Ecosystem Accounting in Armenia: Setting the Scene

The project is being implemented by the Biodiversity Conservation Center (BCC Armenia), in collaboration with the Leibniz Institute of Ecological Urban and Regional Development (IOER), with the participation of experts from leading scientific organizations in Armenia.

This project is funded by the German Federal Environment Ministry's Advisory Assistance Program (AAP) for environmental protection in the countries of Central and Eastern Europe, the Caucasus and Central Asia and other countries neighboring the European Union. It is supervised by the Federal Agency for Nature Conservation (BfN) and the German Environment Agency (UBA).

Technical Report

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1. Introduction

The aim of the project is to create a Prototype of national ecosystem accounting in Armenia in accordance with UN recommendations (SEEA-EA). The project focuses on terrestrial ecosystems and covers two sections of ecosystem accounts in physical terms: ecosystem extent and ecosystem services. Monetary valuations are not considered in the project.

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2. Ecosystem Extent

The mismatch between the total area of the country and marzes derived from land cover data and the official figures is due to discrepancies in the boundaries of the digital maps used, as well as unaccounted variation in pixel area caused by terrain across Armenia. These discrepancies should be addressed in the development of a national ecosystem extent accounting in Armenia.

2.1. Testing available land cover datasetss

The data for Armenia from the following five publicly available global land cover datasets were tested (Fig. 21-1): 1) Dynamic World; 2) ESRI Land Cover; 3) ESA WorldCover; 4) GLC_FCS30D; 5) GLAD Global Land Cover and Land Use Change. See short datasets description in the Table 21-1 and maps in the project web GIS. The following datasets were excluded from analysis (see for details Table 21-1): MODIS MCD12Q1; Copernicus Global Land Cover; ESA CCI/C3S Global Land Cover product; Globeland30; GlobCover; World Terrestrial Ecosystems; The Global Land Cover by National Mapping Organizations (GLCNMO).

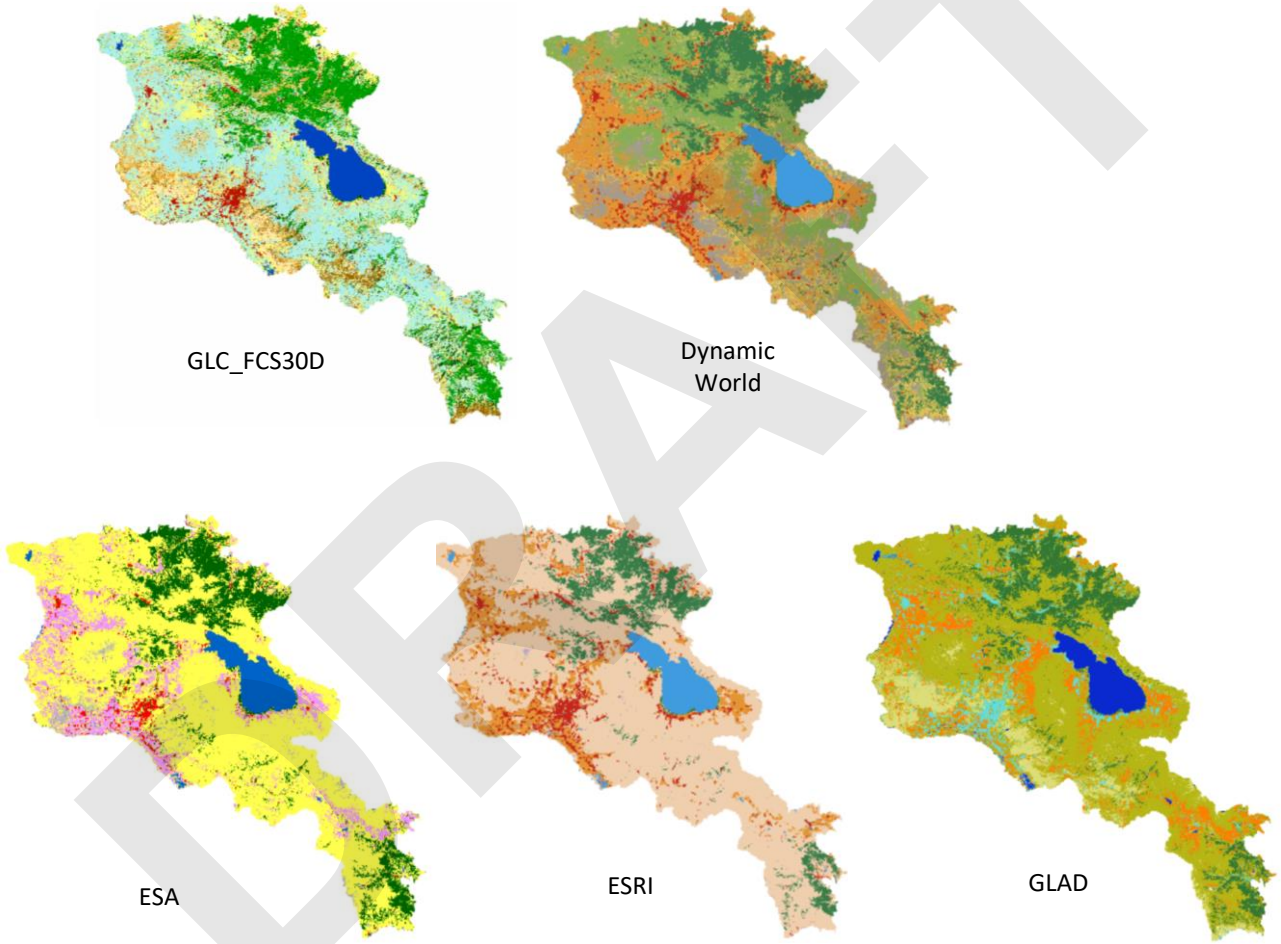


Figure 21-1. Tested land cover datasets

Table 21-1. Brief description of land cover datasets, which were tested and excluded from analysis

	Links	**Data provider**	**Spatial resolution**	**Temporal availability and resolution**	**Land cover classes**	**Future availability**	**General commentary and issues**
Tested land cover datasets							
Dynamic World	**Primary link** https://dynamicworld.app/ **Documentation** https://dynamicworld.app/about, https://www.nature.com/articles/s41597-022-01307-4 **Where to get the data** Google Earth Engine	Google, World Resources Institute. **License** – Creative Commons BY-4.0	10 m	2015 –**2024** near real-time	1. Water 2. Trees 3. Grass 4. Flooded veg. 5. Crops 6. Shrub & scrub 7. Built 8. Bare 9. Snow and ice	Project is based on two mature, well-known technologies: Google Earth Engine as processing and publishing engine and ESA Copernicus Sentinel-2 as data source. GEE is one of the key modern geospatial technologies. Sentinel-2 is a long-term program with scheduled activity up to 2033 (ref). These facts point to a secure future of Dynamic World	Initially published in 2022, Google Earth Engine (GEE) based dynamic land cover dataset. Transparent and open-sourced. It is based on Sentinel-2 data and dynamically updated with new data acquisitions (3-5 days revisit time, excluding cloudy periods). Could be challenging for inexperienced users to get data from GEE as files for analysis (designed to be used inside GEE). Very basic classification scheme (e.g. single class "trees" for all forest types). In general, there is no dataset in basic terms. There is a published machine learning algorithm which could be applied to any set of Sentinel-2 imagery, and this algorithm published together with the data at GEE. So users could request land cover data for particular territory based on a given period of Sentinel-2 acquisitions. Python code sample to retrieve data from GEE (using GEE-map package): https://gist.github.com/eduard-kazakov/6bfa6ca1ab4ead0b2d6a3ed3e94dd277
ESRI Land Cover	**Primary link** https://livingatlas.arcgis.com/landcover/ **Documentation** https://www.impactobservatory.com/static/lulc_methodology_accuracy-ee742a0a389a85a0d4e7295941504ac2.pdf **Where to get the data** https://livingatlas.arcgis.com/landcoverexplorer	ESRI. **License** – Creative Commons by Attribution (CC BY 4.0)	10 m	2017 – **2023** 1 year	1. Water 2. Trees 3. Flooded veg. 4. Crops 5. Built area 6. Bare ground 7. Snow/Ice 8. Clouds 9. Rangeland	Land cover is provided by the world leader in geospatial, ESRI, and based on the well-known ESA Copernicus Sentinel-2 data. Sentinel-2 is a long-term program with scheduled activity up to 2033 (ref). These facts point to a secure future of ESRI Land Cover.	Primary land cover product by ESRI, based on machine learning algorithms and Sentinel-2 data. Published every year. Available for direct download as GeoTIF for each year since 2017. Very basic classification scheme (e.g. single class "trees" for all forest types).
ESA WorldCover	**Primary link** https://esa-worldcover.org/en **Documentation** https://worldcover2021.esa.int/documentation **Where to get the data**	ESA. **License** – Creative Commons Attribution 4.0	10 m	2020 –**2021** 1 year	1. Tree cover 2. Shrubland 3. Grassland 4. Cropland 5. Built-up 6. Bare/sparse veg. 7. Snow and Ice 8. Permanent water bodies	ESA has not officially confirmed that updates will follow annually, but the project has been extended due to its success and user demand. The current release patterns suggest that future updates might continue, though no fixed schedule has been guaranteed by ESA.	Flagman land cover project directed by ESA in cooperation with many partners. Based on Sentinel-2 and Sentinel-1 data (mixing optic and radar data). Distributed in GeoTIFF format via simple web interface.

	https://viewer.esa-worldcover.org/worldcover/	International			9. Herbaceous wetland 10. Mangroves 11. Moss & lichen		
GLAD Global Land Cover and Land Use Change	**Primary link** https://glad.umd.edu/dataset/GLCLUC2020 **Documentation** https://www.frontiersin.org/journals/remote-sensing/articles/10.3389/frsen.2022.856903/full **Where to get the data** https://storage.googleapis.com/earthenginepartners-hansen/GLCLU2000-2020/v2/download.html	University of Maryland. **License** – Creative Commons Attribution 4.0 International	30 m	2000 –**2020** 5 years	1. Terra Firma – True desert 2. Terra Firma – Semi-arid 3. Terra Firma – Dense short vegetation 4. Terra Firma – Tree cover 5. Wetland – Salt pan 6. Wetland – Sparse vegetation 7. Wetland – Dense short vegetation 8. Wetland – Tree cover 9. Open surface water 10. Snow/ice 11. Cropland 12. Built-up 13. Ocean	Dataset is based on Landsat imagery. Three Landsat satellites are still active, the last one (Landsat 9) was launched in 2021. There are plans to continue the mission with Landsat Next in 2030/2031 (ref), so it seems that mission continuity is secure. The GLAD project of University of Maryland is well-known and highly regarded by the community.	Well-known dataset by University of Maryland based on Landsat imagery archives. Project is focused on estimating global land use changes. Important property of this dataset is how it is detailed, with differentiation of trees by height, water retention time etc.
GLC_FCS30D	**Primary link** – https://essd.copernicus.org/articles/16/1353/2024/ **Documentation** – https://essd.copernicus.org/articles/16/1353/2024/ **Where to get the data** – https://zenodo.org/records/8239305	Liangyun Liu, Xiao Zhang, & Tingting Zhao. **License** – Creative Commons Attribution 4.0 International	30 m	1985 –**2022** 1 year	1. Rainfed cropland 2. Herbaceous cover cropland 3. Tree or shrub cover (orchard) cropland 4. Irrigated cropland 5. Open evergreen broadleaved forest 6. Closed evergreen broadleaved forest 7. Open deciduous broadleaved forest 8. Closed deciduous broadleaved forest 9. Open evergreen needle-leaved forest 10. Closed evergreen needle-leaved forest 11. Open deciduous needle-leaved forest 12. Closed deciduous needle-leaved forest 13. Open mixed leaf forest (broadleaved and needle-leaved) 14. Closed mixed leaf forest (broadleaved and needle-leaved) 15. Shrubland 16. Evergreen shrubland 17. Deciduous shrubland 18. Grassland 19. Lichens and mosses 20. Sparse vegetation 21. Sparse shrubland 22. Sparse herbaceous 23. Swamp 24. Marsh 25. Flooded flat 26. Saline 27. Mangrove	Dataset is based on Landsat imagery. Three Landsat satellites are still active, the last one (Landsat 9) was launched in 2021. There are plans to continue the mission with Landsat Next in 2030/2031 (ref), so it seems that mission continuity is secure. According to latest publications, authors have intention to continue providing this data in the future. On the one hand they are supported and funded by the Chinese government, on the other hand the project obviously depended on particular scientists, which could be insecure.	This dataset is developed and supported by a group of scientists from different Chinese institutes. It's well-known and cited hundreds of times, authors support it and add data for new years. Land cover is based on Landsat data time series. Project is supported by the National Natural Science Foundation of China. Product has a diverse classification scheme compared to other datasets. Data is distributed in zip archives available at famous scientific open data portal Zenodo, each GeoTIFF inside zip contains data for 20+ years (one band – one year).

					28. Salt marsh 29. Tidal flat 30. Impervious surfaces 31. Bare areas 32. Consolidated bare areas 33. Unconsolidated bare areas 34. Water body 35. Permanent ice and snow		
Datasets excluded from analysis							
MODIS MCD12Q1*	**Primary link** https://lpdaac.usgs.gov/products/mcd12q1v061/; **Documentation** https://lpdaac.usgs.gov/documents/1409/MCD12_User_Guide_V61.pdf; **Where to get the data** https://search.earthdata.nasa.gov/search	NASA. **License** – No restrictions on reuse, redistribution, or modification	500 m	2000 –**2023** 1 year		MCD12Q1 data is based on the MODIS sensor installed at Terra and Aqua satellites. According to the current plan, Terra MODIS will remain operational and generate the full suite of products until the end of the mission in **December 2025**, and Aqua MODIS will remain operational and generate the full suite of products until the end of the mission in **August 2026** (ref)**.** So we can await product availability **up to 2025**. This product will probably be replaced by a new generation one, but there is no particular information about it yet	We did not consider the MODIS data as a possible landcover for creating an ecosystem map due to its low resolution. However, these data can be used to assess ecosystem services. Well-known global Land Cover dataset, referenced thousands of times. Distributed with 8 different classification schemes. Training data haven't been updated since 2021, so authors ask to be careful about data released after 2021 (ref). Relatively low spatial resolution.
Copernicus Global Land Cover	https://land.copernicus.eu/en/products/global-dynamic-land-cover			2015-2020			Data is available only for 2015-2019, no further updates are planned. Other Copernicus products may be useful for assessing ecosystem services.
ESA CCI/C3S Global Land Cover product	https://www.esa-landcover-cci.org/			1992-2020			Data is available only for 1992-2020. New releases were promised, but there were no actual updates in scheduled dates.
Globeland30	https://www.webmap.cn/commres.do?method=globeDetails&type=brief			2000-2010			Data is available only for 2000 and 2010, no further updates are planned.
GlobCover	https://due.esrin.esa.int/page_globcover.php			2009			Data is available only for 2009, no further updates are planned.
World Terrestrial Ecosystems	https://www.arcgis.com/home/item.html?id=926a206393ec40a590d8caf29ae9a93e			2020			Data is available only for 2020, no further updates are planned.
The Global Land Cover by National Mapping Organizations (GLCNMO)	https://globalmaps.github.io/glcnmo.html			2003-2013			Data is available only for 2003-2013, no further updates are planned.

2.1.A. Area of land cover classes in the tested datasets

To ensure dataset comparability, all tested land cover datasets and Governmental data on land cover area were generalized into five land cover classes: 1) trees; 2) non-woody natural areas; 3) water, wetlands, flooded vegetation; 4) crops; 5) built-up areas.

The Decision of the Government of the Republic of Armenia in April 11, 2019 defined the following land cover classes for national accounting: Cultivated lands; Grasslands; Tree-covered areas; Shrub-covered areas; Water covered areas; Vegetation-free areas. The more detailed disaggregation of land cover classes by land fund categories provided in the Government-reported data, enables the separation of vegetation-free anthropogenic areas, i.e., built-up areas from natural ones (see here) and makes it possible to compare Governmental data and land cover datasets. How to classify grasslands and cultivated lands located within settlement boundaries is a question that needs to be addressed in order to harmonize satellite-based land cover classifications with official land cover statistics. At this stage of the analysis, we kept these lands within grasslands and cultivated lands, respectively.

Further, to ensure comparability of tested datasets and Government-reported data three land cover classes - Grasslands, Shrub-covered areas, and Vegetation-free natural areas - were combined into one class Non-woody natural areas. The data for 2022 were used for comparison, as it represents the midpoint between the dates of the tested land cover datasets.

Share of land cover classes in Armenia

GLC_FCS30D landcover data shows very strong excess of cropland area and excess of forest area. The results of the three land cover datasets — ESRI, ESA, and GLAD — are similar and show a smaller cropland area nd larger grassland area than the Government-reported data. In contrast, the DW dataset shows a larger cropland area and smaller grassland area than the Government data (Fig. 21A-1, 21A-2). Dataset GLC_FCS30D 2022 was excluded from the further analysis, as it differed most significantly from all the other datasets and from Government-reported data.

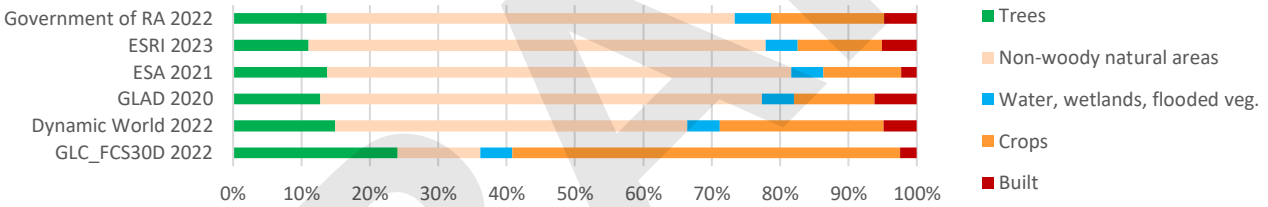


Figure 21A-1. Share of land cover classes in Armenia according the five tested datasets

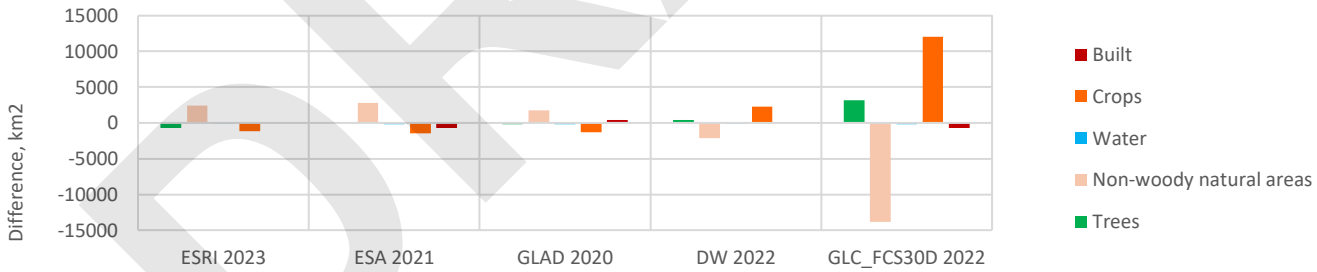


Figure 21A-2. Difference between Government-reported area of land cover classes (2022) and tested datasets

Share of land cover classes across marzes

All four remaining datasets differ significantly from the Government-reported data (Fig. 21A-3). The discrepancies identified at the national level are largely maintained across marzes: ESRI, ESA, and GLAD show larger areas of non-woody natural lands and smaller cropland areas compared to the Government data. In contrast, DW shows smaller non-woody areas and larger cropland areas than the Government data (Fig. 21A-4). This shift persists across the majority of marzes (Fig. 21A-4), suggesting that it is systemic and driven by the differences in the methodology used for satellite image classification. Discrepancies between tested datasets and Government data for forest cover and built-up areas are smaller in magnitude and do not follow the pattern observed in the relationship between cropland and non-woody natural areas. The most prominent shifts include for forest area a reduction in the ESRI data, and increase in the DW data, as well as for built-up area a reduction in the ESA data and increase in the GLAD data. Differences between the land cover datasets and the Government data in terms of water area are minor and fairly consistent across all datasets — each identifies a slightly smaller water area. Figure 21A-5 provides a more detailed view of the area differences across the marzes.

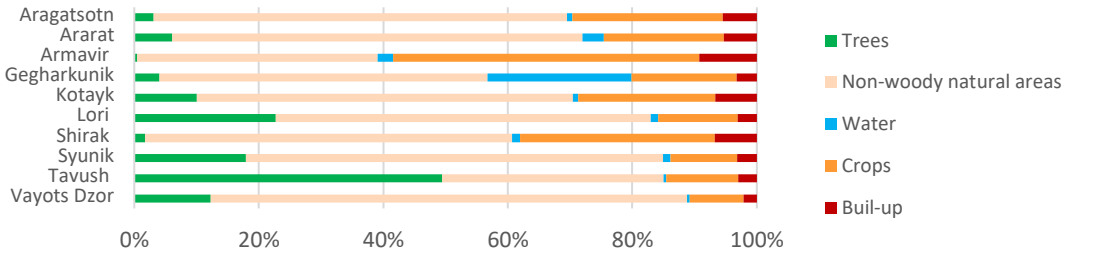
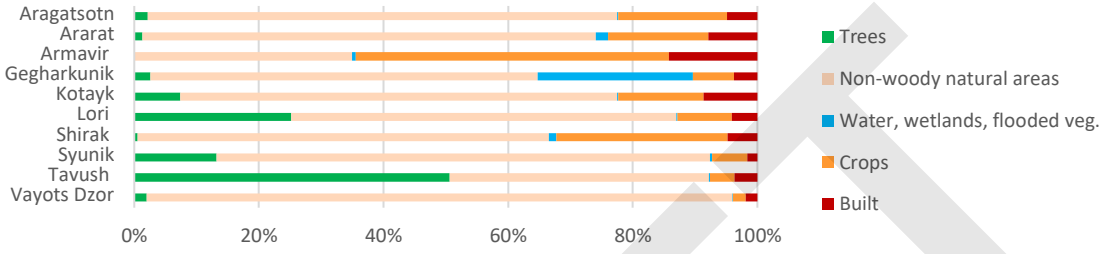
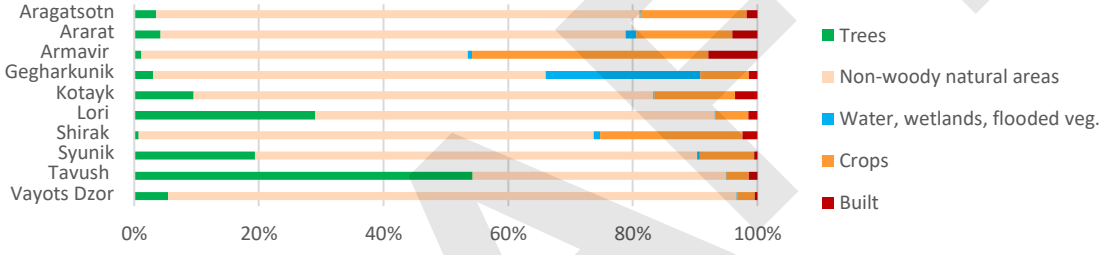
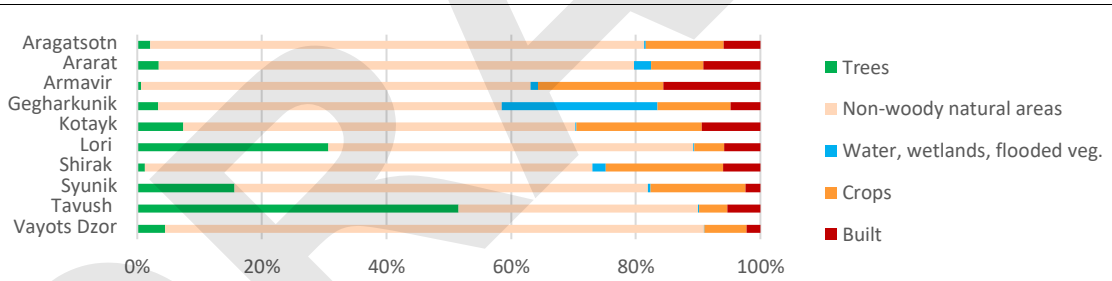
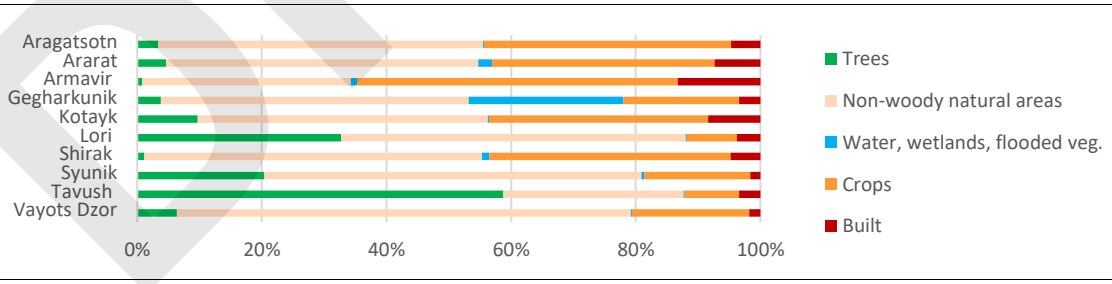
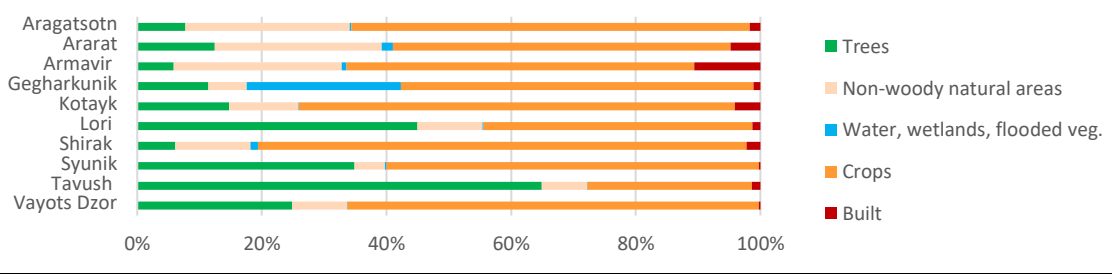
Dataset	*The share of land cover classes area in marzes*
Govern-ment-reported data 2022	
ESRI 2023	
ESA 2021	
GLAD 2020	
Dynamic World 2022	
GLC_ FCS30D 2022	

Figure 21A-3. Land cover class shares across marzes according Government-reported data and tested datasets

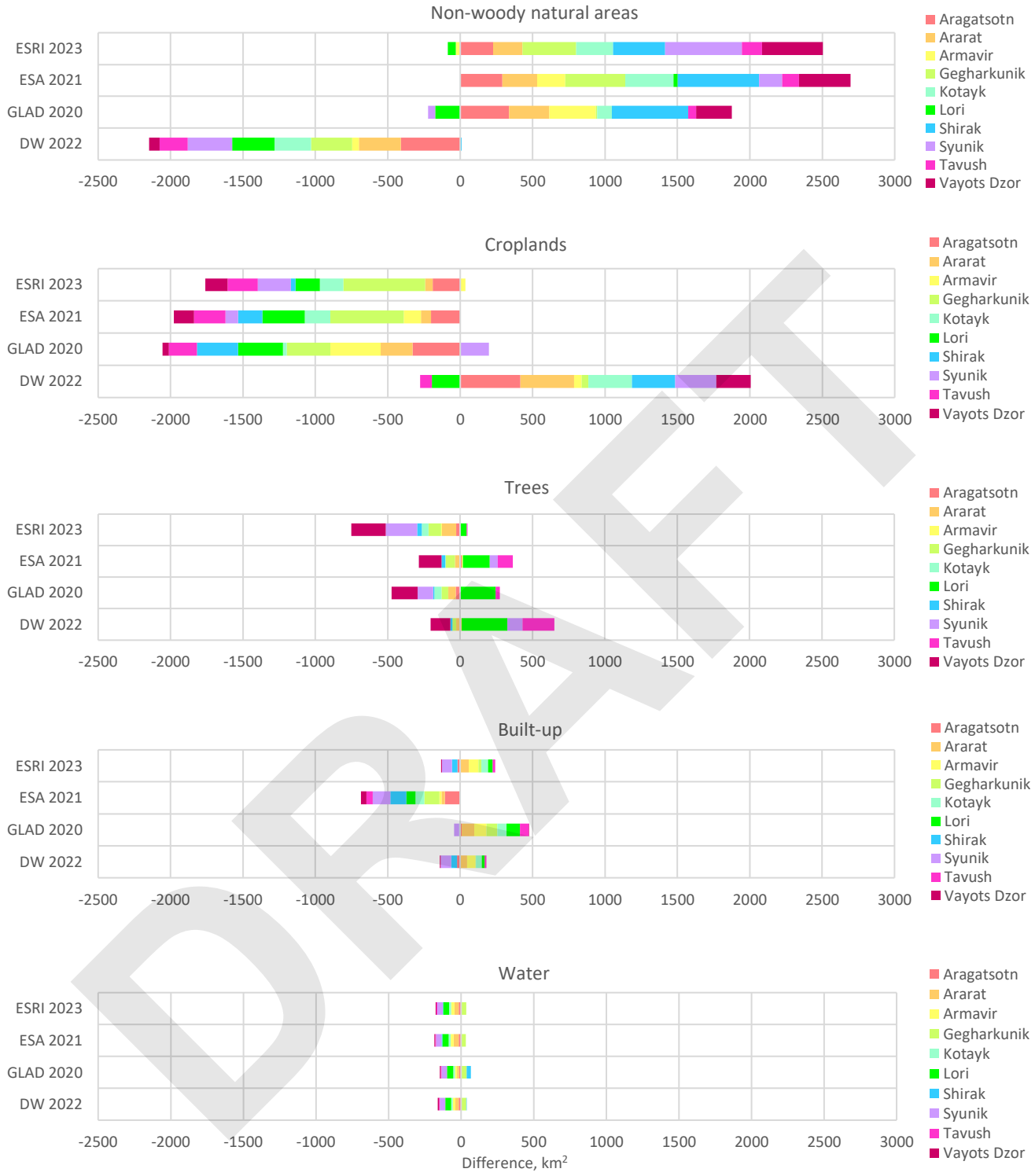


Figure 21A-4. Land cover area difference: Government-reported areas minus areas from tested datasets. Differences between tested datasets and Government-reported data in marzes are shown in different colors. Provincial differences for each land cover class are combined into a single bar to show the total deviation from the Government-reported data.

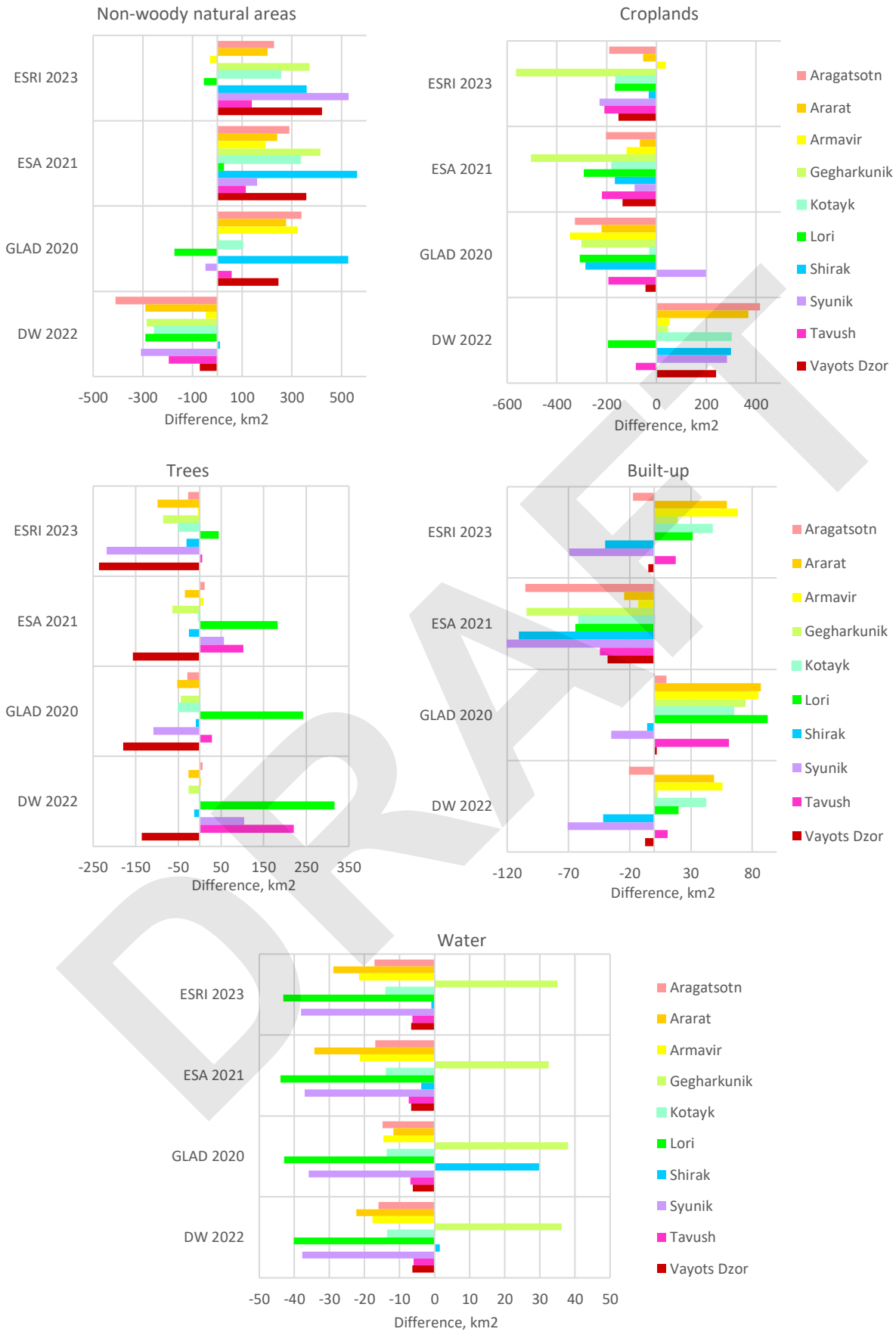


Figure 21A-5. Land cover area difference across marzes: Government-reported areas minus areas from tested datasets

The absolute discrepancy (km^2) is largest for croplands and grasslands, while in relative terms (percentage relative to Government-reported data), it is greatest for croplands and built-up areas (Figure 21A-6).

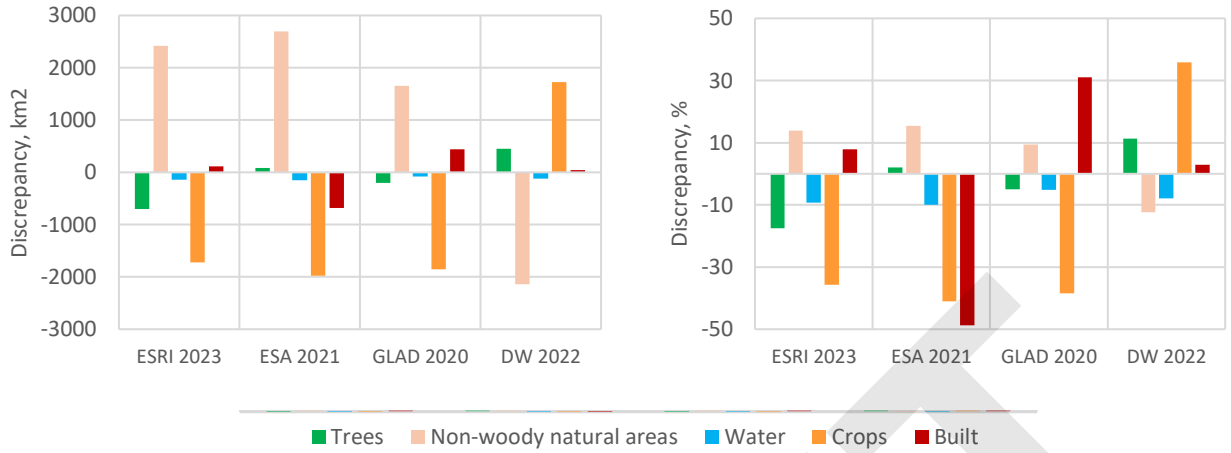


Figure 21A-6. Absolute (km²) and relative discrepancy (% relative to Government-reported data) in area of land cover classes

The smaller area of built-up area in ESA data can be explained by the fact that ESA identifies trees, grasslands, and crops within settlements. The ESA data generally feature smaller patches across all land cover classes (Fig. 21A-7).

