contribute only 2.5% of the region's total forest cover. These findings underline the need for targeted interventions to address the uneven distribution of forest resources, promoting balanced and sustainable development across the region. The study employs open-spatial data extracted via Overpass Turbo, combined with Artificial Intelligence (AI)-assisted spatial processing and Geographical Information Systems (GIS)-based area calculations. The study contributes to sustainability-oriented decision-making by demonstrating how open data and artificial intelligence can support balanced environmental and socio-economic development.*

Keywords: *AI-based geospatial analysis, forest resource management, Karabakh Economic Region, Spatial distribution, Sustainability and regional development*

1 Introduction

1.1 Background and Context

The Karabakh Economic Region, located in the western part of Azerbaijan, has faced significant ecological and socio-economic challenges due to the impact of conflict efforts. This region, which is rich in biodiversity and natural resources, has witnessed severe disturbances in its ecosystem, particularly in forest resources. Forests, which play a crucial role in maintaining ecological balance, supporting biodiversity, and providing livelihoods to local communities, have been adversely affected by land-use changes, deforestation, and other anthropogenic activities exacerbated by the conflict. The restoration and sustainable management of these forests have thus become a key focus in the region's recovery process.

In the context of Azerbaijan, forests represent not only an ecological asset but also a significant socio-economic resource. They provide essential ecosystem services, such as carbon sequestration, water regulation, and soil protection, all of which contribute to the sustainability of the region's agricultural systems and broader environmental health *(Ali et al., 2025)*. However, the uneven distribution of forest resources, often influenced by topography, historical land use patterns, and human activities, has created regional imbalances in forest coverage. Some districts benefit from a higher concentration of forest areas, while others suffer from degraded or fragmented landscapes. Addressing these disparities is essential for creating a more balanced and sustainable regional development strategy.

Geospatial analysis, particularly when combined with artificial intelligence (AI) techniques, offers a promising approach for tackling the complexities of forest resource management in this post-conflict context. AI-based spatial analysis can process large-scale open geospatial data, providing an efficient way to map and analyze the distribution of forest resources, assess their condition, and identify areas requiring restoration or protection (*Sayginer & Nurlu, 2025)*. These methods also offer the advantage of revealing spatial patterns that may not be easily identifiable through traditional approaches, making them invaluable tools for informed decision-making in environmental management.

The integration of AI-driven tools into spatial analysis is especially relevant in regions like Karabakh, where accurate data on forest cover may be scarce or fragmented. By leveraging open data sources, such as those provided by Overpass Turbo, and using advanced AI algorithms to analyse these data, researchers can gain insights into the spatial distribution of forest resources at both regional and district levels *(Overpass Turbo, 2026)*. This can help identify areas of ecological vulnerability, uncover patterns of forest loss or degradation, and guide the allocation of resources for reforestation and conservation efforts *(Bayramov & Pashayeva, 2024)*.

The use of geospatial tools in post-conflict recovery and regional planning can provide crucial support in ensuring that environmental management strategies align with broader goals of sustainable development *(Yadav, Verma, 2026)*. In Karabakh, this approach not only supports the restoration of the natural environment but also contributes to the social and economic resilience of the local communities. The findings of this study will highlight the role of AI-based spatial tools in promoting a balanced, data-driven approach to forest management, offering valuable lessons for similar post-conflict regions around the world.

1.2 Research Problem and Objectives

The Karabakh Economic Region, once rich in forest resources, has experienced significant ecological degradation, particularly due to the adverse effects of conflict and subsequent land-use changes. This degradation has resulted in substantial imbalances in the spatial distribution of forest resources, with certain districts having abundant forest cover while others face significant challenges related to deforestation and land fragmentation. These disparities not only hinder the region's environmental recovery but also threaten the sustainability of its socio-economic systems, including agriculture, local livelihoods, and biodiversity conservation efforts *(Shivaprakash et al., 2022)*.

The lack of comprehensive, high-resolution spatial data on forest distribution in Karabakh further complicates the task of managing and restoring these vital resources. While there have been efforts to restore forest cover in some areas, the absence of a detailed, data-driven understanding of forest resources at both regional and district levels has hampered effective planning and policy formulation. Traditional methods of forest monitoring, relying on limited field surveys and outdated data, fail to capture the dynamic nature of forest distribution and land-use changes in the region *(Alisoy, 2022)*.

This research seeks to address the critical gap in knowledge about the spatial distribution and sustainability of forest resources in the Karabakh Economic Region by employing AI-based geospatial analysis. By leveraging open geospatial data and advanced AI algorithms, this study aims to provide a detailed, spatially explicit analysis of forest cover in the region, identifying key patterns and imbalances that have emerged in the post-conflict context. The research also aims to assess the role of forest resources in supporting sustainable regional development, focusing on how disparities in forest coverage can influence local livelihoods, biodiversity conservation, and regional resilience. *(Giri et al., 2005)*

The objectives of this study are as follows:

- To assess the spatial distribution of forest resources across the Karabakh Economic Region and identify major patterns of forest cover at both regional and district levels.
- To evaluate the inter-district disparities in forest provision and examine the influence of topographical and land-use on the observed spatial distribution of forest resources.
- To analyze the implications of spatial inequalities in forest resources for sustainable environmental management and regional development in the post-conflict Karabakh region.
- To demonstrate the applicability of AI-assisted geospatial analysis methods mapping, monitoring, and evaluating forest resources in support of evidence-based regional planning.
- To formulate recommendations for sustainable forest resource management based on the identified spatial patterns and disparities.

