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, Germany), with the participation of experts from leading scientific organizations in Armenia.

Leibniz Institute of Ecological Urban and Regional Development

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The responsibility for the content of this publication lies with the authors.

Prototype Ecosystem Accounting of Armenia
(Terrestrial Ecosystems)
Version 1

Brief overview of key results

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Content

Aim and Context

Armenia has begun developing a national accounting system aligned with the UN System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA EA), starting with water accounting. The Governmental Decision on the classification of land cover in RA (2019) initiated the first step toward ecosystem accounting by establishing extent accounts for land-cover classes. To support this move toward establishing national ecosystem accounting, a first version of Ecosystem Accounting Prototype (EA PV1) was created aimed at the following core objectives:

- **demonstrate the value of EA as a tool for integrating information on ecosystem extent, condition and services into policy and management decisions.**
- **identify the key challenges for developing EA in Armenia;**
- **define the initial technical and data steps required to launch the first phase of EA in Armenia.**

Ecosystem accounting (EA) constitutes a statistical framework for organizing data about ecosystems and ecosystem services, tracking changes in them. EA data are needed for the following tasks:

- to make visible and understandable to people the material and non-material contribution of living nature to their well-being;

- to assess and track the state of ecosystems and their services;

- to identify and track the impact of human activities on the state of ecosystems and their services; to provide an information basis for decision-making in order to maintain and sustainably use ecosystems and ecosystem services.

The SEEA EA is built on a few core accounts (Figure 1):

1. Ecosystem extent (EE) accounts record the size of ecosystems of different types and changes in it.

2. Ecosystem condition accounts record the condition of ecosystems and the changes in it providing valuable information on the health of ecosystems (*not included in the EA PV1*).

3 & 4. Ecosystem services (ES) accounts record the supply of ES by ecosystems and the use of those ES by economic units, including households.

5. Monetary accounts for ES and ecosystem assets (*not included in the EA PV1*).

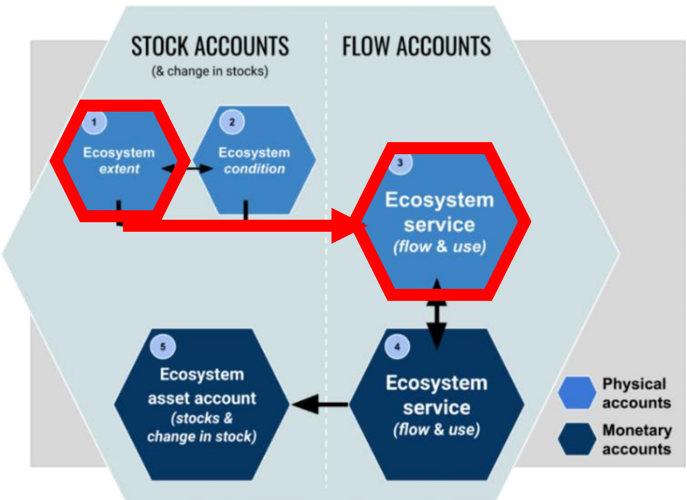


Figure 1. Ecosystem accounts and how they relate to each other (https://seea.un.org/ecosystem-accounting). Accounts included in the EA PV1 are highlighted in red.

Armenia is in the early stages of establishing an ecosystem accounting system aligned with the SEEA EA. While the country already compiles water accounts under SEEA Central Framework (SEEA CF), ecosystem accounts are not yet institutionalized. 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" set out the framework for the annual accounting of the areas of the main land-cover classes in Armenia, based on the results of current land accounting in communities, marzes (provinces), and nationwide.

The EA PV1 provides the following:

- **Physical assessment of terrestrial ecosystems and ecosystem services of Armenia**, following the recommendations of SEEA EA and the European INCA project on ecosystem accounting. Monetary accounts are not included.
- **Statistical tables and maps** presenting EE and ES indicators, along with a summary of main results, data sources, and assessment methodology.
- **Integration of ecosystem extent (EE) and ecosystem services (ES)** into policy and planning across multiple ecosystem accounting areas (EAAs): national level; marzes (regional level); main watersheds; landscape and vegetation zones; and protected areas (PAs).
- **Ecosystem extent (EE) accounts** based on Esri 2023 and 2017 land cover data, using multiple classification approaches: land cover classes (Section 2.2 of the TR); types of natural vegetation (Section 2.3); types of natural landscapes (Section 2.4); and intersections of landscape zones and land cover classes (LLCC) as a proxy for ecosystems (Section 2.5).
- **Assessment of ecosystem services (ES)**, including the potential (capacity) of 13 ES and the flow (supply = use) of three of them ES, covering all ES categories - provisioning, regulating, recreational and intangible (Table 1).

Table 1. List of ES asessed in the EA Prototype V1

Ecosystem services			*Section of TR*
Provisioning ES	1) Production of forage and fodder for cultivated livestock by natural grasslands	Potential Supply=Use	3.2.A
	2) Wild plants biomass production: edible and culinary plants	Potential (score)	3.2.B
	3) Wild plants biomass production: medicinal plants		
	4) Nectar production by wild plants for honey bees to produce honey		
Regulating ES	5) Global climate regulation: carbon storage in soil and tree biomass	Potential	3.1.G
	6) Local climate regulation: ecosystem effect on surface temperature	Potential	3.1.E
	7) Prevention of soil erosion	Potential Supply=Use	3.1.C
	8) Prevention of sediment export to streams		
	9) Baseflow provision	Potential Supply=Use	3.1.B
	10) Flood risk mitigation	Potential	3.1.D
	11) Crop pollination by wild insects	Potential (score)	3.1.H
Recreational ES	12) Natural conditions for recreation	Potential	3.3
Non-material ES	13) Importanse of biodiversity for Armenian culture	Potential (description)	3.4

Materials of the EA Prototype are fully presented on the project website biodiversity-armenia.am and in the Technical Report (https://biodiversity-armenia.am/en/full-report/). References to relevant TR sections are provided below

The EA PV1 was created based on currently available data - published open statistical, cartographic and scientific data for Armenia, as well as global databases. The project did not include the collection of primary data or specialized scientific research.

To map and assess EE and ES we used 10 m-resolution ESRI land cover dataset to exclude built-up areas and cropland from the accounts, as well as to delineate forest and non-forest areas. The ESRI land-cover dataset was selected for EA Prototype V1 after testing several global land-cover datasets (Section 2.1 of the TR). To demonstrate the ability of the EA Prototype to track changes in EE and ES, we selected two reference years—2017 and 2023.

For data preprocessing, EE and ES mapping, and GIS analysis we used the open source QGIS application [QGIS] and custom Python scripts. For assessing and mapping water-related regulating services, we used models from the InVEST GIS tool (Section 3.1.A of TR).

Policy Relevance of EA Prototype V1
Data for integration of ecosystem values into economic and environmental decision-making

The total values of ES potential demonstrate their key importance for the economy and population of Armenia, as well as for assessing the country's contribution to mitigating global and regional environmental problems, including climate change and water crisis.

– Terrestrial ecosystems provide 93% of rivers' baseflow, ensuring water availability in summer and during droughts, which is critically important for Armenia;

– Ecosystems prevent more than 90% of soil water erosion and over 95% of sediment wash-off into streams and water bodies, ensuring water quality;

– Ecosystems reduce spring and early summer flood risk by increasing runoff retention by 11% and decreasing quick flow by 32%;

– Forests cool the land surface in summer due to water evaporation, increasing cooling capacity by 21%.

– Total carbon stock in soils and tree biomass amounts to 151 MtC;

– Natural grasslands provide fodder for one million of livestock units;

– Wild insects could potentially pollinate almost the entire area of agricultural crops.

Table 2. Total potential/capacity of quantitavely estimated ES

ES	Indicators of ES potential/capacity	Indicator values
Production of forage and fodder by natural grasslands	Maximum allowable stocking rate (all grasslands)	0.54 LU/ha* 1,111,000 LU
	Maximum allowable stocking rate (non-degraded grasslands	0.44 LU/ha 913,000 LU
Storage of carbon in ecosystems in soil and tree biomass	Carbon content	53 tC/ha
	Carbon stock	151 MtC
Ecosystem effect on surface temperature	Ecosystem effect on cooling capacity	0.04
Prevention of soil water erosion	Avoided erosion	46.4 t/ha/year 140.4 Mt/year
Prevention of ediment export to streams	Avoided sediment export	4.3 t/ha/year 13.0 Mt/year
Baseflow maintenance	Baseflow provided by ecosystems	47.8 mm/year 2212 million m^3/year
Flood risk mitigation	Ecosystem effect on quick runoff	- 4.1 mm
	Runoff retention provided by ecosystems	0.4 mm 119 million m^3

*LU – livestock unit

ES maps show that under the bare-ground scenario without natural ecosystems, baseflow is almost absent and most water rapidly runs off the land surface (Figure 2). That means that existing baseflow is almost entirely provided by terrestrial ecosystems. Current soil erosion is low, as ecosystems prevent more than 90% of potential erosion (Figure 3).