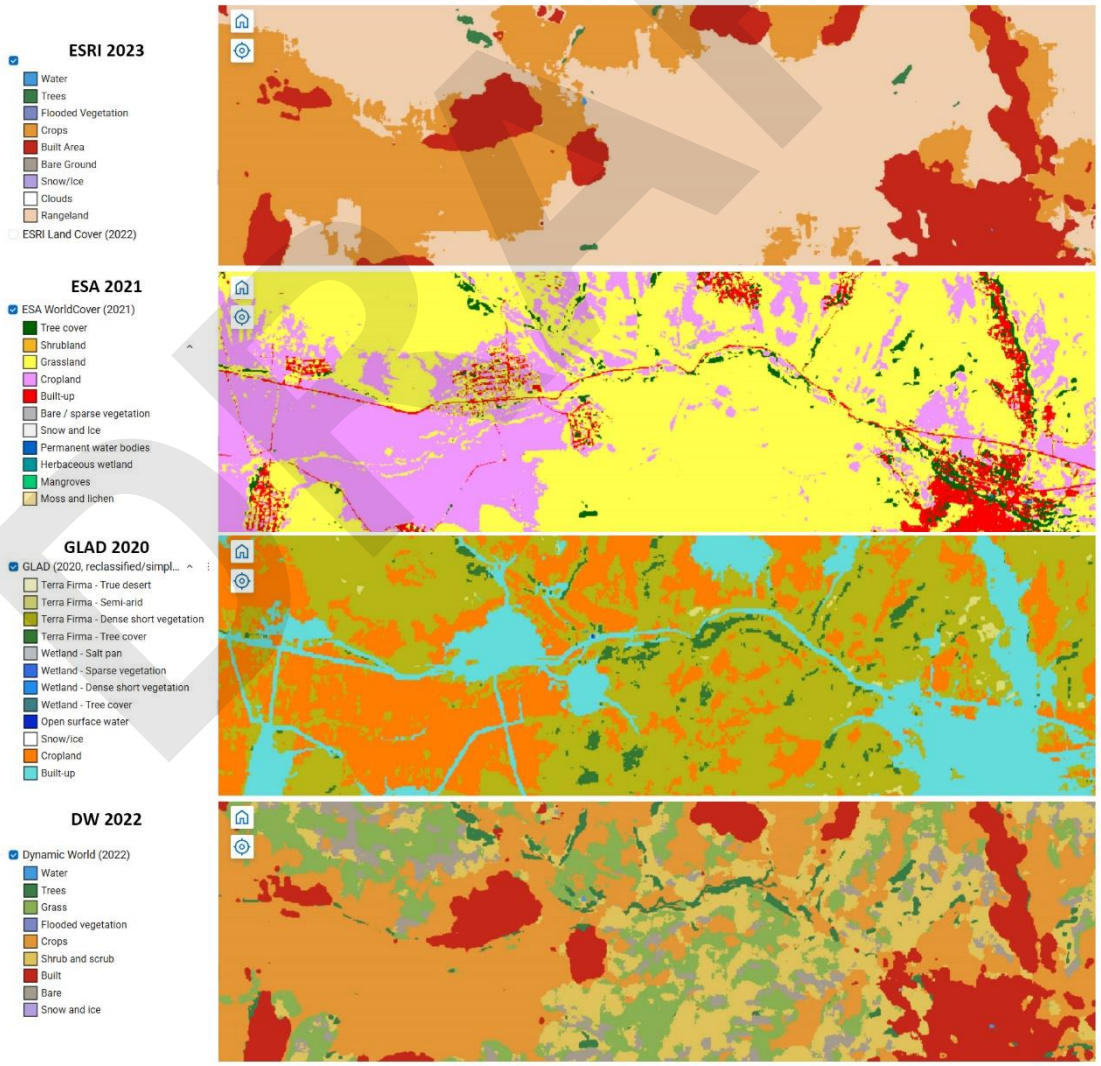


Figure 21A-7. The same area as represented in different land cover datasets

The Government classification of land cover types includes, among others, shrub-covered areas. Of the four land cover datasets retained for analysis, two — ESA and DW — also include this class. However, the shrub areas identified in these datasets differ greatly from the Government-reported areas. According to ESA, shrub area is very small and consistently lower than the Government figures across all marzes. DW, on the contrary, identifies a very large shrub area — several times greater than the Government data (Table 21A-1, Fig. 21A-8). Thus, the presence of a "shrubs" class in these two datasets does not make them more consistent with the Government data.

Table 21A-1. Area of shrub-covered areas in Government-reported data and in two land cover datasets

Marzes	GOV 2022	ESA 2021	DW 2022
Aragatsotn	3.925	0.000	361.594
Ararat	24.962	0.001	387.490
Armavir	6.341	0.001	58.548
Gegharkunik	36.351	0.000	611.396
Kotayk	23.135	0.000	372.450
Lori	48.307	0.057	345.520
Shirak	0.000	0.000	246.146
Syunik	157.423	1.042	1147.185
Tavush	29.433	8.913	310.120
Vayots Dzor	11.479	0.000	843.881

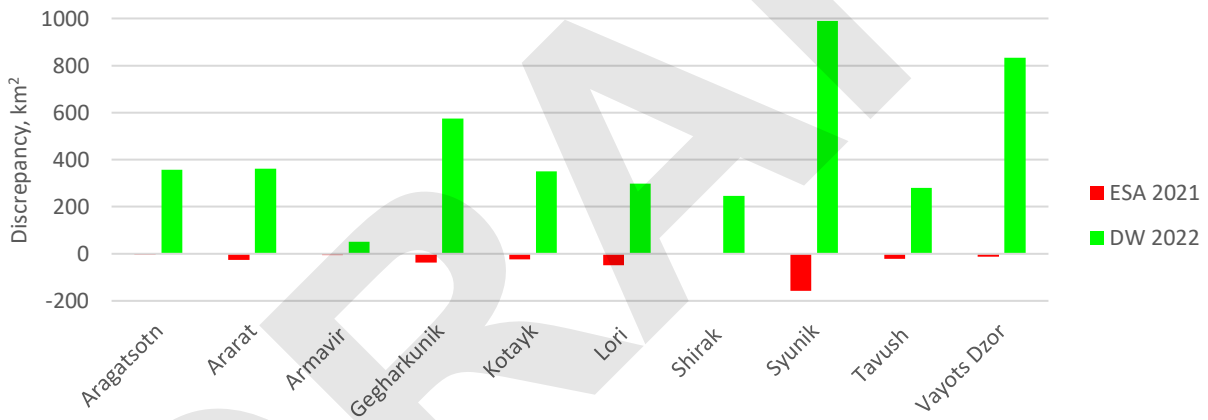


Figure 21A-8. Discrepancy with Government-reported data in shrubland area.

A preliminary overall indicator for assessing land cover data accuracy can be the total discrepancy between land cover class areas in datasets and Government data. The reliability of this indicator increases when absolute errors are summed across the smallest spatial units. In this case, however, data are available only at the marz level, so the indicator we used represents the sum of absolute area discrepancies (by modulus, regardless of sign) across marzes. Overall, all four datasets show a similar total discrepancy from the Government data, ranging from 19.4% to 20.9% of Armenia's total area. The smallest discrepancy is observed in the ESRI dataset, and the largest in ESA (Fig. 21A-9).

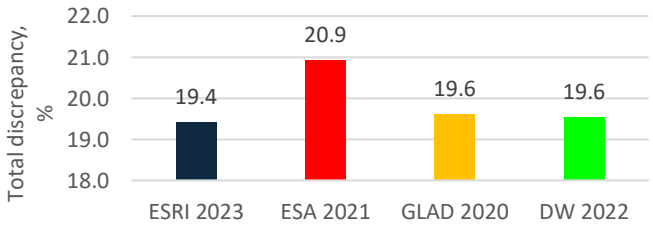


Figure 21A-9. Total relative discrepancy (% relative to total area of Armenia) between tested datasets and Government-reported data

Share of land cover classes across landscape zones

Comparison of land cover class areas across landscape zones according different datasets shows that ESRI, ESA, and GLAD are generally similar to each other (Fig. 21A-10). Dynamic World (DW 2022) data show a significantly larger cropland area compared to the other datasets. This is especially noticeable in mountainous landscapes. Croplands were identified on nearly 10% of the area of the high-altitude and alpine zones. In some mountain ranges (Gegham Range and southwestern slope of the Karabakh plateau) croplands occupy about 20% (Fig. 21A-11), which is inconsistent with reality. In the subalpine zone, croplands occupy more than 10% in total.

Comparison of ESRI, ESA, and GLAD datasets shows that in ESRI, the cropland area is significantly larger in mountain-valley semi-desert and dry steppe zones, whereas in GLAD, the cropland area in mountain-valley semi-desert zone is smaller than in the other two datasets (Fig. 21A-10). The ESA dataset is characterized by larger area of tree cover and smaller built-up area, which is particularly noticeable in the semi-deserts, dry steppe, and forest shelter belt. One of the reasons for this is that, as mentioned above, ESA identifies trees within settlements. The presence of trees in submountain semidesert zone in the ESA data is entirely due to this factor – all trees there are located inside settlements. ESRI and GLAD datasets do not show any tree cover in this zone.

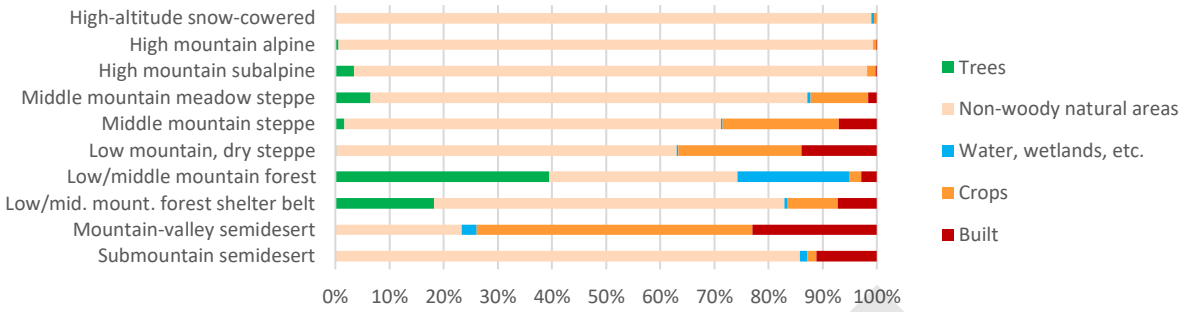
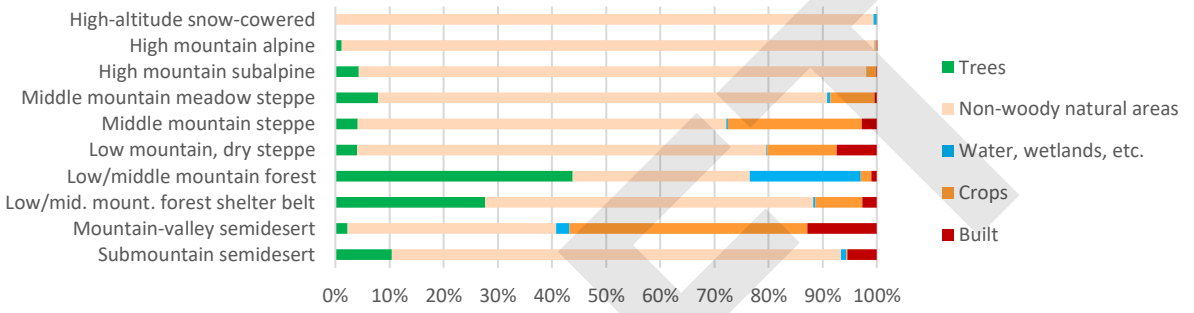
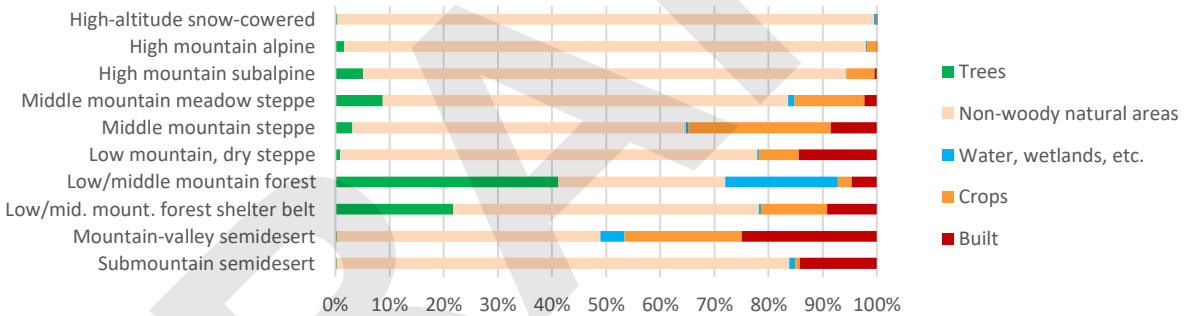
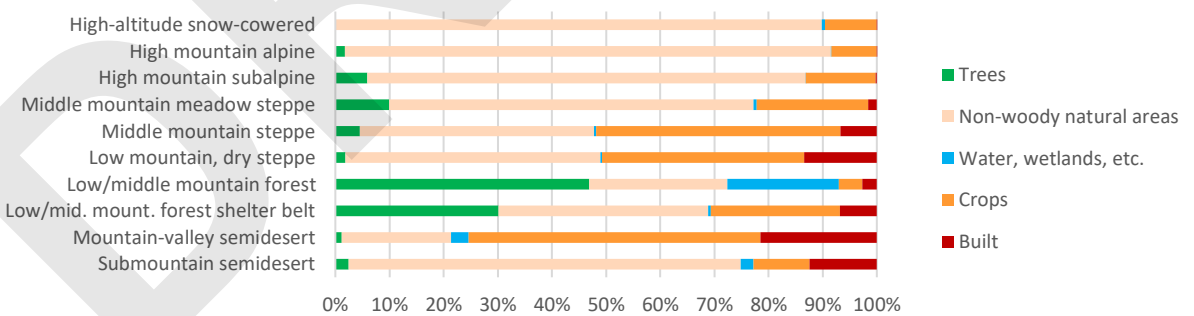
Dataset	*The share of land cover classes area in landscape zones*
ESRI 2023	
ESA 2021	
GLAD 2020	
Dyna-mic World 2022	

Figure 21A-10. Land cover class shares across landscape zones according tested datasets

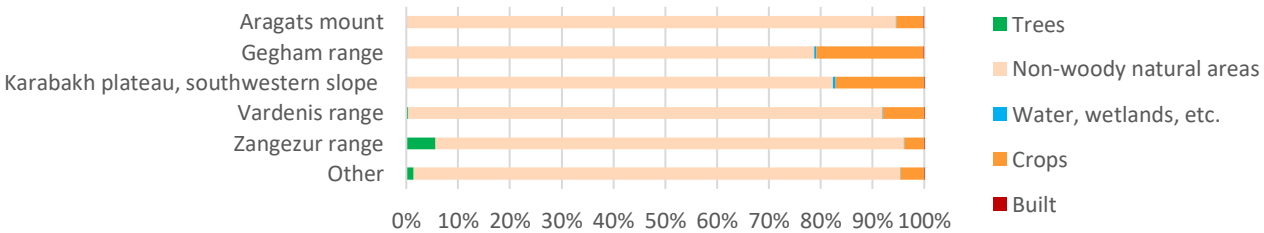


Figure 21A-11. Land cover class shares in high-altitude snow-cowered and high mountain alpine zones across highland systems of Armenia according DW 2022 data

2.1.B. Comparison of cropland area according to land cover datasets and ARMSTAT data

A comparison with ARMSTAT data on cultivated areas was conducted for four land cover datasets – ESRI, ESA, GLAD, and Dynamic World (GLC_FCS30D was excluded from the analysis, see Section 2.1.A). For comparison, we also used 2022 Government-reported data on the area of cultivated land in Armenia.

Cropland area according to landcover data was compared with three ARMSTAT indicators for the same year as the landcover data:

1) Arable land (**Arable** in Figures) , that is, an area intended for cultivation, but not necessarily used every year;

2) Annually cultivated area (**Cultivated** in Figures), that is the sum of annually plowed area, the area of fruit and berry plantations (including greenhouses, hothouses and inter-row fruit-bearing plantations), and vineyards;

3) Annually plowed area (**Plowed** in Figures) that is plantations of grains and leguminous crops, potatoes, vegetables and melons.

According to ESRI, ESA, and GLAD datasets, the cropland area in most marzes is smaller than the area of arable land but larger than annually cultivated area reported by ARMSTAT. The cropland area identified by DW exceeds the arable land reported by ARMSTAT in almost all marzes, except for marzes Lori and Tavush (Figure 21B-1). The cultivated area reported in the 2022 Government data exceeds the arable land area in all marzes (GOV (A) in Fig.21B-1). If the cultivated area within settlements is excluded, the difference with the ARMSTAT data becomes smaller (GOV (B) in Fig.21B-1).

The cropland areas identified by all datasets exceed the annually cultivated area reported by ARMSTAT, except for the GLAD data in marzes Ararat and Armavir.

Figure 21B-2 provides a more detailed breakdown by marz.

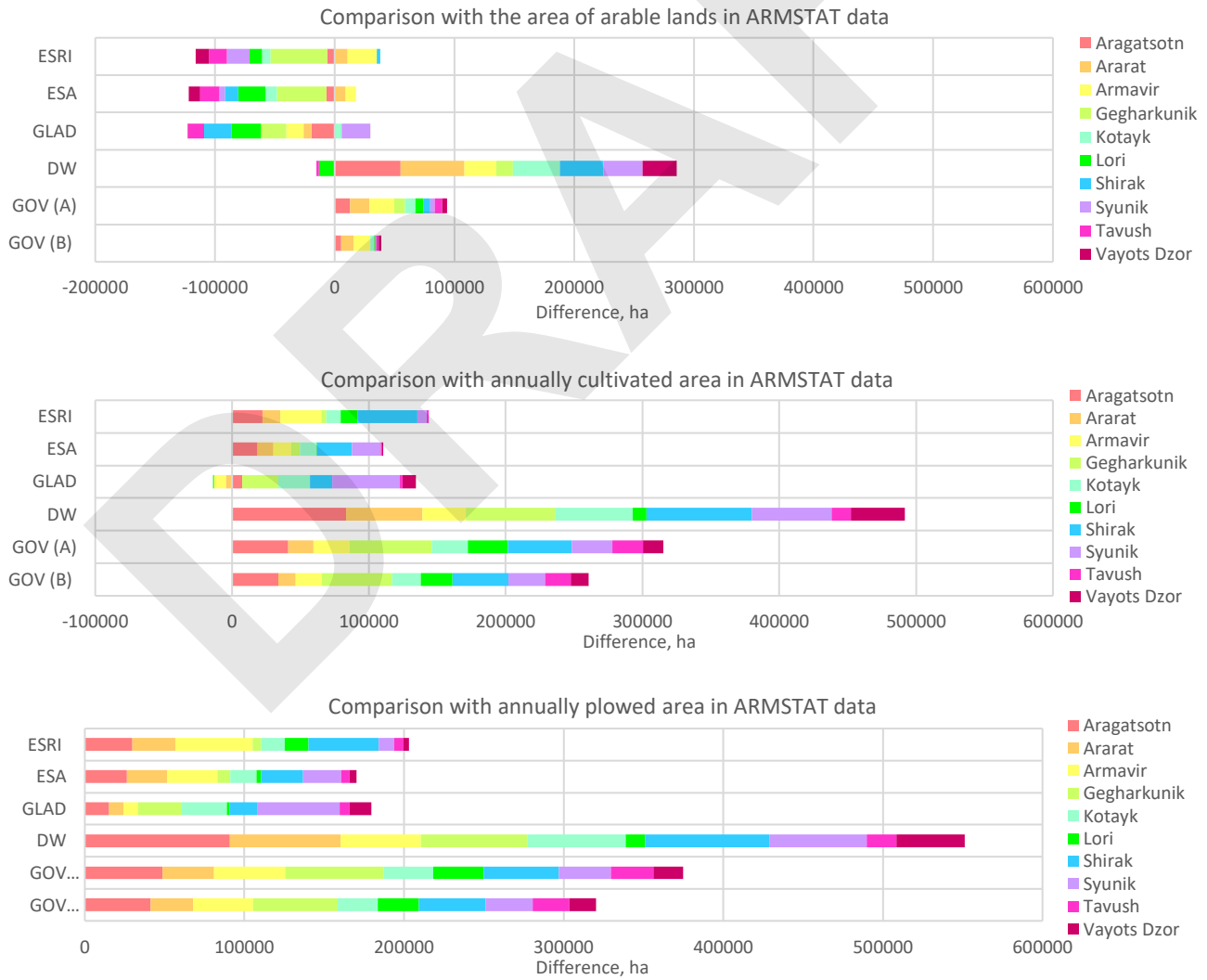


Figure 21B-1. Difference between areas of croplands in tested datasets and ARMSTAT data on arable lands, annually cultivated, and annually plowed areas (dataset data minus ARMSTAT data)

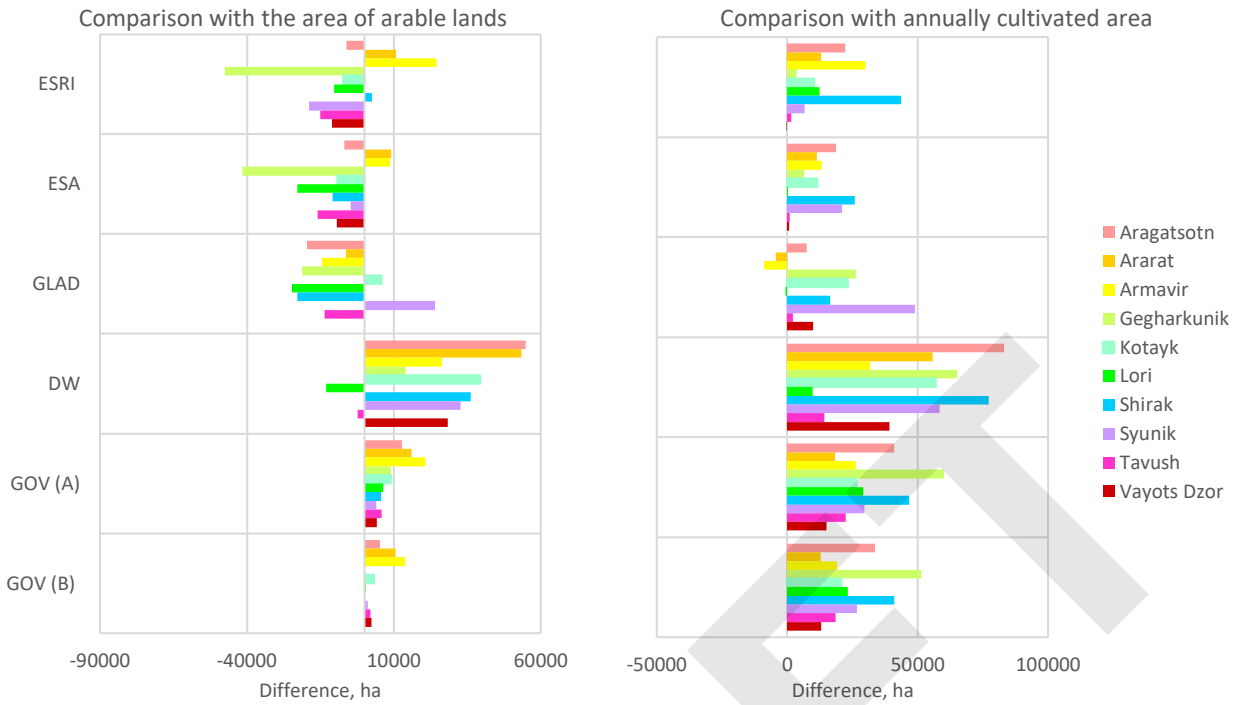


Figure 21B-2. Difference between areas of croplands in tested datasets and ARMSTAT data on arable lands, annually cultivated, and annually plowed areas (dataset data minus ARMSTAT data) across marzes

The fact that in ESRI, ESA, and GLAD datasets the cropland area is smaller than arable area but larger than annually cultivated area indicates that these datasets classify a part of arable lands which are not cultivated during the reference year as croplands. The area of land designated for cultivation that was left uncultivated in the given year is equal to Astat-Cstat, where Cstat is cultivated area in ARMSTAT data; Astat is arable area in ARMSTAT data. Thus, the share of uncultivated fields that are identified in ESRI, ESA, and GLAD datasets as croplands can be defined as U=(C-Cstat)/(Astat-Cstat), where C is cropland area in a dataset. Across the marzes, this figure varies between 0% and 100% (Fig. 21B-3). In cases where the cropland area from land cover datasets exceeds arable land area reported by ARMSTAT, this indicator exceeds 100%. This is most evident in the ESA and ESRI data for the Ararat and Armavir marzes, where these datasets estimate the cropland area to be 20–40% larger than the arable land area reported by ARMSTAT, while approximately 90% of the arable land in these marzes is annually cultivated. The cropland area in all datasets exceeds the annually plowed area. The Government data exceed both annually cultivated and annually plowed area reported by ARMSTAT.

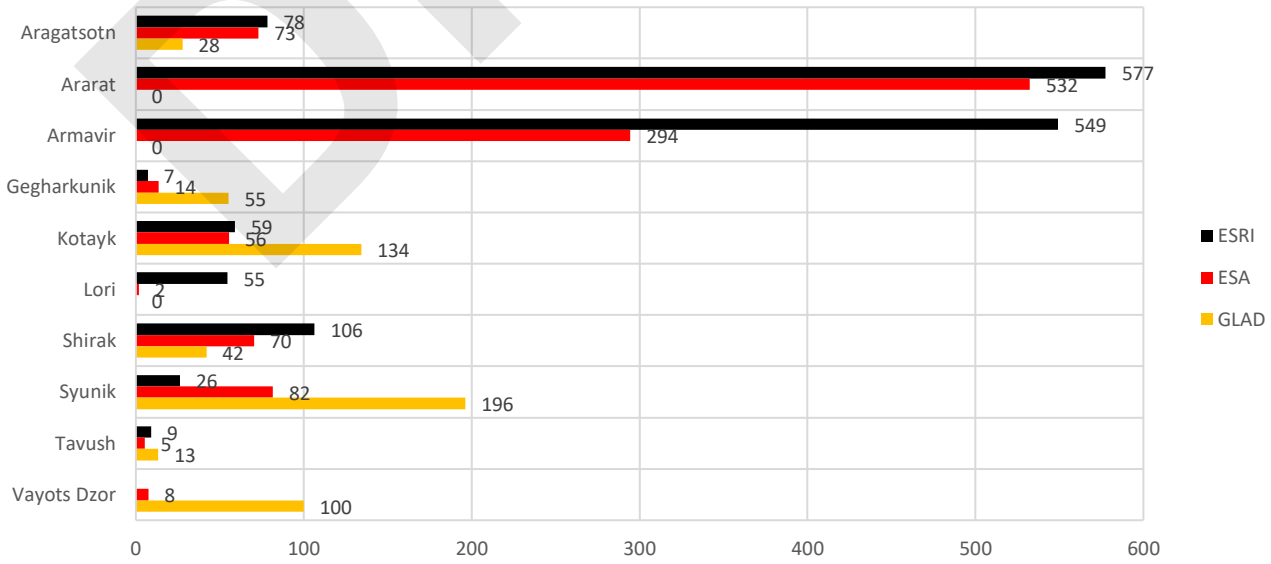


Figure 21B-3. The share (%) of uncultivated arable land that is classified as cropland by the land cover datasets

Similar to the comparisons with Government-reported data (Section 2.1.A), a preliminary overall indicator for assessing land cover data accuracy can be the total discrepancy between cropland areas in datasets and ARMSTAT data which is the sum of absolute area discrepancies (by modulus, regardless of sign) across marzes (Figure 21B-4). Overall, ESRI, ESA, and GLAD datasets show a similar total discrepancy from the ARMSTAT data, DW shows a substantial overestimation of cropland area.

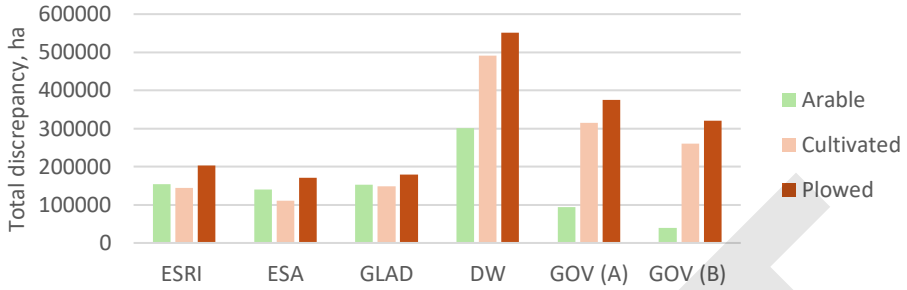


Figure 21B-4. Total discrepancy between cropland areas in datasets and ARMSTAT

2.1.C. Selection of land cover dataset for use in the project

The ESRI land cover dataset was selected as the basis for the project implementation. The ESA and GLAD datasets can be additionally used for specific methodological tasks. The choice was made based on the following reasons:

- GLC_FCS30D land cover data shows very strong excess of cropland area and excess of forest area and was therefore excluded.

- Dynamic World dataset shows good agreement with the Government-reported data in indicator of total area discrepancy. However, it significantly overestimates cropland area compared to ARMSTAT data and shows strong excess of cropland area in the mountains. Therefore, it was excluded.

- ESA, ESRI and GLAD are similar in identified areas of of the generalized land cover classes and are most consistent with ARMSTAT data on cropland area.

- ESRI data provide the best opportunity for demonstrating the accounting of ecosystem indicator dynamics from 2017 and 2023.

2.2. Extent of land cover classes in Armenia

2.2.A. Extent of land cover classes reported by Government of Armenia

The Decision of the Government of the Republic of Armenia in April 11, 2019 n 431-n "On approval of the procedure for classification of the land cover of the Republic of Armenia" defined the following land cover classes for national accounting: Cultivated lands; Grasslands; Tree-covered areas; Shrub-covered areas; Water covered areas; Vegetation-free areas.

Table 2.2.A-1. Land cover of the Republic of Armenia (2974258.8 ha area) by classes, 2020-2024

Land cover classes	As of July 1, 2020	As of July 1, 2021	As of July 1, 2022	As of July 1, 2023	As of July 1, 2024
Cultivated lands	538361.22	538580.09	538930.12	538919.19	539620.52
Grasslands	1366386.896	1371066.28	1370749.11	1370618.62	1363686.44
Tree-covered areas	400522.06	400375.84	400279.49	382109.06	382361.15
Shrub-covered areas	34200.612	34193.77	34135.56	34124.48	34374.33
Water covered areas	151491.8	153889.698	153890.39	172088.29	172117.81
Vegetation-free areas	483295.83	476152.342	476274.17	476398.959	482098.73

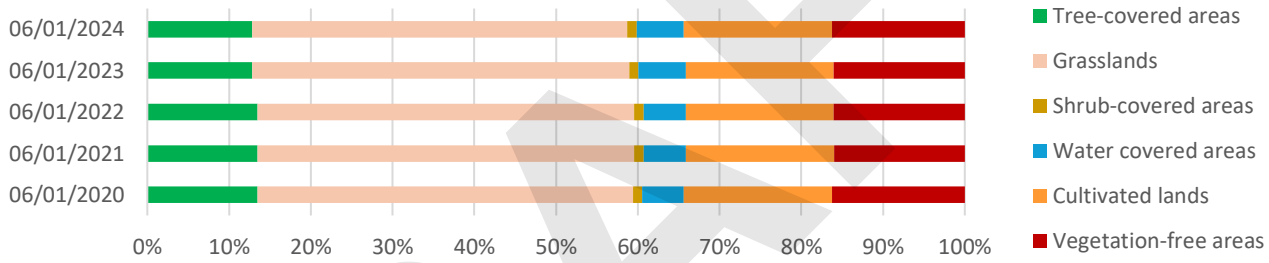


Figure 22A-1. The share of land cover classes in Armenia by Government-reported data

The more detailed disaggregation of land cover classes by land fund categories provided in the Government-reported data, enables the separation of vegetation-free anthropogenic areas, i.e., built-up areas from natural ones and makes it possible to compare Governmental data and land cover datasets (see here). The result with reclassified vegetation-free areas for Armenia and across marzes is shown un Fig.22A-2.

How to classify grasslands and cultivated lands located within settlement boundaries is a question that needs to be addressed in order to harmonize satellite-based land cover classifications with official land cover statistics. At this stage of the analysis, we kept these lands within grasslands and cultivated lands, respectively.

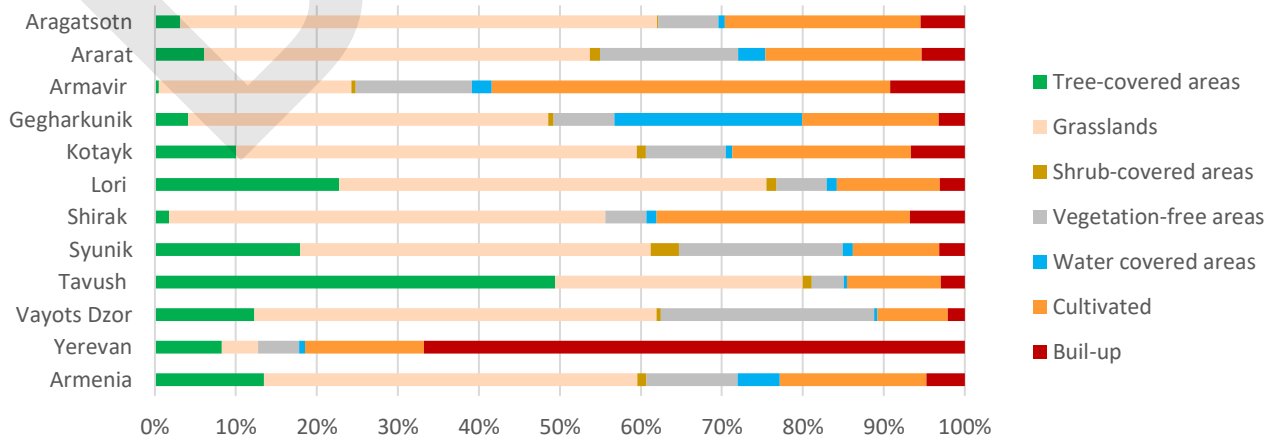


Figure 22A-2. The share of land cover classes in Armenia and across marzes by Government-reported data

Sources:
(2021) http://www.irtek.am/DOCUMENTS/PDF/148034_havelvac.pdf
(2021) https://faolex.fao.org/docs/pdf/arm209550.pdf
(2022) http://www.irtek.am/views/act.aspx?aid=156501
(2022) https://www.arlis.am/DocumentView.aspx?DocID=171671
(2023) https://www.e-draft.am/projects/6427/about
(2024) https://www.e-draft.am/projects/7902/about

2.2.B. Extent of land cover classes by ESRI data

Since the ESRI land cover dataset was selected for use in the project (Section 2.1.A), the subsequent extent assessment was conducted by ESRI data вased on the area of 1 pixel equal to 100 m^2. The extent of different land cover classes according to the other datasets can be found in the Section 2.1.A.