By addressing these objectives, this research aims to contribute valuable insights into the restoration and sustainable management of forest resources in post-conflict regions, offering lessons that can be applied to similar contexts worldwide.

1.3 Research Questions

The primary aim of this study is to explore the spatial distribution of forest resources in the Karabakh Economic Region and the implications of these patterns for sustainable development. To achieve this, several research questions have been formulated to guide the investigation and ensure comprehensive analysis. These questions are designed to address both the ecological and socio-economic dimensions of forest resource management in the region, with a particular focus on the role of AI-based geospatial analysis. The key research questions are as follows:

1. *How are forest resources spatially distributed across the Karabakh Economic Region at regional and district levels?*

This question seeks to map the spatial distribution of forest resources at both the regional and district levels, identifying areas with high and low forest coverage. The analysis will help uncover patterns of forest fragmentation and concentration, providing insights into the overall state of forest resources in the region.

2. *What inter-district disparities exist in forest provision, and what topographical and land-use factors contribute to these differences?*

This question aims to identify and understand the differences in forest coverage between districts, considering factors such as topography, land-use patterns, and historical land management practices. It will explore why some districts have better access to forest resources than others and how these disparities affect regional development.

3. *What are the implications of spatial inequalities in forest resources for sustainable environmental management and regional development in post-conflict Karabakh region?*

This question focuses on the environmental factors that shape forest distribution, such as elevation, slopes, and land-use practices (e.g., agriculture, urbanization). Understanding these relationships will provide critical insights into the natural and anthropogenic drivers of forest imbalances in the Karabakh region.

4. *How can AI-assisted geospatial analysis support the assessment and monitoring of forest resources for evidence-based planning and management?*

This question evaluates the effectiveness of AI-driven spatial tools in forest monitoring and management. It will assess how these tools can contribute to more precise, evidence-based decision-making in forest restoration, conservation, and sustainable development planning. It will explore how forest resources can help restore ecological balance, support local livelihoods,

and enhance socio-economic resilience in the post-conflict recovery phase (*Nagiyev & Bayramov, 2026)*.

5. *What are the implications of spatial imbalances in forest resources for the long-term sustainability and resilience of the Karabakh region?*

This question explores the broader implications of the identified disparities in forest distribution for the region's socio-economic development and environmental management. It will help to determine how these imbalances might influence future planning efforts and regional recovery initiatives.

2 Methods

2.1 Data Collection

The data collection for this study primarily focuses on acquiring open geospatial data to facilitate the analysis of forest resources in the Karabakh Economic Region. Due to challenges in obtaining traditional ground-based data, particularly in post-conflict areas, the study leverages publicly accessible datasets and remote sensing technologies. This ensures the use of current, reliable data for spatial analysis (*Belgiu & Drăguţ, 2016)*.

Open geospatial data was gathered using Overpass Turbo, a tool that queries OpenStreetMap (OSM) data. The data extracted includes information on land cover, forest areas, protected regions, and other relevant features such as the extent of forest cover, areas designated as protected (e.g., national parks or state reserves), and human-impacted land use patterns *(Liu, Xia, 2016)*. These datasets are valuable for analyzing forest distribution patterns and understanding human impacts on forest resources, particularly in regions affected by conflict.

Administrative boundaries data for the Karabakh Economic Region and its districts were sourced from publicly available datasets, providing the necessary geographic framework to analyses forest coverage and disparities at both the regional and district levels. This boundary data aligns with the local governance structures, which are crucial for making informed decisions on resource management.

Topographic data, including elevation, was sourced from global datasets such as Shuttle Radar Topography Mission (SRTM) data (*SRTM, 2026*). This was essential for understanding how physical features like elevation and slope influence forest distribution in the region. Such data helps determine areas that are conducive to forest growth, further aiding in the analysis of spatial patterns in forest coverage.

Land cover and land use data were also incorporated, sourced from global platforms like the European Space Agency's Copernicus Land Monitoring Service and the Global Land Cover database (*European Space Agency, 2026*). This data helps provide context for forest distribution, enabling the study to understand the broader landscape in which forests are located, including areas undergoing agricultural expansion or urbanization that could affect forest coverage *(Alisoy, 2022)*.

By integrating these diverse data sources, the study provides a comprehensive spatial analysis of forest resources in the Karabakh Economic Region. The combination of open data, AI-driven analysis, and satellite imagery allows for a thorough, evidence-based understanding of forest distribution patterns, offering valuable insights into sustainable forest management and post-conflict regional planning (*Wang et al., 2025, Wen et al., 2025)*.

2.2 Spatial Analysis and Calculations

The analytical framework of this study consisted of five consecutive stages: data preparation, spatial integration, forest identification and classification, quantitative spatial analysis, and cartographic interpretation.

In the first stage, all collected geospatial datasets were improved into the GIS environment (QGis). Administrative boundaries, forest polygons, land-use layers, and topographic datasets were transformed into a common coordinate reference system to ensure spatial compatibility and eliminate geometric inconsistencies. Data cleaning procedures were applied to remove duplicate records, incomplete polygons, and topological errors.

The second stage involved the integration of forest-cover information with administrative boundaries of the Karabakh Economic Region. Using GIS overlay operations, forest polygons were intersected with district boundaries, enabling the calculation of forest area indictors for each administrative unit. The procedure allowed the determination of both absolute forest area (ha) and relative forest coverage (%).

During the third stage, AI-assisted classification procedures were applied to support the identification of and categorization of forest resources. AI-supported pattern recognition and spatial clustering techniques were used to distinguish forest areas from other land-cover categories and to identify individual forest massifs. As a result, 81 forest areas were identified and classified according to their spatial characteristics and geographical location. The classification results were subsequently verified through GIS-based visual inspection and cross-referencing with available datasets.