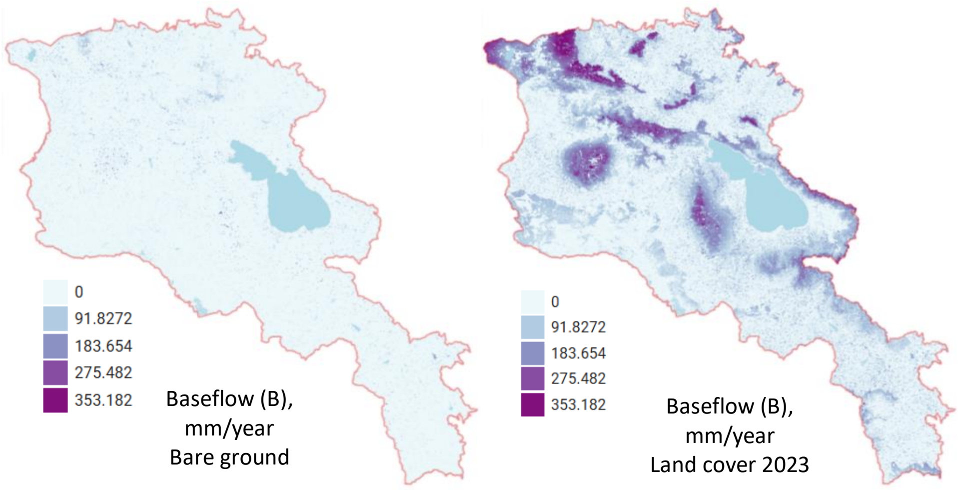


Figure 2. Baseflow on bare ground and under current land cover

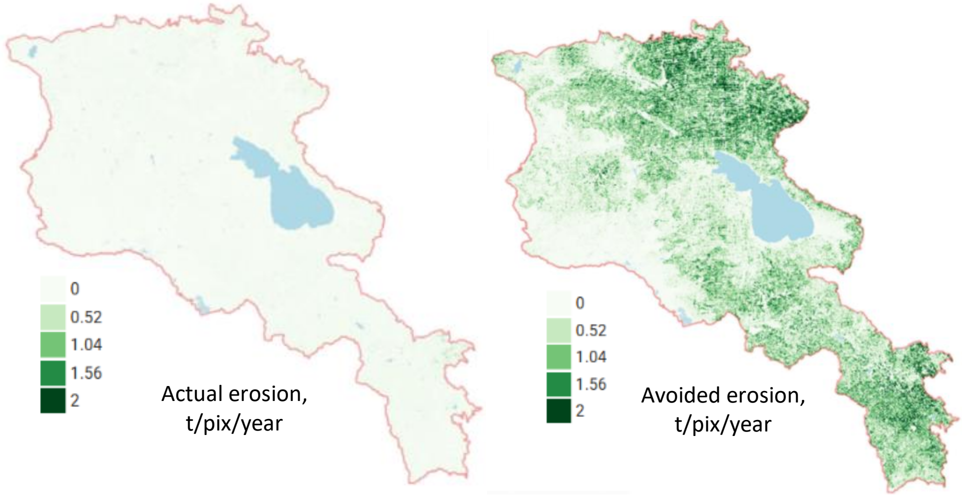


Figure 3. Actual and avoided erosion under current land cover

Biodiversity Conservation Decision-Making

Accounting for ecosystem extent is based on vegetation types (Section 2.3). This approach:
- captures the full diversity of terrestrial ecosystems when the ecosystem map has an optimal level of detail;
- assesses ecosystem rarity,
- tracks changes in ecosystem area by combining academic vegetation maps with updated land-cover data;
- evaluates the contribution of different marzes to the conservation of ecosystem diversity in Armenia.
Ecosystem rarity and trends in extent are the two main indicators for compiling the Red List of Ecosystems of Armenia.

Vegetation types most accurately reflect the characteristics of terrestrial ecosystems, because vegetation reflects all the main habitat conditions (climate, soil, topography) and forms the trophic basis of ecosystems and largely determines both their functioning and their species diversity.

The most widespread natural ecosystems in Armenia are steppe and subalpine meadows (exceeding 5,000 km² and 4,000 km² respectively), followed by forests and grasslands in forest zone each covering approximately 3,000 km². The smallest zones are marshes and juniper woodlands (270 and 130 km², respectively), as well as the extreme small desert zone, which consists of a single patch covering only 7 km² (Figure 4; Section 2.3.A of TR).

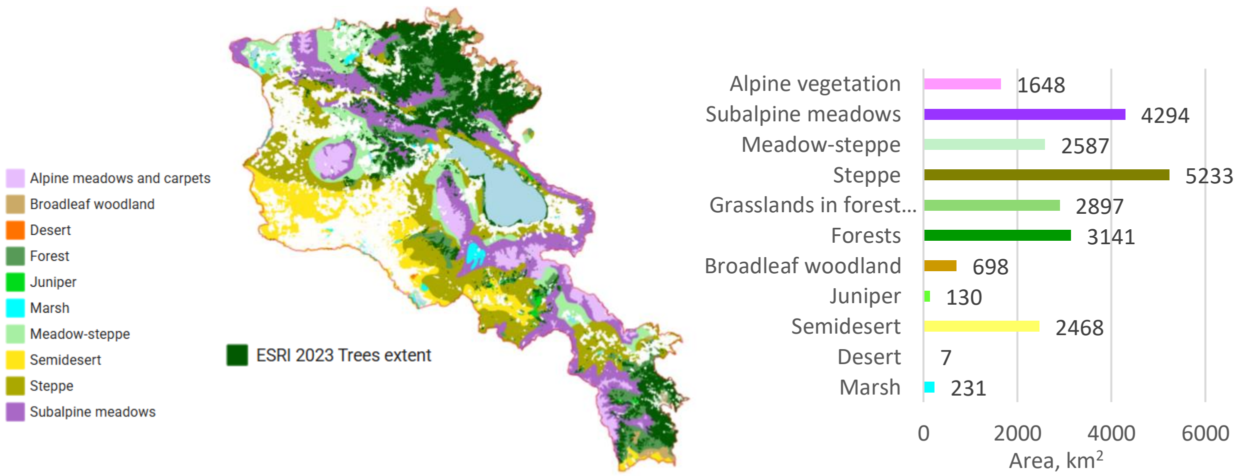


Figure 4. Assessed ecosystem types (left) and their total area in Armenia, km² (right). White color indicates anthropogenic areas

Currently, desert, juniper woodlands, and marshes have the smallest areas (less than 1% of Armenia's area). Broadleaf woodlands are also rare (2%). The most widespread are steppe and subalpine meadows (18% and 14%) followed by forests (11%). Other types of grasslands account from 6% to 10% of Armenia's area and can be considered common (Figure 5; Section 2.3.B of TR).

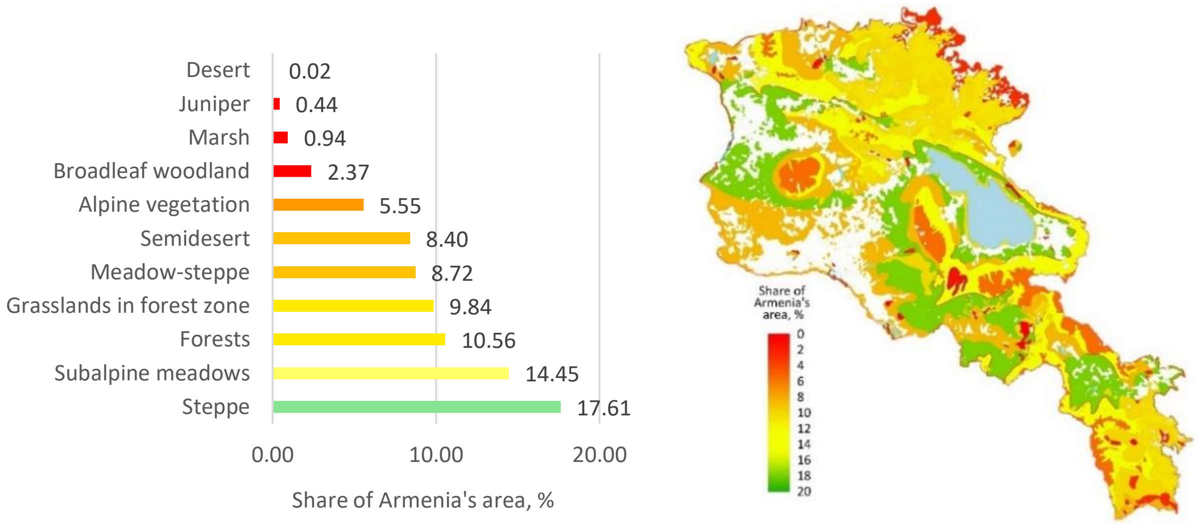


Figure 5. Ranking of ecosystems by rarity (left) and rarity map of ecosystems (right). White color indicates anthropogenic areas

Total ecosystem extent is greatest in Syunik marz and smallest in Armavir marz (Figure 6a; Section 2.3.A of TR). Alpine and subalpine ecosystems are the 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 marzes of Aragatsotn, Armavir, and Ararat.

However, ecosystem area alone is not sufficient to assess a marz's importance for conserving Armenia's ecosystem diversity, because it does not account for ecosystem rarity. To assess marz's importance we took into account what share of the national area of each ecosystem type is located in each marz. According to this criterion, the marz of Ararat is the most important for conserving Armenia's ecosystem diversity, as it contains the country's only desert area (100%). The high value of Syunik marz is determined by the fact that it encompasses the full range of ecosystem types. The contribution of Gegharkunik is largely determined by the high proportion of marshes located within it, and the contribution of Vayots Dzor by the high proportion of juniper woodlands (Figure 6b; Section 2.3.B of TR).

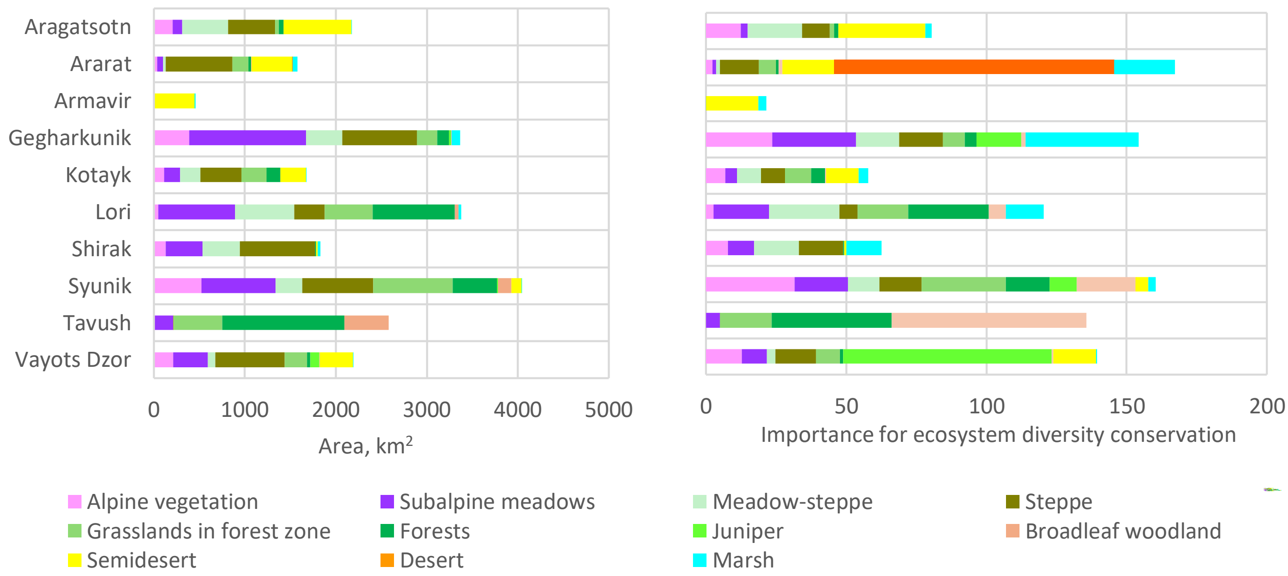


Figure 6. Ecosystem extent across marzes (left) and marz importance for conserving ecosystem diversity in Armenia by the sum of the shares (%%) of the national area of ecosystem types that are conserved within the marzes (right).