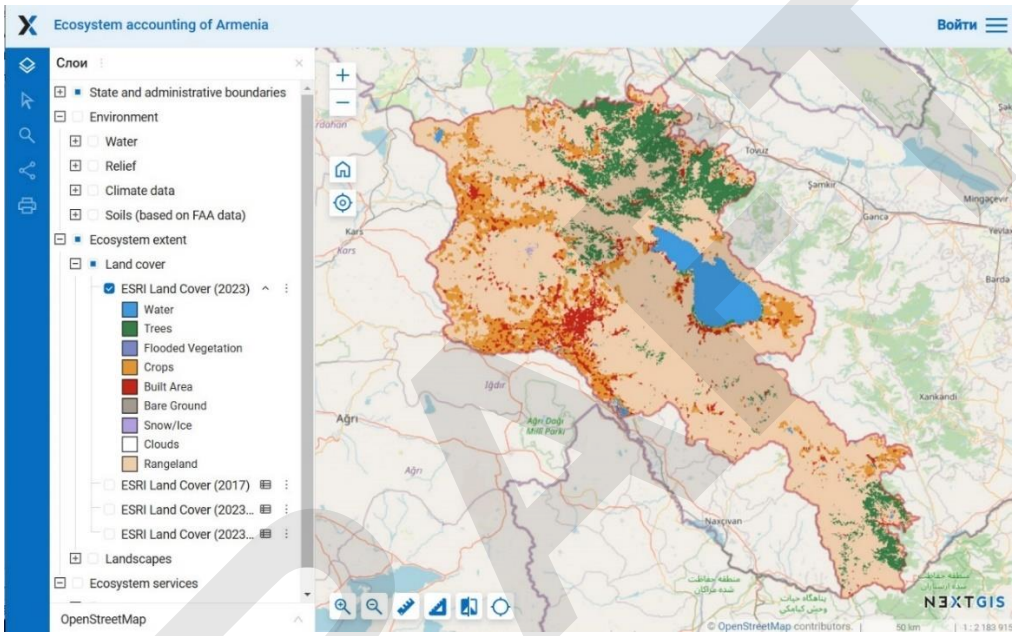


Figure 22B-1. ESRI dataset for the territory of Armenia

For detailed maps see project Web-GIS, sections "Ecosystem extent - Landcover"

National and marz levels

The majority of Armenia's territory is covered by grasslands (68% according to ESRI data), forests occupy 11% (13% according to Government data), croplands and built-up areas account for 12% and 5%, respectively. The most human-transformed marz is Armavir, where croplands and built-up areas together make up over 60% of the territory. The least transformed marzes are Vayots Dzor, Tavush, and Syunik. Forests cover the largest area in Tavush (around 50%), and are also widespread in Lori, where they exceed 20% of the territory (Tables 22B-1 and 22B-2; Figures 22B-2 and 22B-3).

Table 22B-1. Area of land cover classes in 2017, km^2

	Rangeland	Trees	Bare ground	Snow/Ice	Flooded veget.	Water	Crops	Built Area	Total
Aragatsotn	2,161.08	52.54	12.60	0.02	0.00	3.43	380.13	126.33	2,736.12
Ararat	1,522.66	30.47	16.35	0.01	11.71	29.16	359.92	144.64	2,114.91
Armavir	455.53	2.84	5.45	0.00	1.81	6.67	645.14	146.25	1,263.70
Gegharkunik	3,320.37	134.93	19.08	0.04	1.40	1,274.09	315.10	182.98	5,248.00
Kotayk	1,506.57	171.74	7.47	0.74	0.01	2.49	270.63	155.14	2,114.80
Lori	2,558.39	869.51	4.55	0.02	0.44	2.64	189.21	138.24	3,763.00
Shirak	1,998.79	13.08	4.31	0.00	0.07	27.21	537.55	137.61	2,718.63
Syunik	3,571.06	634.26	33.14	0.13	0.04	17.98	170.64	66.09	4,493.35
Tavush	1,234.28	1,304.10	1.34	0.00	0.00	4.00	91.52	91.00	2,726.24
Vayots Dzor	2,157.65	47.10	14.01	0.02	0.01	2.76	35.26	39.74	2,296.54
Armenia	20,549.27	3,261.03	119.68	0.97	15.47	1,371.25	3,018.23	1,372.59	29,708.49

Table 22B-2. Area of land cover classes in 2023, km²

	Rangeland	Trees	Bare Ground	Snow/Ice	Flooded vegetation	Water	Crops	Built Area	Total
Aragatsotn	2,096.86	48.25	3.48	6.38	0.00	3.50	438.49	139.17	2,736.12
Ararat	1,560.01	26.20	6.94	0.04	6.74	32.42	305.46	177.10	2,114.91
Armavir	461.83	0.55	2.05	0.00	0.15	7.10	609.26	182.76	1,263.70
Gegharkunik	3,239.85	129.56	4.28	0.94	0.65	1,274.08	404.99	193.66	5,248.00
Kotayk	1,508.64	153.10	1.08	1.60	0.00	2.57	265.38	182.43	2,114.80
Lori	2,424.92	883.74	2.83	0.31	0.79	3.81	298.87	147.73	3,763.00
Shirak	1,784.67	13.43	0.91	2.47	0.00	31.48	742.89	142.79	2,718.63
Syunik	3,650.25	507.74	12.65	0.09	0.02	15.86	233.22	73.53	4,493.35
Tavush	1,227.75	1,316.33	0.05	0.04	0.02	4.35	82.03	95.67	2,726.24
Vayots Dzor	2,174.55	38.13	2.51	0.35	0.00	2.35	33.28	45.37	2,296.54
Armenia	20,185.02	3,117.51	37.33	12.21	8.39	1,378.29	3,422.08	1,547.66	29,708.49

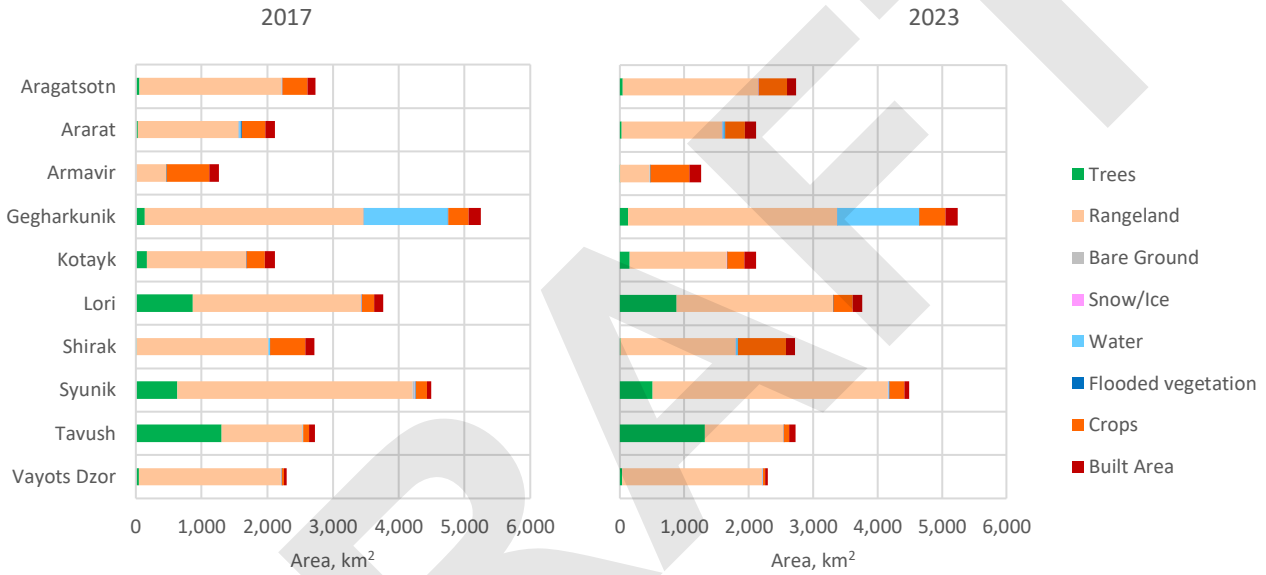


Figure 22B-2. Area of land cover classes in 2017 and 2023, km²

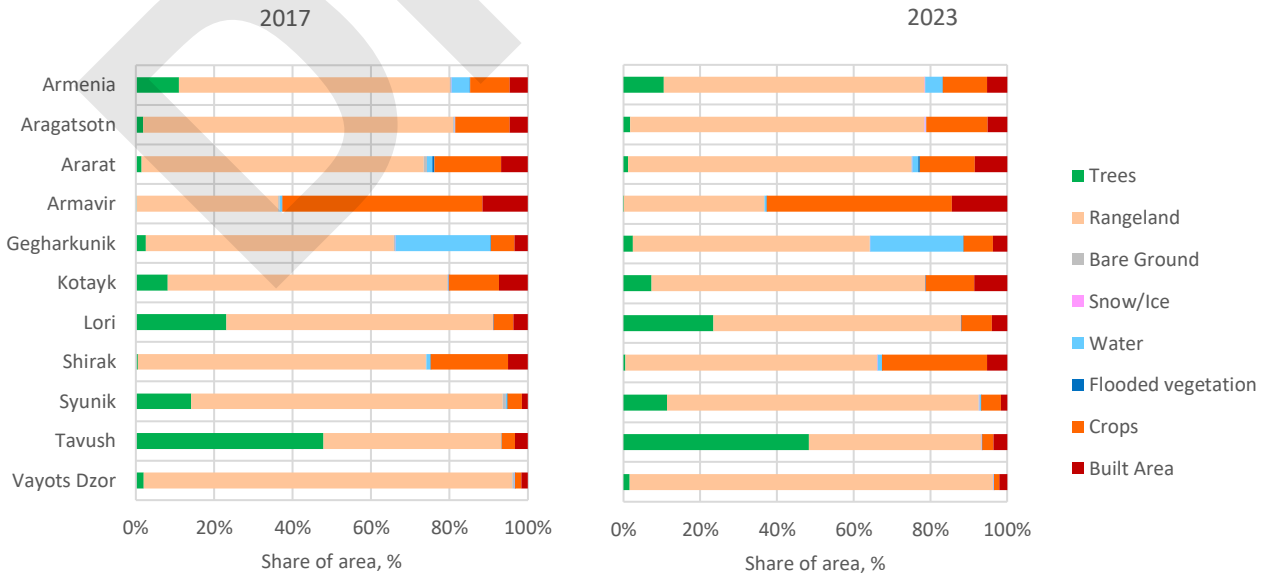


Figure 22B-3. The share of land cover classes in 2017 and 2023, %

Between 2017 and 2023, according to ESRI data, the area of croplands and built-up areas in Armenia increased by 404 km² and 175 km², respectively, while the area of forests and grasslands decreased by 144 km² and 364 km² (Table 22B-3). The most significant changes occurred in Shirak marz, where cropland area increased by 200 km² at the expense of grasslands . Similar but less extensive cropland expansion at the expense of grasslands took place in Lori, Gegharkunik, and Aragatsotn. In contrast, in Armavir and Ararat, cropland area decreased. In Armavir, this was due to an increase in built-up areas, while in Ararat, it resulted from both an expansion of built-up areas and grasslands. In Syunik marz, forest area noticeably declined due to an increase in grasslands and croplands (Table 22B-3; Figure 22B-4 a). Relative changes in land cover areas present a somewhat different picture. In 2023, the ESRI land cover dataset shows an 80% loss of tree cover in Armavir marz compared to 2017, although this loss is barely noticeable in absolute terms due to the initially small woody area in that marz. The largest relative increase in cropland area was identified in Lori marz — nearly 60% (Figure 22B-4 b).

Table 22B-3. Changes in area of land cover classes from 2017 to 2023, km²

	Rangeland	Trees	Bare Ground	Snow/Ice	Flooded vegetation	Water	Crops	Built Area
Aragatsotn	-64.22	-4.29	-9.12	6.36	0.00	0.06	58.36	12.84
Ararat	37.35	-4.28	-9.42	0.04	-4.96	3.27	-54.46	32.46
Armavir	6.30	-2.29	-3.41	0.00	-1.65	0.43	-35.88	36.50
Gegharkunik	-80.52	-5.37	-14.81	0.90	-0.75	-0.02	89.89	10.68
Kotayk	2.07	-18.64	-6.39	0.86	-0.01	0.08	-5.26	27.28
Lori	-133.47	14.22	-1.72	0.28	0.35	1.17	109.66	9.50
Shirak	-214.12	0.34	-3.40	2.47	-0.06	4.26	205.33	5.18
Syunik	79.18	-126.52	-20.49	-0.04	-0.02	-2.12	62.58	7.44
Tavush	-6.54	12.23	-1.28	0.04	0.02	0.35	-9.49	4.68
Vayots Dzor	16.90	-8.97	-11.50	0.33	-0.01	-0.41	-1.98	5.63
Armenia	-364.25	-143.52	-82.35	11.23	-7.08	7.04	403.85	175.08

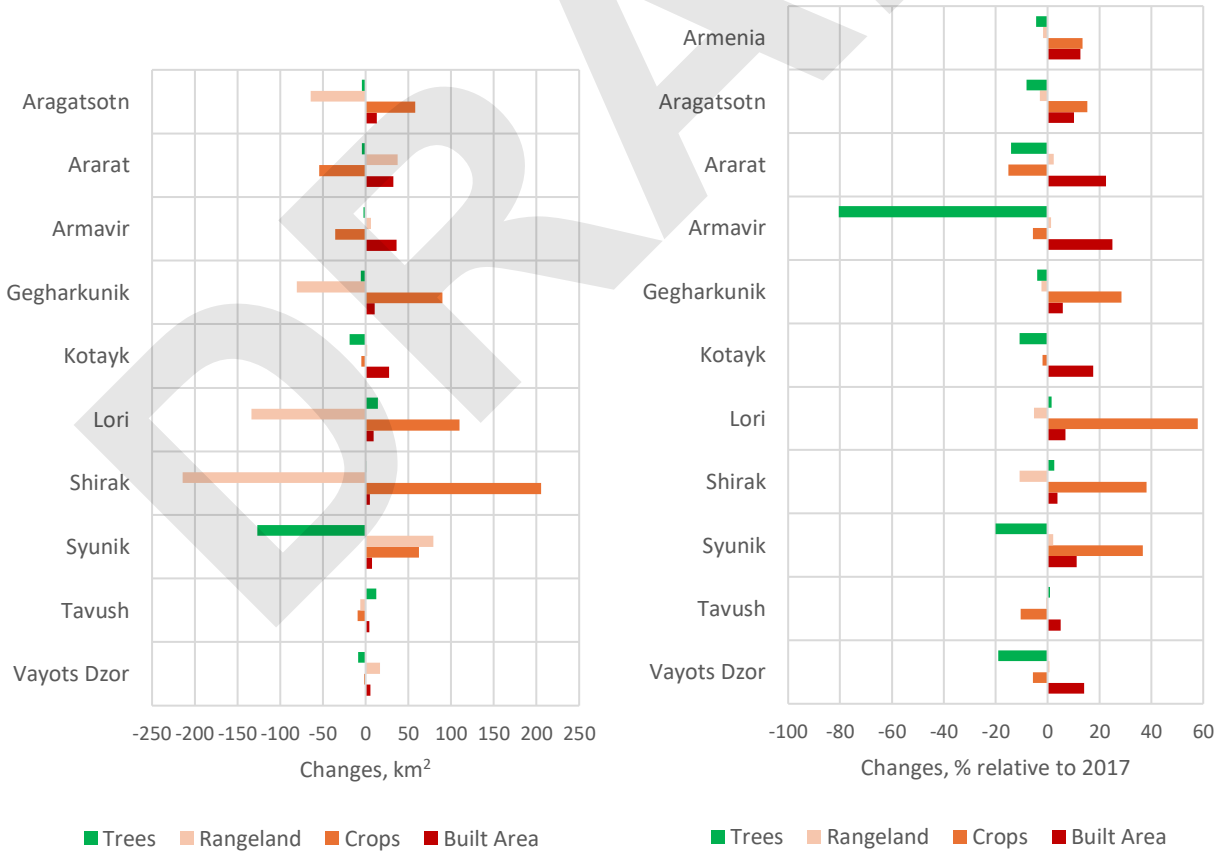


Figure 22B-4. Absolute (km²) and relative (% of 2017 area) changes in area of the main land cover classes in Armenia and across marzes from 2017 to 2023

Watersheds

Land cover class extent accounting was also carried out for the large watersheds, since one of the key purposes of ecosystem accounting is to assess water-regulating ecosystem services, which are modeled at the watershed level. Since in Armenia watershed boundaries largely coincide with marz boundaries (the Hrazdan, Metsamor, and Arpa watersheds each include two marzes), the pattern of land cover class area distribution and its changes from 2017 to 2023 mirrors the pattern identified at the marz level.

The most human-transformed watersheds are Metsamor (marzes Aragatsotn and Armavir) and Akhuryan (marz Shirak), where croplands and built-up areas together make up around 30% of the territory. The least transformed watersheds are Aghstev (marz Tavush) and Vorotan (marz Syunik). Forests cover large areas in Aghstev watershed (marz Tavush) and Debed watershed (marz Lori) (Tables 22B-4 and 22B-5; Figures 22B-5 nd 22B-6).

Table 22B-4. Area of land cover classes in watersheds in 2017, km²

	Trees	Rangeland	Bare Ground	Snow/Ice	Flooded vegetation	Water	Crops	Built Area
Aghstev	1401.27	1600.07	1.99	0.01	0.00	3.70	69.63	98.72
Akhuryan	9.30	1999.78	4.42	0.00	0.07	27.25	599.85	144.59
Arpa	79.92	3839.27	30.63	0.15	10.84	26.36	288.32	134.83
Debed	843.51	2719.90	4.83	0.02	0.44	3.11	212.89	141.05
Hrazdan	243.39	4384.18	27.42	0.65	1.68	1281.05	765.19	545.57
Metsamor	49.32	2420.53	17.31	0.02	2.41	11.80	911.62	241.75
Vorotan	634.26	3573.45	32.93	0.13	0.04	17.98	170.65	66.09

Table 22B-4. Area of land cover classes in watersheds in 2023, km²

	Trees	Rangeland	Bare Ground	Snow/Ice	Flooded vegetation	Water	Crops	Built Area
Aghstev	1397.07	1590.30	0.09	0.08	0.02	4.04	80.02	103.76
Akhuryan	9.54	1801.94	0.90	2.36	0.00	31.54	789.01	149.95
Arpa	66.30	3890.99	9.26	0.73	6.22	29.55	249.59	157.67
Debed	865.33	2575.47	2.84	0.27	0.79	4.29	325.58	151.17
Hrazdan	228.70	4305.51	6.24	2.17	0.67	1280.73	794.73	630.37
Metsamor	42.74	2356.44	5.25	6.48	0.66	12.27	949.72	281.20
Vorotan	507.74	3652.35	12.65	0.11	0.02	15.86	233.26	73.54

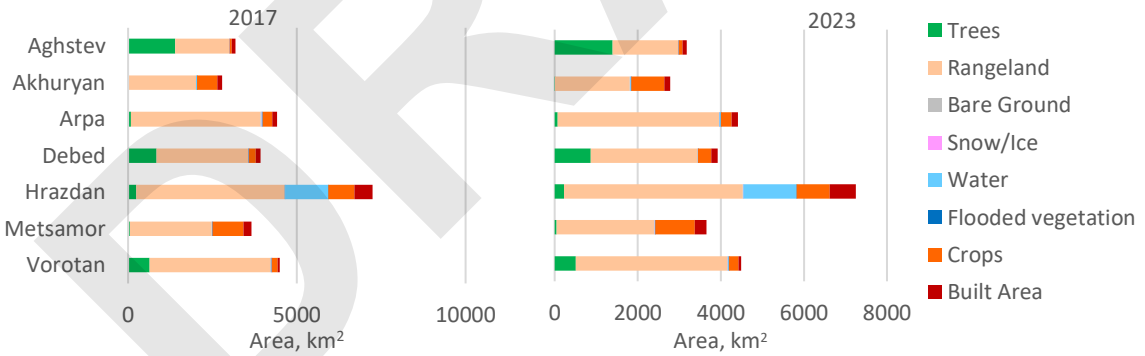


Figure 22B-5. Area of land cover classes across watersheds in 2017 and 2023, km²

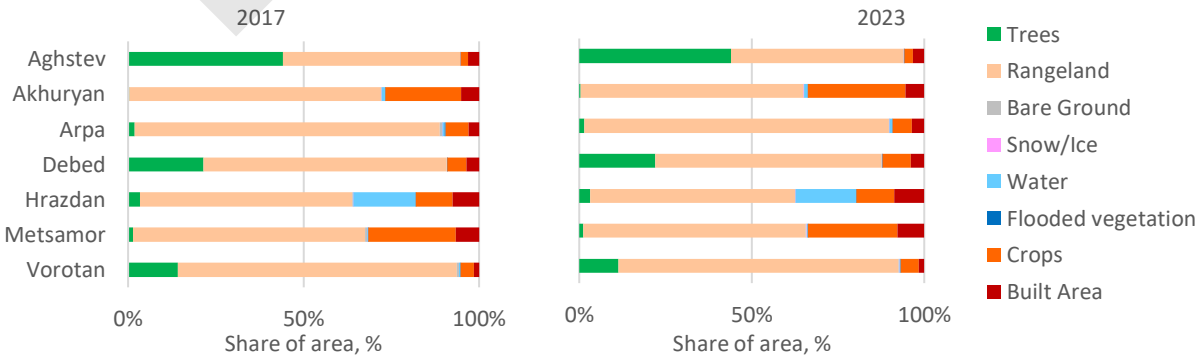


Figure 22B-6. The share of land cover classes across watersheds in 2017 and 2023, %

The most significant changes in land cover area occurred in Akhurian watershed (Shirak marz), where cropland area increased by 200 km² at the expense of grasslands. Similar but less extensive cropland expansion at the expense of grasslands took place in Debed watershed (Lori marz). In the Razdan and Metsamor watersheds, grassland areas decreased due to the expansion of croplands and built-up areas. Changes in the Arpa watershed are driven by changes in Ararat marz, where cropland area decreased due to the expansion of built-up areas and grasslands. In Vorotan watershed (Syunik marz), forest area noticeably declined due to an increase in grasslands and croplands (Table 22B-5; Figure 22B-7 a).

Relative changes show the largest relative increase in cropland area in Debed watershed (Lori marz) and significant increase in cropland area in Vorotan watershed (Syunik marz) and Akhuryan watershed (Shirak marz). In the Vorotan, Arpa, and Metsamor watersheds, forest area decreased by 10–20% (Figure 22B-7 b).

Table 22B-5.Changes in area of land cover classes from 2017 to 2023, km2

	Trees	Rangeland	Bare Ground	Snow/Ice	Flooded vegetation	Water	Crops	Built Area
Aghstev	-4.20	-9.77	-1.90	0.08	0.02	0.34	10.39	5.04
Akhuryan	0.25	-197.84	-3.52	2.36	-0.06	4.29	189.17	5.35
Arpa	-13.62	51.72	-21.36	0.58	-4.62	3.19	-38.73	22.85
Debed	21.82	-144.43	-1.99	0.25	0.35	1.18	112.69	10.12
Hrazdan	-14.69	-78.67	-21.18	1.52	-1.01	-0.32	29.54	84.81
Metsamor	-6.59	-64.09	-12.06	6.46	-1.75	0.47	38.10	39.46
Vorotan	-126.52	78.89	-20.28	-0.02	-0.02	-2.12	62.62	7.45

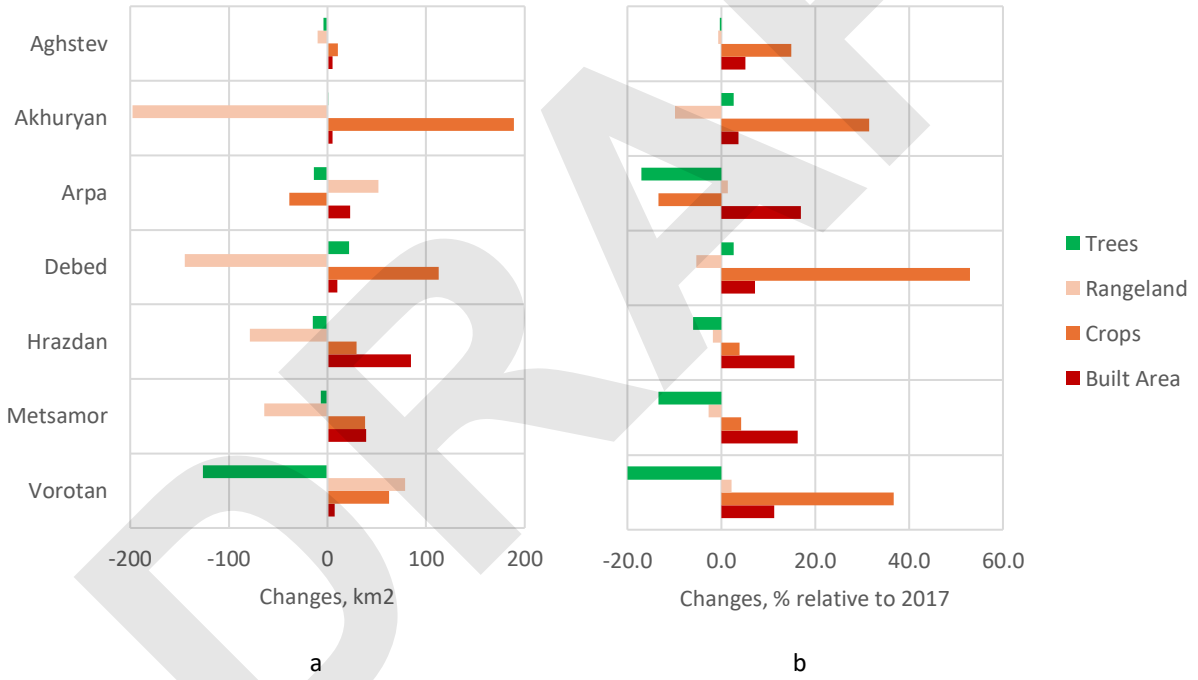


Figure 22B-7. Absolute (km²) and relative (% of 2017 area) changes in area of the main land cover classes across watersheds from 2017 to 2023

2.3. Extent of vegetation/ecosystem types

2.3.A. Extent of vegetation zones and current vegetation in Armenia

The assessment of the extent of vegetation types was made based on a vegetation map created by the project experts Alla Aleksanyan and Vardan Asatryan (Fig. 23A-1a). The map was created based on Barseghyan (2007) and other materials.

The current natural area of vegetation zones is defined as the potential area of a given vegetation type minus cropland and built-up areas based on ESRI land cover data 2023 (Fig. 23A-1b).

Academic vegetation maps cannot reflect small patches of tree cover located within non-forest zones. In Armenia, such patches are typically associated with specific landforms— such as canyons, gorges, and slopes — where atypical conditions for non-forest zones allow tree vegetation to persist. However, these tree cover patches are visible in land cover datasets. Integrating the vegetation map with land cover data makes it possible to account for forest distribution beyond the typical forest vegetation zone (Fig. 23A-1c).

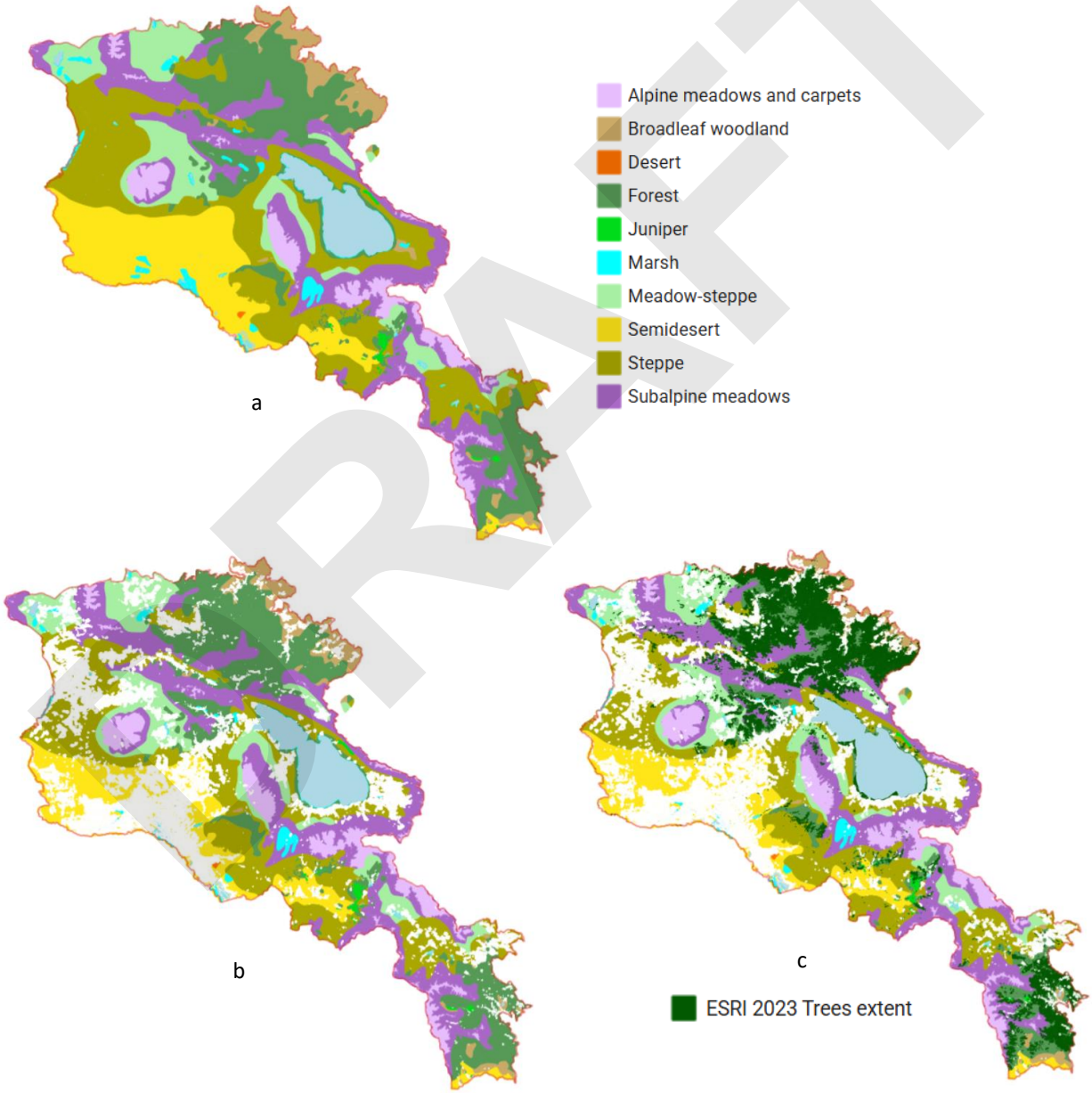


Figure 23A-1. Maps of vegetation: a) potential distribution of vegetation types; b) current natural area of vegetation zones; c) vegetation, including current tree cover [For detailed map see project Web-GIS, sections Ecosystem Extent/Vegetation/Vegetation map 2025]

According to ESRI data, the most human-transformed vegetation zone is semi-desert, where 57% of natural areas remain. It is followed by marshes and steppe with 71% and 76% of natural areas remaining, respectively.Tree cover occupies more than 40% of the forest zone and more than 20% of the broadleaf woodland zone. Significant forest patches are also present in subalpine meadows, meadow-steppe, and steppe zones. In the remaining zones, the tree cover identified by ESRI occupies a very small area — from 0 to 4 km². In the marsh zone, water bodies occupy a substantial area (Lake Sevan is excluded from the analysis) (Table 23A-1; Figure 23A-2).

Table 23A-1. Current area of land cover classes across vegetation zones, km²

	Trees	Rangeland	Bare ground	Snow/Ice	Water/ flooded veg.	Crops	Built area	No data/ clouds	Total	Share of natural LC classes, %
Alpine vegetation	0.61	1632.30	10.32	11.65	1.97	3.46	0.78	2.83	1663.92	100
Subalpine meadows	254.58	4266.55	5.53	0.27	3.03	84.53	24.84	19.79	4659.12	98
Meadow-steppe	76.39	2549.78	0.22	0.04	7.25	451.65	91.45	22.66	3199.42	83
Steppe	94.59	5217.84	3.25	0.00	5.05	1302.02	399.16	27.97	7049.88	76
Forest	2397.98	2888.01	3.92	0.00	30.51	154.96	197.66	21.76	5694.79	94
Juniper	4.23	130.60	0.12	0.00	0.09	0.17	0.89	0.05	136.15	99
Broadleaf woodland	263.67	691.61	2.65	0.00	7.28	123.48	82.12	27.23	1198.03	83
Semidesert	3.46	2462.38	9.03	0.00	33.04	1211.12	715.19	50.39	4484.59	57
Desert	0.00	6.67	0.22	0.00	0.00	0.52	0.28	0.00	7.69	90
Marsh	0.82	228.14	1.01	0.00	49.54	85.19	32.46	3.09	400.25	71
Armenia	3096.34	20073.85	36.27	11.96	137.74	3417.09	1544.83	175.76	28493.85	83

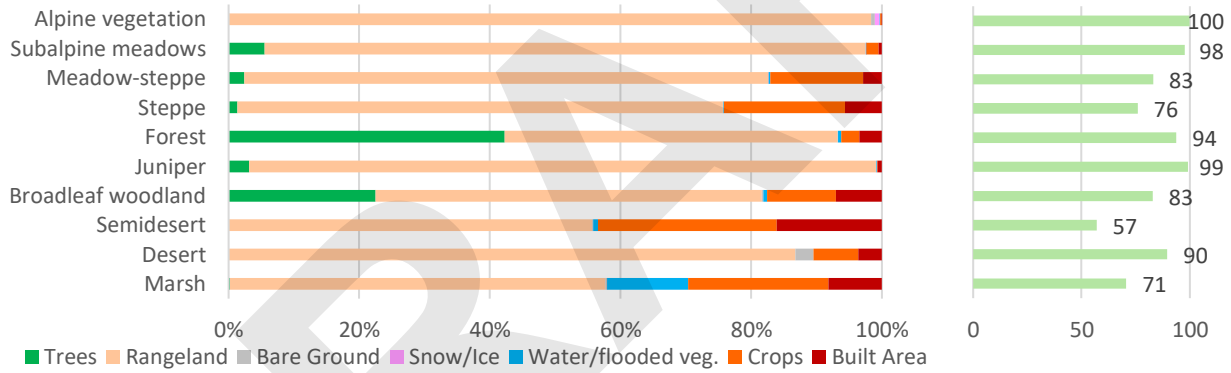


Figure 23A-2. Share of land cover classes across vegetation zones, %

After excluding the area of croplands and built-up areas, zones A and B occupy the largest area in Armenia — each exceeding 5,000 km². The subalpine meadow zone is also extensive, covering more than 4,500 km². The smallest zones by area are marshes and juniper woodlands (283 and 135 km², respectively), as well as the extreme small desert zone, which consists of a single patch covering only 7 km² (Table 23A-2; Figure 23A-3a). Considering all tree-covered areas as forest, the most widespread vegetation types are steppe and subalpine meadows, followed by forests in all vegetation zones and grasslands in forest zone each covering approximately 3,000 km². The areas of other vegetation zones change little, as tree cover within them is minimal (Figure 23A-3b).