The fourth stage focused on quantitative spatial analysis. Forest area was calculated for each identified forest massif and administrative district. Comparative indicators were generated to assess the proportion of forest resources within individual districts and across the entire Karabakh Economic Region. To evaluate territorial disparities, descriptive statistical measures and proportional distribution analysis were applied, allowing the identification of districts with high and low levels of forest provision.

The final stage involved cartographic visualization and spatial interpretation. The results were represented through thematic map and statistical table illustrating the geographical distribution of forest resources. Attention was given to identifying relationships between forest distribution and geographical conditions. The spatial patterns revealed by the analysis were subsequently interpreted in the context of sustainable forest management, environmental planning, and post-conflict regional development.

2.3 AI-Assisted Analytical Framework and Disclosure of AI Use

Artificial Intelligence (AI)-assisted analytical approaches were employed in this study to enhance the efficiency and accuracy of spatial data processing and classification. The research combined Geographic Information Systems (GIS) and AI-supported analytical techniques to identify and classify forest resources within the Karabakh Economic Region.

AI-based tools were used during several stages of the research process, including the processing of spatial datasets, identification of forest areas, classification of land-cover characteristics, and detection of spatial patterns. These procedures facilitate the analysis of large volumes of geospatial information and support the identification of inter-district disparities in forest resource distribution.

The role of AI in this study was limited to analytical support and data-processing assistance. AI tools were not used to make scientific judgements, formulate conclusions, or independently interpret research findings. To ensure academic transparency and research integrity, all final assessments, interpretations, calculations, cartographic outputs, and policy recommendations presented in this paper remain the sole responsibility of the author. The use of AI-assisted methods served exclusively as a supplementary analytical instrument intended to improve the efficiency, consistency, and reproducibility of the spatial analysis conducted within the study.

3 Results

3.1 Forest Coverage and Spatial Distribution

As a result of the AI-assisted spatial analysis, numerous forest areas of varying sizes were identified across the Karabakh Economic Region. The total number of identified forest areas across ten administrative units (nine districts and one city territory) amounts to 81. Information on their area and regional distribution is presented in Table 1.

Table 1. Distribution and Proportional Analysis of Forest Resources Across the Karabakh Economic Region

№	Administrative Unit (District / City)	Forest Name	Type of Forest Resource	Forest Area (ha)	Share of Forest Area, %			
					Within the studied forests of the administrative unit	Within the total forest areas of the administrative unit	Within the total area of the administrative unit	Within the total forests areas of the Karabakh Economic Region
1.	Khankandi city (Total Forest Areas: 321,45 ha)	Alchag	Forest	6,3	2,73	1,96	0,06	0,00
2.		Findigli (Hazelnut)		12,3	5,33	3,83	0,12	0,01
3.		Judur		8,1	3,51	2,52	0,08	0,01
4.		Khirmanli		103,0	44,67	32,04	1,03	0,07
5.		Yavarli		32,0	13,88	9,95	0,32	0,02
6.		Yeskhirman		10,1	4,38	3,14	0,10	0,01
7.		Afatli	Valley	25,5	11,06	7,93	0,26	0,02
8.		Girkhan		5,4	2,34	1,68	0,05	0,00
9.		Sajjahan		2,7	1,17	0,84	0,03	0,00
10.		Sayali		9,8	4,25	3,05	0,10	0,01
11.		Tut (Mulberry)		11,6	5,03	3,61	0,12	0,01
12.		Zadaganlar		1,2	0,52	0,37	0,01	0,00
13.		Tut (Mulberry)	Orchards	1,0	0,43	0,31	0,01	0,00
14.		Mirzahasan	Slope	1,6	0,69	0,50	0,02	0,00
Total by Administrative Unit				***230,6***	***100,00***	***71,74***	***2,31***	***0,23***
*	Aghjabadi district (Total Forest Areas: 485,3 ha)	n/a	–	0	0	0	0,28	0,35
Total by Administrative Unit				***0***	***0***	***0***	***0,28***	***0,35***
15.	Aghdam district (Total Forest Areas: 804,43 ha)	Soltanbud	Forest	571,0	100,00	70,98	0,52	0,41
Total by Administrative Unit				***571,0***	***100,0***	***70,98***	***0,52***	***0,58***
16.	Aghdara district	Aghbat	Forest	730,0	4,44	1,20	0,44	0,52
17.		Aghvang		136,0	0,83	0,22	0,08	0,10
18.		Amakomadara		719,0	4,38	1,19	0,43	0,52