Data on changes in ecosystem extent from 2017 to 2023 highlights the most strongly transformed ecosystem types in Armenia (meadow-steppe, steppes, forests) and marzes (Shirak, Lori, Gegharkunik). The total area of natural ecosystems in Armenia decreased by 578.9 km² (-2.5%) transformed mostly to croplands. Transition matrices between land-cover classes and natural ecosystems show which processes drive changes in ecosystem extent and make it possible to account for the area of unchanged and recently transformed ecosystems (Section 2.3.C of TR).

Changes in ecosystem extent were assessed based on ESRI land cover data. For more accurate monitoring, the development of a national land cover is required. Increase in the area of croplands and built-up areas from 2017 to 2023 has led to a decrease in the area of natural ecosystems. The area of the most ecosystem types decreased. The most significant reductions, both in absolute and relative terms, occurred in the meadow-steppe (254 km², 8.9% relative to area in 2017). Steppes and forests declined by roughly 4%. The very small absolute decrease in the area of marshes and desert correspond to relative declines of 2.6% and 3%, respectively—comparable to the reductions in steppe and forest. The extent of grasslands in the forest zone, juniper woodlands and alpine vegetation slightly increased (Figure 7).

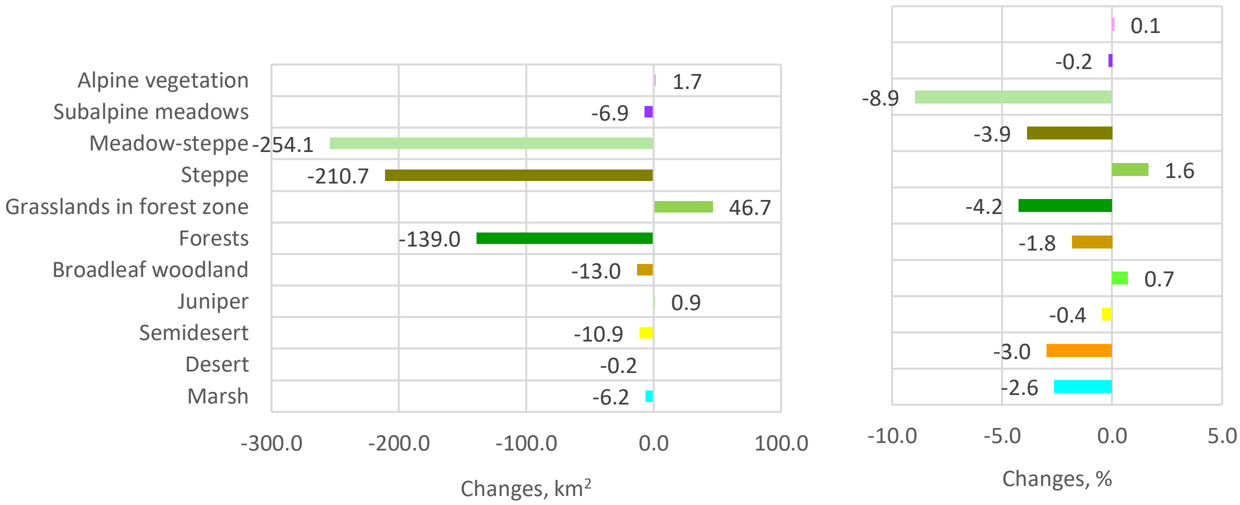


Figure 7. Net changes in ecosystem extent (left) and relative to 2017 (right)

The most noticeable losses of natural ecosystems, primarily - steppe and meadow-steppe - occurred in marzes of Shirak, Lori, Gegharkunik, and Aragatsotn. In Syunik forest area decreased while the area of grasslands in the forest zone increased (Figure 8). A noticeable increase in ecosystem extent occurred only in the Ararat marz, due to an expansion of semi-desert areas.

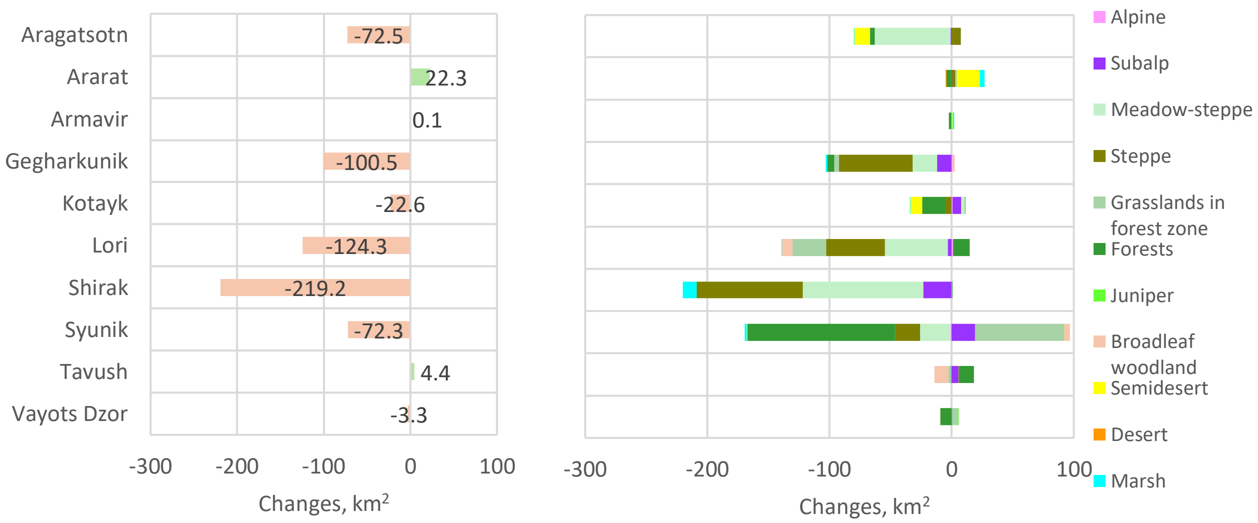


Figure 8. Changes in total ecosystem extent (left) and changes in the extent of different ecosystem types (right) across marzes

The largest transformations recorded for various grassland types turned into croplands. Particularly, 370 km² of steppes, 270 km² of meadow-steppes, 144 km² of semideserts, and 61 km² of subalpine meadows were converted into croplands. The total increase in cropland area amounted to 970 km². The reverse process—conversion of croplands back into grasslands—was weaker and could not compensate for their loss. The exceptions are semideserts and woodlands, where the reverse transition from croplands exceeded new agricultural expansion. Based on the formal ratio of areas over the six-year period, the intensity of agricultural development in these zones has decreased. The opposite trend is observed in meadow-steppes and alpine meadows, where reverse transitions are extremely small, indicating an increase in agricultural expansion intensity (Figure 9).

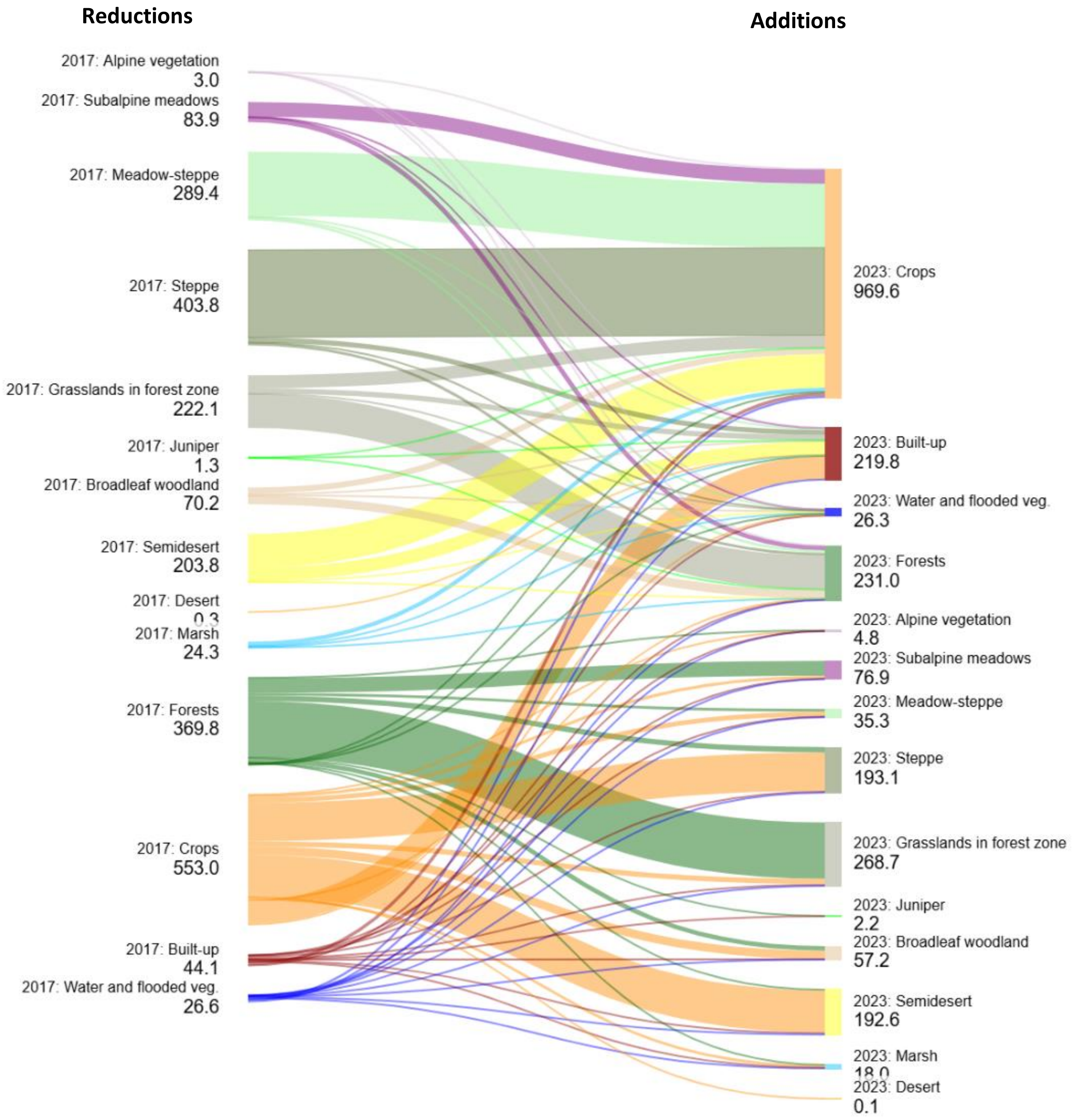


Figure 9. Transitions between vegetation zones and land cover classes, km^2. Self-transitions (categories remaining the same) are not shown