Table 23A-2. Natural area of vegetation zones in 2017 and 2023 and changes in it, km²

Vegetation types	*Area in 2023, km²*	*Area in 2017, km²*	*Changes 2023-2017, km²*	*Changes, % relative to 2017*
Alpine meadows and carpets	1660.84	1662	-1.16	-0.07
Subalpine meadows	4552.95	4601.92	-48.97	-1.06
Meadow-steppe	2658.2	2906.94	-248.74	-8.56
Steppe	5352.42	5571.67	-219.25	-3.94
Juniper	135.2	135.38	-0.18	-0.13
Forest	5345.91	5394.29	-48.38	-0.90
Broadleaf woodland	993.16	985.22	7.94	0.81
Semidesert	2560.1	2575.06	-14.96	-0.58
Desert	6.89	7.11	-0.22	-3.09
Marsh	282.79	291	-8.21	-2.82

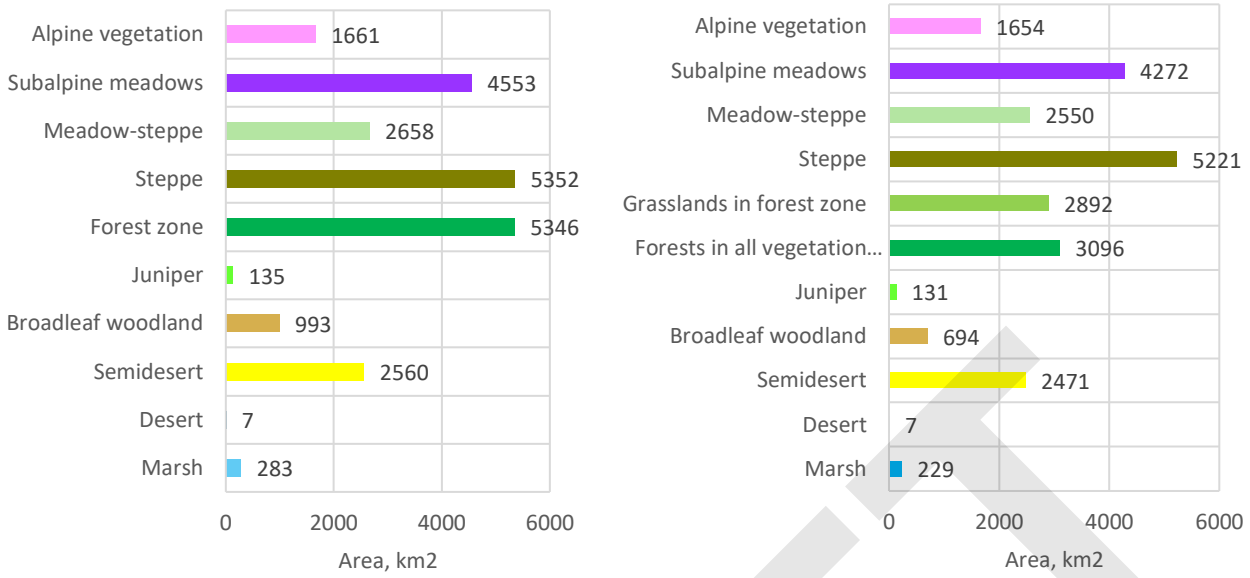


Figure 23A-3. Natural area of vegetation zones (a) and area of vegetation types including current tree cover, km²

2.3.B. Rarity of vegetation/ecosystem types in Armenia

Currently, zones of desert, juniper woodlands, and marshes have the smallest natural areas (less than 1% of Armenia's area), while the most widespread are zones forest and steppe (each is around 18% of Armenia's area). Treating all tree cover as forest change a little the overall picture introducing one more relatively common vegetation type — grasslands in forest zone, which accounts for 10% of Armenia's territory. Total forest area in all vegetation zones (about 10%) is significantly smaller than the area of the entire forest zone (18%), which is visible at rarity maps (Fig. 23B-2).

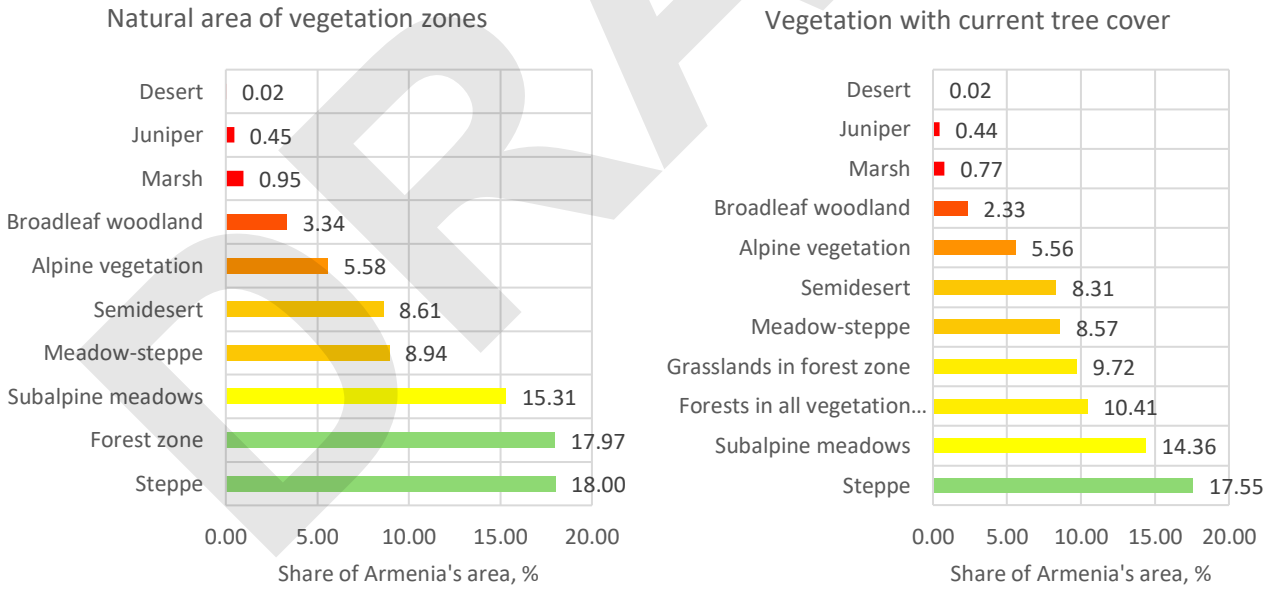


Figure 23B-1. Ranking of vegetation types by rarity: a) natural area of vegetation zones; b) vegetation with current tree cover.

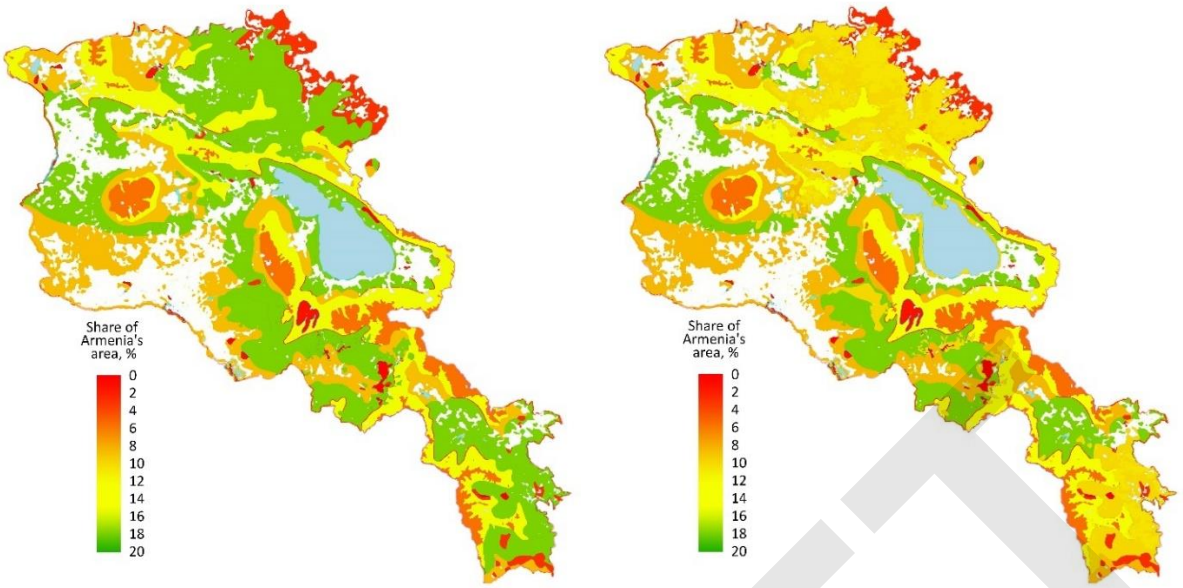


Figure 23B-2. Rarity maps: a) natural area of vegetation zones; b) vegetation with current tree cover.

2.3.C. Changes in natural area of vegetation zones from 2017 to 2023 in Armenia

From 2017 to 2023, the area of all zones not occupied by croplands and built-up areas decreased. The only exception is the broadleaf woodland zone, where anthropogenic areas slightly declined, allowing more space for ecosystems. The most significant reductions, both in absolute and relative terms, occurred in the meadow-steppe and steppe zones (Table 23A-2; Figure 23C-1).

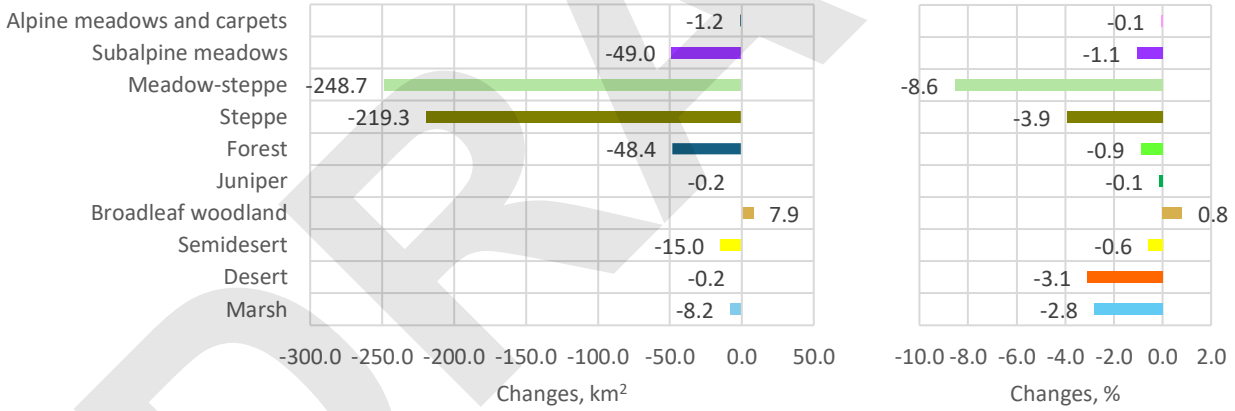


Figure 23C-1. Changes in area of natural vegetation zones from 2017 to 2023

Table 23C-1. Natural area of vegetation zones in Armenia in 2017 and 2023, and changes in it

Vegetation types	*Area in 2023, km2*	*Area in 2017, km2*	*Changes, km2*	*Changes, % relative to 2017*
Alpine meadows and carpets	1660.84	1662	-1.16	-0.07
Subalpine meadows	4552.95	4601.92	-48.97	-1.06
Meadow-steppe	2658.2	2906.94	-248.74	-8.56
Steppe	5352.42	5571.67	-219.25	-3.94
Juniper	135.2	135.38	-0.18	-0.13
Forest	5345.91	5394.29	-48.38	-0.90
Broadleaf woodland	993.16	985.22	7.94	0.81
Semidesert	2560.1	2575.06	-14.96	-0.58
Desert	6.89	7.11	-0.22	-3.09
Marsh	282.79	291	-8.21	-2.82

2.3.D. Marz level

The natural extent (i.e., the area not occupied by croplands or built-up areas) of vegetation zones is greatest in Syunik marz and smallest in Armavir marz (Figure 23D-1). The forest zone (including forests and grasslands within the boundaries of the forest vegetation zone) occupies the largest areas in the provinces of Lori, Syunik, and Tavush. Alpine and subalpine zones are most extensive in Syunik and Gegharkunik marzes. Steppe and meadow-steppe occupy substantial areas across all marzes except Armavir and Tavush, with the greatest extents in Gegharkunik and Shirak. The largest areas of natural semidesert have been preserved in the provinces of Aragatsotn, Armavir, and Ararat.

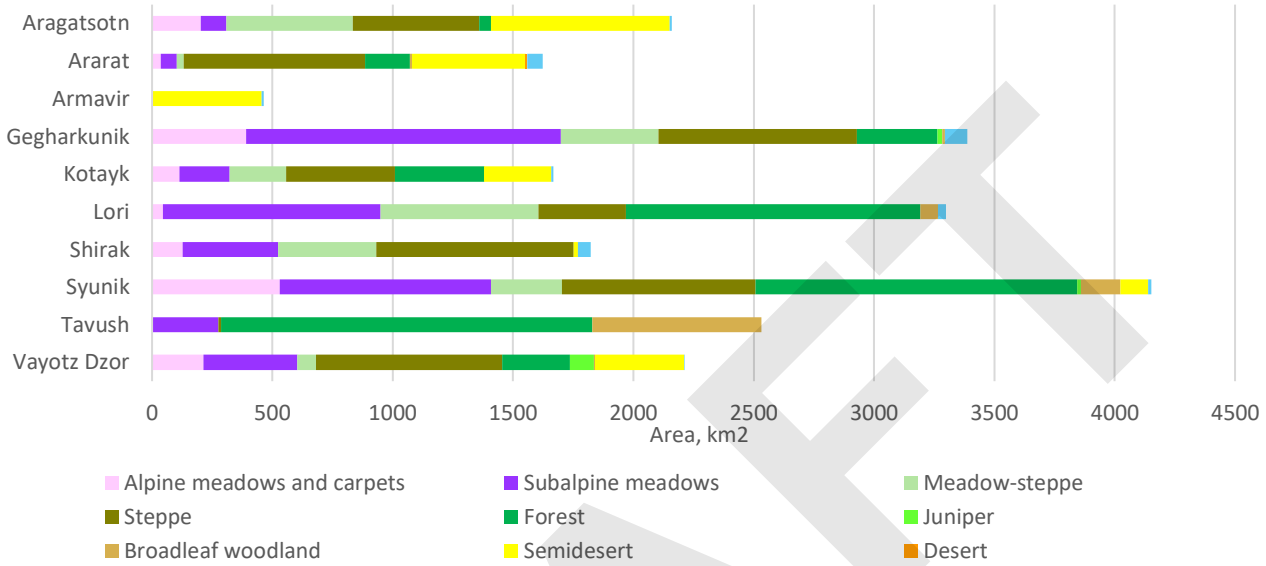


Figure 23D-1. Natural area of vegetation zones by provinces in 2023

Changes in the natural area of vegetation zones from 2017 to 2023 are small in absolute terms—on the order of tens of square kilometers or less. The most noticeable losses of natural area occurred in the steppe and meadow-steppe zones, especially in the provinces of Shirak, Gegharkunik, and Lori (Fig. 23D-2a; Table 23D-1). However, when expressed as the share of area lost or gained relative to 2017, the gain of open woodlands in Gegharkunik and the loss of marshes in Shirak and Aragatsotn become evident (Fig. 23D-2b; Table 23D-1).

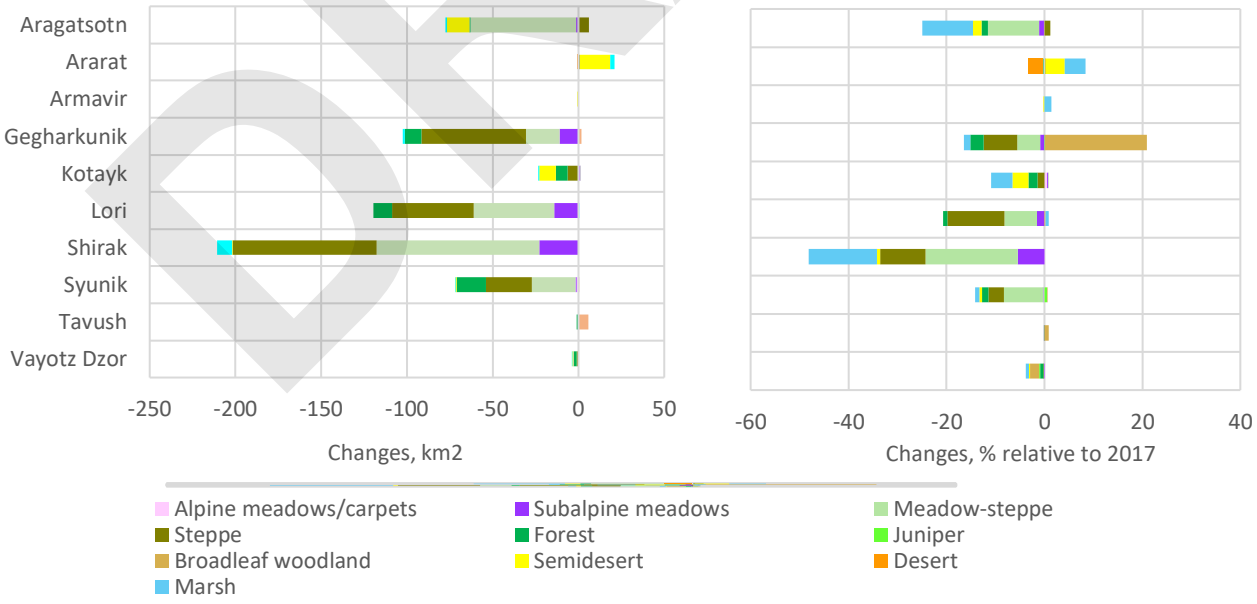


Figure 23D-2. Changes in matural area of vegetation zones by provinces from 2017 to 2023: a) absolute changes, km2; b) chare of lost/gained area, % relative to 2017.

Table 23D-1. Natural area of vegetation zones by provinces in 2017 and in 2023 and changes in it

	Araga-tsotn	Ararat	Arma-vir	Geghar-kunik	Kotayk	Lori	Shirak	Syunik	Tavush	Vayotz Dzor
Area in 2017, km2										
Alpine meadows/carpets	202.91	37.22	0	391.14	113.09	44.06	126.15	531.77	0.31	212.53
Subalpine meadows	107.04	64.63	0	1318.69	207.76	918.78	420.54	878.41	275.63	390.67
Meadow-steppe	586.56	30.74	0	425.1	234.72	703.85	503.67	320.9	0	78.76
Steppe	519.54	751.04	0	884.92	458.07	410.25	903.53	830.27	11.81	774.26
Forest	49.49	187.2	0	343.67	377.1	1235.36	0	1354.65	1542.98	282.16
Juniper	0	0	0	20.6	0	0	0	13.67	0	101.06
Broadleaf woodland	0	9.46	0	8.8	1.68	73.27	0	163.98	696.06	4.74
Semi-desert	756.42	453.14	456.89	0	288.68	0	17.25	116.41	0	370.26
Desert	0	7.11	0	0	0	0	0	0	0	0
Marsh	7.87	61.66	7.62	94.09	8.55	31.68	61.9	13.07	0	1.48
Area in 2023, km2										
	Araga-tsotn	Ararat	Arma-vir	Geghar-kunik	Kotayk	Lori	Shirak	Syunik	Tavush	Vayotz Dzor
Alpine meadows/carpets	202.59	37.16	0	391.05	113.68	44.06	126.14	530.55	0.31	212.47
Subalpine meadows	106.04	64.63	0	1307.91	208.24	904.53	397.7	878.07	275.54	390.5
Meadow-steppe	524.94	30.77	0	405.23	234.95	656.93	408.82	295.18	0	78.74
Steppe	525.73	751.66	0	824.14	451.72	362.86	819.41	803.66	11.81	773.48
Forest	48.88	187.13	0	334.03	370.1	1224.23	0	1337.58	1541.85	280.41
Juniper	0	0	0	20.62	0	0	0	13.74	0	100.79
Broadleaf woodland	0	9.46	0	10.63	1.68	73.41	0	164.17	701.92	4.65
Semi-desert	743.31	470.97	456.02	0	279.08	0	17.15	115.78	0	369.73
Desert	0	6.89	0	0	0	0	0	0	0	0
Marsh	7.05	64.27	7.73	92.94	8.18	31.88	53.23	12.95	0	1.47
Changes 2023-2017, km2										
	Araga-tsotn	Ararat	Arma-vir	Geghar-kunik	Kotayk	Lori	Shirak	Syunik	Tavush	Vayotz Dzor
Alpine meadows/carpets	-0.32	-0.06	0	-0.09	0.59	0	-0.01	-1.22	0	-0.06
Subalpine meadows	-1	0	0	-10.78	0.48	-14.25	-22.84	-0.34	-0.09	-0.17
Meadow-steppe	-61.62	0.03	0	-19.87	0.23	-46.92	-94.85	-25.72	0	-0.02
Steppe	6.19	0.62	0	-60.78	-6.35	-47.39	-84.12	-26.61	0	-0.78
Forest	-0.61	-0.07	0	-9.64	-7	-11.13	0	-17.07	-1.13	-1.75
Juniper	0	0	0	0.02	0	0	0	0.07	0	-0.27
Broadleaf woodland	0	0	0	1.83	0	0.14	0	0.19	5.86	-0.09
Semi-desert	-13.11	17.83	-0.87	0	-9.6	0	-0.1	-0.63	0	-0.53
Desert	0	-0.22	0	0	0	0	0	0	0	0
Marsh	-0.82	2.61	0.11	-1.15	-0.37	0.2	-8.67	-0.12	0	-0.01
Changes 2023-2017, % relative to 2017										
	Araga-tsotn	Ararat	Arma-vir	Geghar-kunik	Kotayk	Lori	Shirak	Syunik	Tavush	Vayotz Dzor
Alpine meadows/carpets	-0.16	-0.16	0.00	-0.02	0.52	0.00	-0.01	-0.23	0.00	-0.03
Subalpine meadows	-0.93	0.00	0.00	-0.82	0.23	-1.55	-5.43	-0.04	-0.03	-0.04
Meadow-steppe	-10.51	0.10	0.00	-4.67	0.10	-6.67	-18.83	-8.01	0.00	-0.03
Steppe	1.19	0.08	0.00	-6.87	-1.39	-11.55	-9.31	-3.20	0.00	-0.10
Forest	-1.23	-0.04	0.00	-2.81	-1.86	-0.90	0.00	-1.26	-0.07	-0.62
Juniper	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.51	0.00	-0.27
Broadleaf woodland	0.00	0.00	0.00	20.80	0.00	0.19	0.00	0.12	0.84	-1.90
Semi-desert	-1.73	3.93	-0.19	0.00	-3.33	0.00	-0.58	-0.54	0.00	-0.14
Desert	0.00	-3.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Marsh	-10.42	4.23	1.44	-1.22	-4.33	0.63	-14.01	-0.92	0.00	-0.68

2.3.E. Reduction of the potential distribution area of vegetation types identified on the 1961 vegetation map

For this analysis, the vegetation map from the 1961 Atlas of the Armenian SSR (1961), digitized by Vardan Asatryan, and the ESRI land cover data for 2023 were used. The current distribution of vegetation types was considered as potential vegetation zones (Figure 23E-1a), excluding croplands and built-up areas based on ESRI data for 2023 (Figure 23E-1b).

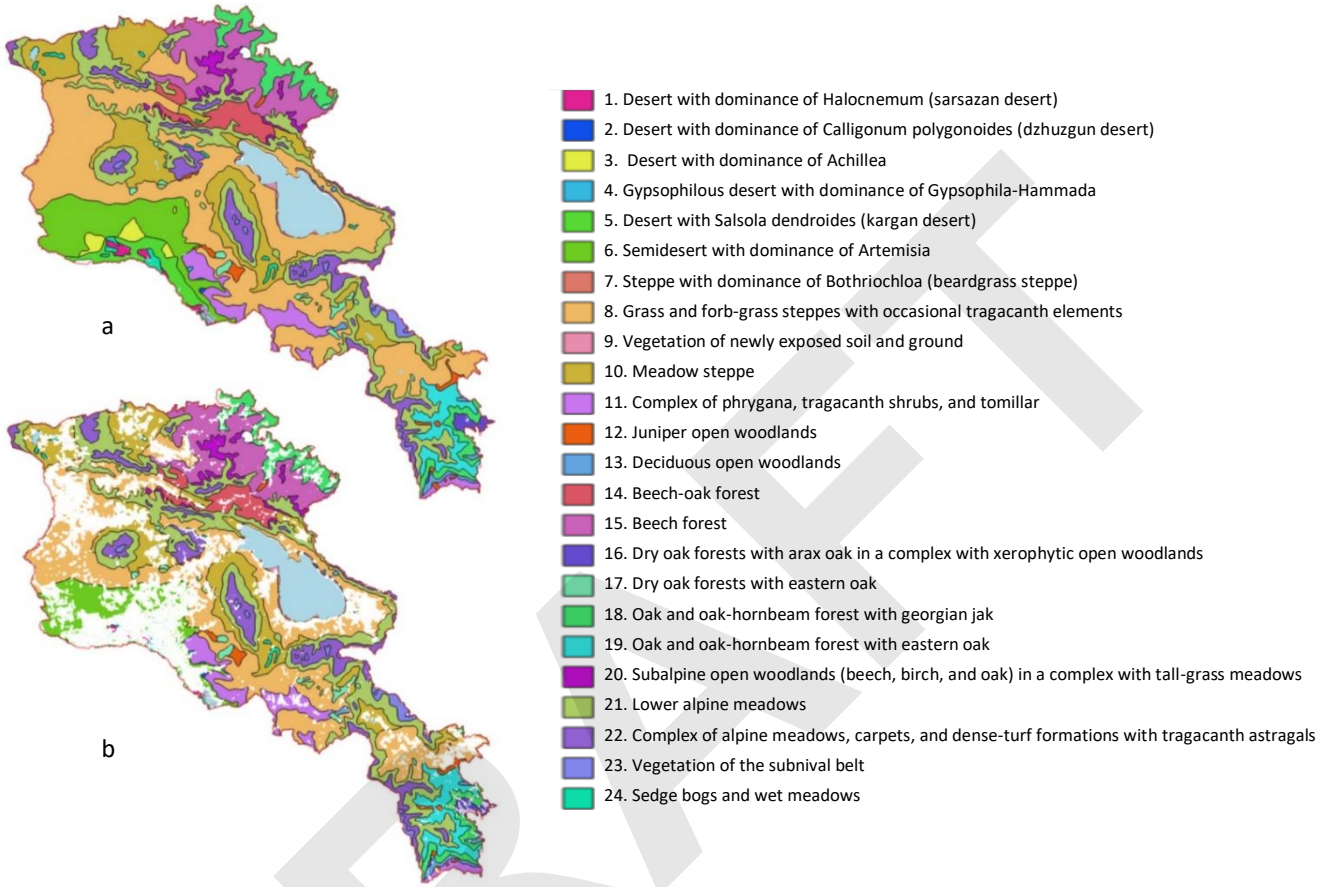


Figure 23E-1. Vegetation map of 1961: a) potential vegetation; b) vegetation excluding croplands and built-up areas in 2023. For detailed maps see in the Section Ecosystem Extent/Vegetation

Ranking of vegetation types by their current rarity (Figure 23E-2) shows that, at present, all desert types (1–5) as well as steppe with dominance of Bothriochloa (type 7) are the rarest. Each of them occupies less than 100 km². The potential distribution areas of the two rarest desert types (2 and 4), each occupying less than 10 km², have largely preserved and mostly not covered by croplands or built-up areas according to ESRI data. The distribution area of steppe with dominance of Bothriochloa (7) also appears to be relatively well preserved.

The most severely affected was the distribution area of desert with dominance of Achillea (3), of which only 7% remains, as well as desert with Salsola dendroides (5), with only 16% remaining. The distribution area of desert with dominance of Halocnemum (1) has also been significantly reduced, with 43% remaining. These three vegetation types have experienced the greatest decline among all types shown on the map.

Relatively rare vegetation types occupying between 100 and 200 km² — deciduous and juniper open woodland (12, 13) and variants of oak forests (16, 17) — have relatively well-preserved distribution areas, with 85–99% remaining.

Among the more widespread vegetation types, occupying between 200 and 1,000 km², a significant reduction was observed only for sedge bogs and wet meadows (type 24), which declined to 63%. The distribution areas of other types — subnival vegetation, subalpine open woodlands, variants of oak and birch-oak forests, as well as shrublands — have been largely unaffected by human activity, with 94–100% of their area remaining intact.

Among the common and widespread vegetation types occupying more than 1,000 km², significant reductions have occurred in semi-desert with dominance of Artemisia (type 6) with 57% remaining and the most widespread vegetation zone - grass and forb-grass steppes (type 8) with 75% remaining, both of which are located in areas of arable agriculture.

Table 23E-1. Potential and current areas of vegetation types and the degree of their preservation

Vegetation zones	*Total potential distribution area, km2*	*Area not occupied by croplands and built-up areas in 2023, km2*	*Area share not occupied by croplands and built-up areas relative to the total potential distribution area, %*
1. Desert with dominance of Halocnemum (sarsazan desert)	135.1	57.5	42.5
2. Desert with dominance of Calligonum polygonoides (dzhuzgun desert)	7.4	6.6	89.6
3. Desert with dominance of Achillea	256.0	17.6	6.9
4. Gypsophilous desert with dominance of Gypsophila-Hammada	9.8	8.1	82.6
5. Desert with Salsola dendroides (kargan desert)	582.7	95.3	16.4
6. Semidesert with dominance of Artemisia	2107.2	1201.5	57.0
7. Steppe with dominance of Bothriochloa (beardgrass steppe)	39.1	31.3	80.0
8. Grass and forb-grass steppes with occasional tragacanth elements	8614.1	6464.9	75.1
9. Vegetation of newly exposed soil and ground	124.5	107.8	86.6
10. Meadow steppe	3347.4	2781.2	83.1
11. Complex of phrygana, tragacanth shrubs, and tomillar	944.1	886.5	93.9
12. Juniper open woodlands	209.5	198.9	94.9
13. Deciduous open woodlands	153.5	151.6	98.8
14. Beech-oak forest	650.5	625.7	96.2
15. Beech forest	1934.6	1884.0	97.4
16. Dry oak forests with arax oak in a complex with xerophytic open woodlands	143.1	121.1	84.6
17. Dry oak forests with eastern oak	200.9	199.1	99.1
18. Oak and oak-hornbeam forest with georgian jak	1252.1	1088.1	86.9
19. Oak and oak-hornbeam forest with eastern oak	737.8	728.2	98.7
20. Subalpine open woodlands (beech, birch, and oak) in a complex with tall-grass meadows	360.6	360.5	100.0
21. Lower alpine meadows	4398.9	4370.6	99.4
22. Complex of alpine meadows, carpets, and dense-turf formations with tragacanth astragals	1932.9	1919.6	99.3
23. Vegetation of the subnival belt	246.7	245.7	99.6
24. Sedge bogs and wet meadows	327.8	207.2	63.2

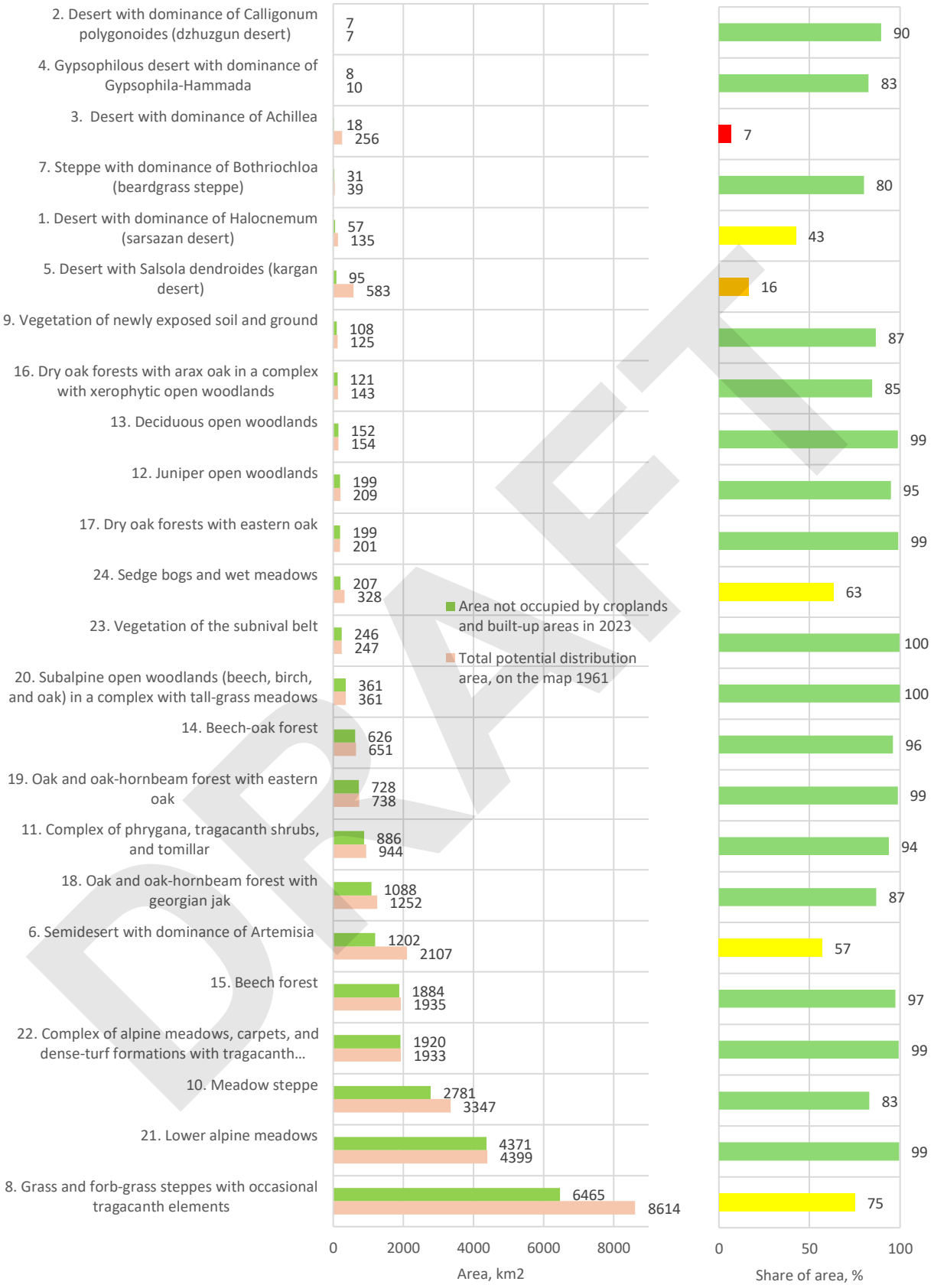


Figure 23E-2. Potential area of vegetation types and their current state: a) potential area of each vegetation type and the area remaining as of 2023; vegetation types are ranked by their rarity in 2023; b) share of the area not occupied by croplands and built-up areas relative to the total potential distribution area, %.

2.4. Extent of natural landscapes

2.4.A. Extent of natural landscapes in Armenia

To estimate extent of natural landscapes, the map of landscape zones published in the Fifth National Report of Armenia to the CBD (2014) was used (available in digital form in Forest Atlas of Armenia FAA), along with ESRI land cover data for 2017 and 2023 as well as ESA 2021 data for comparison (Fig. 24A-1).

The area of natural landscapes was calculated as the area of a given landscape zone minus waterbodies and anthropogenically transformed territories, that is, built-up areas and croplands.

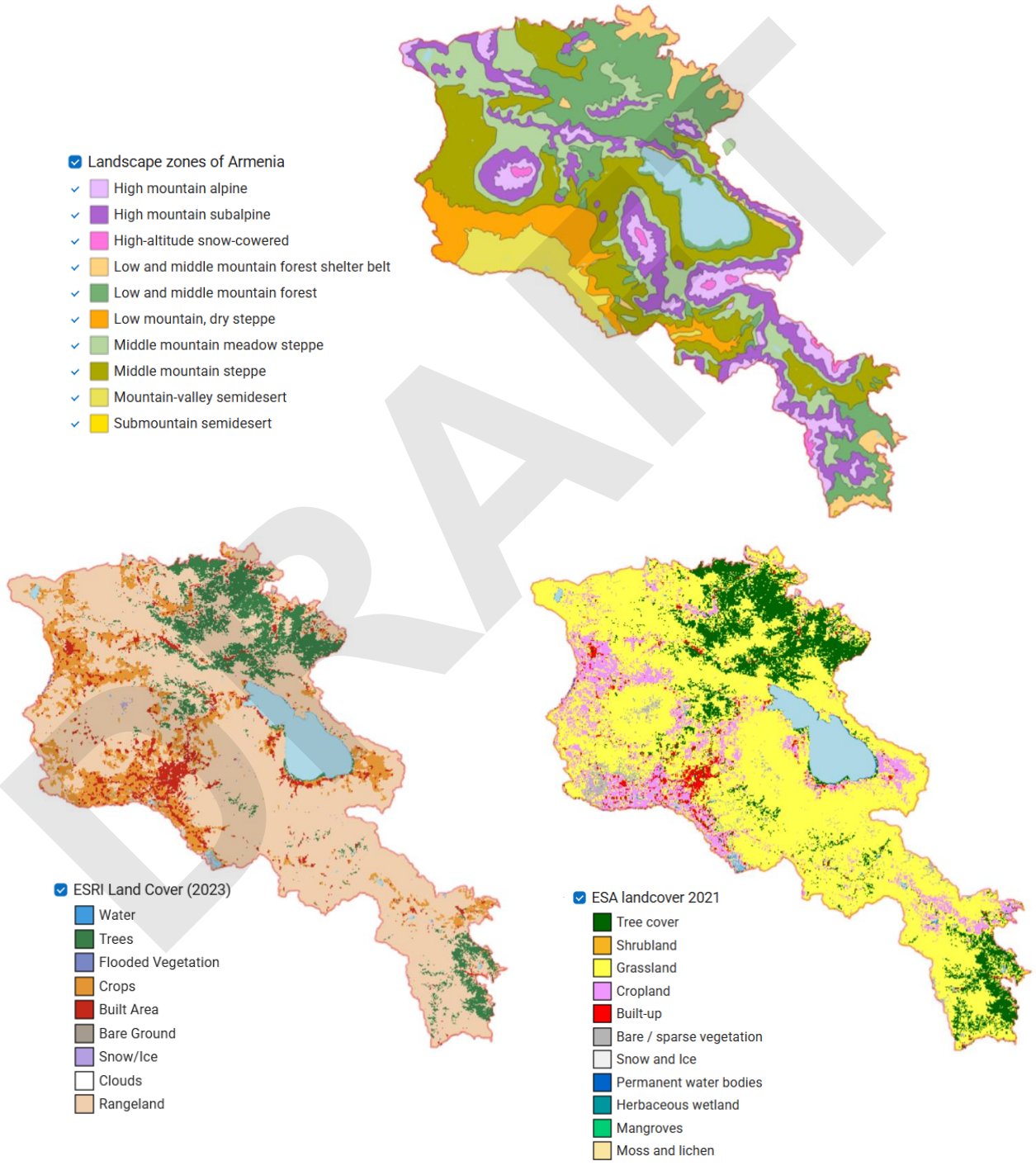


Figure 24A-1. The maps used for estimation of the extent of natural landscapes. For detailed maps see project Web-GIS, section "Ecosystem extent"

According to ESRI data, the most human-transformed zone is mountain-valley semi-desert, where only 27% of natural landscapes remain. It is followed by low mountain dry steppe and the middle mountain steppe zones, with 65% and 71% of natural landscapes remaining, respectively. High-mountain snow-covered, alpine, and subalpine zones have been almost unaffected by human activity. Forests are most widespread in zones of low-middle mountain forest (38%) and low-middle mountain forest shelter belt (17%). There is almost no forests in the half of landscape zones - high-altitude snow-cowered, alpine, dry steppe, and semi-deserts (Figures 24A-2 and 24A-3; Table 24A-1).