19.	(Total Forest Areas: 60645,12 ha)	Barambat		3620,0	22,03	5,97	2,18	2,60
20.		Bayat		2800,0	17,04	4,62	1,69	2,01
21.		Daliklar		87,8	0,53	0,14	0,05	0,06
22.		Khalazan		298,0	1,81	0,49	0,18	0,21
23.		Khicik Gafgaz (Lesser Caucasus)		1260,0	7,67	2,08	0,76	0,90
24.		Oruk		6700,0	40,78	11,05	4,04	4,80
25.		Khazandara	Valley	78,8	0,48	0,13	0,05	0,06
		Total by Administrative Unit		***16429,6***	***100,00***	***27,09***	***9,90***	***43,47***
*	Barda district (Total Forest Areas: 1103,64 ha)	n/a	–	0	0	0	1,16	0,79
		Total by Administrative Unit		***0***	***0***	***0***	***1,16***	***0,79***
*	Fuzuli district (Total Forest Areas: 500,15 ha)	n/a	–	0	0	0	0,36	0,36
		Total by Administrative Unit		***0***	***0***	***0***	***0,36***	***0,36***
26.	Khojaly district (Total Forest Areas: 31781,23 ha)	Arkhashan	Forest	5,6	0,04	0,02	0,01	0,00
27.		Baghlar		6,2	0,05	0,02	0,01	0,00
28.		Daghdoshu		131,0	1,01	0,41	0,14	0,09
29.		Daghlig (Mountainous)		5850,0	45,11	18,41	6,29	4,19
30.		Darili		77,5	0,60	0,24	0,08	0,06
31.		Goruglu		47,2	0,36	0,15	0,05	0,03
32.		Gushtshubaba		89,2	0,69	0,28	0,10	0,06
33.		Injadara		1920,0	14,81	6,04	2,06	1,38
34.		Kapanak (Butterfly)		40,3	0,31	0,13	0,04	0,03
35.		Khanzada		39,5	0,30	0,12	0,04	0,03
36.		Kheykhali		84,6	0,65	0,27	0,09	0,06
37.		Kohnadara		88,9	0,69	0,28	0,10	0,06
38.		Naragif		545,0	4,20	1,71	0,59	0,39
39.		Otgishlag		428,0	3,30	1,35	0,46	0,31
40.		Saribayli		72,2	0,56	0,23	0,08	0,05
41.		Tarifdash		2020,0	15,58	6,36	2,17	1,45
42.		Topkhana		164,0	1,26	0,52	0,18	0,12
43.		Tukhangaya		43,0	0,33	0,14	0,05	0,03
44.		Yal		32,0	0,25	0,10	0,03	0,02
45.		Aghaverdi	Valley	1,7	0,01	0,01	0,00	0,00
46.		Avazushaghi		15,5	0,12	0,05	0,02	0,01
47.		Behzad		126,0	0,97	0,40	0,14	0,09
48.		Dayirmandara		34,7	0,27	0,11	0,04	0,02
49.		Gamishdara		1,5	0,01	0,00	0,00	0,00
50.		Ganlidara		3,8	0,03	0,01	0,00	0,00
51.		Garaghatdara		16,3	0,13	0,05	0,02	0,01
52.		Garar		18,8	0,14	0,06	0,02	0,01
53.		Garayli		29,7	0,23	0,09	0,03	0,02
54.		Girkhlar		639,0	4,93	2,01	0,69	0,46
55.		Hajiyurdu		3,9	0,03	0,01	0,00	0,00
56.		Jajali		6,2	0,05	0,02	0,01	0,00
57.		Jayir		56,0	0,43	0,18	0,06	0,04
58.		Mohajara		4,7	0,04	0,01	0,01	0,00
59.		Rahbar		30,5	0,24	0,10	0,03	0,02
60.		Shostan		13,8	0,11	0,04	0,01	0,01
61.		Sutshular		11,7	0,09	0,04	0,01	0,01

62.		Umurlu		13,7	0,11	0,04	0,01	0,01
63.		Kusa	Slope	8,3	0,06	0,03	0,01	0,01
64.		Mikhtokan		239,0	1,84	0,75	0,26	0,17
65.		Boyurtkanlik (Blackberry plants)	Plantation	6,4	0,05	0,02	0,01	0,00
66.		Narlig (Pomegranate plants)		1,8	0,01	0,01	0,00	0,00
Total by Administrative Unit				***12967,2***	***100,00***	***40,80***	***13,94***	***22,78***
67.	Khojavand district (Total Forest Areas: 35974,4 ha)	Aghoghlan	Forest	26,3	0,87	0,07	0,02	0,02
68.		Ayiboghan		393,0	13,05	1,09	0,26	0,28
69.		Bala Gorug		2,8	0,09	0,01	0,00	0,00
70.		Daraakhulu		59,3	1,97	0,16	0,04	0,04
71.		Gulbaz		123,0	4,08	0,34	0,08	0,09
72.		Khan Arkhi		5,1	0,17	0,01	0,00	0,00
73.		Khirdapara		190,0	6,31	0,53	0,13	0,14
74.		Kondalan		290,0	9,63	0,81	0,19	0,21
75.		Soyugash Arkhi		153,0	5,08	0,43	0,10	0,11
76.		Yashilatir		35,7	1,19	0,10	0,02	0,03
77.		Zoghallig		74,6	2,48	0,21	0,05	0,05
78.		Haband	Valley	1640,0	54,46	4,56	1,09	1,18
79.		Vang		18,5	0,61	0,05	0,01	0,01
Total by Administrative Unit				***3011,3***	***100,00***	***8,37***	***1,99***	***25,79***
80.	Shusha district (Total Forest Areas: 7278,52 ha)	Maralgachan	Forest	1320,0	100,00	18,14	4,55	0,95
Total by Administrative Unit				***1320,0***	***100,00***	***18,14***	***4,55***	***5,22***
81.	Tartar district (Total Forest Areas: 601,1 ha)	Evoglu	Forest	86,3	100,00	14,36	0,21	0,06
Total by Administrative Unit				***86,3***	***100,00***	***14,36***	***0,21***	***0,43***
Total by Karabakh Economic Region				**34616,0**	**100,00**	***24,82***	**3,47**	***13,96***

Source: Compiled by the author based on AI-assisted geospatial analysis of Overpass-Turbo, OpenStreetMap spatial datasets, and GIS-based calculations conducted within the QGIS environment.