Tracking not only the net ecosystem extent changes but also the transitions between natural ecosystems and anthropogenic areas and vice versa is crucial for conserving biodiversity and maintaining ecosystem services. New areas that have formally been added to the extent of ecosystems after being released from croplands or built-up areas are abandoned fields or wastelands that are far from natural ecosystems both in terms of biodiversity and ecosystem functioning.

Land-use Planning and Sustainable Ecosystem Use to Maintain ES

Contribution of different ecosystem types to the delivery of ES in Armenia and across marzes/watersheds provide an information basis for territorial planning aimed at maintaining key ES, helping decision-makers determine the ecosystem types that are most valuable for delivering ES, identify priority areas for ecosystem conservation/restoration, optimize land-use allocations.

ES of baseflow provision (Section 3.1.B of TR)

Subalpine and alpine, subalpine, and meadow-steppe ecosystems are most effective in baseflow provisioning, ensuring water in dry seasons. Totally the largest volume of baseflow is provided by subalpine, alpine, meadow-steppe, steppe, and semidesert ecosystems (Figure 10). The low baseflow capacity of forests can be explained by the fact that they are typically located on steeper slopes than grasslands and evaporate large amounts of water, which reduces their ability to convert precipitation into baseflow. However, this does not diminish the importance of forests for this ecosystem service, because on steep slopes the effectiveness of other ecosystems would also be low.

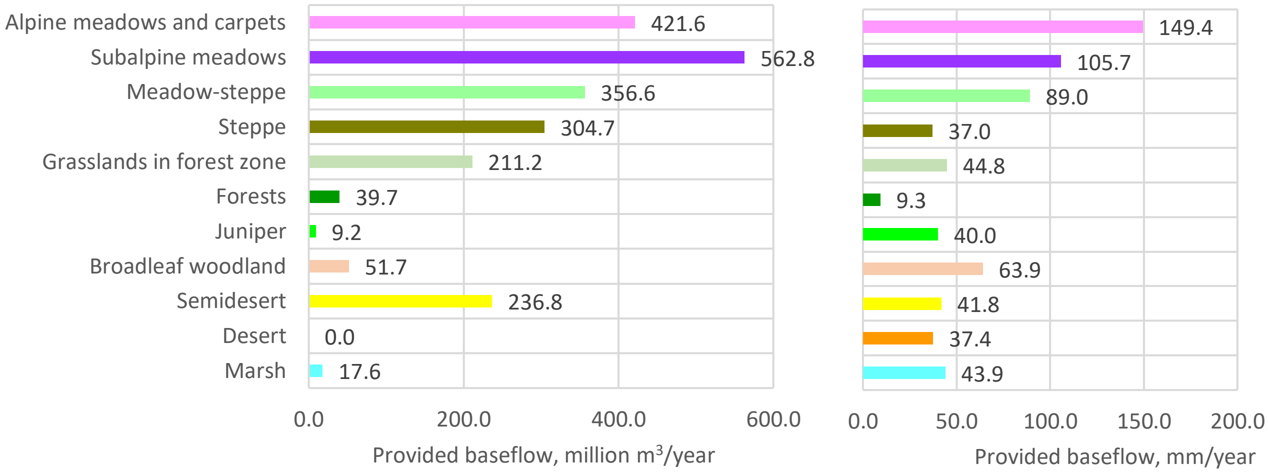


Figure 10. Indicators of baseflow provided by different ecosystem types in Armenia

The largest volumes of baseflow are provided by the ecosystems of the Arpa, Debed, Metsamor, and Vorotan basins, and the smallest by the Aghstev basin. Alpine vegetation is most important for baseflow provision in the Arpa and Vorotan basins; subalpine vegetation—in the Debed basin; steppe—in the Arpa basin (Figure 11).

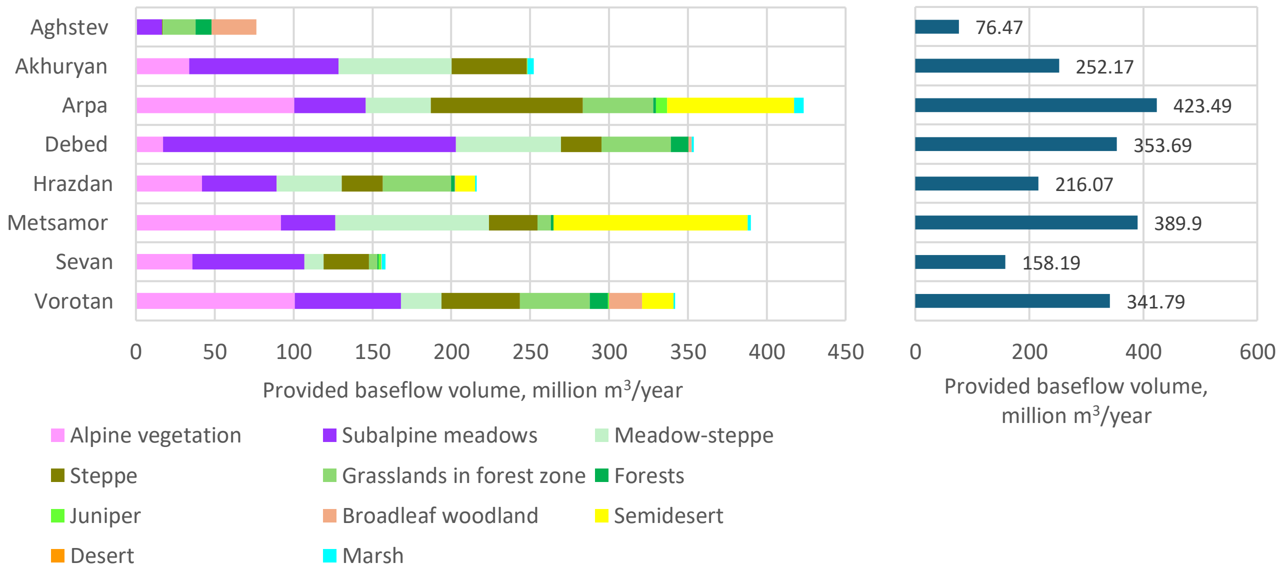


Figure 11. Baseflow provided by different vegatation types (left) and total values across watersheds (right)

Pollination of crops by wild insects, Section 3.1.H of TR

Wild insects could potentially pollinate almost the entire area of agricultural crops in Armenia. The conservation and restoration of pollinator habitats within agricultural landscapes is critically important. Excluding small patches of natural vegetation (ES mapping based on ESRI data), the potential presence area of key pollinators covers 65% of cropland on average in Armenia (52–97% across marzes). When such patches are included (ESA data), pollinators could potentially occur across almost all croplands, covering 99% nationwide (Figure 12).

Figure 12. Acually and potentially pollinated area across marzes (left) and pollinated share of total cropland area in the marz (right) based on ESRI and ESA land cover data. Potentially pollinated area refers to all cropland, while actually pollinated area accounts for the share of entomophilous crops in the marz.

Provision of biomass and nectar by wild plants, Section 3.2.B of TR

The three provisioning ES supplied by wild plants — the benefits from edible/culinary, medicinal, and nectar-producing (honey) plants — were assessed in scores based on the number of plant species in these groups. The largest total number of species across all three groups is found in the forest and steppe vegetation zones, while the smallest number occurs in the desert and alpine zones. The largest ES potential is found in marzes that have extensive areas of forest and steppe zones (Syunik, Lori, Tavush). The high ES value in the Gegharkunik marz is due to the large area of subalpine meadows, which, along with forests and steppes, also host a considerable number of useful plant species. The lowest level of ES provision is observed in Armavir marz due to the small area of remaining natural ecosystems which are almost entirely semi-deserts with a relatively low number of useful plant species (Figure 13). In Tavush marz, the overwhelming majority of the ES is provided by forests and woodlands, while in Shirak and Aragatsotn marzes it is delivered mainly by typical and meadow steppes.