ESA data show a generally similar picture, but with smaller built-up area and larger area of tree cover and bare ground, which is particularly noticeable in the semi-deserts, dry steppe, and forest shelter belt (Figure 24A-2 and 24A-3; Table 24A-2). One of the reasons for this is that, as mentioned above, ESA identifies trees within settlements. The presence of trees in submountain semidesert zone in the ESA data is entirely due to this factor – all trees there are located inside settlements (see Section 2.1.A). In the semi-desert zone, some areas classified by ESRI as croplands were identified by ESA as bare ground and grasslands. As a result, the degree of transformation of this zone is considerably lower in ESA data than in ESRI data.

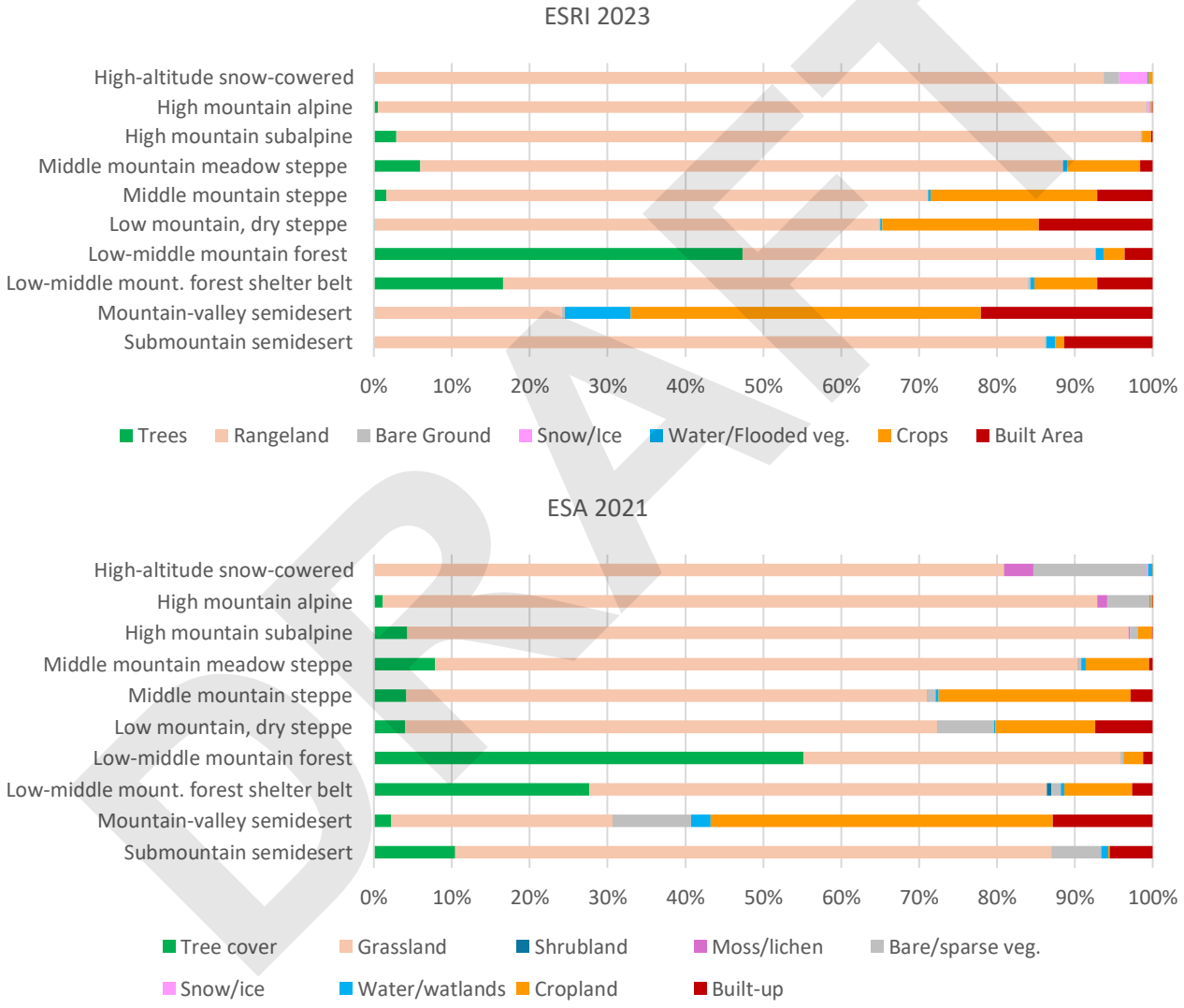


Figure 24A-2. Share of land cover classes within landscape zones according ESRI 2023 and ESA 2021 data

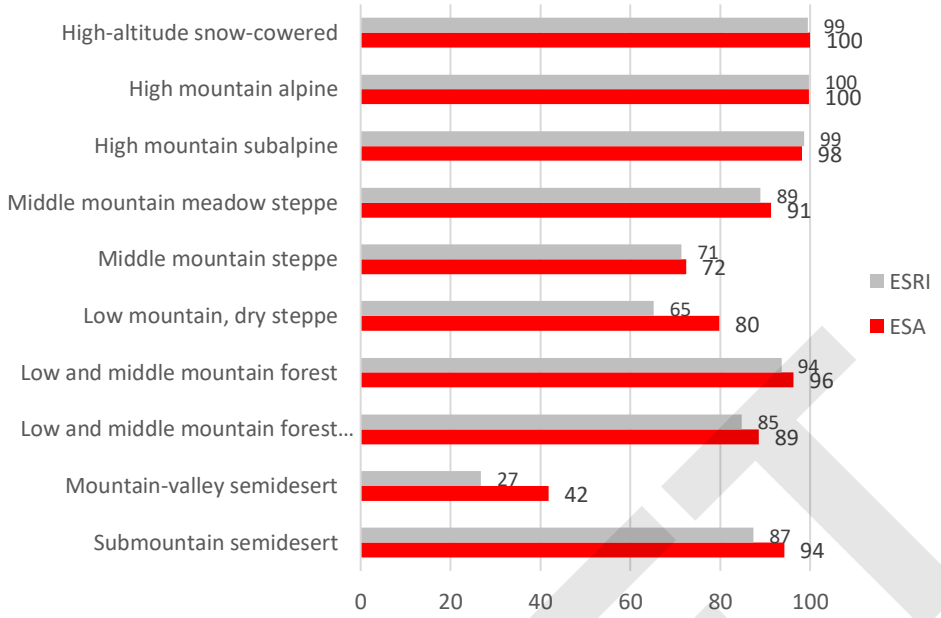


Figure 24A-3. Share of area of natural land cover classes within landscape zones (%) according ESRI and ESA data

Table 24A-1. Area of land cover classes within landscape zones according to ESRI 2023 data, km²

	Trees	Rangeland	Bare Ground	Snow/ Ice	Water/ Flooded veg.	Crops	Built Area	Total
High-altitude snow-cowered	0.06	183.27	3.83	7.09	0.32	1.01	0.00	195.58
High mountain alpine	9.90	1948.68	5.67	4.45	1.83	3.72	1.38	1975.62
High mountain subalpine	125.93	4222.75	3.73	0.00	2.73	49.13	10.25	4414.52
Middle mountain meadow steppe	294.31	4057.45	4.27	0.00	27.14	460.92	78.35	4922.44
Middle mountain steppe	108.88	4723.60	2.97	0.00	20.69	1454.46	484.65	6795.24
Low mountain, dry steppe	3.21	1461.86	3.35	0.00	5.61	454.76	329.90	2258.69
Low-middle mountain forest	2361.03	2261.51	2.81	0.00	50.26	133.77	180.49	4989.87
Low-middle mount. forest shelter belt	195.79	796.09	3.87	0.00	6.34	95.20	84.08	1181.37
Mountain-valley semidesert	0.52	411.32	5.75	0.00	144.50	766.06	376.07	1704.21
Submountain semidesert	0.00	14.93	0.03	0.00	0.20	0.19	1.97	17.33
Sevan	0	0	0	0	1227	0	0	1227.00

Table 24A-2. Area of land cover classes within landscape zones according to ESA 2021 data, km²

	Tree cover	Grass-land	Shrub-land	Moss/ lichen	Bare/ sparse veg.	Snow/ ice	Water/ Wet-lands	Crop-land	Built-up	Total
High-altitude snow-cowered	0.01	189.85	0.00	8.91	34.14	0.44	1.37	0.00	0.00	234.72
High mountain alpine	22.95	1814.63	0.00	25.59	106.82	0.11	2.24	5.78	0.11	1978.24
High mountain subalpine	189.42	4066.87	0.00	6.11	45.19	0.01	1.87	78.13	3.13	4390.74
Middle mountain meadow steppe	391.79	4088.71	0.00	0.92	21.20	0.00	28.58	404.81	22.02	4958.03
Middle mountain steppe	283.17	4578.27	0.18	0.00	69.91	0.00	23.36	1688.78	191.46	6835.12
Low mountain, dry steppe	90.96	1549.08	0.00	0.00	165.79	0.00	5.12	289.93	167.83	2268.72
Low-middle mountain forest	2751.63	2034.38	2.97	0.00	10.54	0.00	3.74	122.38	62.19	4987.84
Low-middle mount. forest shelter belt	327.59	695.87	6.82	0.00	14.03	0.00	5.26	103.17	31.54	1184.29
Mountain-valley semidesert	36.26	458.47	0.00	0.00	160.83	0.00	39.78	706.90	206.75	1608.98
Submountain semidesert	1.78	13.08	0.00	0.00	1.09	0.00	0.16	0.03	0.94	17.08
Sevan	0.00	0.00	0.00	0.00	0.00	0.00	1279.24	0.00	0.00	1279.24

The extent of natural areas within landscape zones differs significantly from the total extent of those zones (Figure 24A-4). When comparing the total area of the landscape zones, middle mountain steppes far exceed all other landscape zones. However, if anthropogenic areas are excluded, four types of natural landscapes have similar extents, each covering 15–16% of Armenia's territory – middle mountain steppe and meadow steppe, subalpine and forest zones. Mountain-valley semi-desert zone is shrinking the most – from 5.4% to 1.4-2.3% – as it has been transformed by human activity to the greatest extent. Differences in the estimated extent of natural landscapes between ESRI and ESA are greatest for the zones most heavily transformed by human activity, as ESA identifies smaller areas of croplands and built-up land (see above).

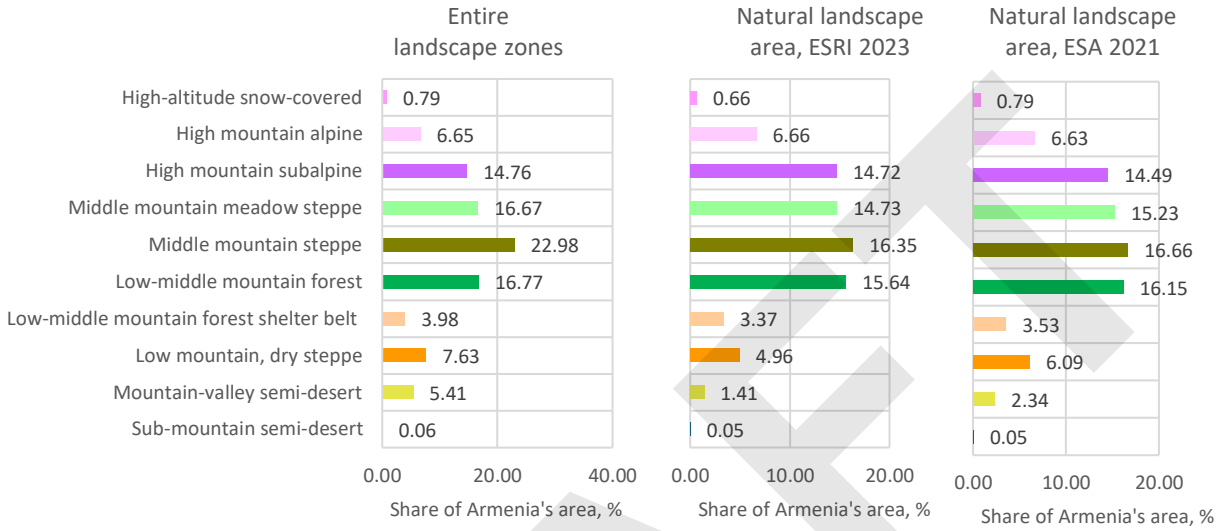


Figure 24A-4. The share of landscape zones and natural landscapes in Armenia's total area, %

2.4.B. Changes in extent of natural landscapes from 2017 to 2023 based on ESRI data

The extent of most natural landscapes decreased from 2017 to 2023 due to the expansion of human-occupied areas (croplands and built-up zones), as described in the Section 2.2.B. A noticeable increase in natural area was observed only in mountain-valley semi-desert in marzes Armavir and Ararat (see Section 2.4.C below)

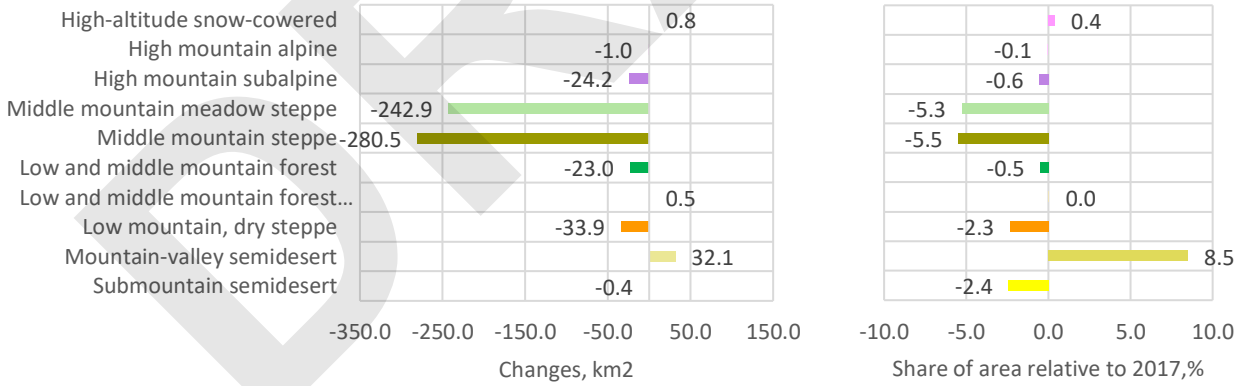


Figure 24B-1. Absolute and relative changes in natural landscape extent

2.4.C. Natural landscape extent at marz level

In terms of the extent of natural landscapes in marzes, ESRI and ESA provide a very similar picture. The main part of the forest landscape zone is located in three marzes — Lori, Tavush, and Syunik. The largest areas of alpine and subalpine landscapes are found in Syunik and Gegharkunik, although these landscapes are also notably present in all other marzes except Armavir and Tavush. Steppe landscapes are present in all marzes, but in Tavush and Armavir marzes, their area is small. The remaining natural areas of mountain-valley semi-desert are mainly located in the marzes of Ararat and Armavir. Submountain semi-desert is represented by small patches only in the south of Syunik marz (Figure 24C-1; Tables 24C-1, 24C-2).

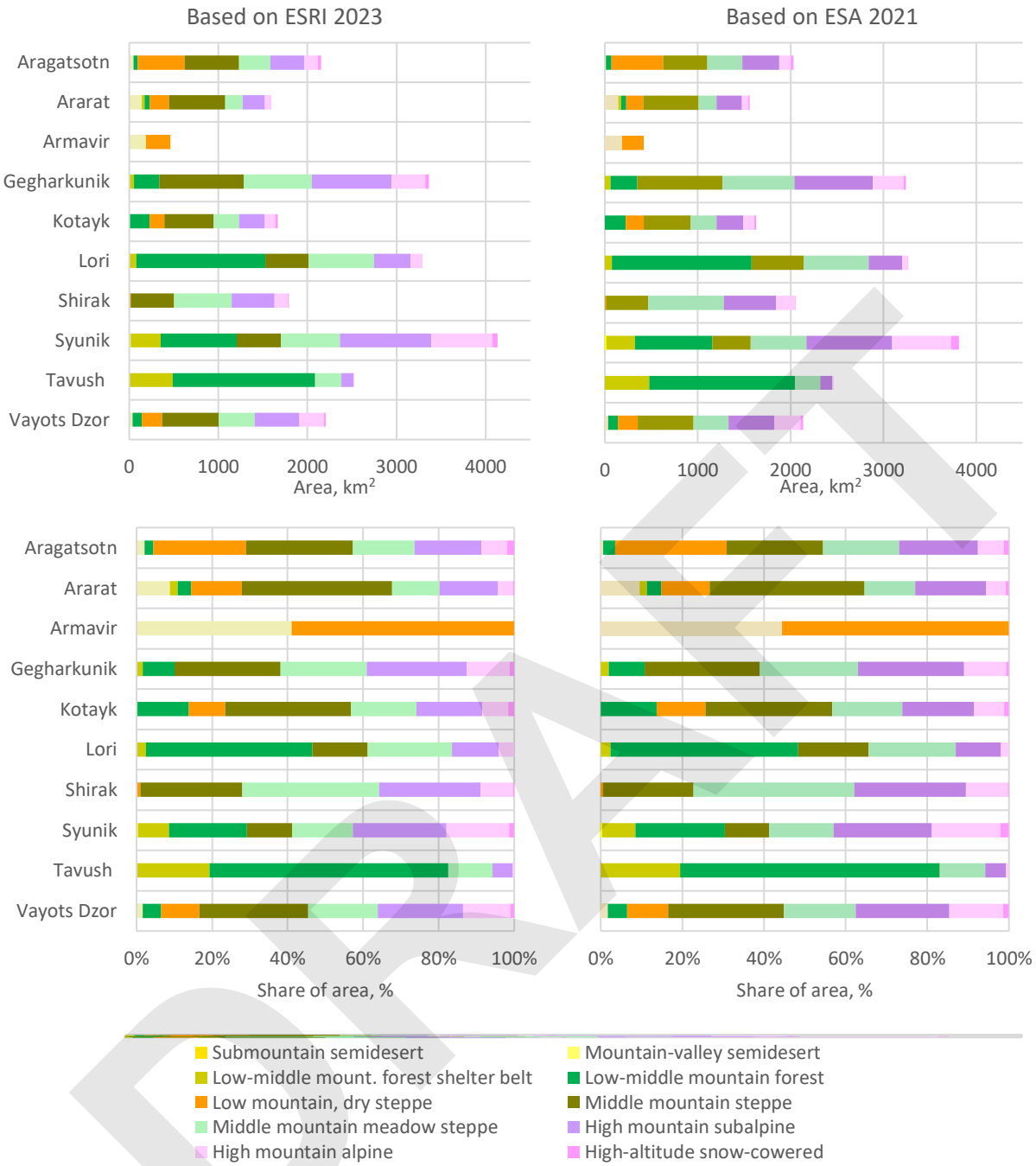


Figure 24C-1. Area and share of natural landscapes in marzes

Table 24C-1. Area of natural landscapes, based on ESRI 2023 land cover data, km²

Landscape zone	Aragat sotn	Ararat	Arma-vir	Geghar kunik	Kotayk	Lori	Shirak	Syunik	Tavush	Vayots Dzor
High-altitude snow-cowered	39.1	5.9	0.0	40.2	26.2	0.0	7.5	54.5	0.0	20.9
High mountain alpine	146.4	62.6	0.0	380.5	114.8	134.5	152.9	688.8	10.2	278.0
High mountain subalpine	383.5	245.1	0.0	892.1	290.0	407.7	479.4	1021.6	134.1	499.5
Middle mount. meadow steppe	351.3	199.8	0.0	768.9	288.0	735.7	648.7	664.7	294.6	404.3
Middle mountain steppe	611.2	631.7	0.0	943.5	553.7	481.4	482.9	494.4	0.0	636.7
Low mountain, dry steppe	527.8	214.3	272.5	0.0	160.4	0.0	19.0	0.0	0.0	224.1
Low-middle mountain forest	50.1	55.7	0.0	284.5	231.3	1448.1	0.0	854.0	1595.4	106.3
Low-mid. mount. forest shelter belt	0.0	33.7	0.0	53.3	0.0	81.3	0.0	338.2	489.3	0.0
Mountain-valley semidesert	45.1	139.6	189.3	0.0	0.0	0.0	0.0	0.0	0.0	37.0
Submountain semidesert	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0

Table 24C-2. Area of natural landscapes, based on ESA 2021 land cover data, km²

Landscape zone	Aragats otn	Ararat	Arma-vir	Geghar kunik	Kotayk	Lori	Shirak	Syunik	Tavush	Vayots Dzor
High-altitude snow-cowered	25.6	13.7	0.0	24.8	19.2	0.0	5.1	81.2	0.0	29.6
High mountain alpine	128.2	72.6	0.0	331.2	119.1	63.1	212.4	639.3	16.7	282.8
High mountain subalpine	393.5	271.4	0.0	842.9	287.5	361.7	561.3	919.2	127.2	489.4
Middle mount. meadow steppe	378.0	195.1	0.0	778.4	279.1	699.1	811.6	601.3	274.1	376.5
Middle mountain steppe	478.6	591.4	0.0	915.3	506.6	562.9	457.4	411.9	0.2	604.4
Low mountain, dry steppe	555.8	184.8	232.9	0.0	195.7	0.0	11.2	0.0	0.0	213.2
Low-middle mountain forest	59.0	54.8	0.0	286.9	222.7	1502.0	0.0	836.1	1567.9	102.7
Low-mid. mount. forest shelter belt	0.0	28.6	0.0	63.3	0.0	77.6	0.0	309.6	479.1	0.0
Mountain-valley semidesert	11.6	147.5	186.3	0.0	0.0	0.0	0.0	0.0	0.0	36.1
Sub-mountain semidesert	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.4	0.0	0.0

According to the ESRI land-cover data, the natural area of steppe and meadow-steppe landscapes decreased in all marzes except Vayots Dzor, Tavush, and Ararat (these landscape zones are absent in Armavir); subalpine landscape decreased in Shirak mars; low-mountain dry steppe – in Aragatsotn and Armavir marzes (Figure 24C-2; Table 24C-3). The only noticeable increases in the natural (non-cropland, non-built-up) area of landscape zones are the increase in mountain-valley semidesert area in the Ararat and Armavir marzes and in area of low mountain, dry steppe in Ararat, driven by a reduction in cropland in these marzes (see Section 2.2.B).

Table 24C-3. Changes in the area of natural landscapes from 2017 to 2023, % relative to 2017

	Aragats-otn	Ararat	Arma-vir	Geghar-kunik	Kotayk	Lori	Shirak	Syunik	Ta-vush	Vayots Dzor	Total
	Changes, km2										
High-altitude snow-cowered	0.01	0.02	0.00	0.00	0.73	0.00	0.00	-0.02	0.00	0.00	0.75
High mountain alpine	-1.34	-0.06	0.00	0.12	-0.03	0.00	-0.01	0.39	0.00	-0.10	-1.03
High mountain subalpine	-1.25	-0.27	0.00	4.27	-0.88	-0.61	-20.75	-4.58	-0.01	-0.13	-24.20
Middle mountain meadow steppe	-50.33	0.25	0.00	-14.64	0.38	-21.47	-131.42	-25.29	-0.10	-0.24	-242.86
Middle mountain steppe	3.15	0.60	0.00	-79.17	-24.57	-85.90	-61.12	-33.06	0.00	-0.45	-280.52
Low and middle mountain forest	-2.17	0.01	0.00	-7.23	5.60	-10.54	0.00	-7.54	-0.74	-0.41	-23.03
Low-mid. mount. forest shelter belt	0.00	-0.09	0.00	-3.13	0.00	-2.25	0.00	1.33	4.63	0.00	0.48
Low mountain, dry steppe	-18.98	9.98	-19.59	0.00	-3.44	0.00	-0.66	0.00	0.00	-1.19	-33.88
Mountain-valley semidesert	-0.36	13.03	20.23	0.00	0.00	0.00	0.00	0.00	0.00	-0.76	32.14
Submountain semidesert	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.37	0.00	0.00	-0.37
	Share of changed area, relative to 2017, %										
	Aragats-otn	Ararat	Arma-vir	Geghar-kunik	Kotayk	Lori	Shirak	Syunik	Ta-vush	Vayots Dzor	
High-altitude snow-cowered	0.03	0.39	0.00	0.00	2.88	0.00	0.00	-0.03	0.00	0.00	
High mountain alpine	-0.91	-0.09	0.00	0.03	-0.02	0.00	0.00	0.06	0.00	-0.04	
High mountain subalpine	-0.32	-0.11	0.00	0.48	-0.30	-0.15	-4.15	-0.45	-0.01	-0.03	
Middle mountain meadow steppe	-12.53	0.12	0.00	-1.87	0.13	-2.84	-16.85	-3.67	-0.04	-0.06	
Middle mountain steppe	0.52	0.10	0.00	-7.74	-4.25	-15.14	-11.24	-6.27	0.00	-0.07	
Low and middle mountain forest	-4.16	0.01	0.00	-2.48	2.48	-0.72	0.00	-0.88	-0.05	-0.38	
Low-mid. mount. forest shelter belt	0.00	-0.28	0.00	-5.55	0.00	-2.70	0.00	0.39	0.95	0.00	
Low mountain, dry steppe	-3.47	4.89	-6.71	0.00	-2.10	0.00	-3.36	0.00	0.00	-0.53	
Mountain-valley semidesert	-0.80	10.29	11.97	0.00	0.00	0.00	0.00	0.00	0.00	-2.01	
Submountain semidesert	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.43	0.00	0.00	

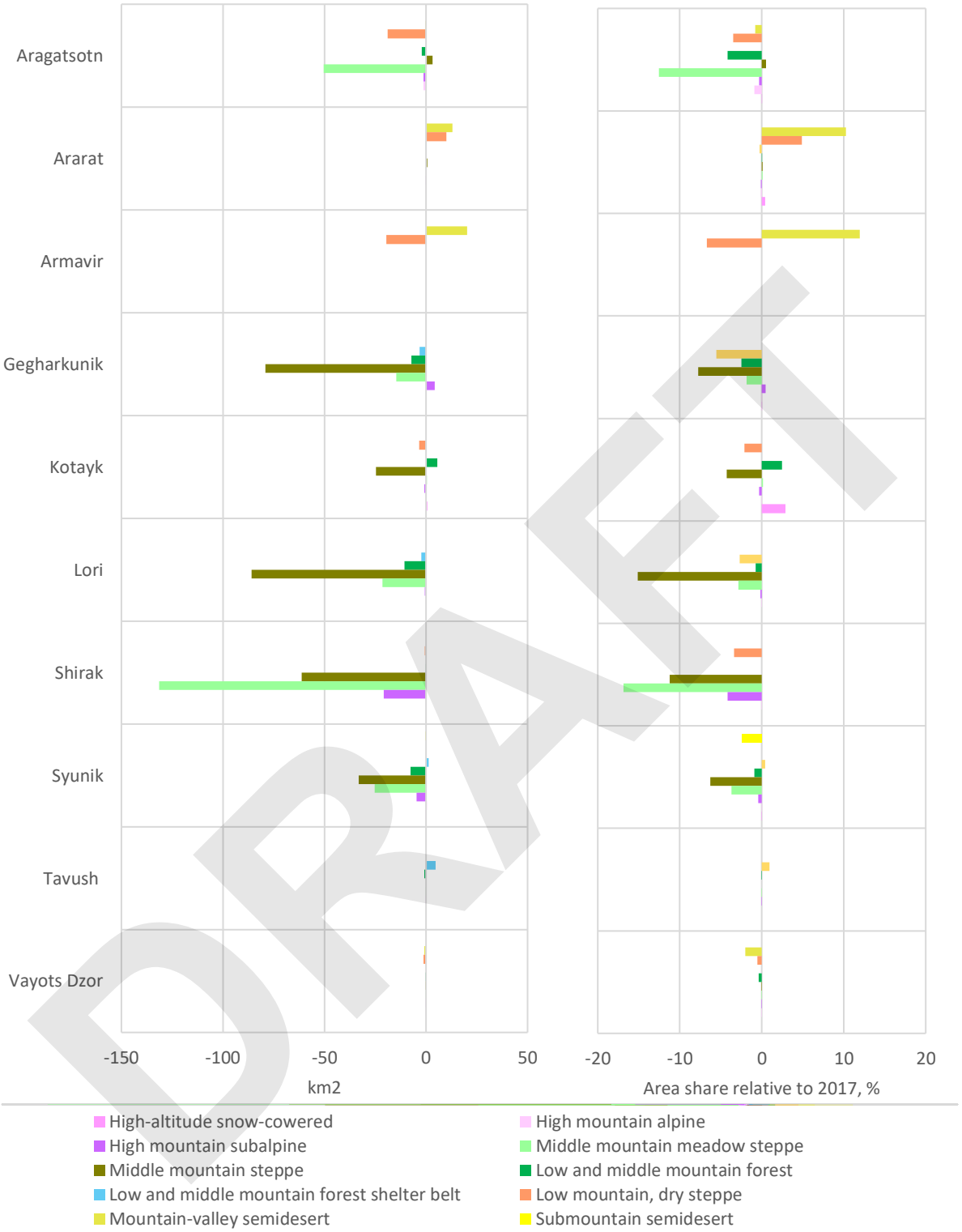


Figure 24C-2. Changes in natural landscape extent from 2017 to 2023, based on ESRI data: a) absolute changes, km2; b) share of changed area relative to 2017, %

2.4.D. Assessment of marz importance for conservation of natural landscape diversity in Armenia

To assess the importance of provinces for conserving natural landscapes in Armenia, we used the indicator of the total share of landscape areas located within each province relative to the total area of that landscape in Armenia. This approach was applied to ensure that the value of rare landscapes is not diminished.

The rankings based on ESRI and ESA data are very similar, differing only in the positions of some provinces with similar indicators in the middle of the list. According to the criterion we used, Syunik marz has the greatest value for conserving Armenia's landscape diversity, because it contains the highest cumulative share of the national extent of all landscape zones. The high summed Syunik value is largely due to the fact that 100% of submountain semidesert zone occurs in Syunik. However, even without it, Syunik still ranks above the other marzes. The least valuable are Shirak, Kotayk, and Armavir marzes (Fig. 24D-1; Tables 24D-1 and 24D-2).

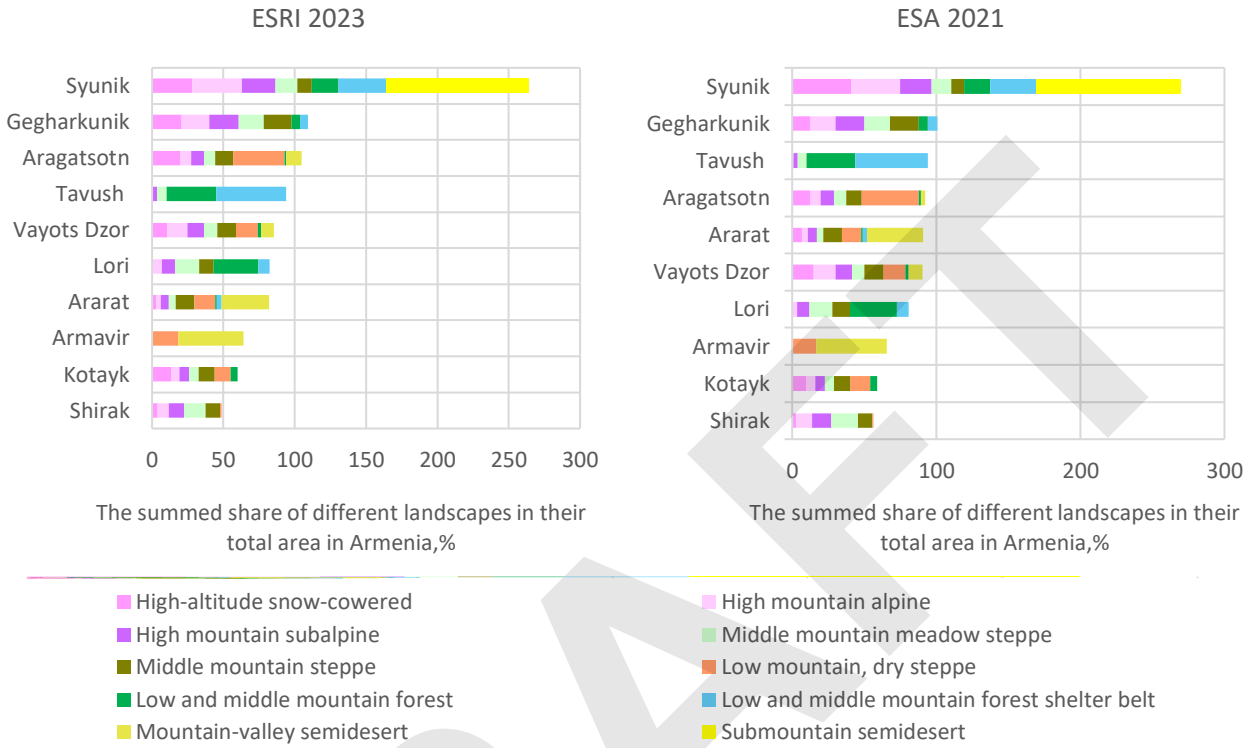


Figure 24D-1. The rankings of marz importance for conservation of natural landscape diversity in Armenia. The total percentage for provinces can exceed 100%.

Table 24D-1. The share of different landscapes in their total area in Armenia according to ESRI data, %. The total percentage for provinces can exceed 100%.