In addition to these identified areas, the study also revealed the presence of numerous unnamed and large-scale forest massifs within the research area, indicating that the actual forest coverage may be even more extensive than documented. As shown in Table 1, the total forest area calculated within the framework of this study in the Karabakh Economic Region is 139,495.34 ha. Of this, 34,616 ha (24.82%) are directly studied forests, which are primarily located in the districts of Aghdara, Khojali, and Khojavand. For each of these forests, data on area and forest type were determined and classified. The study found that the forest coverage in the Karabakh Economic Region constitutes 13.96%. This figure is 1.46-2.46 percentage points higher than the national average, but it remains insufficient for industrial use of forests. The districts of Aghjabadi, Aghdam, Barda, Fuzuli, and Tartar are the least endowed with forest resources. The total forest area in these districts is up to 3,500 hectares, accounting for only 2.5% of the overall regional forest cover. On the other hand, the districts rich in forest resources are Aghdara (43.47%), Khojavand (25.79%), and Khojali (22.78%).

3.2 Inter-District Disparities

The analysis of inter-district disparities in forest resources, as shown in Table 1, reveals significant differences in the distribution and proportion of forest cover across the Karabakh

Economic Region. Some districts, such as Khojavand and Aghdara, have a notably high proportion of forest area relative to their total territory. This is driven by the presence of extensive forests like Ayiboghan and Haband Valley, which make Khojavand a key district for ecological management and conservation. Similarly, Aghdara, with a forest coverage of 43.47%, houses some of the region's largest forest areas, such as Oruk and Barambat, positioning it as an important district for sustainable forest management and reforestation initiatives.

In contrast, Shusha, although home to significant forest areas like Maralgachan, contributes only 5.22% of the total forest cover in the region, highlighting a less extensive forest resource base. Districts like Tartar, with 0.43% of the total forest area, and Aghdam, with 0.58%, have limited forest coverage, indicating a clear need for intervention to address deforestation and enhance their forest resource base. Barda and Fuzuli, with minimal or absent forest areas, face the most significant deficits in forest resources and require urgent efforts for afforestation.

Additionally, Khojaly, although rich in forest resources overall, shows internal disparities with some areas like Arkhashan having very small forest areas compared to large expanses like Daghlig (Mountainous), indicating that even within relatively forest-rich districts, disparities exist. These findings underscore the need for targeted and balanced forest management strategies across the Karabakh Economic Region to address these disparities and promote sustainable environmental development throughout all districts.

3.3 Interpretation of Findings

The findings of this study, as illustrated by the spatial analysis of forest distribution in the Karabakh Economic Region, reveal both the extensive forest cover in some districts and the significant gaps in others. The high proportion of forest areas in districts like Aghdara and Khojavand reflects the potential for these areas to contribute significantly to regional ecological stability and biodiversity conservation. These districts, with their substantial forest areas, play a crucial role in supporting both local ecosystems and broader environmental health, providing a strong foundation for sustainable management initiatives. The forests in these districts are critical not only for conservation but also for supporting socio-economic activities such as tourism, agriculture, and carbon sequestration.

The findings are consistent with previous research highlighting the importance of topographical conditions in shaping forest distribution patterns. Alisoy (2022) demonstrated that forest landscapes in Azerbaijan are strongly influenced by elevation and terrain characteristics, while Giri et al. (2005) emphasized the relationship between land-cover dynamics and vegetation distribution. The present study confirms these observations within the Karabakh Economic Region. The results support broader understanding that mountainous environments provide more favorable conditions for forest preservation and expansion than lowland agricultural territories.

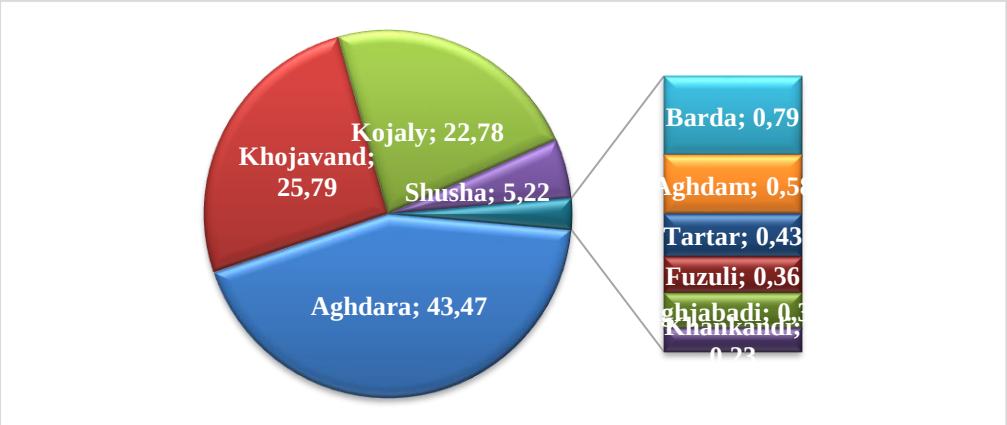
In fact, districts like Tartar, Aghdam, and Barda demonstrate much lower forest coverage, which poses challenges for regional sustainability. The scarcity of forest resources in these areas indicates potential ecological vulnerability, making them more susceptible to environmental degradation, soil erosion, and loss of biodiversity. The minimal forest cover in these districts also limits the ability to harness the ecosystem services that forests provide, such as regulating water cycles, preventing desertification, and offering habitats for wildlife. The disparities between districts highlight the need for targeted afforestation and reforestation efforts in these less forested areas to restore ecological balance and enhance resilience against climate change.