Analogous assessments for the ES of Preventing sediment export to streams and the ES of forage/fodder production see in Sections 3.1.C1 and 3.2.A1 of TR

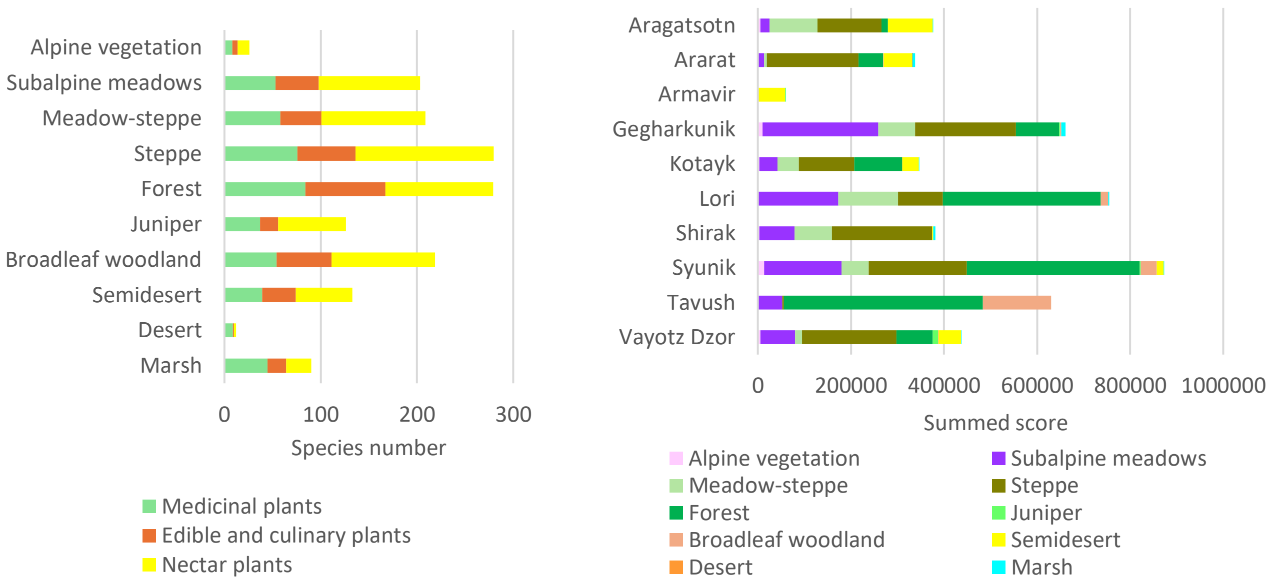


Figure 13. Potential ES across ecosystem types (left) and marzes (right)

The balance between ES potential, the demand for ES, and ES current use allows identifying areas where ecosystems are sufficient to meet current and future needs in ES, areas of ES overuse or underuse, and supports informed decisions on whether ES use may be increased or should be decreased.

ES of baseflow provisioning, Section 3.1.B2 of TR

Water consumption exceeds baseflow volume, provided by ecosystems in two watersheds —Metsamor and Hrazdan (Figure 14; Section 3.1.B2 of TR). The largest share of total water use comes from the agriculture, forestry and fish breeding sector, which underscores the importance of baseflow to ensure water availability during the dry season.

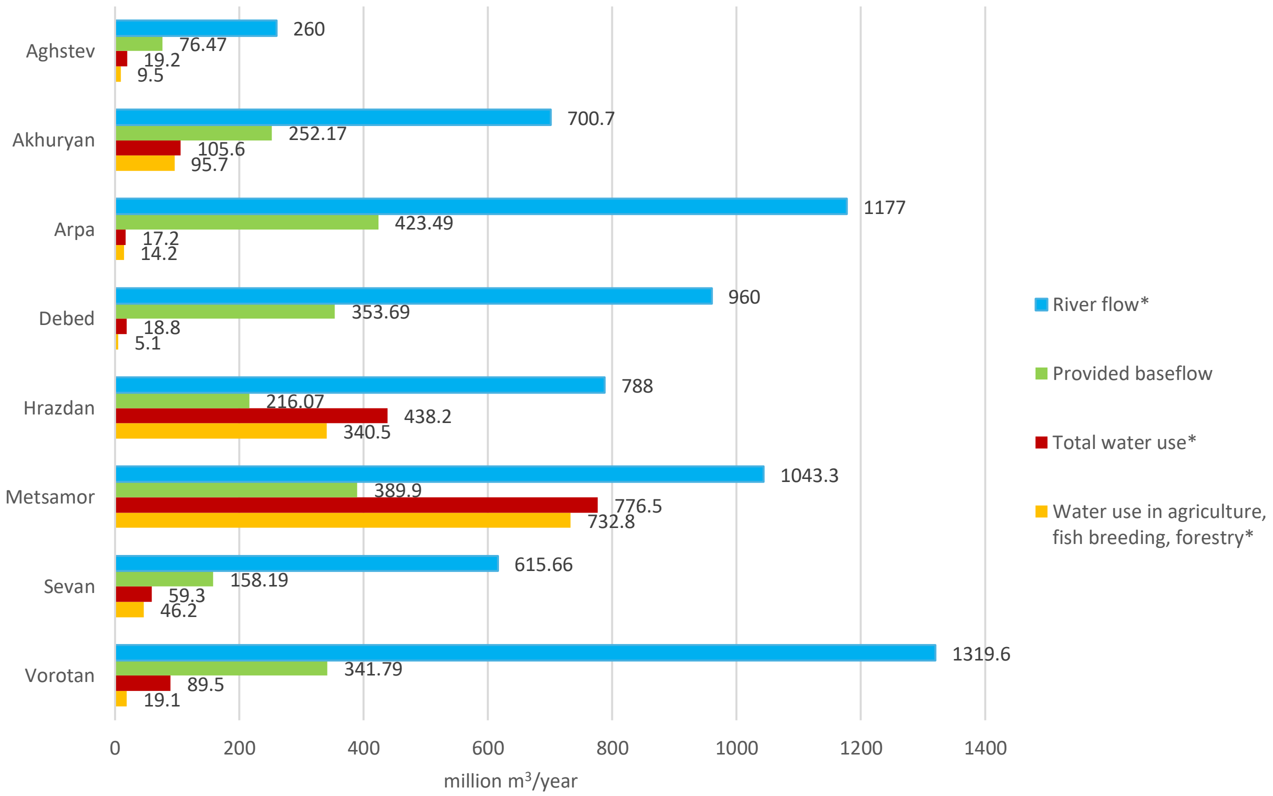


Figure 14. ES potential–use balance: river flow, provided baseflow and water use across watersheds

In the Metsamor and Hrazdan watersheds, baseflow provides 63% and 54% of agricultural water consumption, respectively. In the other watersheds baseflow exceeds water consumption by many times. However, water use nowhere exceeds total river flow. In the Arpa, Debed and Vorotan watersheds there is a substantial unused potential of baseflow, whereas the ecosystems of the Hrazdan and Metsamor watersheds do not meet the demand for water consumption (Figure 15).

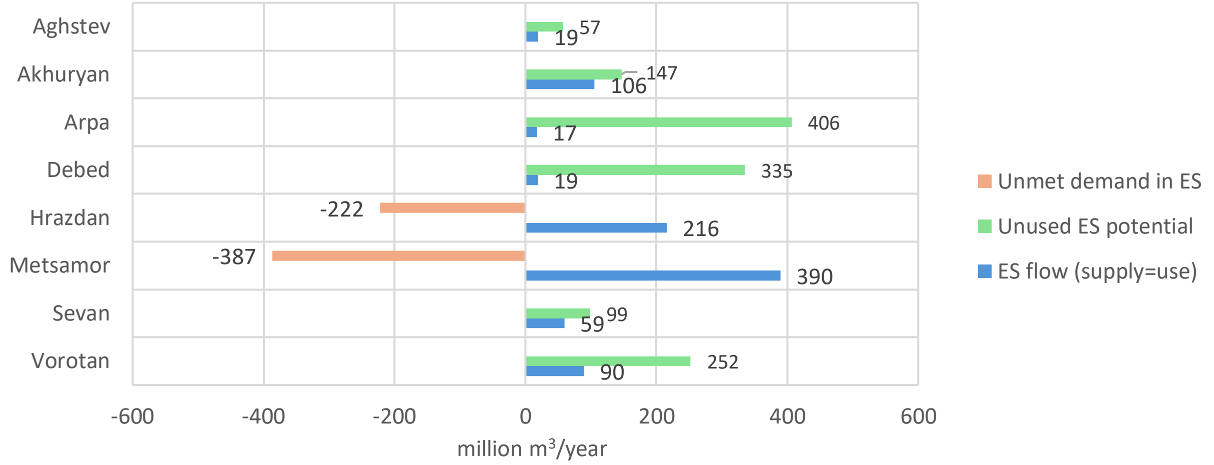


Figure 15. Baseflow supply/use (ES flow), unmet demand in ES and unused ES potential across watersheds

The assessment of potential-use balance for the ES of baseflow provisioning was made only for baseflow volume for methodological purposes, to demonstrate approaches to assessing the ES potential–supply-use balance. It is obvious that water demand is satisfied not only by baseflow but by total river flow, which in all watersheds exceeds current water consumption.

ES of sediment export prevention, Section 3.1.C3 of TR

The ES of sediment export prevention is most important in the Metsamor and Hrazdan watersheds with the highest water consumption preventing 0.48 Mt and 0.35 of sediment from entering the volume of water used. This ES is less important in the Arpa and Debed watersheds with small volume of water use (Figure 16; Section 3.1.C3 of TR). This assessment was made under the assumption that all water is abstracted from surface sources. In the future, it will be necessary to account for the share of water consumption derived from artesian and groundwater.

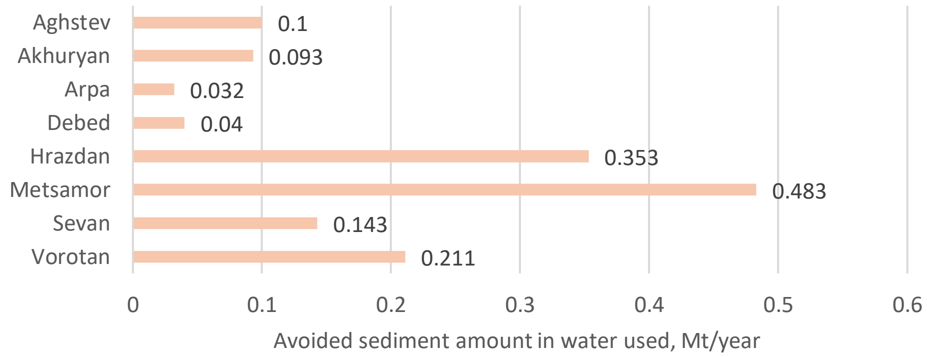


Figure 16. Use of ES of sediment export prevention: avoided total amount of sediment in the volume of water consumed

ES of forage and fodder production, Section 3.2.A3 of TR

The ES of forage and fodder production by natural grasslands, assuming an even distribution of livestock across the territory, has unused potential in all marzes except Armavir. The level of ES use ranges from 10% (Vayots Dzor) to 59% (Ararat) and is sensitive to whether land degradation is taken into account (Figure 17). In Armavir marz, the livestock numbers are 6–9 times higher than the total carrying capacity of grasslands. This indicates overuse of this ES in Armavir, if livestock are grazed on natural pastures.