	Syunik	Geghar-kunik	Aragats-otn	Tavush	Vayots Dzor	Lori	Ararat	Arma-vir	Kotayk	Shirak
	2023									
High-altitude snow-cowered	28.05	20.71	20.11	0	10.74	0	3.03	0	13.5	3.85
High mountain alpine	34.99	19.33	7.44	0.52	14.12	6.83	3.18	0	5.83	7.77
High mountain subalpine	23.47	20.49	8.81	3.08	11.47	9.37	5.63	0	6.66	11.01
Middle mountain meadow steppe	15.26	17.65	8.07	6.76	9.28	16.89	4.59	0	6.61	14.89
Middle mountain steppe	10.22	19.51	12.64	0	13.17	9.96	13.06	0	11.45	9.99
Low mountain, dry steppe	0	0	35.94	0	15.26	0	14.59	18.56	10.93	1.3
Low and middle mountain forest	18.46	6.15	1.08	34.49	2.3	31.31	1.2	0	5	0
Low-mid. mountain forest shelter belt	33.97	5.35	0	49.13	0	8.16	3.39	0	0	0
Mountain-valley semidesert	0	0	10.81	0	8.87	0	33.44	45.33	0	0
Sub-mountain semidesert	100	0	0	0	0	0	0	0	0	0
Total share	264.42	109.2	104.9	93.99	85.21	82.51	82.11	63.89	59.98	48.8
	2017									
High-altitude snow-cowered	28.2	20.8	20.2	0.0	10.8	0.0	3.0	0.0	13.2	3.9
High mountain alpine	35.0	19.3	7.5	0.5	14.1	6.8	3.2	0.0	5.8	7.8
High mountain subalpine	23.4	20.3	8.8	3.1	11.4	9.3	5.6	0.0	6.6	11.4
Middle mountain meadow steppe	15.0	17.0	8.7	6.4	8.8	16.5	4.3	0.0	6.3	17.0
Middle mountain steppe	10.3	20.0	11.9	0.0	12.5	11.1	12.3	0.0	11.3	10.6
Low mountain, dry steppe	0.0	0.0	36.2	0.0	14.9	0.0	13.5	19.4	10.9	1.3
Low and middle mountain forest	18.5	6.3	1.1	34.3	2.3	31.4	1.2	0.0	4.9	0.0
Low-mid. mountain forest shelter belt	33.8	5.7	0.0	48.7	0.0	8.4	3.4	0.0	0.0	0.0
Mountain-valley semidesert	0.0	0.0	11.7	0.0	9.8	0.0	32.7	43.6	0.0	0.0
Sub-mountain semidesert	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total share	264.3	109.4	106.2	93.0	84.6	83.5	79.3	63.0	58.9	52.0

Table 24D-2. The share of different landscapes in their total area in Armenia according to ESA 2021 data, %. The total percentage for provinces can exceed 100%.

%	Syunik	Geghar-kunik	Tavush	Aragats-otn	Ararat	Vayots Dzor	Lori	Armavir	Kotayk	Shirak
High-altitude snow-cowered	40.78	12.45	0	12.85	6.88	14.86	0	0	9.63	2.57
High mountain alpine	34.27	17.76	0.9	6.87	3.89	15.16	3.38	0	6.38	11.39
High mountain subalpine	21.61	19.81	2.99	9.25	6.38	11.5	8.5	0	6.76	13.19
Middle mountain meadow steppe	13.69	17.72	6.24	8.61	4.44	8.57	15.91	0	6.35	18.47
Middle mountain steppe	9.1	20.21	0	10.57	13.06	13.35	12.43	0	11.19	10.1
Low mountain, dry steppe	0	0	0	39.88	13.26	15.3	0	16.71	14.04	0.81
Low and middle mountain forest	18.05	6.19	33.85	1.27	1.18	2.22	32.43	0	4.81	0
Low-middle mountain forest shelter belt	32.32	6.6	50	0	2.99	0	8.1	0	0	0
Mountain-valley semidesert	0	0	0	3.04	38.68	9.45	0	48.84	0	0
Submountain semidesert	100	0	0	0	0	0	0	0	0	0
Total share	269.81	100.74	93.97	92.33	90.76	90.4	80.75	65.55	59.16	56.53

From 2017 to 2023, summed value indicator changed by no more than 3% across marzes (Figure 24D-2). The value for Shirak marz declined from 52.0% to 48.8%, primarily due to a decrease in the share of the national meadow-steppe extent conserved there. For Ararat marz, this indicator rose from 79.3% to 82.1% owing to increases in the shares of the forest, steppe, and semidesert zones. For the other marzes, changes in the aggregate indicator were smaller.

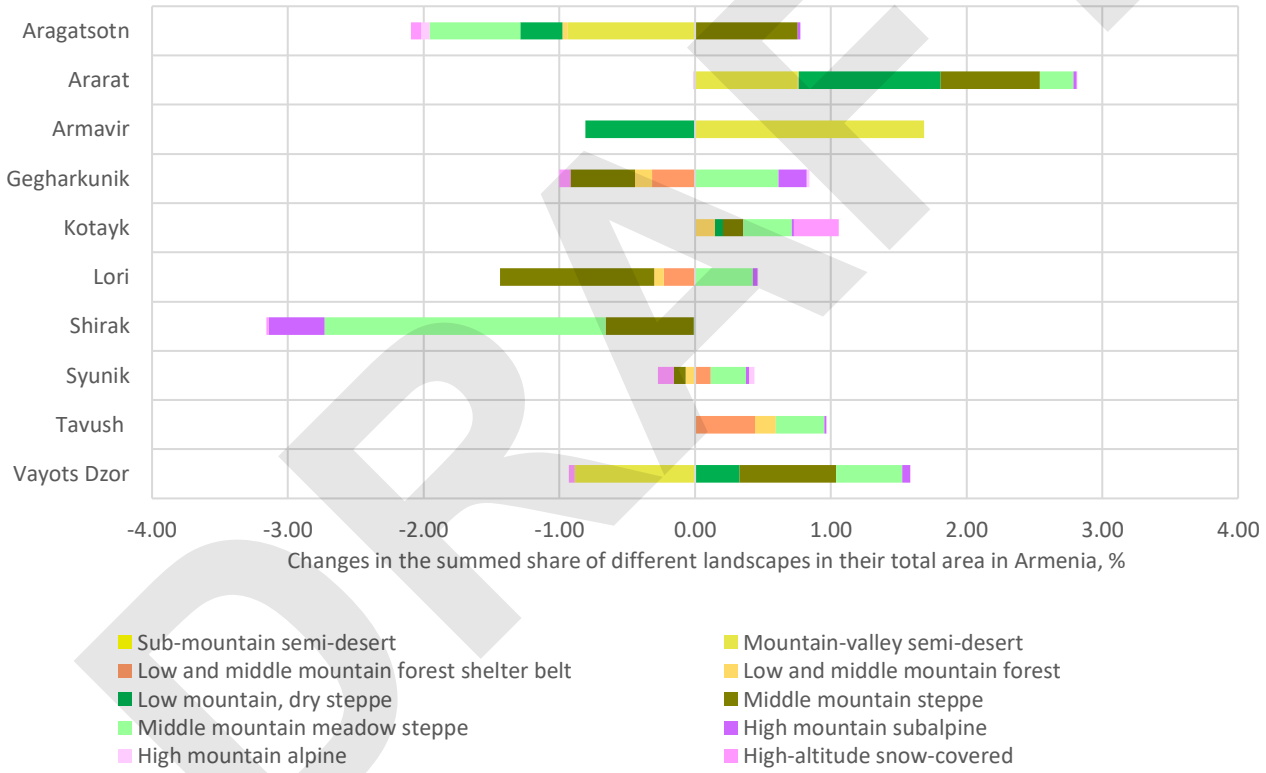


Figure 24D-2. Changes in marz importance for conservation of natural landscape diversity in Armenia from 2017 to 2023.

2.5. Extent of ecosystems based on landscape-land cover classes (LLCCs)

The methodology is described in detail in the publication: Bukvareva E., Grigoryan A., Dubinin M., Kazakov E. Integrating actual land cover data and landscape zone map to assess terrestrial ecosystems in Armenia. Explora: Environment and Resource 4996. https://doi.org/10.36922/eer.4996

The assessment presented in this section uses the same data sources as Section 2.4: the map of landscape zones of Armenia; ESRI land cover data for 2017 and 2023; and ESA 2021 data.

We intersected ten landscape zones with terrestrial land cover classes. The ESRI land cover dataset includes four terrestrial natural classes (trees, rangelands, bare ground, and snow/ ice), the ESA dataset includes six terrestrial natural classes (tree cover, shrubland, grassland, moss and lichen, bare and sparse vegetation, and snow and ice). The intersection of ten landscape zones with land cover classes resulted in 60 and 40 combinations, respectively. We termed these combinations as LLCCs since they serve as proxies for ecosystems at this stage of analysis without precisely defining the ecosystems they represent. For simplicity of analysis, LLCCs were grouped into 20 combinations, woody (W) and non-woody (N-W) LLCCs in each landscape zone. We found it appropriate to combine all N-W natural classes (shrubland, grassland, moss and lichen, bare and sparse vegetation, and snow and ice) into one category named N-W LLCCs for several reasons: (i) to reduce the number of analyzed LLCCs for a clearer interpretation of the results, (ii) due to relative imprecision in distinguishing between different non-tree land cover classes, (iii) because of the very small area covered by shrubland, moss and lichen, and snow and ice, and (iv) because the IUCN and EUNIS ecosystem and habitat classifications,[20,22,26] including the EUNIS version adapted for Armenia,[34] group shrub vegetation with heathlands and tundra rather than woody vegetation. Thus, the resulting map includes 20 LLCCs obtained by intersecting woody and non-woody areas with 10 landscape zones.

2.5.A. Extent and rarity of LLCC in Armenia

In all landscape zones, non-woody LLCC combinations occupy the predominant area. The only exception is the low and middle mountain forest zone, where woody combinations account for 51% of the natural area (Fig. 25A-1).

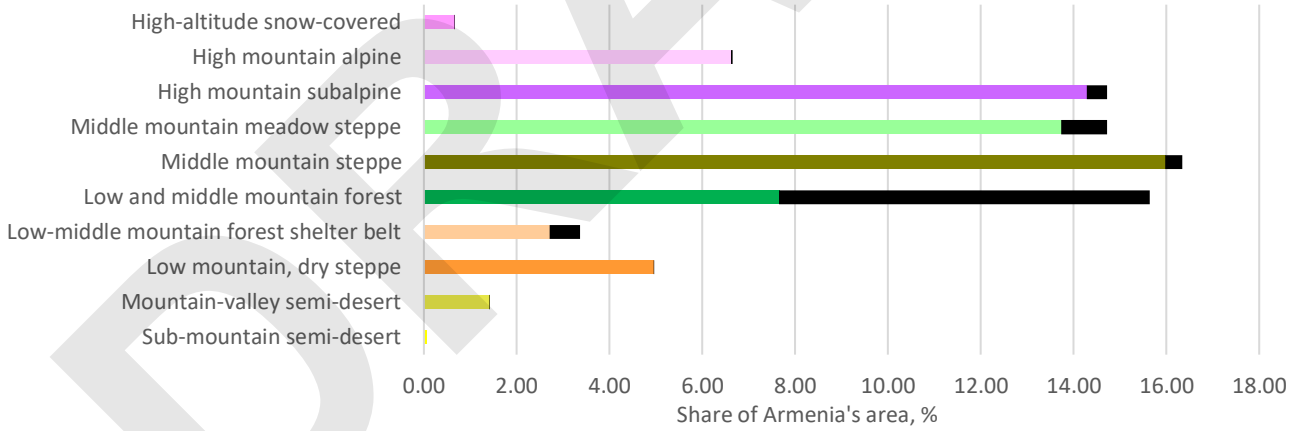


Figure 25A-1. Extent of non-woody LLCC combinations (shown in different colors) and woody combinations (shown in black) across landscape zones in Armenia

The area of the 20 analyzed W LLCCs and N-W LLCCs ranges from 0.005 km2 to 4,700 km2. Half of these LLCCs occupy <1% of the country's area and can thus be formally classified as rare (Figure 25A-2). This group includes nearly all woody LLCCs, except those in the low and middle mountain forest, forest shelter belt, and middle mountain meadow steppe. Among N-W LLCCs, only two, located in the sub-mountain semi-desert and high-altitude zones, were classified as rare. Three LLCCs, N-W ecosystems in subalpine, middle-mountain, and meadow steppe zones, are widespread, each covering between 14% and 16% of the country's territory. The remaining LLCCs fall between these extremes. Notably, most of the rare LLCCs do not align with the dominant vegetation types of their respective landscape (e.g., trees in high-altitude zones or semi-deserts). These anomalies require careful verification, as they may result from land cover interpretation errors or may belong to anthropogenic areas. Despite the differences in ESA and ESRI land cover data, the rarity rankings of LLCCs derived from both sources are very similar.

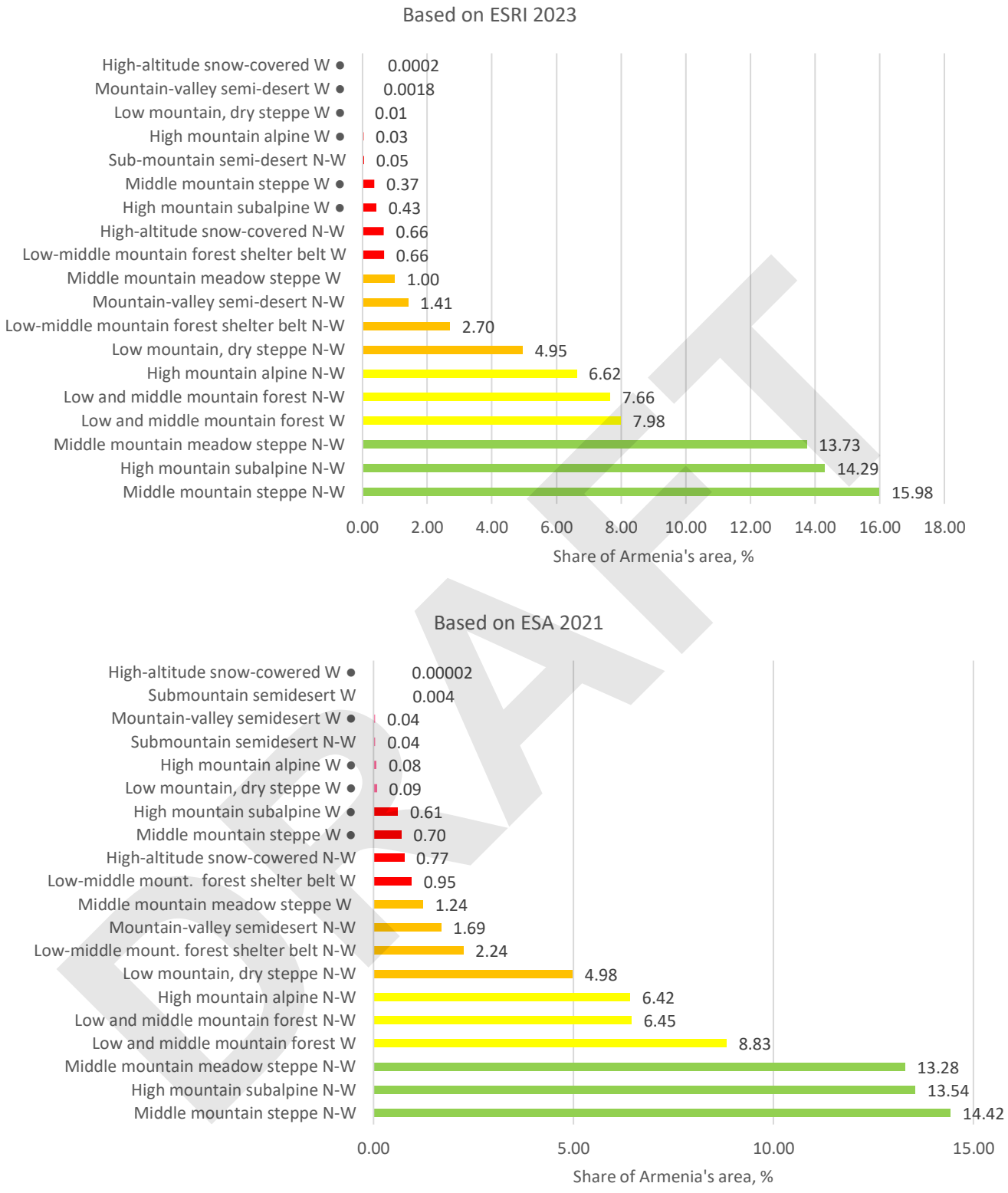


Figure 25A-2. Ranking LLCC types by their area; woody LLCCs are indicated as W, non-woody as N-W; LLCCs occupying no more than 5% of the area of corresponding landscape zone are marked with a '●' symbol

Maps of LLCC rarity, based on these rankings, show a similar distribution pattern (Figure 25A-3). The rarest LLCCs, covering <1% of the country's area, are distributed in small areas throughout the country, especially in the south, notably in the province of Syunik. Relatively rare LLCCs, occupying 1 – 5% of the country's area, are primarily found in the Ararat Valley and its surroundings. These include mountain-valley semi-desert and low-mountain dry steppe LLCCs. Although

these LLCCs formally cover a large area, natural vegetation occupies only a small area due to significant anthropogenic transformation. The most widespread LLCCs are located in the central part of the country.

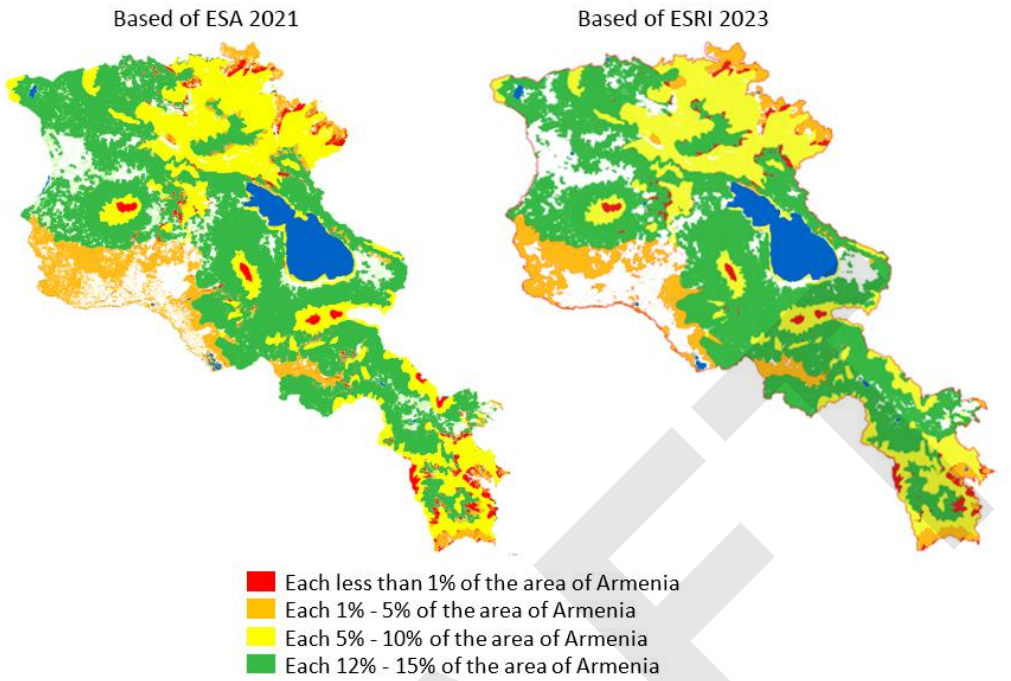


Figure 25A-3. Maps of LLCC rarity based on ESA and ESRI land cover datsets

2.5.B. Marz level: LLCC extent and marz importance for conservation of LLCC diversity in Armenia

This section is primarily aimed at analyzing the role of the marzes in conserving Armenia's ecosystem diversity. Therefore, instead of using absolute extent values in km², we use the indicator of the share of the area of each LLCC that is preserved within the marzes: $S_{im}=LLCC_{im}/LLCC_{ia}*100\%$, where $LLCC_{im}$ is the area of *LLCC i*-type in marz *m*, and $LLCC_{ia}$ is the total area of *LLCC i*-type in Armenia. This indicator was applied to ensure that the value of rare LLCCs is not diminished.

The pattern of distribution of non-woody LLCCs across marzes generally mirrors the distribution of landscape zones. Moreover, these patterns are very similar based on ESRI and ESA data. In contrast, the distribution of woody LLCCs differs significantly both from landscapes zones and between ESRI and ESA datasets. According to ESRI, marzes Gegharkunik, Kotayk, Lori, and Tavush account for a larger share of woody LLCCs than of landscape zones overall. In contrast, Aragatsotn, Ararat, Shirak, Syunik, and Vyots Dzor account for a smaller share of woody LLCCs (Figure 25B-1, a-c). According to ESA, marzes Lori, Syunik, and Tavush account for a larger share of woody LLCCs while Aragatsotn, Armavir, Gegharkunik, and Shirak account for a smaller share of woody LLCCs (Figure 25B-1, d-f).

Marked discrepancies appear when rare LLCCs are concentrated entirely within a single marz—for instance, nearly 100% of woody LLCCs in the high-altitude snow covered zone of Gegharkunik according to ESRI (Fig. 25B-1c), versus nearly 100% of the same LLCC type in Syunik according to ESA (Fig. 25B-1f). These patterns are most likely the result of land-cover misclassifications affecting different marzes in the two datasets. A similar inconsistency is observed in the submountain semi-desert zone, where ESA records 100% of woody LLCC in this zone in Syunik (Fig. 25B-1f), while ESRI reports none. Such differences reflect the different methodologies of image interpretation applied in the ESA and ESRI datasets (see Section 2.1.A). Overall, the most significant inconsistencies are associated with the rarest LLCCs—woody LLCCs in general, and especially their rarest variants in high-altitude and semi-desert zones—some of which may represent artifacts of land-cover classification rather than actual distribution patterns.

The cumulative value of index S_{im} indicates the overall contribution of a marz to the conservation of LLCC diversity in Armenia. As shown in Figure 25B-1, the contribution of the marzes to the conservation of non-woody LLCCs is similar to their contribution to the conservation of natural landscapes as a whole, whereas their role in conserving woody LLCCs follows a somewhat different pattern.

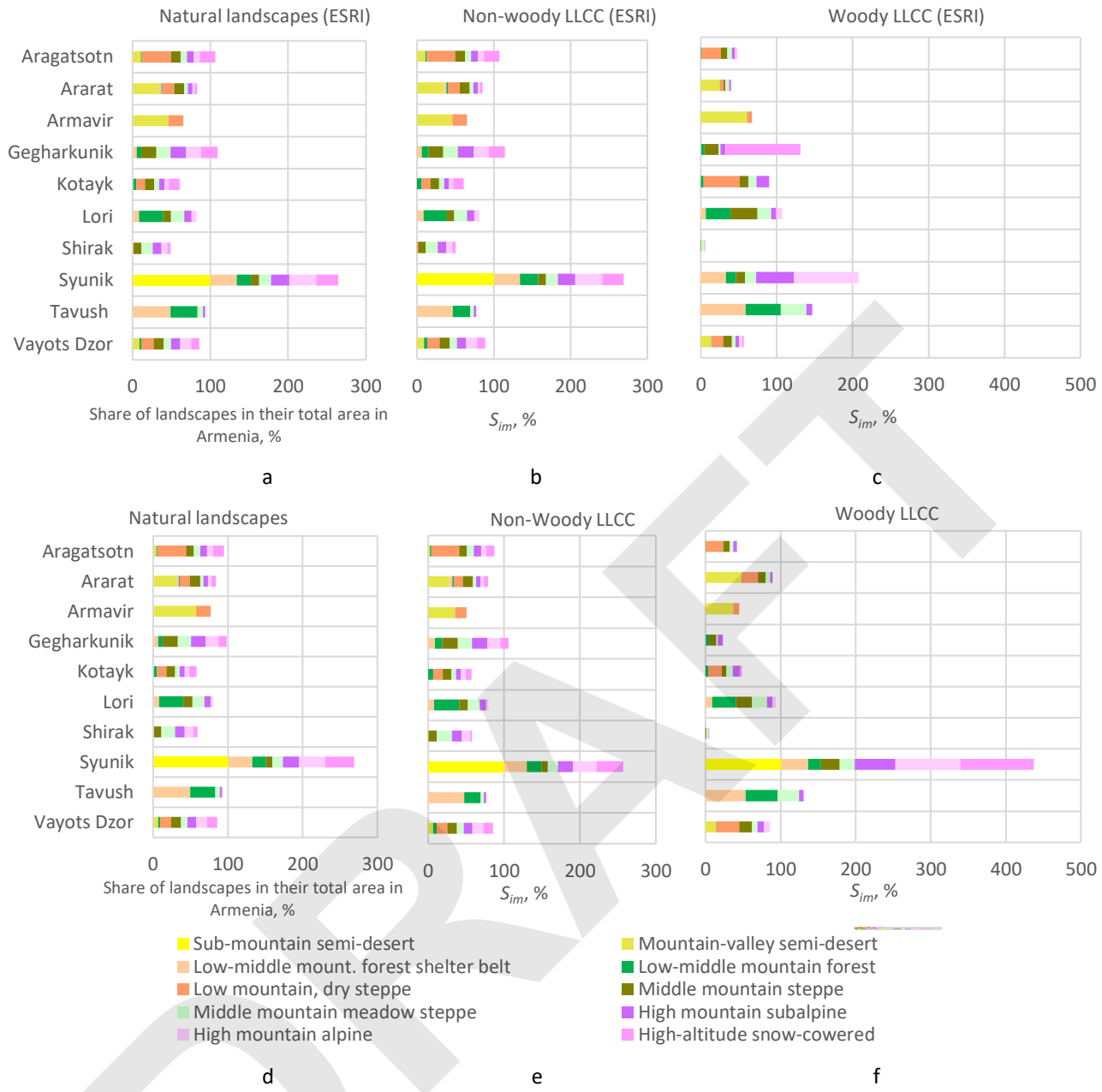


Figure 25B-1. The share of the area of natural landscapes and LLCCs in their total area in Armenia, %: a-c) Based on ESRI data; d-f) Based on ESA data. The scales have been made uniform for easier comparison of the data.

Figure 25B-1. The proportion of natural landscapes in their total area in Armenia, S_{im} %, based on ESRI 2023 data

	Sub-mountain semi-desert	Mountain-valley semi-desert	Low-mid. mountain forest shelter belt	Low and middle mountain forest	Low mountain, dry steppe	Middle mountain steppe	Middle mountain meadow steppe	High mountain subalpine	High mountain alpine	High-altitude snow-cowered
	Natural landscapes as a whole									
Aragatsotn	0.00	10.98	0.00	1.08	37.21	12.64	8.07	8.81	7.44	20.11
Ararat	0.00	33.96	3.39	1.20	15.11	13.06	4.59	5.63	3.18	3.03
Armavir	0.00	46.05	0.00	0.00	19.22	0.00	0.00	0.00	0.00	0.00
Gegharkunik	0.00	0.00	5.35	6.15	0.00	19.51	17.65	20.49	19.33	20.71
Kotayk	0.00	0.00	0.00	5.00	11.31	11.45	6.61	6.66	5.83	13.50
Lori	0.00	0.00	8.16	31.31	0.00	9.96	16.89	9.37	6.83	0.00
Shirak	0.00	0.00	0.00	0.00	1.34	9.99	14.89	11.01	7.77	3.85
Syunik	100.00	0.00	33.97	18.46	0.00	10.22	15.26	23.47	34.99	28.05
Tavush	0.00	0.00	49.13	34.49	0.00	0.00	6.76	3.08	0.52	0.00
Vayots Dzor	0.00	9.01	0.00	2.30	15.80	13.17	9.28	11.47	14.12	10.74

	Non-woody LLCC									
Aragatsotn	0.00	10.99	0.00	1.57	37.24	12.74	8.21	8.93	7.47	20.12
Ararat	0.00	33.98	4.21	2.24	15.13	13.31	4.55	5.72	3.20	3.04
Armavir	0.00	46.03	0.00	0.00	19.24	0.00	0.00	0.00	0.00	0.00
Gegharkunik	0.00	0.00	6.50	8.47	0.00	19.52	18.79	20.90	19.42	20.68
Kotayk	0.00	0.00	0.00	6.34	11.24	11.46	6.33	6.37	5.85	13.51
Lori	0.00	0.00	8.47	30.41	0.00	9.37	16.79	9.44	6.83	0.00
Shirak	0.00	0.00	0.00	0.00	1.35	10.20	15.67	11.33	7.80	3.85
Syunik	100.00	0.00	34.14	24.03	0.00	10.18	15.31	22.69	34.74	28.06
Tavush	0.00	0.00	46.67	22.42	0.00	0.00	4.79	2.95	0.52	0.00
Vayots Dzor	0.00	9.00	0.00	4.54	15.80	13.22	9.57	11.68	14.17	10.75
	Woody LLCC									
Aragatsotn	0.00	0.00	0.00	0.62	25.74	8.31	6.05	4.65	1.99	0.48
Ararat	0.00	25.29	0.00	0.22	4.43	2.34	5.09	2.66	0.00	0.00
Armavir	0.00	60.71	0.00	0.00	6.58	0.00	0.00	0.00	0.00	0.00
Gegharkunik	0.00	0.00	0.66	3.93	0.00	19.10	2.00	6.99	0.55	97.75
Kotayk	0.00	0.00	0.00	3.72	47.68	11.21	10.53	16.47	1.00	0.00
Lori	0.00	0.00	6.88	32.17	0.00	35.36	18.24	6.82	7.70	0.00
Shirak	0.00	0.00	0.00	0.00	0.00	0.66	4.17	0.31	0.00	0.00
Syunik	0.00	0.00	33.26	13.13	0.00	12.10	14.62	49.80	84.48	0.00
Tavush	0.00	0.00	59.20	46.07	0.00	0.00	33.94	7.56	0.00	0.00
Vayots Dzor	0.00	14.01	0.00	0.15	15.57	10.94	5.37	4.74	4.27	1.77

Figure 25B-2. The proportion of natural landscapes in their total area in Armenia, S_{im} %, based on ESRI 2023 data

	Sub-mountain semi-desert	Mountain-valley semi-desert	Low-mid. mount. forest shelter belt	Low-middle mountain forest	Low mountain, dry steppe	Middle mountain steppe	Middle mountain meadow steppe	High mountain subalpine	High mountain alpine	High-altitude snow-cowered
	Natural landscapes as a whole									
Aragatsotn	0.00	4.31	0.00	1.27	38.30	10.55	8.60	9.27	7.83	14.42
Ararat	0.00	31.22	3.19	1.20	13.62	13.50	4.44	6.34	4.07	6.01
Armavir	0.00	57.41	0.00	0.00	19.66	0.00	0.00	0.00	0.00	0.00
Gegharkunik	0.00	0.00	6.58	6.23	0.00	20.01	17.69	19.86	17.35	10.96
Kotayk	0.00	0.00	0.00	4.81	13.15	11.17	6.34	6.76	6.27	9.92
Lori	0.00	0.00	8.06	32.43		12.27	15.85	8.42	3.20	0.00
Shirak	0.00	0.00	0.00	0.00	0.76	10.08	18.41	13.14	11.47	5.66
Syunik	100.00	0.00	32.76	18.03	0.00	9.00	13.77	21.63	34.35	39.49
Tavush	0.00	0.00	49.39	33.78	0.00	0.00	6.21	2.96	0.85	0.00
Vayots Dzor	0.00	7.07	0.00	2.24	14.50	13.43	8.69	11.63	14.61	13.55
	Non-woody LLCC									
Aragatsotn	0.00	2.25	0.00	2.20	36.34	10.49	8.92	9.36	6.58	10.94
Ararat	0.00	27.54	4.19	2.15	11.86	12.98	4.26	6.46	3.73	5.86
Armavir	0.00	35.38	0.00	0.00	15.26	0.00	0.00	0.00	0.00	0.00
Gegharkunik	0.00	0.00	8.94	9.50	0.00	20.40	19.15	20.17	16.99	10.60
Kotayk	0.00	0.00	0.00	6.52	12.62	11.28	6.13	6.55	6.10	8.20
Lori	0.00	0.00	7.54	33.17	0.00	11.83	15.42	8.47	3.19	0.00
Shirak	0.00	0.00	0.00	0.00	0.74	10.39	19.82	13.63	10.89	2.19
Syunik	100.00	0.00	29.84	19.57	0.00	8.18	13.02	19.91	31.77	34.74
Tavush	0.00	0.00	47.61	21.71	0.00	0.00	4.12	2.82	0.86	0.00
Vayots Dzor	0.00	6.67	0.00	4.80	13.56	12.97	8.66	11.52	14.41	12.65
	Woody LLCC									
Aragatsotn	0.00	0.19	0.00	0.60	22.55	8.98	4.79	4.64	0.00	0.00
Ararat	0.00	48.34	0.02	0.47	20.77	10.72	6.10	3.00	0.04	0.00
Armavir	0.00	37.04	0.00	0.00	7.88	0.00	0.00	0.00	0.00	0.00
Gegharkunik	0.00	0.00	0.80	3.76	0.00	10.06	1.44	7.07	0.12	0.00
Kotayk	0.00	0.00	0.00	3.54	18.30	5.86	8.42	9.72	0.27	2.60
Lori	0.00	0.00	9.06	31.79	0.00	21.13	20.29	7.06	4.10	0.00
Shirak	0.00	0.00	0.00	0.00	0.18	1.01	3.03	0.41	0.24	0.00
Syunik	100.00	0.00	36.71	16.89	0.00	25.29	20.15	53.83	86.99	97.40
Tavush	0.00	0.00	53.40	42.62	0.00	0.00	28.66	5.93	0.00	0.00
Vayots Dzor	0.00	14.43	0.00	0.32	30.32	16.96	7.12	8.34	8.24	0.00

Based on the rankings of overall marz contribution to the conservation of all LLCC types (the sum of S_i indices for each marz) derived from the ESRI and ESA datasets, only the top-ranked province (Syunik) and the lowest-ranked province (Shirak) remain consistent (Figure 25B-2 a,b). The positions of other marzes vary within the rankings. When accounting all LLCC types, the rankings are largely influenced by the rarest LLCCs, which may be errors in the land cover datasets. For

example, Syunik province ranks exceptionally high based on ESA data because almost all pixels of three rare LLCCs (woody areas in high-altitude snowy and alpine zones and sub-mountain semi-desert) are concentrated there. This pattern is not observed in ESRI data. Conversely, Gegharkunik province ranks second in the ESRI-based ranking because almost all woody pixels in the high-altitude snowy zone are concentrated there. If the rarest LLCCs, occupying no more than 5% of the landscape zone's area (marked with a "●" symbol in Figure 25A-2), are excluded from the calculations, the province rankings based on ESRI and ESA data become more similar (Figure 25B-2 c,d). However, some provinces with similar indicators occupy different positions in the middle of the list.

Figure 25B-2. The rankings of marz cumulative importance for conserving LLCC diversity in Armenia (the sum of Si indices for each marz): a,b) all LLCCs; b,c) excluding LLCCs that occupy no more than 5% of the landscape zone's area. The LLCCs are shown in red, the less rare ones in orange, the relatively common in yellow, and the most common in green, as in the figure 25A-2. The total percentage for provinces can exceed 100%.