The substantial disparities identified between western mountainous districts and eastern lowland districts are also supported by findings in international literature. Studies by Lia and Xia (2016) and Belgiu and Drăgut (2016) demonstrate that land-use patterns and environmental conditions are among the most significant determinants of forest distribution.

The presence of large, relatively unfragmented forest areas in districts like Aghdara and Khojavand underscores the importance of maintaining and expanding these areas through sustainable practices. These districts represent a unique opportunity to preserve and strengthen forest ecosystems, as they contribute significantly to the region's overall forest cover. However, it is equally crucial to address the deficits in forest resources in other districts. The limited forest cover in Tartar and Aghdam, for example, emphasizes the necessity of promoting reforestation and forest protection measures to prevent further environmental degradation and support sustainable development.

Figure 1 compares the distribution of forest areas across the administrative districts of the Karabakh Economic Region.

Figure 1. Distribution of forest areas across the administrative districts of the Karabakh Economic Region



Source: Data obtained from the research findings.

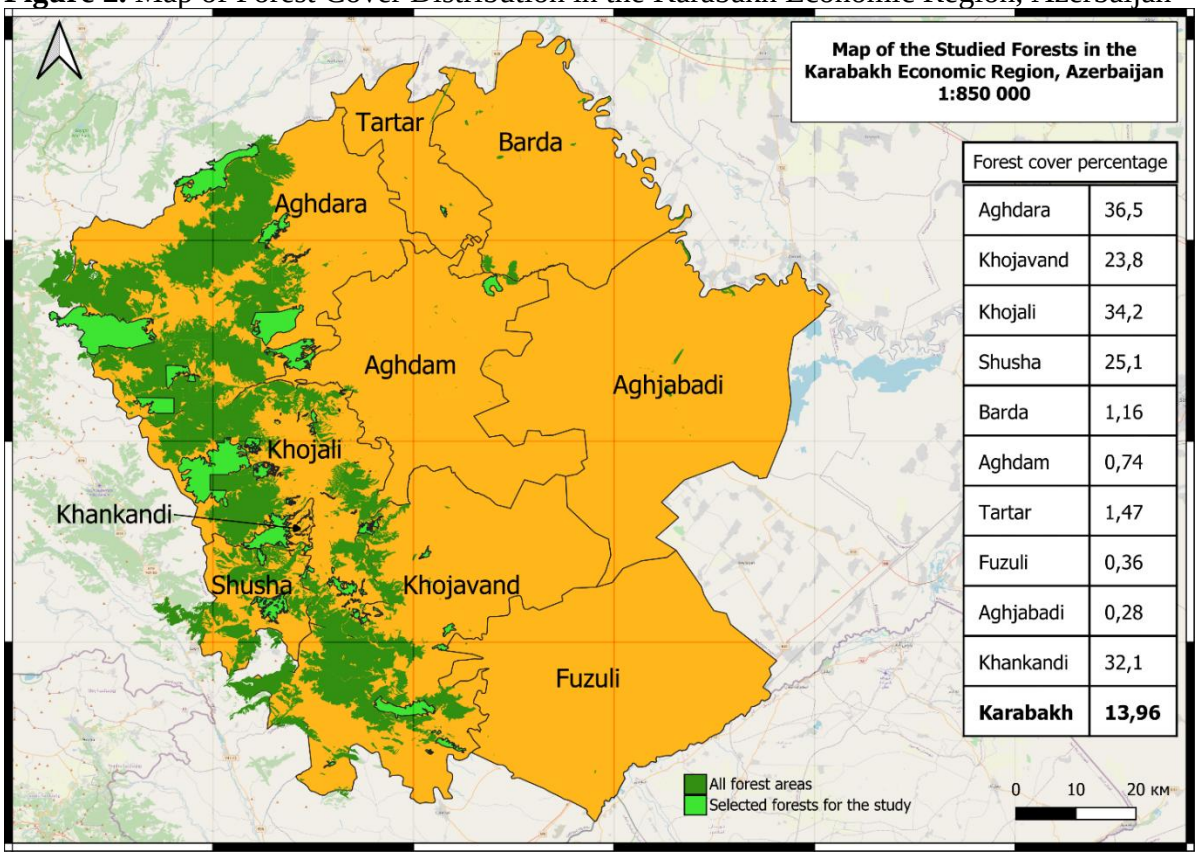
In summary, the findings suggest that while certain districts in the Karabakh Economic Region are well-endowed with forest resources, others face considerable challenges in maintaining adequate forest cover. These disparities provide a clear mandate for targeted policy interventions, including afforestation programs, improved forest management practices, and the promotion of sustainable land-use policies to ensure that all districts in the region benefit from the ecological, economic, and social advantages that forests provide. Addressing these inter-district disparities will be essential for fostering long-term environmental sustainability and promoting a more balanced approach to forest resource management across the region.

The findings also have broader implications for post-conflict recovery and territorial resilience in Karabakh. Nagiyev & Bayramov (2026) argue that sustainable reintegration and long-term regional recovery depend not only on socio-economic investments but also on the restoration of environmental assets and ecosystem functions. The results of the present study support this perspective by demonstrating that forest-rich districts possess stronger ecological foundations for sustainable development, while districts with limited forest resources may face additional challenges in achieving environmental stability and long-term resilience.

Consequently, reducing spatial inequalities in forest provision should be considered an important component of post-conflict regional development policy.

The map in Figure 2 illustrates the distribution of forest cover across the Karabakh Economic Region, highlighting the forest cover percentage for each administrative district.

Figure 2. Map of Forest Cover Distribution in the Karabakh Economic Region, Azerbaijan



Source: Source: Data obtained from the research findings.