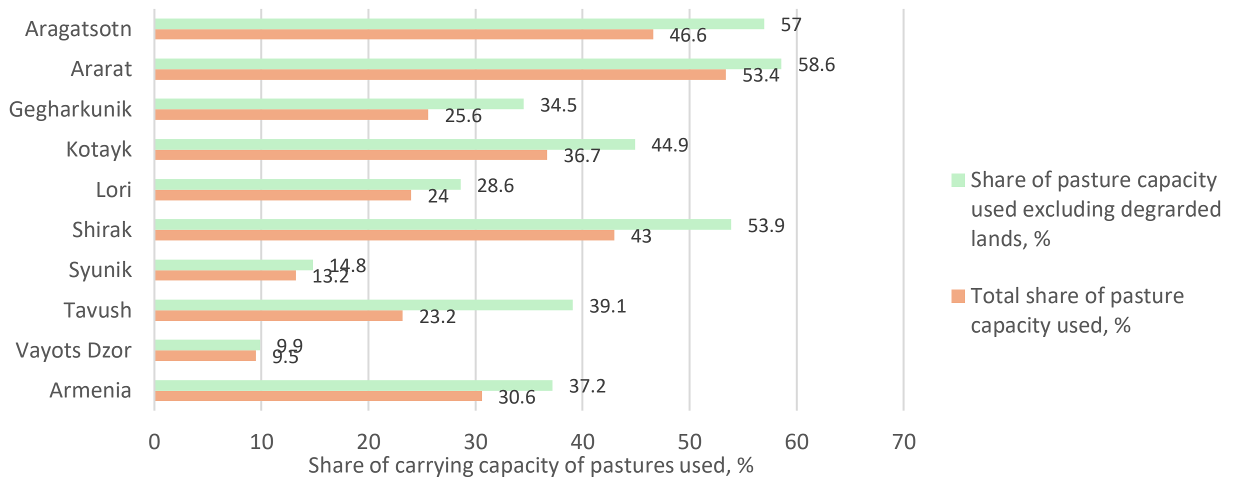


Figure 17. Share of carrying capacity of pastures used with and without taking into account pasture degradation (data on marz Armavir are not shown)

Land-use planning for Climate Change Mitigation

Accounting for the ES of carbon storage and the ecosystem cooling effect helps identify priority ecosystems/areas and guides land-use planning for mitigating climate change at global and local scales. It shows which territories contribute most to climate regulation and therefore require special conservation or sustainable management. It also helps planners avoid decisions that could reduce ecosystem carbon stocks or increase local heat stress.

Global climate regulation: carbon storage in ecosystems (Section 3.1.G of TR)

In Armenia, the main carbon stock (90%) is stored in soils, which highlights the importance of soil-protection programmes and ecosystem services that prevent carbon emissions into the atmosphere. They are particularly important in those regions and natural zones where ecosystems contain large amounts of soil carbon. These include all mountain grassland ecosystems, steppe, grasslands in forest zones and forests which contain around 60 tC/ha (Figure 18). With ecosystem area taken into account, the largest carbon stocks are found in forest, steppe and subalpine ecosystems.

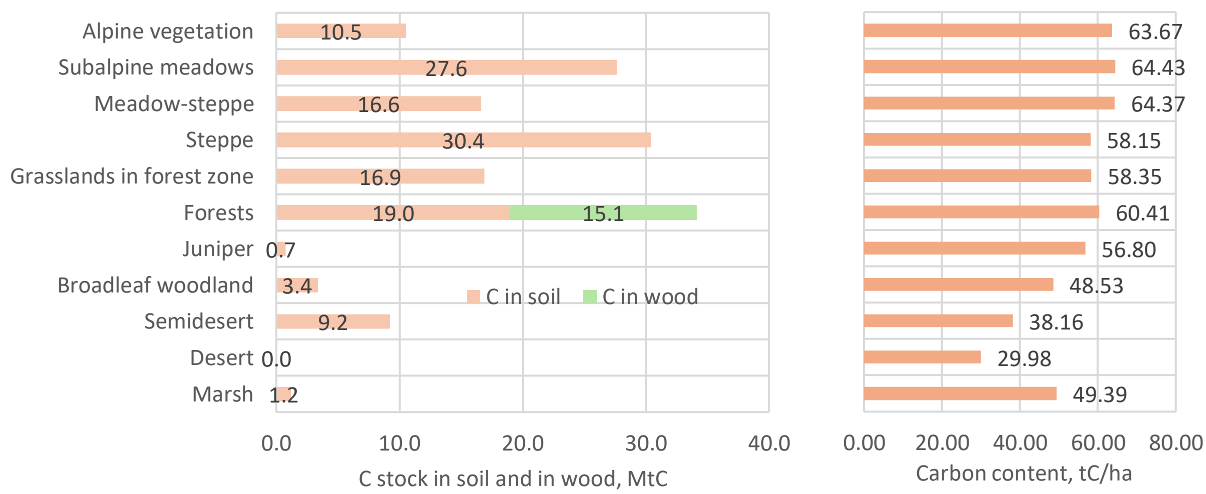


Figure 18. Carbon stock, MtC (left) and carbon content in soil, tC/ha (right) across ecosystem types

Across marzes, average C-content generally varies around 60 tC/ha, except in Armavir and Ararat, which have lower C-content (33 and 48 tC/ha, respectively) due to their carbon-poor semi-desert soils. The total carbon stock is the highest in marzes Syunik and Lori (24 and21 MtC), and the lowest in marz Armavir (1.5 MtC) because of low carbon content in soil and small area of ecosystems (Figure 18). The carbon stock in tree biomass makes a noticeable addition to soil carbon only in marzes Tavush and Lori. Across vegetation types total carbon stock is the highest in forests with a large portion of C in wood, followed by steppe and subalpine zones. C stock is the lowest in woodlands, marshes and desert due to their limited extent (Figure 19).

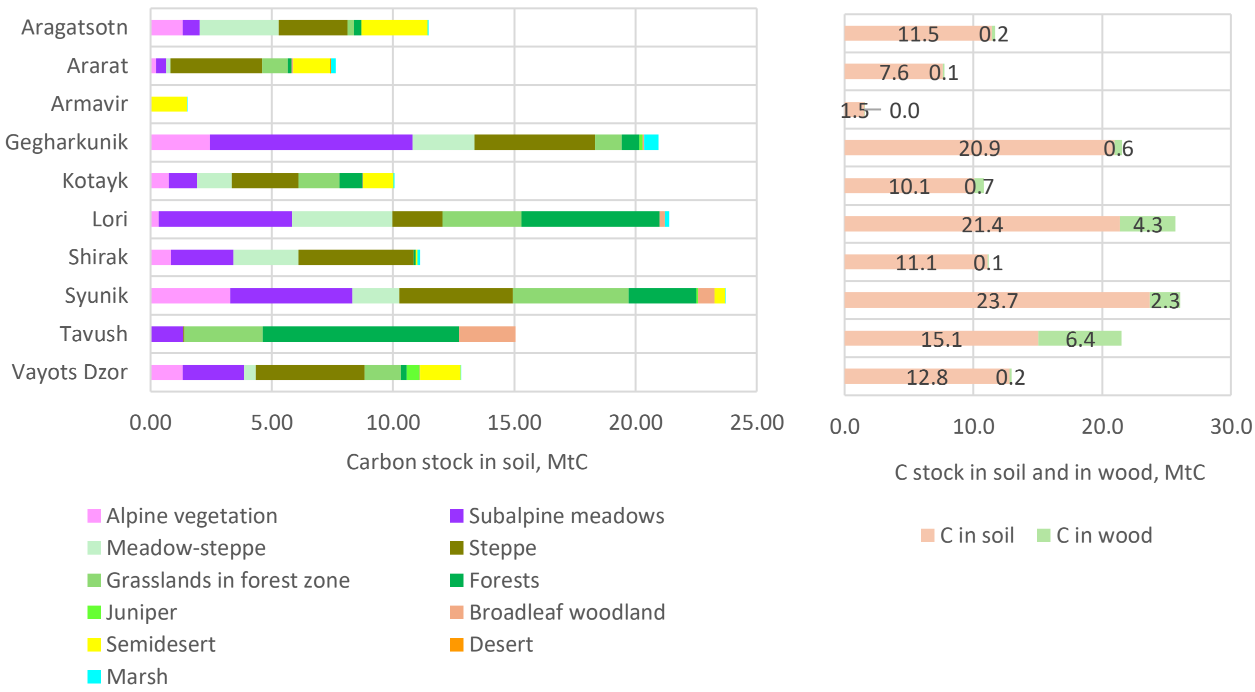


Figure 19. Carbon stock, MtC in soil in different vegetation types across marzes (left) total C stock in soil and wood across marzes (right). Area of the marz Gegharkunik is accounted excluding Lake Sevan

Local climate regulation: ecosystem effect on temperature, cooling effect, Section3.1.E of TR

Forests in Armenia have the highest cooling capacity. Broadleaf woodlands and grasslands within the forest zone also provide a slight cooling effect. Other vegetation types have a very weak, but still warming effect compared to bare ground (Figure 20). Thus, natural ecosystems cool the marzes Tavush, Lori, Syunik, and Kotayk and slightly warms marzes that lack forests. In the marzes Tavush and Lori, forest increases cooling capacity by 77% and 57%, respectively.