Table 25B-3. Mars importance for conserving all LLCC types in Armenia (the sum of Si indices for each marz)

	Aragats-otn	Ararat	Arma-vir	Geghar-kunik	Kotayk	Lori	Shirak	Syunik	Tavush	Vayots Dzor
	ESRI 2023									
High mountain alpine N-W	7	4	0	17	6	3	11	32	1	14
High mountain alpine W	0	0	0	0	0	4	0	87	0	8
High mountain subalpine N-W	9	6	0	20	7	8	14	20	3	12
High mountain subalpine W	5	3	0	7	10	7	0	54	6	8
High-altitude snow-cowered N-W	11	6	0	11	8	0	2	35	0	13
High-altitude snow-cowered W	0	0	0	0	3	0	0	97	0	0

Low mountain, dry steppe N-W	36	12	15	0	13	0	1	0	0	14
Low mountain, dry steppe W	23	21	8	0	18	0	0	0	0	30
Low-middle mount. forest N-W	2	2	0	10	7	33	0	20	22	5
Low-middle mount. forest shelter belt W	0	0	0	1	0	9	0	37	53	0
Low-middle mount. forest shelter… N-W	0	4	0	9	0	8	0	30	48	0
Low-middle mount. forest W	1	0	0	4	4	32	0	17	43	0
Middle mountain meadow steppe N-W	9	4	0	19	6	15	20	13	4	9
Middle mountain meadow steppe W	5	6	0	1	8	20	3	20	29	7
Middle mountain steppe N-W	10	13	0	20	11	12	10	8	0	13
Middle mountain steppe W	9	11	0	10	6	21	1	25	0	17
Mountain-valley semidesert N-W	2	28	35	0	0	0	0	0	0	7
Mountain-valley semidesert W	0	48	37	0	0	0	0	0	0	14
Submountain semidesert N-W	0	0	0	0	0	0	0	100	0	0
Submountain semidesert W	0	0	0	0	0	0	0	100	0	0
Total share	129	168	96	129	106	173	63	694	208	171
	ESA 2021									
High mountain alpine N-W	7	4	0	17	6	3	11	32	1	14
High mountain alpine W	0	0	0	0	0	4	0	87	0	8
High mountain subalpine N-W	9	6	0	20	7	8	14	20	3	12
High mountain subalpine W	5	3	0	7	10	7	0	54	6	8
High-altitude snow-cowered N-W	11	6	0	11	8	0	2	35	0	13
High-altitude snow-cowered W	0	0	0	0	3	0	0	97	0	0
Low mountain, dry steppe N-W	36	12	15	0	13	0	1	0	0	14
Low mountain, dry steppe W	23	21	8	0	18	0	0	0	0	30
Low-middle mount. forest N-W	2	2	0	10	7	33	0	20	22	5
Low-middle mount. forest shelter belt W	0	0	0	1	0	9	0	37	53	0
Low-middle mount. forest shelter… N-W	0	4	0	9	0	8	0	30	48	0
Low-middle mount. forest W	1	0	0	4	4	32	0	17	43	0
Middle mountain meadow steppe N-W	9	4	0	19	6	15	20	13	4	9
Middle mountain meadow steppe W	5	6	0	1	8	20	3	20	29	7
Middle mountain steppe N-W	10	13	0	20	11	12	10	8	0	13
Middle mountain steppe W	9	11	0	10	6	21	1	25	0	17
Mountain-valley semidesert N-W	2	28	35	0	0	0	0	0	0	7
Mountain-valley semidesert W	0	48	37	0	0	0	0	0	0	14
Submountain semidesert N-W	0	0	0	0	0	0	0	100	0	0
Submountain semidesert W	0	0	0	0	0	0	0	100	0	0
Total share	129	168	96	129	106	173	63	694	208	171

Table 25B-4. Mars importance for conserving LLCC types excluding LLCCs that occupy no more than 5% of the landscape zone's area in Armenia (the sum of Si indices for each marz)

	Aragats-otn	Ararat	Arma-vir	Geghar-kunik	Kotayk	Lori	Shirak	Syunik	Tavush	Vayots Dzor
	ESRI 2023									
High mountain alpine N-W	7	4	0	17	6	3	11	32	1	14
High mountain alpine N-W	7	3	0	19	6	7	8	35	1	14
High mountain subalpine N-W	9	6	0	21	6	9	11	23	3	12
High-altitude snow-cowered N-W	20	3	0	21	14	0	4	28	0	11
Low and middle mountain forest N-W	2	2	0	8	6	30	0	24	22	5
Low and middle mountain forest W	1	0	0	4	4	32	0	13	46	0
Low mountain, dry steppe N-W	36	15	19	0	11	0	1	0	0	15
Low/mid. mount. forest shelter belt N-W	0	4	0	7	0	8	0	34	47	0
Low/mid. mount. forest shelter belt W	0	0	0	1	0	7	0	33	59	0
Middle mount. meadow steppe W	6	5	0	2	11	18	4	15	34	5
Middle mountain meadow steppe N-W	8	5	0	19	6	17	16	15	5	10
Middle mountain steppe N-W	13	13	0	20	11	9	10	10	0	13
Mountain-valley semidesert N-W	11	33	45	0	0	0	0	0	0	9
Submountain semidesert N-W	0	0	0	0	0	0	0	100	0	0
Total	112	90	64	121	75	139	54	330	217	94
	ESA									
High mountain alpine N-W	7	4	0	17	6	3	11	32	1	14
High mountain subalpine N-W	9	7	0	20	7	9	14	20	3	12
High-altitude snow-cowered N-W	11	6	0	11	8	0	2	35	0	13
Low mountain, dry steppe N-W	36	12	15	0	13	0	1	0	0	14
Low-middle mount. forest N-W	2	2	0	10	7	33	0	20	22	5
Low-middle mount. forest shelter belt W	0	0	0	1	0	9	0	37	53	0
Low-middle mount. forest shelter… N-W	0	4	0	9	0	8	0	30	48	0
Low-middle mount. forest W	1	1	0	4	4	32	0	17	43	0

Middle mountain meadow steppe N-W	9	4	0	19	6	15	20	13	4	9
Middle mountain meadow steppe W	5	6	0	1	8	20	3	20	29	7
Middle mountain steppe N-W	11	13	0	20	11	12	10	8	0	13
Mountain-valley semidesert N-W	2	28	35	0	0	0	0	0	0	7
Submountain semidesert N-W	0	0	0	0	0	0	0	100	0	0
Total share	112	93	61	93	69	141	51	331	202	86

The contribution of marzes Tavush, Syunik, and Lori to the conservation of LLCC diversity differs of their importance for landscape diversity (Section 2.4). Moreover, these differences are revealed in both the ESRI and ESA data, indicating that they are not the result of land-cover misclassifications (Figure 25B-3). These three marzes stand out from the others because they preserve most of the woody LLCCs (Figure 25B-4), which are generally rarer in Armenia than the non-woody ones.

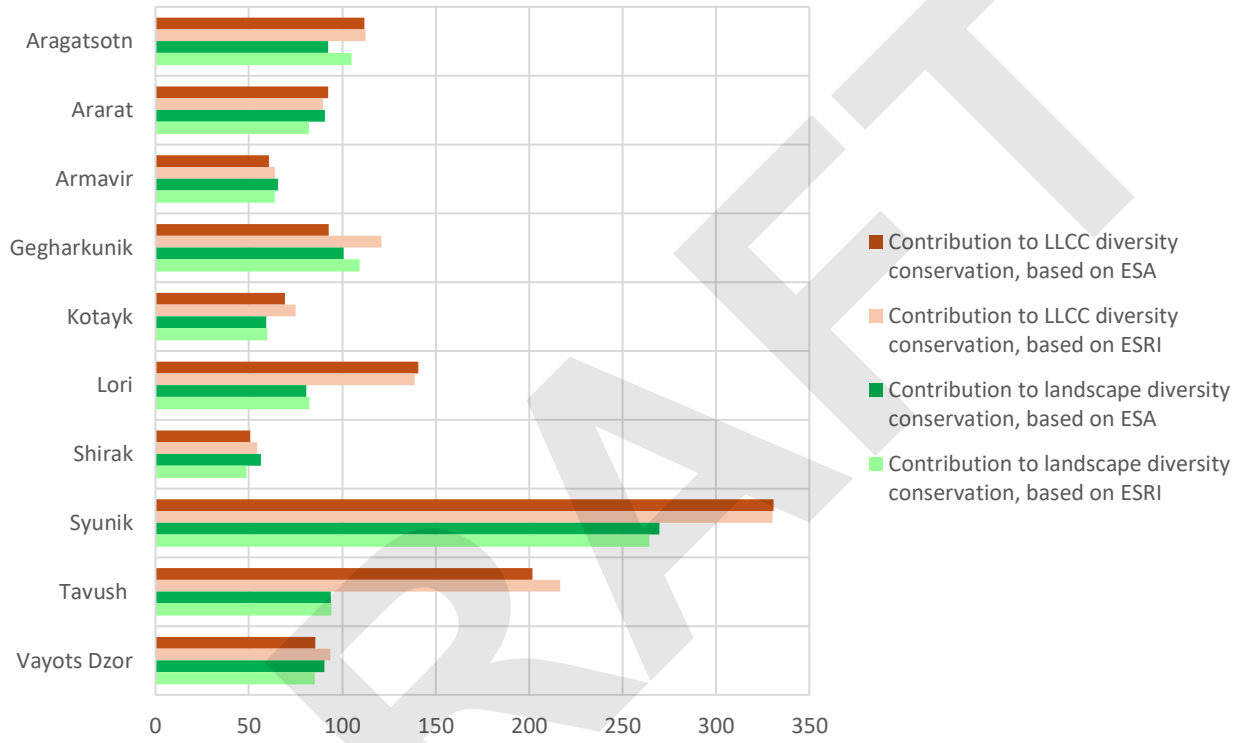


Figure 25B-3. Marz contribution to conservation of LLCC and landscape diversity in Armenia, based on ESRI and ESA data

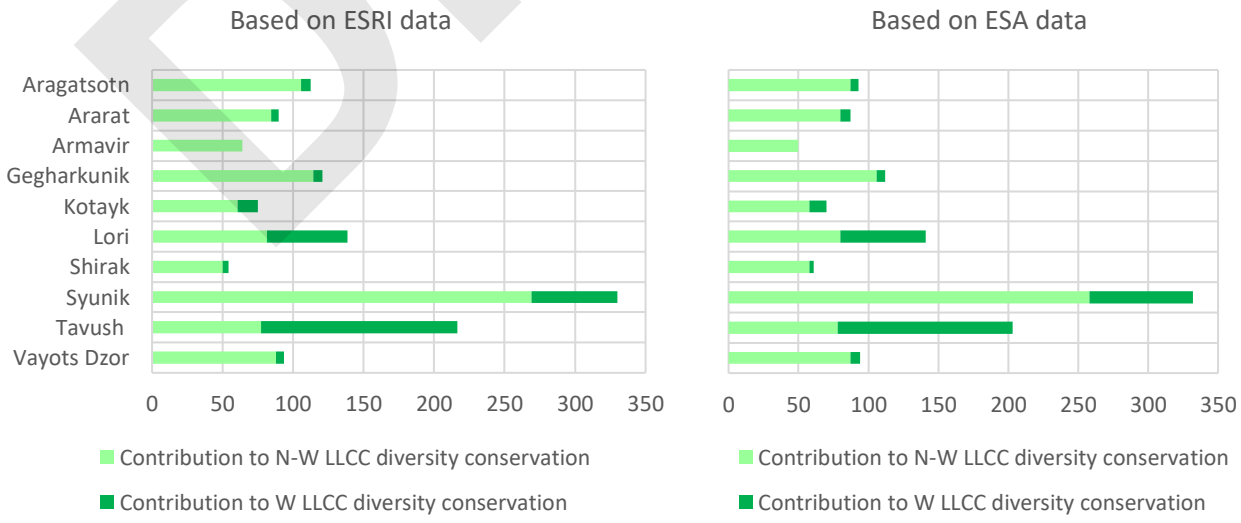


Figure 25B-4. Marz contribution to conservation of non woody and woody LLCC diversity in Armenia, based on ESRI and ESA data.

2.5.C. Changes in LLCC extent and marz importance for conservation of LLCC diversity in Armenia

Land cover changes recorded by ESRI data from 2017 to 2023 have resulted in changes in the area of natural landscapes and LLCC extent (Figure 25C-1). The data on LLCC changes provides the following additional information compared to the data on landscape changes (Section 2.4.B):

- The area of woody LLCCs has decreased more significantly than that of non woody LLCCs within the middle-mountain meadow steppe;
- The total reduction in the area of mountain forest landscapes is driven by opposing changes in woody and N-W LLCCs, specifically, a decrease in woody LLCCs and an increase in N-W LLCCs;
- The total area of the forest shelter belt has remained unchanged, although the woody LLCCs within it have decreased.

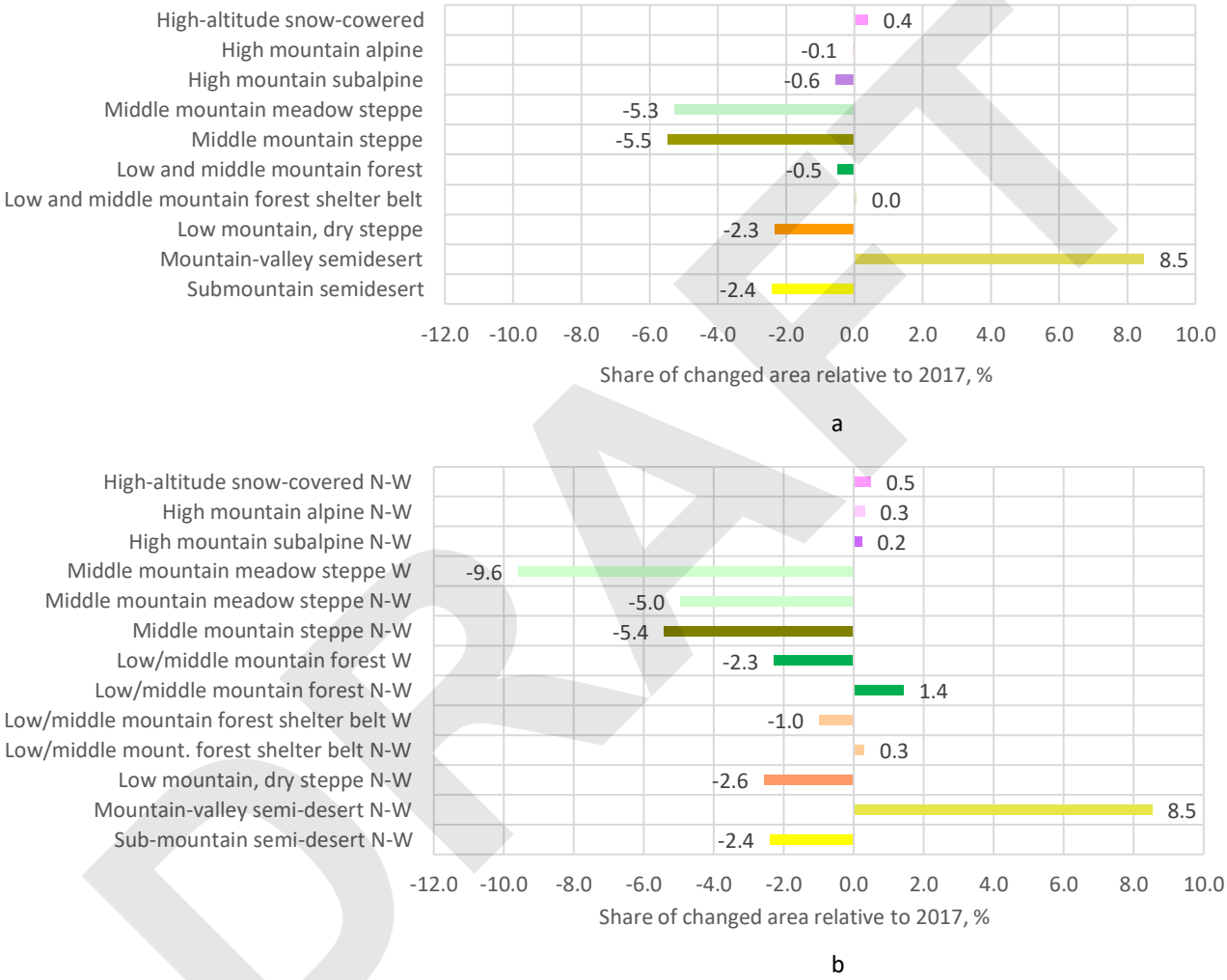


Figure 25C-1. Changes in the extent of natural landscapes (a) and LLCC (b) from 2017 to 2023 based on ESRI data

For the assessment of changes in provincial importance (Figure 25C-2), the data on LLCCs provides the following additional information: (i) the importance of the Syunik province for conserving LLCCs has decreased, even though it has remained unchanged with respect to landscapes and (ii) the importance of the Tavush province for conserving LLCCs has grown significantly more than it has for landscapes.

Preliminary conclusions for organizing ecosystem accounting from the LLCC exercise are as follows:

- The LLCC map makes it possible to identify rare LLCCs, however, rare LLCCs with a very small area must be carefully validated to exclude land cover classification errors;
- The rarer the LLCCs are, the greater the differences in estimates between the land-cover datasets. The same can be expected when accounting for real rare ecosystems with small areas;
- LLCC mapping provides additional information compared to the data on landscape extent.

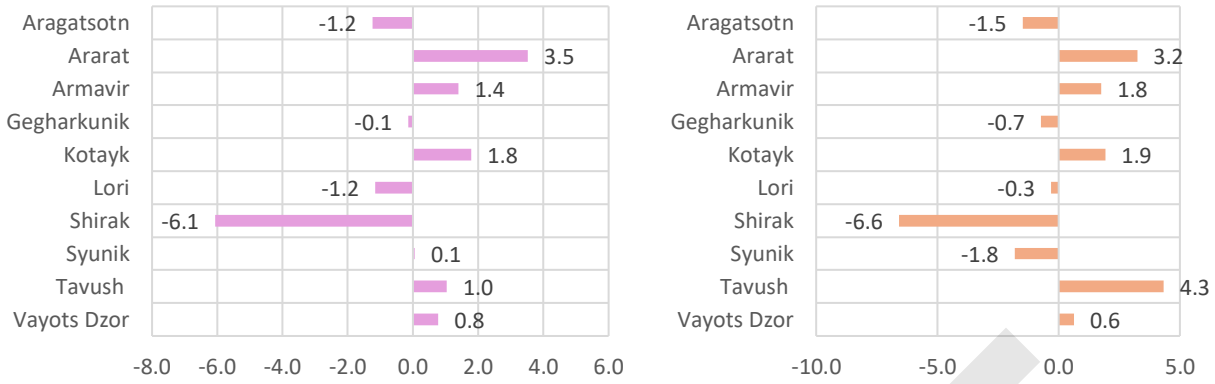


Figure 25C-2. Changes in marz importance for conservation of diversity of natural landscapes (a) and LLCC (b) in Armenia from 2017 to 2023 based on ESRI data

2.6. Ecosystem extent in protected areas

2.6.A. Extent of protected areas in Armenia

In accordance with Decree N 1059-Ա (25.09.2014) of the Government of the Republic of Armenia, the PAs in 2014 were as follows:

- 3 state reserves ("Khosrov Forest", "Shikahogh" and "Erebuni"), which occupy an area of 35,439.6 hectares or 1.19% of the total area of Armenia,
- 4 national parks ("Sevan", "Dilijan", "Lake Arpi" and "Arevik"), which occupy an area of 236,802.1 hectares or 7.96% of the total area of Armenia,
- 232 natural monuments,
- 27 state sanctuaries, which occupy an area of 114,812.7 hectares or 3.95% of the total area of Armenia.

The total area of state reserves, sanctuaries, and national parks was 387,054.4 hectares, which accounted for 13.1% of Armenia's total territory.

Table 1. PAs areas in 2014 according to the Ministry of Environment of Armenia

PA	*Area, ha*
STATE RESERVES	
Khosrov Forest	23 213.5
Shikahogh	12 137.1
Erebuni	89.0
NATIONAL PARKS	
Sevan	147 455.0
Dilijan	33 765.0
Lake Arpi	21 179.3
Arevik	34 401.8
NATURAL SANCTUARIES	
Akhnabad	25.0
Arjatkhlenu	40.0
Juniper sparse forest	3 312.0
Gyulagarak	2 576.0
Herher sparse forest	6 139.0
Jermuk Forest	3 865.0
Sosu Park	64.2
Aragats Alpine	300.0
Banks pine	4.0
Goravan sand dunes	95.99
Caucasian rosehip	1 000.0
Arzakan-Meghradzor	13 532.0
Gandzakar	6 813.0
Getik	5 728.0
Ijevan	5 908.0
Margahovitti	3 368.0
Yeghegnadzor	4 200.0
Goris	1850.0
Red worm	219.85
Boghakar	2 728.0
Black Lake	240.0
Deep wound	50.28
Hanqavan Hydrological	5 169.04
Jermuk Hydrological	17 371.0
Zangezur	25 870.64
Zikatar	150.0
Khustup	6946.74

2.6.B. Ecosystem extent in PAs based on ESRI land cover data

At the present stage, we do not have access to official data covering all Armenian PAs for the period after 2014, official digitized maps of PA boundaries, or land cover data specifically refined for the territory of Armenia. Therefore, the following analyses are based on the available digital PA map referenced below and the global ESRI land cover dataset.

The use of the ESRI land cover dataset for relatively small PA areas leads to significant errors in area estimation. In the examples below, we demonstrate only the type of analysis that can, in principle, be conducted for ecosystem accounting of PAs based on land cover data. All resulting estimates are of methodological value only and should be refined using official PA boundaries and land cover data provided by the PAs.

This example of accounting is based on the PA map provided by Acopian Center for the Environment, American University of Armenia (Figure 26B-1), the vegetation map prepared in the framework of our project (Section 2.3), and ESRI land cover data from 2017 and 2023.

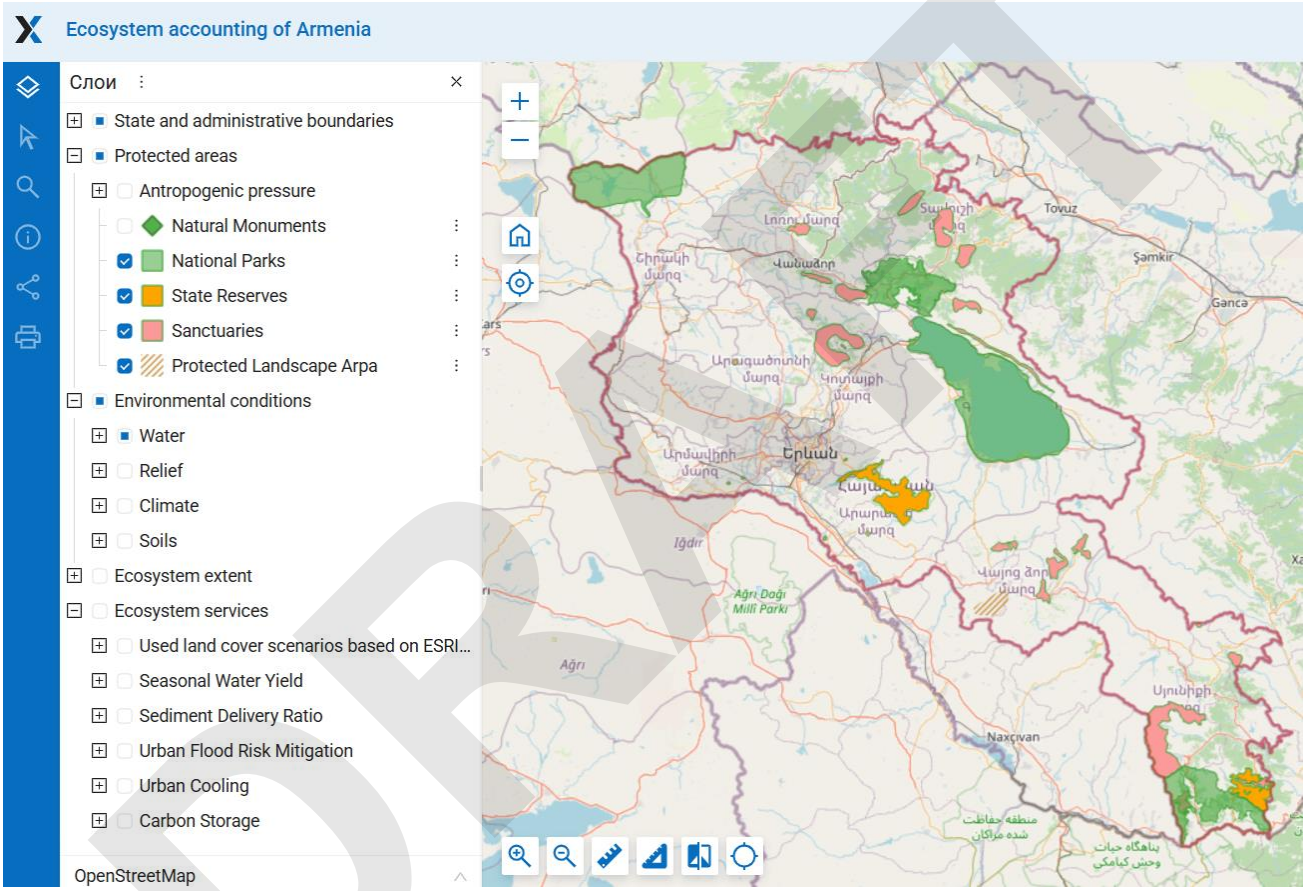


Figure 26B-1. The map of protected areas of Armenia. For details see project WEB GIS, Protected areas here. (The location of the Goravan Sands Sanctuary needs to be clarified)

The extent of land-cover classes in the PAs indicates the area of woody vegetation and the degree of human-induced transformation (Figure 26B-2; Table 26B-1). According to ESRI (2023), the entire area of the Ararat Vordan Karmir Sanctuary is occupied by croplands and built-up areas. Human-modified territories cover about half of the Goravan Sands and Goris Sanctuaries. The areas of Sevan and Arpi Lake National Parks, as well as the Khor Virap Sanctuary, are also significantly transformed. Forest vegetation occupies most of the territory of the Shikahogh Reserve and the Dilijan National Park, as well as the Gandzakar–Upper Aghdan, Ijevan, Pine of Gyulagarak, and Zikatar Sanctuaries. By contrast, forest is almost absent in the Erebuni Reserve, Arpi Lake National Park, and in 11 other sanctuaries.

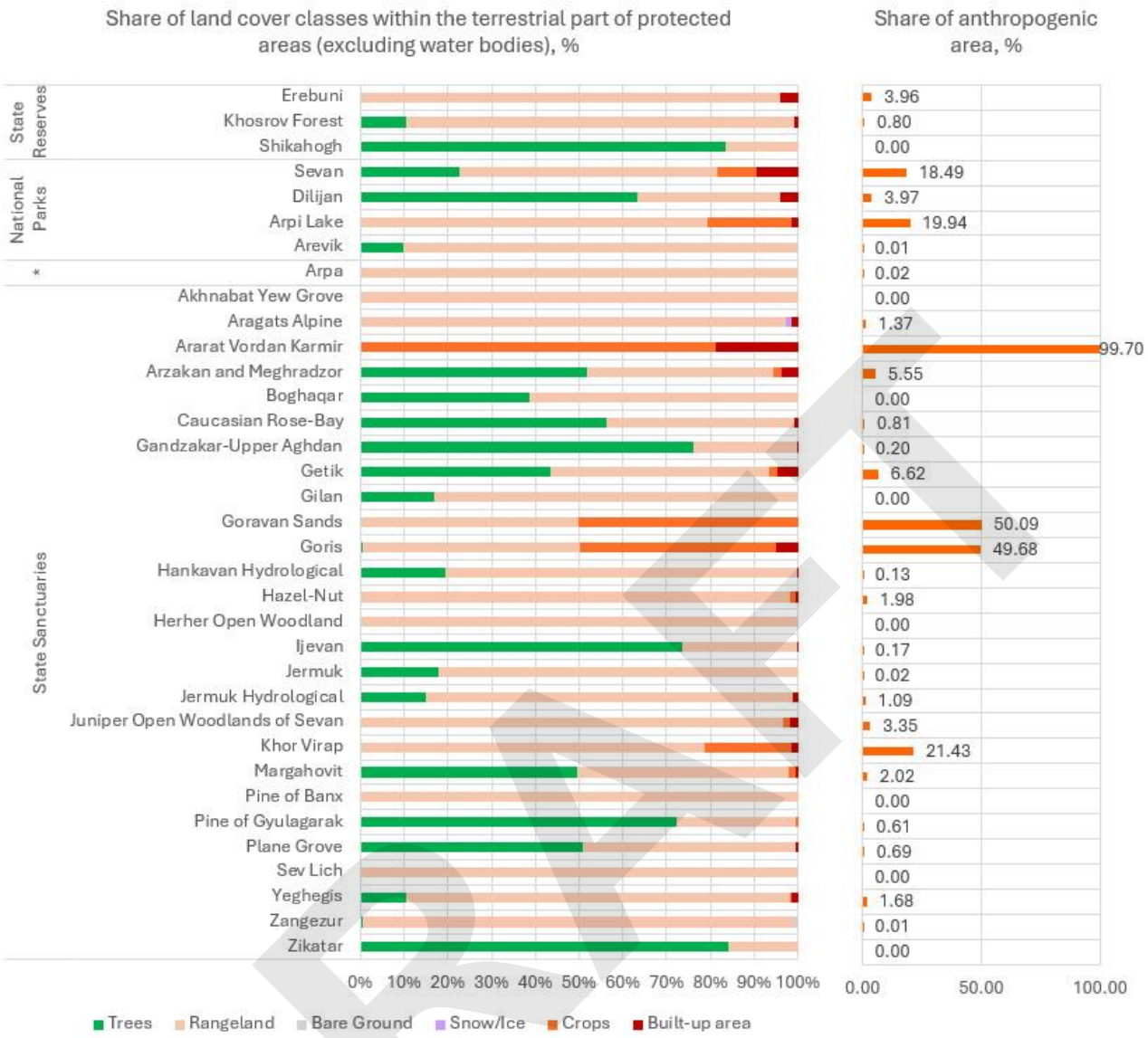


*Figure 26B-2. The share of area of land cover classes and anthropogenic areas, %. *Arpa is protected landscape*

All vegetation zones are represented in the PAs. The area of some PAs is entirely covered by vegetation of a single zone, for example: Goravan Sands – desert; Erebuni, Ararat, and Khor Virap — semi-desert;Hazel Nut – broadleaf woodlands; Gandzakar-Upper Aghdan, Goris, Hankavan Hydrological, Pine of Gyulagarak, Plane Grove – forest zone; Akhnabat Yew Grove, Pine of Banx, Sev Lich — subalpine meadows; Aragats Alpine – alpine meadows (Figure 26B-3).

Overall, vegetation zones are unevenly represented in the PAs. The forest zone occupies the largest area within the PAs—about 1,400 km². Other zones are much smaller, ranging from 500 km² of subalpine zone to 46 km² of marshes (Figure 26B-4 a). The shares of the zones' areas preserved in the PAs are also highly unequal. 26% and 32% of the forest and juniper zones are preserved in the PAs while for the semi-desert, steppe, and open woodland zones this share is less than 10% (Figure 26B-4 b). The desert zone is not indicative in this analysis, as it is represented by only one small unique site).

Between the total area of a vegetation zone and the share of its area preserved in the PAs, a weak, non-significant tendency towards a negative relationship between the total zonearea of a vegetation zone and its representation in the PAs: the larger the total area of a zone, the lower its representation in the PAs (Figure 26B-5). Even from this weak trend it is possible to distinguish zones that are better represented in the PAs, lying above the trend line (juniper, forest), and underrepresented zones, lying below the trend line (semi-desert, broadleaf woodland).

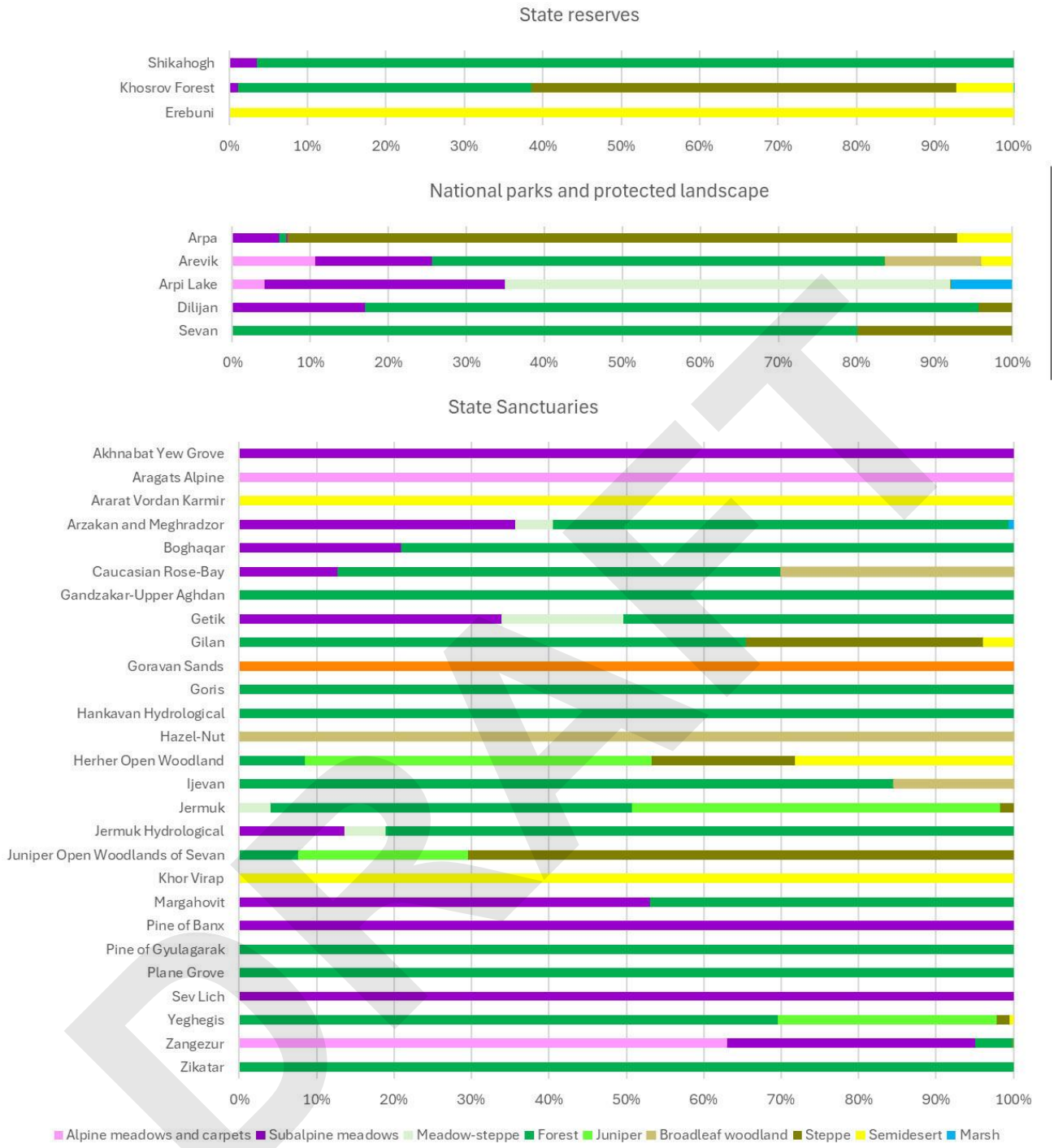


Figure 26B-3. The share of area of vegetation zones in PAs, %

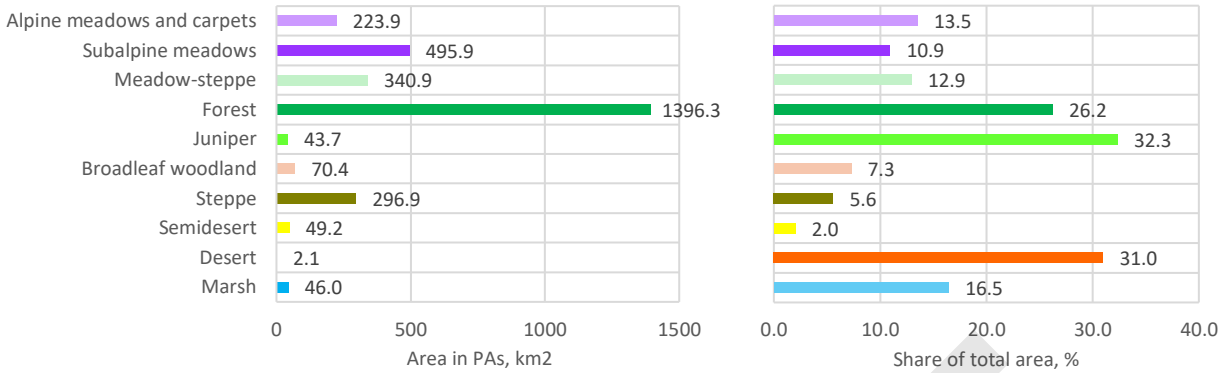


Figure 26B-4. Area and the share of the natural area of a vegetation zone located in the PAs

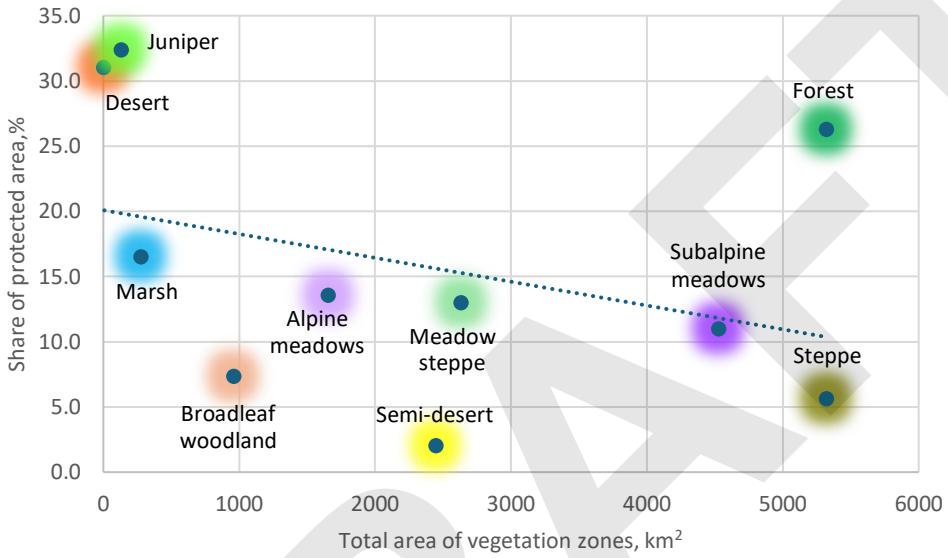


Figure 26B-5. A weak, non-significant tendency towards a negative relationship between the total area of a vegetation zone and its representation in the PAs.