The areas marked in green represent the forested regions, while the rest of the district is shown in orange. The greens represent all forest areas, while the light greens indicate the 81 forested areas selected for the study. Aghdara stands out with the highest forest cover at 36.5%, followed by Khojaly with 34.2%, and Shusha with 25.1%. Other districts such as Khojavand and Shusha have a relatively higher percentage compared to regions like Fuzuli and Aghjabadi, which have very low forest cover. The total forest cover for the entire Karabakh Economic Region is 13.96%. This data underlines significant regional disparities, with certain areas exhibiting substantial forest cover while others, particularly in the eastern districts, remain poorly forested. The map visually conveys these differences and highlights the need for targeted reforestation efforts in less forested areas.

4 Discussion

4.1 Discussion of Findings in Relation to Research Questions

The results of the AI-assisted spatial analysis reveal substantial differences in the distribution of forest resources across the Karabakh Economic Region and provide important insights into the environmental and developmental implications of these spatial patterns. The findings not only identify the geographical concentration of forest resources in specific districts but also highlight significant territorial disparities associated with topographical conditions, land-use structures, and post-conflict development processes. By integrating geospatial analysis with contemporary approaches to sustainable forest management, the study contributes to a better understanding of how forest resources can support ecological stability, territorial resilience, and evidence-based regional planning. The following discussion interprets the findings in relation to the research questions and compares them with the existing scientific literature.

The results of the study provide clear answers to the research questions formulated in this research and demonstrate value of AI-assisted geospatial analysis for understanding forest resource distribution in the Karabakh Economic Region.

The spatial analysis revealed a highly uneven distribution of forest resources throughout the region. A total of 81 identified forest areas with a combined area of 34 616 ha were analyzed. The overall forest cover of the Karabakh Economic Region was calculated at 13,96%. Forest resources are strongly concentrated in the mountainous western districts, particularly Aghdara (43,47% of the region's studied forest resources), Khojavand (25,79%), and Khojaly (22,78%). In contrast, eastern and lowland districts such as Aghjabadi, Aghdam, Barda, Fuzuli, and Tartar possess very limited forest resources. These findings confirm the existence of pronounced spatial concentration of forests within a relatively small number of districts.

The analysis identified substantial disparities in forest provision among districts. Forest-rich districts are predominantly located within mountainous landscapes associated with the Lesser Caucasus system, where environmental conditions favor forest development and preservation. Conversely, districts characterized by lowland terrain and intensive agricultural land use demonstrate considerably lower levels of forest cover. Historical land-use patterns and long-term agricultural utilization have further reduced forest resources in these territories. Therefore, topography and land-use structure emerge as principal factors explaining the observed inequalities in forest distribution across the region.

The identified disparities have important implications for environmental sustainability and regional development. Forest-rich districts provide critical ecosystem services, including biodiversity conservation, carbon sequestration, soil protection, and water regulation. These functions contribute directly to ecological stability and create opportunities for sustainable economic activities such as eco-tourism and nature-based development. In contrast, districts with limited forest resources face greater vulnerability to environmental degradation, land degradation processes, and reduced ecosystem resilience. Consequently, spatial imbalances in forest resources may contribute to unequal environmental and socio-economic development trajectories within the region unless targeted interventions are implemented.

The study demonstrates that AI-assisted geospatial analysis provides an effective framework for identifying, mapping, classifying and evaluating forest resources across large territories. The integration of spatial datasets and GIS-based analytical techniques enabled the precise localization and measurement of forest areas, as well as the identification of territorial disparities. These capabilities support evidence-based decision-making by providing planners and policymakers with reliable information for forest conservation, restoration, and regional development initiatives. The results indicate that AI-assisted spatial analysis can significantly improve the efficiency and accuracy of forest resource assessment in post-conflict territories where field-based data collection remains limited due to the ongoing demining of the territory and the unexploded ordnances (UXOs).

The findings suggest that future forest management policies should prioritize afforestation and reforestation programs in districts with limited resources. At the same time, existing forest-rich territories require strengthened conservation measures to preserve their ecological functions. Forest management strategies should be integrated with broader land-use planning frameworks and climate adaptation policies. The adoption of AI-supported monitoring systems, combined with field verification and community-based forest management approaches, would contribute to a more balanced and sustainable distribution of forest resources across the region.

4.2 Recommendations for Future Research and Policy

Future research and policy initiatives in the Karabakh Economic Region should focus on addressing the identified disparities in forest distribution and ensuring sustainable forest management across all districts. First, comprehensive field studies and data collection should be conducted to complement the existing geospatial analysis. While remote sensing and AI-based tools provide valuable insights, on-the-ground verification is essential for accurately assessing forest health, biodiversity, and specific restoration needs. These field surveys should focus on underrepresented districts, such as Tartar, Aghdam, and Barda, where forest resources are limited, to identify areas with the highest potential for restoration.

Policy efforts should prioritize the creation of a regional forest management strategy that considers the unique characteristics of each district. This strategy should include clear guidelines for afforestation and reforestation, with specific goals for increasing forest cover in areas with low forest resources. Incentives for landowners and local communities to participate in forest conservation and sustainable land use should be considered, alongside the development of community-based forest management programs. These programs would empower local stakeholders to play a more active role in forest protection and restoration while fostering economic opportunities through sustainable forest use, such as non-timber forest products, eco-tourism, and carbon credits.

In addition, policy makers should focus on improving the integration of forest management with broader land-use planning and climate adaptation strategies. This includes addressing the pressures of urbanization and agriculture on forest ecosystems and promoting sustainable practices that balance development with environmental preservation. Strategies should incorporate climate change resilience, ensuring that forest ecosystems in the region can adapt to changing environmental conditions, particularly considering the ongoing challenges posed by climate change.