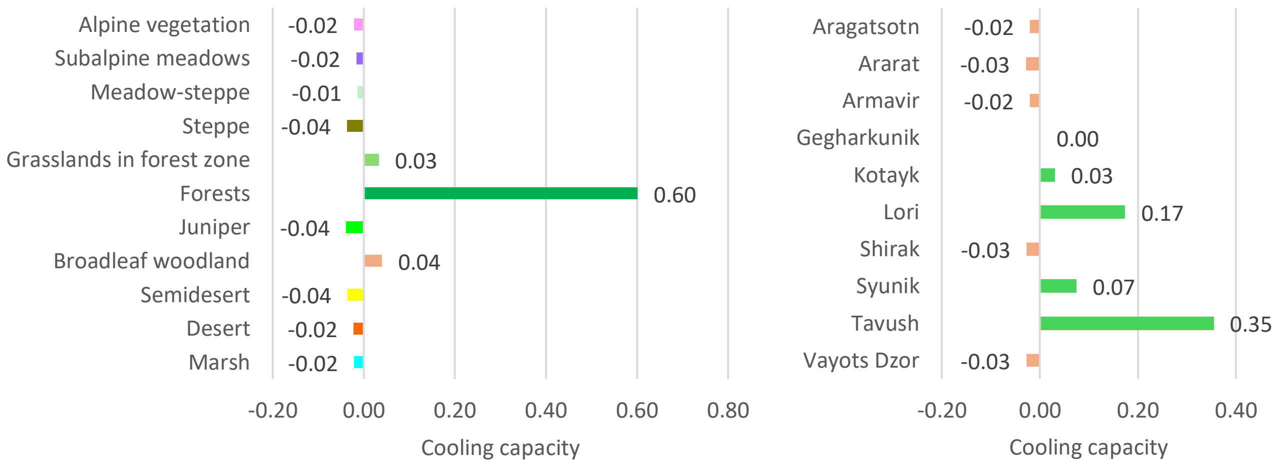


Figure 20. Cooling capacity of differenet vegetation types (left) and across marzes (right)

The influence of ecosystems on temperature is most important for settlements and their surroundings. Across the 1,016 settlements, 729 (72% of those assessed) have surrounding ecosystems that produce virtually no change in cooling capacity relative to bare ground. In 133 settlements (13%), the ecosystems reduce cooling capacity, i.e., exert a warming effect; these are settlements surrounded by grasslands in dry climatic zones. In 154 settlements (15%), ecosystems increase cooling capacity, i.e., exert a cooling effect; these settlements are surrounded by forests or by grasslands in the moderately humid zone. For 20 settlements surrounded by forest, including Dilijan, Jermuk, and Tsakhkadzor, the cooling effect is especially noticeable, increasing cooling capacity by 0.10–0.35 (Figure 21).

Figure 21. The effect of surrounding ecosystems on cooling capacity within settlements

Land-Use Planning for Risk Reduction

Accounting for the ES of flood mitigation and erosion prevention provides informational support for territorial planning aimed at reducing risks associated with soil erosion and flooding. It helps identify ecosystems and naturally protect infrastructure, agricultural land and settlements from water-related hazards. It also enables planners to prioritize conservation or restoration measures in areas where the loss of ecosystem functions could lead to increased damage, higher public costs or greater risks for local communities.

ES of flood risk mitigation, Section 3.1.D of TR

Ecosystems reduce quick runoff by an average of 4 mm (−32%) and increase runoff retention by 0.4 m³/pix (+11%) during extreme spring rainfall. Without this ES, replacing natural vegetation with bare ground would noticeably decrease runoff retention and increase quick runoff (Figure 22).

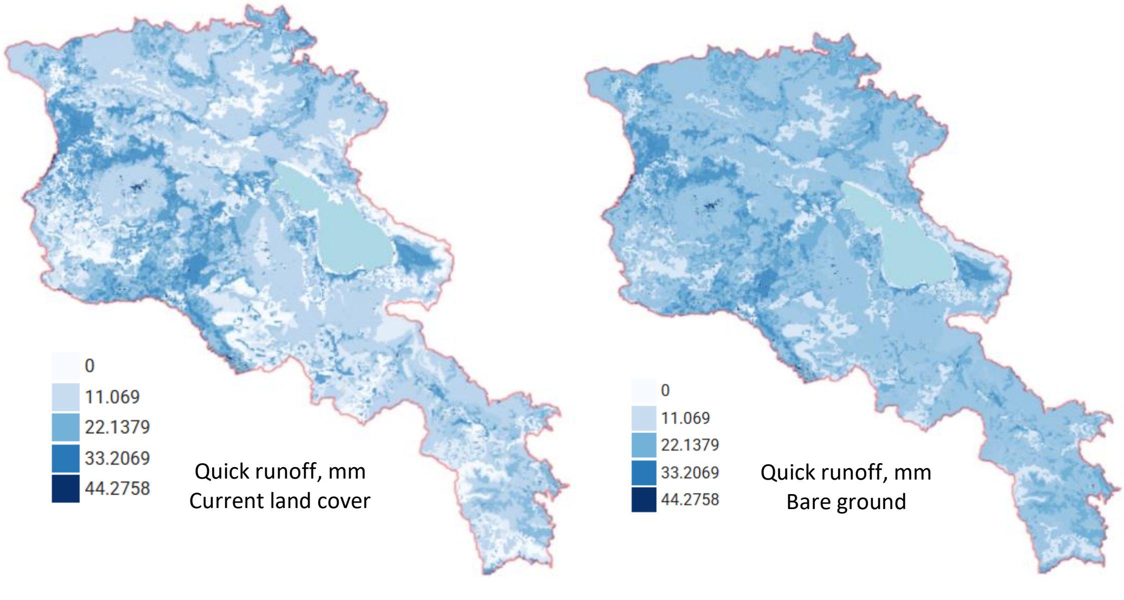


Figure 22. Maps of ES indicators under the extreme spring rainfall (50 mm).

The total runoff retention volume is the highest in the marzes of Syunik and Gegharkunik, where mountain grasslands make a substantial contribution in both cases. Runoff retention volume is the lowest in Armavir marz (Figure 23). Among vegetation types, steppe and subalpine meadows provide the largest total contribution. The smallest contribution comes from open woodlands, deserts, and marshes due to their limited area (Figure 24).

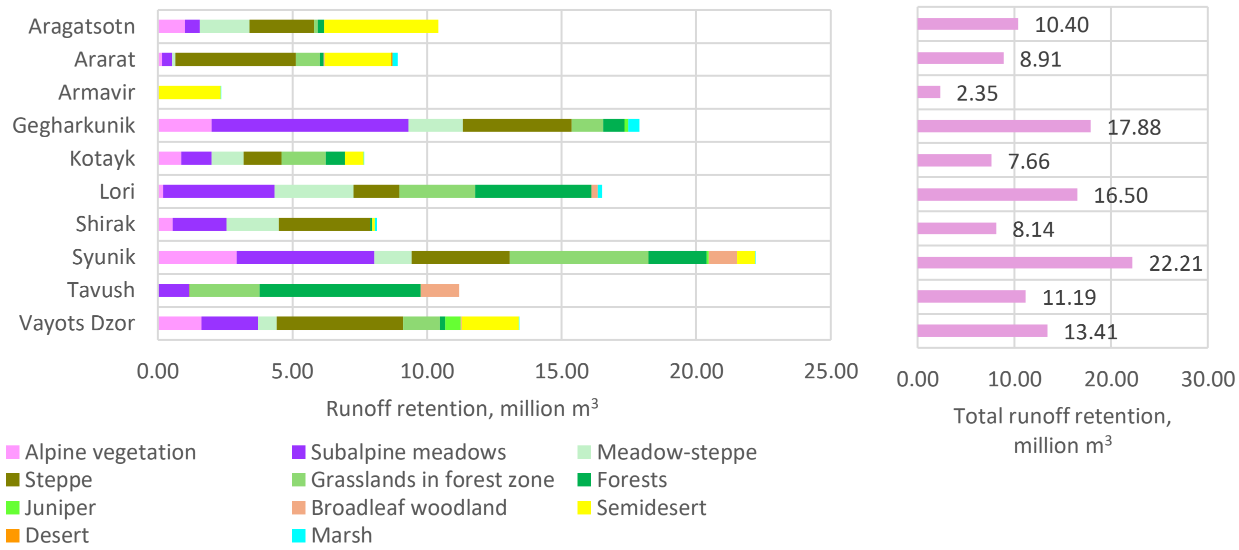


Figure 23. Runoff retention provided by ecosystems across marzes

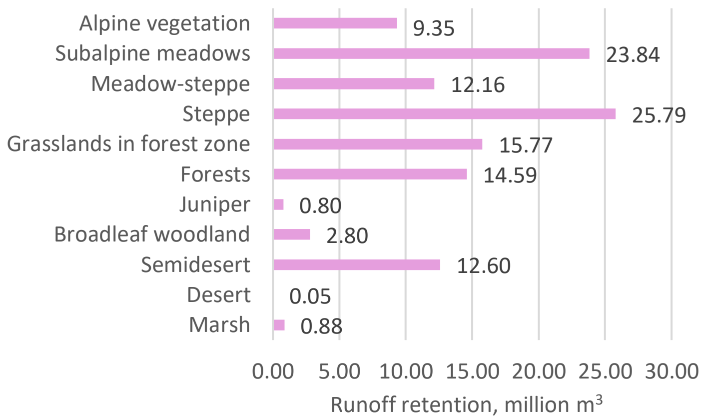


Figure 24. Total runoff retention provided by different vegetation types

ES of preventing erosion, Section 3.1.C of TR

Among ecosystems, forests are the most effective in preventing erosion and provide the largest overall contribution to this ES in Armenia, despite their relatively small area. All types of woodlands and grasslands, except for semi-desert and desert, are also highly effective in erosion prevention. The total avoided erosion values are high for subalpine meadows, steppes, and grasslands within the forest zone (Figure 25).