Table 26B-1. Area of land cover classes in PAs, han (the total area of PAs shown on the map used may differ from the official data, as the PA boundaries on the map require further clarification)*

PA type	*PA*	*Trees*	*Rangeland*	*Bare Ground*	*Snow/ Ice*	*Water and flooded vegetation*	*Crops*	*Built-up area*	*Total area of PA**
State Reserves	Erebuni	0	84.84	0	0	0	0	3.5	88.30
	Khosrov Forest	2404.91	20231.17	31.76	0	0.51	5.33	176.63	22868.59
	Shikahogh	9854.31	1937.14	0	0	0	0	0	11810.26
National Parks	Sevan	5525.1	14346.23	13.23	0	126863.3	2173.48	2336.68	151374.99
	Dilijan	24757.79	12862.58	0	0	5.21	11.41	1546.26	39214.50
	Arpi Lake	186.33	43922.3	8.64	0	2123.82	10719.45	810.1	57828.90
	Arevik	4158.48	37530.44	36.28	1.25	3.11	0	5.12	41852.62
Protected landscape	Arpa	1.49	8148.12	1.01	0	0	0	1.7	8158.56
State Sanctuaries	Akhnabat Yew Grove	0	24.85	0	0	0	0	0	24.86
	Aragats Alpine	0	276.72	0.17	4.1	15.67	0	4.11	301.07
	Ararat Vordan Karmir	0	0.37	0	0	0	166.63	38.36	205.60
	Arzakan and Meghradzor	7503.25	6181.2	3.39	0	7.27	285.16	521.26	14518.08
	Boghaqar	1112.76	1757.96	0	0	0	0	0	2872.27
	Caucasian Rose-Bay	1037.93	794.25	0	0	0	0	15.02	1848.58
	Gandzakar-Upper Aghdan	2973.96	925.74	0	0	0	0.07	7.73	3910.26
	Getik	1354.88	1559.37	0.03	0	1.65	58.24	148.68	3124.67
	Gilan	48.48	238.6	0.23	0	0	0	0	287.41
	Goravan Sands	0	106.47	0	0	0	106.93	0	213.47
	Goris	11.93	934.73	0	0	0	847.96	96.39	1901.05

	Hankavan Hydrological	191.05	783.42	0	0	0	0	1.3	976.53
	Hazel-Nut	0	40.73	0	0	0	0.58	0.24	41.48
	Herher Open Woodland	7.17	2047.41	6.58	0	35.85	0	0	2098.67
	Ijevan	5725.75	2048.54	0	0	0	5.7	7.29	7793.64
	Jermuk	726.01	3336.61	0	0	0	0.94	0	4066.48
	Jermuk Hydrological	388.69	2163.31	0	0	0.05	0	28.1	2581.86
	Juniper Open Woodlands of Sevan	8.9	3764.79	21.6	0	0.2	60.96	70.75	3930.40
	Khor Virap	0.01	124.8	0	0	0.28	31.71	2.45	159.37
	Margahovit	2285.4	2222.63	0	0.14	0	69.85	23.13	4604.38
	Pine of Banx	0	4.62	0	0	0	0	0	4.61
	Pine of Gyulagarak	1768.24	661.81	0	0	0	14.27	0.61	2446.95
	Plane Grove	1098.25	1049.34	0	0	0	1.43	13.58	2174.57
	Sev Lich	0	150.56	0.47	0	89.14	0	0	240.32
	Yeghegis	230.75	1927.08	0.45	0	0	0.52	36.32	2196.95
	Zangezur	127.06	24156.19	241.24	3.54	33.9	2.03	0	24711.29
	Zikatar	2691.57	504.37	0	0	0	0	0	3198.61

Table 26B-2. Area of vegetation zones in PAs, ha (the total area of PAs shown on the map used may differ from the official data, as the PA boundaries on the map require further clarification)*

PA type	PA	Alpine meadows and carpets	Sub-alpine meadows	Meadow-steppe	Forest	Juniper	Broad-leaf woodland	Steppe	Semi-desert	Marsh	No data	Total area of PA*
State Reserves	Erebuni	0	0	0	0	0	0	0	88.34	0	0	88.34
	Khosrov Forest	0	268.64	0	8533.69	0	14.72	12399.13	1626.9	3.58	3.65	22850.31
	Shikahogh	0	405.25	0	11224.97	0	0	0	0	0	176.04	11806.26
National Parks	Sevan	0	0	16.03	20957.52	0	0	5204.09	0	0	125080.4	151258.04
	Dilijan	0	6667.11	15.37	30799.09	0	0	1701.68	0	0	0	39183.25
	Arpi Lake	2375.27	17575.65	32567.5	0	0	0	40.31	0	4514.36	726.2	57799.33
	Arevik	4371.3	6231.62	0	23943.92	0	5172.4	0	1651.39	0	461.3	41831.9
Protected landscape	Arpa	0	490.08	0	73.14	17.23	0	6997.61	574.26	0	0	8152.32
State Sanctuaries	Akhnabat Yew Grove	0	24.85	0	0	0	0	0	0	0	0	24.85
	Aragats Alpine	300.77	0	0	0	0	0	0	0	0	0	300.77
	Ararat Vordan Karmir	0	0	0	0	0	0	0	205.36	0	0	205.36
	Arzakan and Meghradzor	1.87	5171.99	699.07	8547.13	0	0	0	0	86.52	0	14506.58
	Boghaqar	0.32	600.73	0	2269.67	0	0	0	0	0	0	2870.72
	Caucasian Rose-Bay	0	235.19	0	1051.5	0	560.51	0	0	0	0	1847.2
	Gandzakar-Upper Aghdan	0	0	0	3907.5	0	0	0	0	0	0	3907.5
	Getik	0	1057.62	491.27	1573.96	0	0	0	0	0	0	3122.85
	Gilan	0	0	0	187.18	0	0	87.72	11.24	0	1.17	287.31
	Goravan Sands	0	0	0	0	0	0	0	213.4 (desert)	0	0	213.4
	Goris	0	0	0	1900.32	0	0	0	0	0	0	1900.32
	Hankavan Hydrological	0	0	0	975.77	0	0	0	0	0	0	975.77
	Hazel-Nut	0	0	0	0	0	41.55	0	0	0	0	41.55
	Herher Open Woodland	0	0	0	177.97	938.57	0	388.05	592.42	0	0	2097.01
	Ijevan	0	0	0	6581.18	0	1206.1	0	0	0	0	7787.28
	Jermuk	0	0	164.7	1896.6	1932.97	0	69.29	0	0	0	4063.56

	Jermuk Hydrological	0	351.27	136.5	2092.38	0	0	0	0	0	0	2580.15
	Juniper Open Woodlands of Sevan	0	0	0	298.17	861.8	0	2767.2	0	0	0	3927.2
	Khor Virap	0	0	0	0	0	0	0	159.25	0	0	159.25
	Margahovit	0	2440.85	0	2160.31	0	0	0	0	0	0	4601.16
	Pine of Banx	0	4.62	0	0	0	0	0	0	0	0	4.62
	Pine of Gyulagarak	0	2.62	0	2442.31	0	0	0	0	0	0	2444.93
	Plane Grove	0	0	0	2160.46	0	0	0	0	0	12.97	2173.43
	Sev Lich	0.07	240.1	0	0	0	0	0	0	0	0	240.17
	Yeghegis	0	0	0	1527.23	619.0	0	37.75	11.1	0	0	2195.12
	Zangezur	15340.85	7825.73	0	1148.02	0	45.62	0	0	0	336.6	24696.79
	Zikatar	0	0	0	3195.94	0	0	0	0	0	0	3195.94

2.6.C. Changes in the area of land cover classes in state reserves and national parks

According to ESRI, between 2017 and 2023 the most notable changes occurred in Arpi Lake National Park, where the area of croplands increased by more than half, and in the Erebuni Reserve, where it decreased by one third. In the Arevik Reserve, the forest area decreased by 18% (Figure 26C-1).

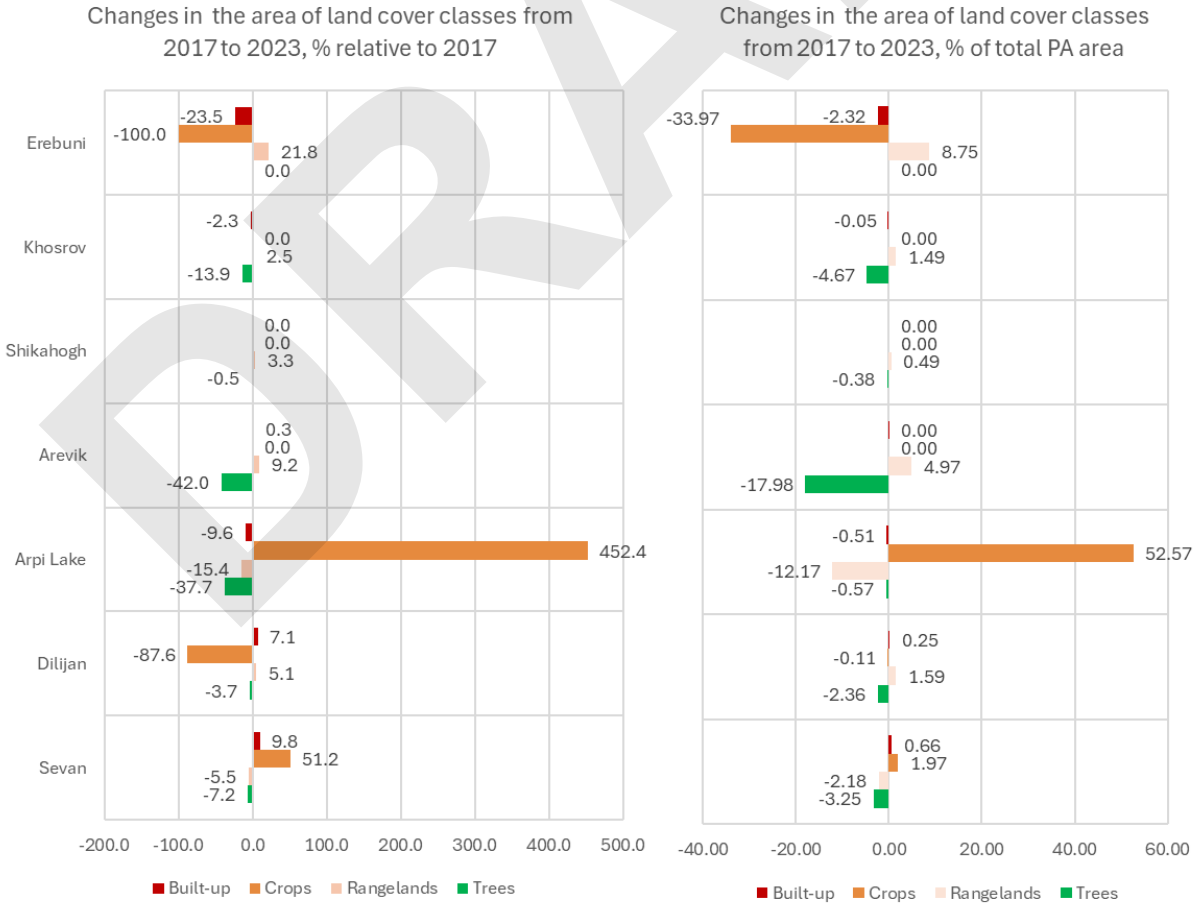


Figure 26C-1. Changes in the area of land cover classes within PAs

2.6.D. Distance from natural monuments to anthropogenic areas and roads

As an example of assessing anthropogenic threats to 'point' ecosystems and natural objects of very small area, distances were measured between the natural monuments shown on the PA map provided by Acopian Center for the Environment, American University of Armenia (Figure 26D-1), and anthropogenic areas (built-up areas and croplands according to the ESRI 2023 land cover data), roads including main roads and all other roads including trails from the dataset of Forest Atlas of Armenia, and population polygons with more than 100 residents based on the Kontur Population Dataset (Figure 26D-2).

This example shows, that even minor errors in land cover classification—amounting to just a few pixels—can significantly distort the calculated distances to natural monuments. Therefore, to obtain reliable results, it is essential to use land cover data specifically refined for Armenia.

Unfortunately, at this stage the lack of an officially approved digital map of PA boundaries, combined with errors in the ESRI land-cover data, prevents accurate accounting of ecosystem extent within PAs. For PAs with small areas, even minor land-cover errors can significantly distort the actual proportions of different ecosystem types. Moreover, the misclassification of anthropogenic areas where none exist leads to inaccurate assessments of threats to natural ecosystems and natural monuments. For instance, the misclassification of cropland and built-up areas in the high-mountain zone of the Gegham Ridge in the land-cover data artificially reduced the estimated distance between natural monuments and anthropogenic territories (26D-4).

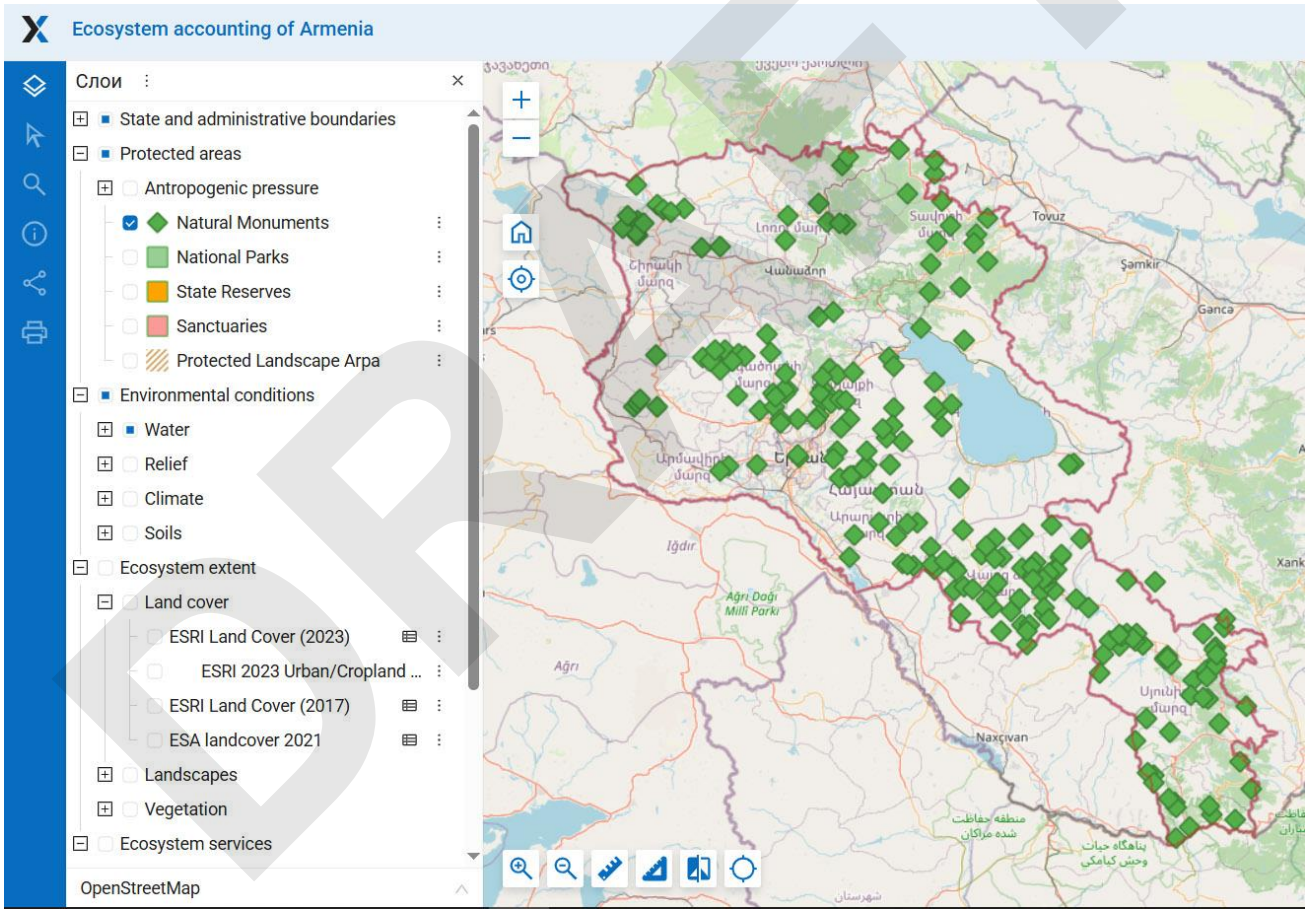


*Figure 26D-1. The map of natural monuments used (in details see project WEB GIS **Section Protected Areas**)*

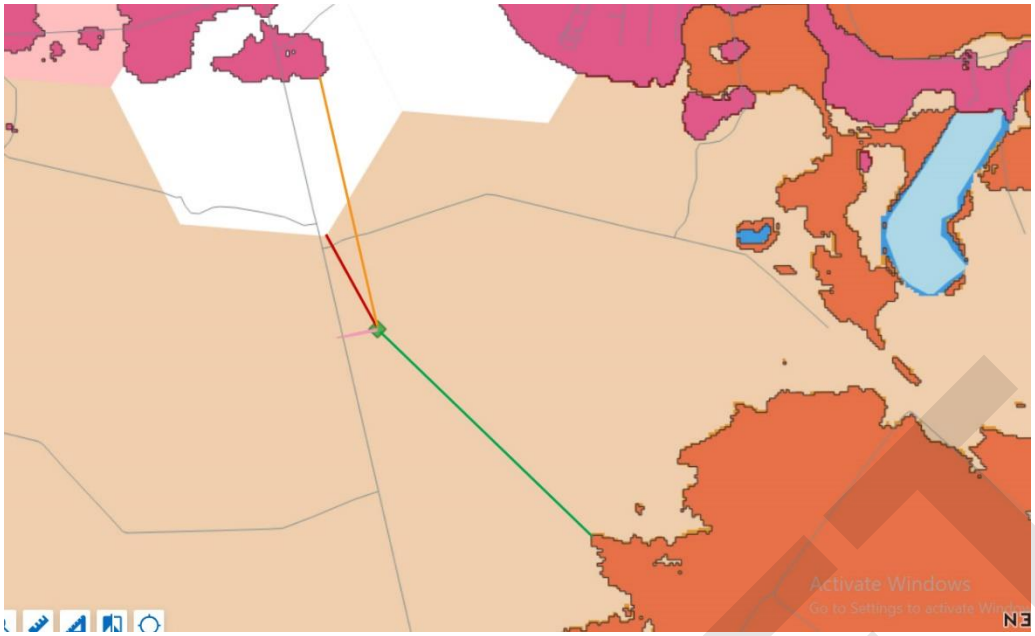


Figure 26D-2. An Example of distances for Dasak Biological Monument in Armavir marz

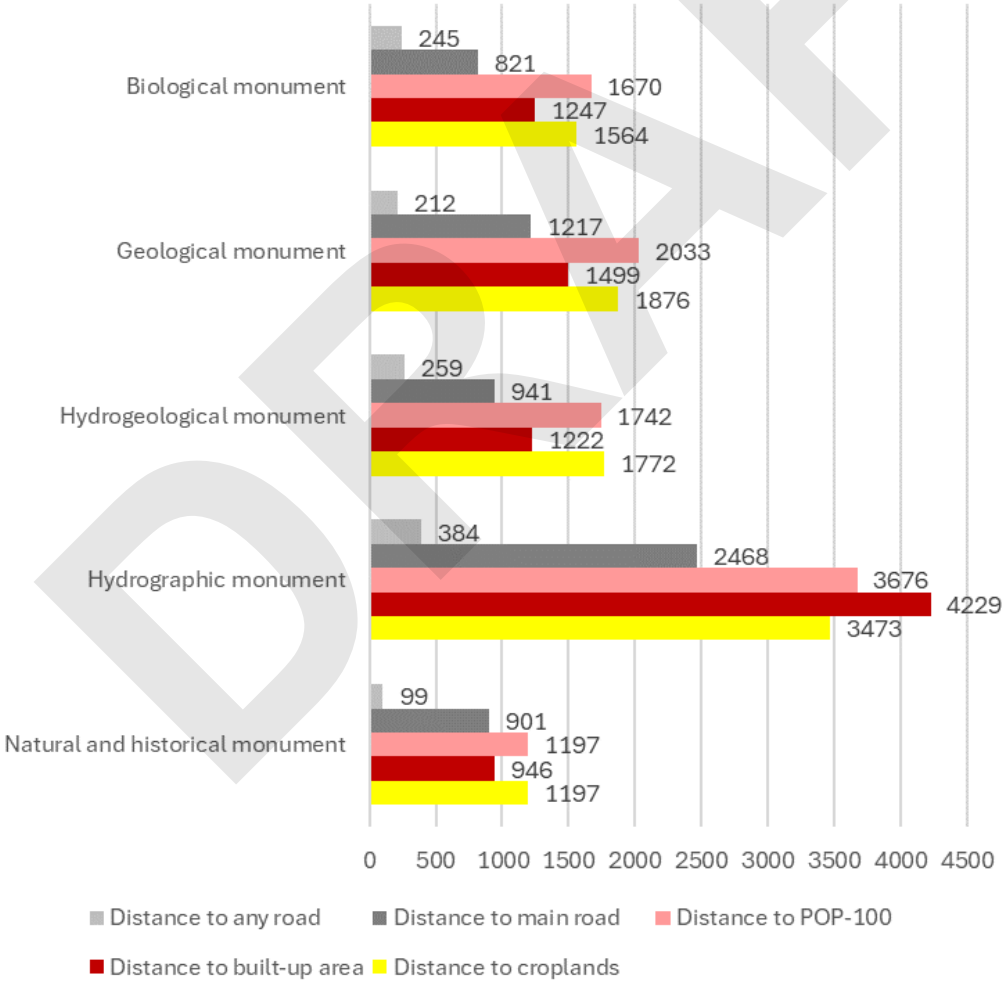


Figure 26D-3. Distance from different categories of natural monuments to various types of anthropogenic areas and roads, in meters (Pop-100 - hexagons with a population of more than 100 people).

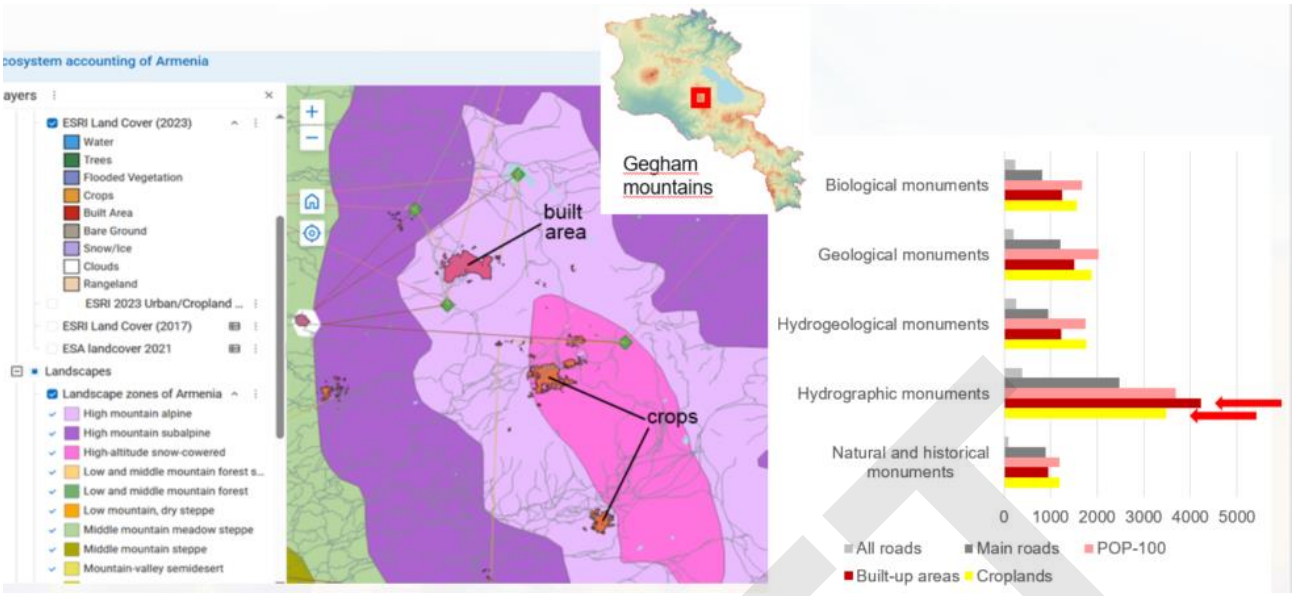


Figure 26D-4. Erroneous underestimation of the distance between anthropogenic areas and hydrographic monuments due to ESRI land cover mistakenly detecting croplands and built-up areas on the Gegham Ridge.

2.7. Approaches for the inclusion of Armenia in the Global Ecosystem Atlas

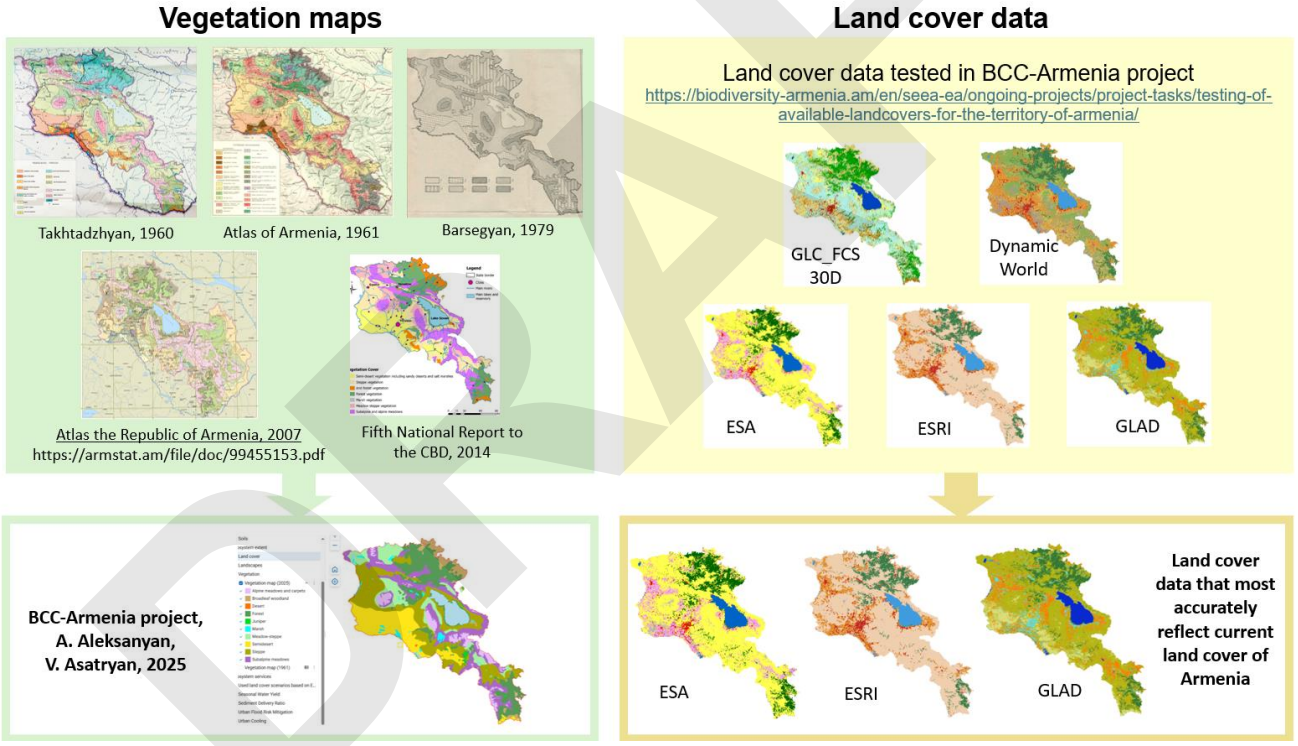
The Global Ecosystems Atlas (GEA) will be the first comprehensive harmonized open resource on the extent, change, condition and risk of all the world's ecosystems. The inclusion of Armenia in the GEA is seen by us as an important step to support efforts toward launching national ecosystem accounting.

Our approach consists in the integration of academic vegetation and landscape maps with regularly updated land cover data. Academic maps take into account the ecological and biodiversity features of terrestrial ecosystems that are difficult or impossible to detect from space. Regularly updated land cover data allows for timely monitoring of changes in the extent of natural ecosystems. This approach was tested for extent accounting of natural vegetation types (Section 2.3) and natural landscapes (Section 2.4).

2.7.A. Initial data to start

Armenia has an world-class scientific tradition in botany and geobotany. Over many decades, Armenian scientists have developed a wide range of vegetation and landscape maps with varying levels of detail. The updated vegetation map was prepared within the framework of our project (Section 2.3).

Since Armenia currently lacks a national regularly updated land cover dataset, we tested five land cover datasets available in open access (Section 2.1). Three of them — ESRI, ESA, and GLAD datasets — most accurately reflect the current land cover of Armenia and can be used for the zero version of the Armenia ecosystem map for the GEA. However, as shown by our analysis, all global land cover datasets contain significant errors, and therefore, the ecosystem map of Armenia and the ecosystem accounting should eventually be based on a corrected national land cover dataset.



2.7.B. Zero version of Armenian ecosystem map for the Atlas

Based on the currently available materials — the vegetation map and global land cover data (we used ESRI 2023) — a zero version of the map can be created, which clearly requires further refinement. Combination of vegetation types and land cover data can be reclassified according to the IUCN ecosystem typology adopted in the GEA.

From the land cover data, we use three classes:

– trees, which are reclassified as T2.2 Deciduous temperate forests;

– built-up areas, reclassified as T7.4 Urban and industrial ecosystems;

– croplands, which, for the zero version, are reclassified as T7.1 Annual croplands

As our analysis comparing cropland areas from land cover datasets and ARMSTAT data has shown (Section 2.1.B), tested land cover datasets include the following categories of agricultural land in the 'cropland' class:

– annually plowed areas (T7.1 Annual croplands);

– perennial agricultural plantations, i.e., vineyards and orchards (T7.3 Plantations);

– some of the fields that have not been plowed this year (T7.5 Derived semi-natural pastures and oldfields).

At this stage, we do not have the data necessary to separate these three categories within cropland land cover class, therefore, we reclassified it as T7.1 Annual croplands. Land categories such as "T7.2 Sown pastures and fields" and forest plantations aimed at timber production are not typical for Armenia; therefore, we did not consider them.

All remaining terrestrial land cover classes — that is, all non-woody natural areas — are reclassified based on the vegetation zones delineated on the vegetation map:

– alpine vegetation is reclassified as T6.4 Temperate alpine grasslands and shrublands;

– subalpine meadows and meadow-steppe are reclassified as T4.5 Temperate subhumid grasslands;

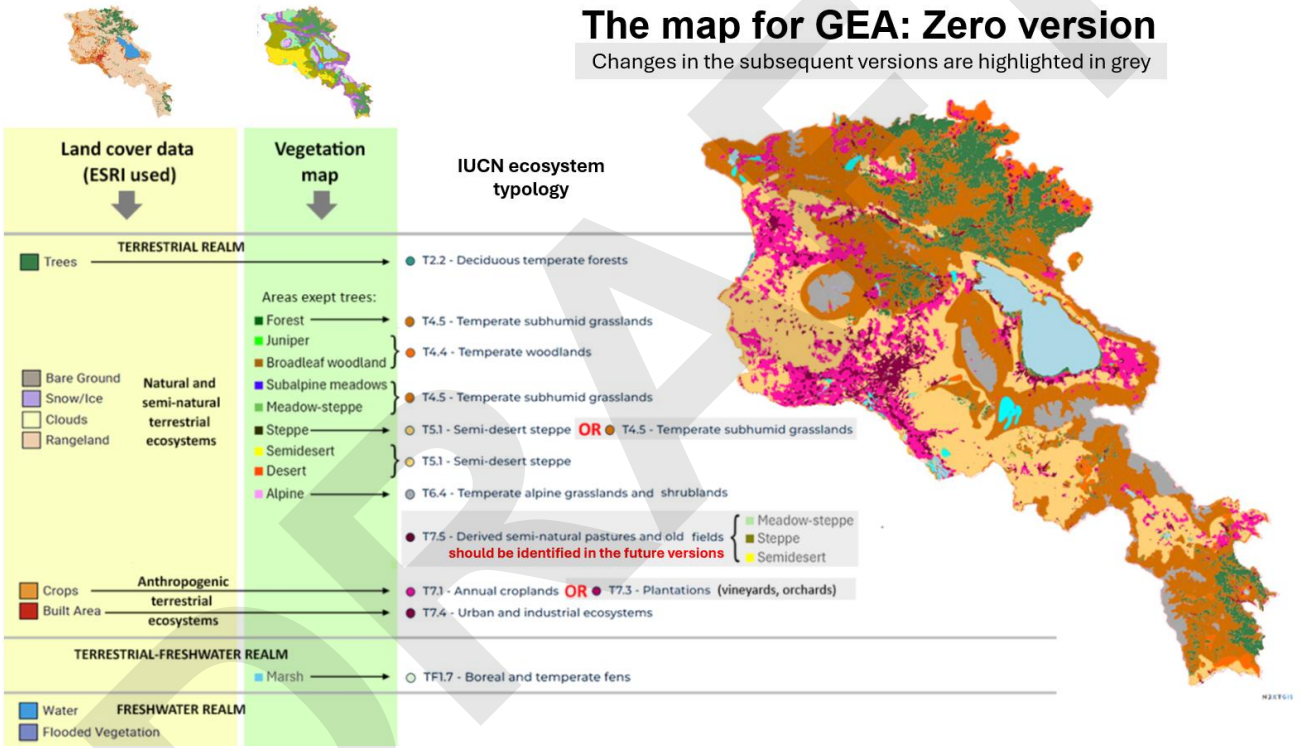
– steppe is reclassified as T5.1 Semi-desert steppes for the zero version, however, in future versions, a part of the steppe zone may also be reclassified as T4.5 Temperate subhumid grasslands;

– grasslands within forest vegetation zone are reclassified as T4.5 Temperate subhumid grasslands;

– juniper and broadleaf woodlands are reclassified as T4.4 Temperate woodlands;

– semidesert and desert are reclassified as T5.1 Semi-desert steppes.

Category "T7.5 Derived semi-natural pastures and oldfields" can be found in three vegetation zones: meadow-steppe, steppe, and semidesert. However, at this stage, we do not have the data necessary to identify T7.5 within these zones.



2.7.C. Subsequent versions of the map

Currently, we are at the stage of the **Zero version** of the map, which can be created based on the materials of our project within a minimal timeframe. Moving forward, two main stages of improvement for this map can be foreseen. Along this path, improvements are needed both in the vegetation map and in the land cover data.

Version 1 is a refined version of the map for the GEA. On the side of the vegetation map, its development requires probably an identification of areas of T4.5 Temperate subhumid grasslands within steppe zone. On the land cover side, this requires at least the following major data refinements:

– Correction of obvious errors in land cover data (e.g., built-up areas and croplands in high mountain zones);

– Refinement of T7.1 Annual cropland areas;

– Identification of T7.3 plantation areas (vineyards and orchards)

– Identification of T7.5 derived semi-natural grasslands, which can require analysis of satellite imagery and agricultural statistics not only for the current period but also for previous years.

The creation of Version 1 will greatly contribute to the development of ecosystem accounting in Armenia, as it will provide more accurate delineation of croplands.

Version 2 provides full synergy with the process of developing ecosystem accounting in Armenia and lays the foundation for creating the Red List of Ecosystems of Armenia.

On the side of academic knowledge, it represents a map of terrestrial ecosystems map with the next level of detail in both ecosystem typology and their boundaries, including both ecosystems with an area large enough to be represented on the map at the resolution of the land cover used, and unique, rare, and relict "point" ecosystems of very small size. On the side of land cover data, it consists in national land cover dataset along with a methodology for its regular updating.