Future research should explore the potential of emerging technologies, such as drones and AI-powered environmental monitoring systems, to enhance forest monitoring and management. These technologies can provide real-time data on forest health, growth, and threats, enabling quicker and more informed decision-making. Additionally, further research into the socio-economic benefits of forests, including their role in local livelihoods, carbon sequestration, and disaster risk reduction, would help build a stronger case for investing in forest conservation and restoration at the policy level.

The effectiveness of AI-assisted geospatial analysis observed in this study consistently with recent emphasizing the growing role artificial intelligence in environmental monitoring and forest management. Sayginer and Nurlu (2025), Shivaprakash et al. (2022), Wang et al. (2025), and Yadav and Verma (2026) argue that AI-based analytical frameworks improve the efficiency of forest inventory, classification, and monitoring process.

The significance of forest resources extends beyond ecological functions and includes their contribution to the preservation of natural and cultural heritage. Bayramov & Pashayeva (2024) emphasise the importance of integrated approaches to heritage conservation and sustainable territorial development in the liberated regions of Azerbaijan. In this context, the forest ecosystems of Karabakh represent not only environmental assets but also important components of the region’s natural landscape and territorial identity. Therefore, forest conservation strategies should be integrated with broader regional planning and heritage management initiatives.

By addressing these research gaps and implementing targeted policy measures, the Karabakh Economic Region can develop a more balanced and sustainable approach to forest management, contributing to the long-term ecological, social, and economic resilience of the region.

REFERENCES

1. Ali, G., Mijwil, M. M., Adamopoulos, I., & Ayad, J. (2025). Leveraging the internet of things, remote sensing, and artificial intelligence for sustainable forest management. *Babylonian Journal of Internet of Things*, 2025, 1-65. https://doi.org/10.58496/BJIoT/2025/001
2. Alisoy, N. (2022). Monitoring of forest landscape of Shamakhi district on the basis of remote sensing methods. *Journal of Baku Engineering University-Chemistry and Biology*, *6*(1), 65-72.
3. Bayramov, I. A., & Pashayeva, S. V. (2024). Directions of application of the eco-museum approach to the conservation of the natural and cultural heritage of the East Zangezur region of the Republic of Azerbaijan // *Agora International Journal of Economical Sciences (AIJES),18* (2), 35-43. https://doi.org/10.15837/aijes.v18i2
4. Belgiu, M., & Drăguţ, L. (2016). Random forest in remote sensing: A review of applications and future directions. *ISPRS Journal of Photogrammetry and Remote Sensing*, *114*, 24-31. https://doi.org/10.1016/j.isprsjprs.2016.01.011
5. European Space Agency. (2026). Copernicus land monitoring service. European Space Agency. Retrieved April 2, 2026, from https://land.copernicus.eu/pan-european/corine-land-cover
6. Giri, C., Zhu, Z., & Reed, B. C. (2005). A comparative analysis of the normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI) for land cover classification. *Remote Sensing of Environment*, *94*(2), 183-196. https://doi.org/10.1016/j.rse.2004.10.015
7. Liu, X., & Xia, X. (2016). Support vector machine (SVM) for land cover classification using remote sensing data: A review. *Remote Sensing*, *8*(11), 910. https://doi.org/10.3390/rs8110910
8. Nagiyev, S. G, & Bayramov, I. A. (2026). From Forced Displacement to Territorial Resilience: Socio-Economic Preconditions for Sustainable Reintegration in Post-Conflict Karabakh // *Baku State University Journal of Earth Sciences and Environment*, *3*(1), 35-45. https://doi.org/10.5281/zenodo.19162303
9. Overpass Turbo. (2026). Overpass turbo. OpenStreetMap Foundation. Retrieved April 2026, from https://overpass-turbo.eu/
10. Sayginer, C., & Nurlu, E. (2025). AI-driven geospatial analysis in ecosystem management: integration of machine learning methods. *Turkish Journal of Forest Science*, *9*(2), 560-584. https://doi.org/10.32328/turkjforsci.1704059
11. Shivaprakash, K. N., Swami, N., Mysorekar, S., Arora, R., Gangadharan, A., Vohra, K., ... & Kiesecker, J. M. (2022). Potential for artificial intelligence (AI) and machine learning (ML) applications in biodiversity conservation, managing forests, and related services in India. *Sustainability*, *14*(12), 7154. https://doi.org/10.3390/su14127154
12. Shuttle Radar Topography Mission (SRTM). (2026). SRTM data from NASA. NASA. Retrieved April 2026, from https://www2.jpl.nasa.gov/srtm/
13. Wang, T., Zuo, Y., Manda, T., Hwarari, D., & Yang, L. (2025). Harnessing artificial intelligence, machine learning and deep learning for sustainable forestry management and conservation: Transformative potential and future perspectives. *Plants*, *14*(7), 998. https://doi.org/10.3390/plants14070998
14. Wen, M., Chen, Q., & Lv, Z. (2025). Spatial distribution characteristics of marine economy based on AI-assisted multi-source data fusion and random forest analysis. sustainability, *17*(24), 11090. https://doi.org/10.3390/su172411090
15. Yadav, M., & Verma, M. K. (2026). Examining the role of geospatial data and AI in conducting comprehensive forestry inventories and mapping to support sustainable forest management. Advanced Geospatial Intelligence and AI for Environmental Resilience and Sustainable Development (pp. 215-235).