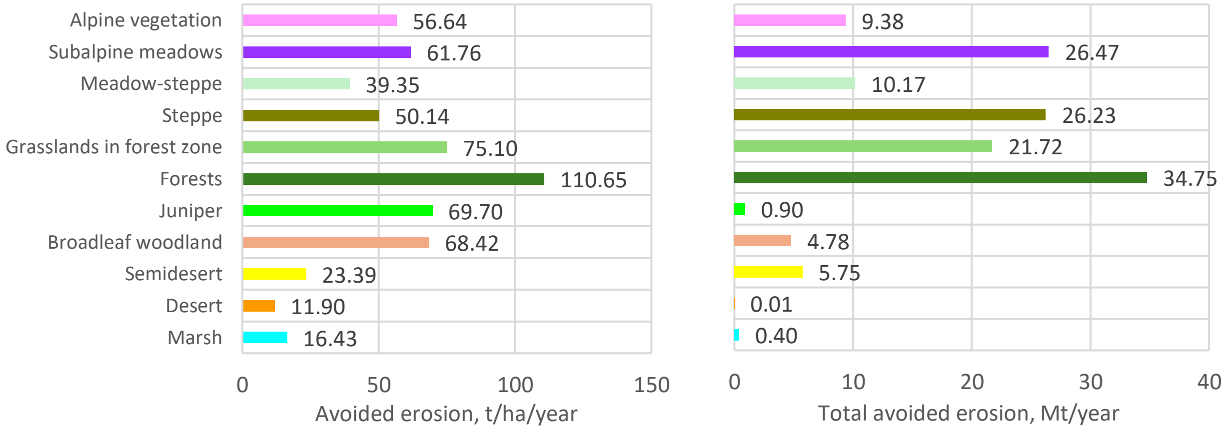


Figure 25. Avioded erosion across ecosystem types

The highest rates of total avoided erosion were calculated for Syunik, Lori, and Tavush marzes. The lowest values of avoided erosion were found for Armavir (Figure 26). In Tavush marz, forests provide the largest share of erosion prevention (62%). In other marzes, erosion is prevented mainly by steppe and subalpine ecosystems, although forests also play a significant role in Lori and Syunik.

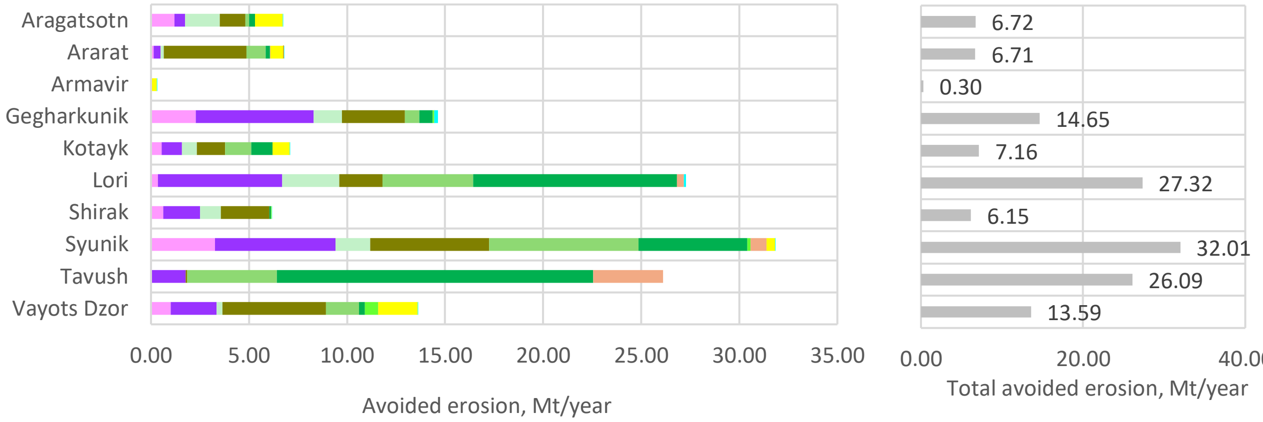


Figure 26. Avoided erosion across marzes

Changes in ES as result of land cover changes

Changes in ES were estimated as the result of land-cover changes. The overall 2.5% reduction in the extent of natural ecosystems from 2017 to 2023 has led to a 0.5–2.7% reduction in the potential of all assessed ES. These data clearly show how changes in ecosystem extent directly affect both ES overall supply and their spatial distribution. Such information is essential for planning and prioritizing measures that maintain or enhance ecosystem benefits for communities and sectors across Armenia.

EA Prototype V1 takes into account changes in ES only resulting from land-cover changes that occurred according to ESRI data between 2017 and 2023 (Figure 26). Climate change and changes in ecosystem condition were not considered at this stage. Changes in all ES are sporadic and multidirectional across locations, as illustrated by the example of avoided erosion (Figure 27). The potential of all assessed ES has decreased, albeit slightly — by 0.5% to 2.7% for Armenia as a whole (Table 3), which is consistent with the relatively small magnitude of natural ecosystem area loss. Below, we present examples for the ES of erosion preventing, but analogous data are available in TR for all assessed ES.

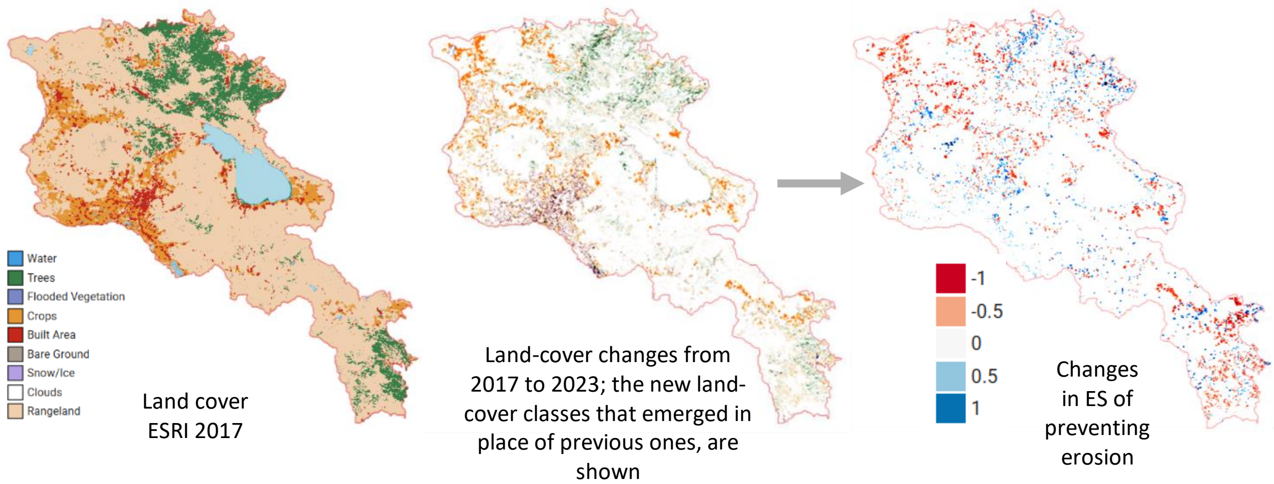


Figure 27. Land-cover change as a driver of ES change

Table 3. Total changes in ES from 2017 to 2023

ES	*Indicator*	*Absolute changes*	*Relative changes to 2017 value, %*
Baseflow provisioning	Baseflow volume, provided by ecosystems	-49.1 million m^3/year	-2.2%
Preventing soil erosion	Avoided erosion	-1.18 Mt	-0.9%
Preventing sediment export	Avoided sediment export	-0.06 Mt	-0.5%
Flood mitigation	Runoff retention, provided by ecosystems	-2.79 million m^3	-2.3%
Ecosystem effect on surface temperature	Cooling capacity	-0.002	-1%
Carbon storage	Carbon stock in ecosystems	-4.26 Mt	-2.7%
Fodder production	Carrying capacity of grasslands	-23600 LU	-2.1%

Relative changes in ES potential of preventing erosion are 0.1–5% for marzes and 0.6–7% for vegetation types. However, for certain vegetation types within marzes, changes reach up to 71% for avoided erosion and 88% for avoided sediment export (forests in Armavir). In absolute terms, the most noticeable changes occurred in the marzes of Syunik, Lori, and Shirak. In Syunik, the ES capacity of forests decreased while the capacity of grasslands within the forest zone increased, apparently due to the replacement of some forests by grasslands. In Lori, the opposite pattern is observed: ES capacity increased for forests and decreased for forest grasslands and steppes. However, these opposing changes were not able to fully offset each other, and the overall change was negative. (Figure 28).

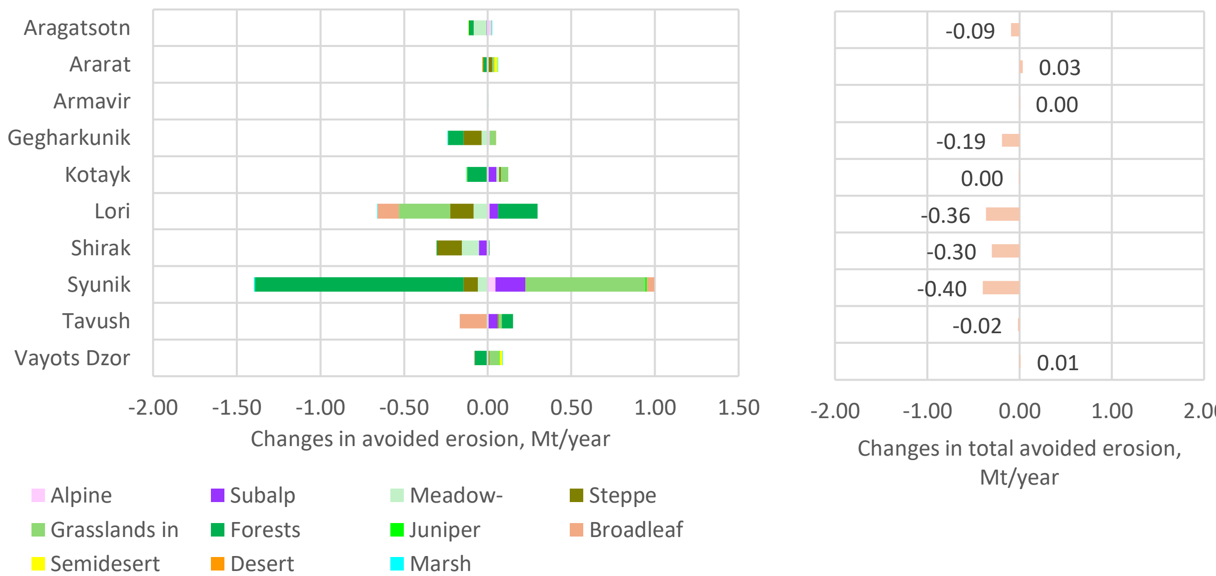


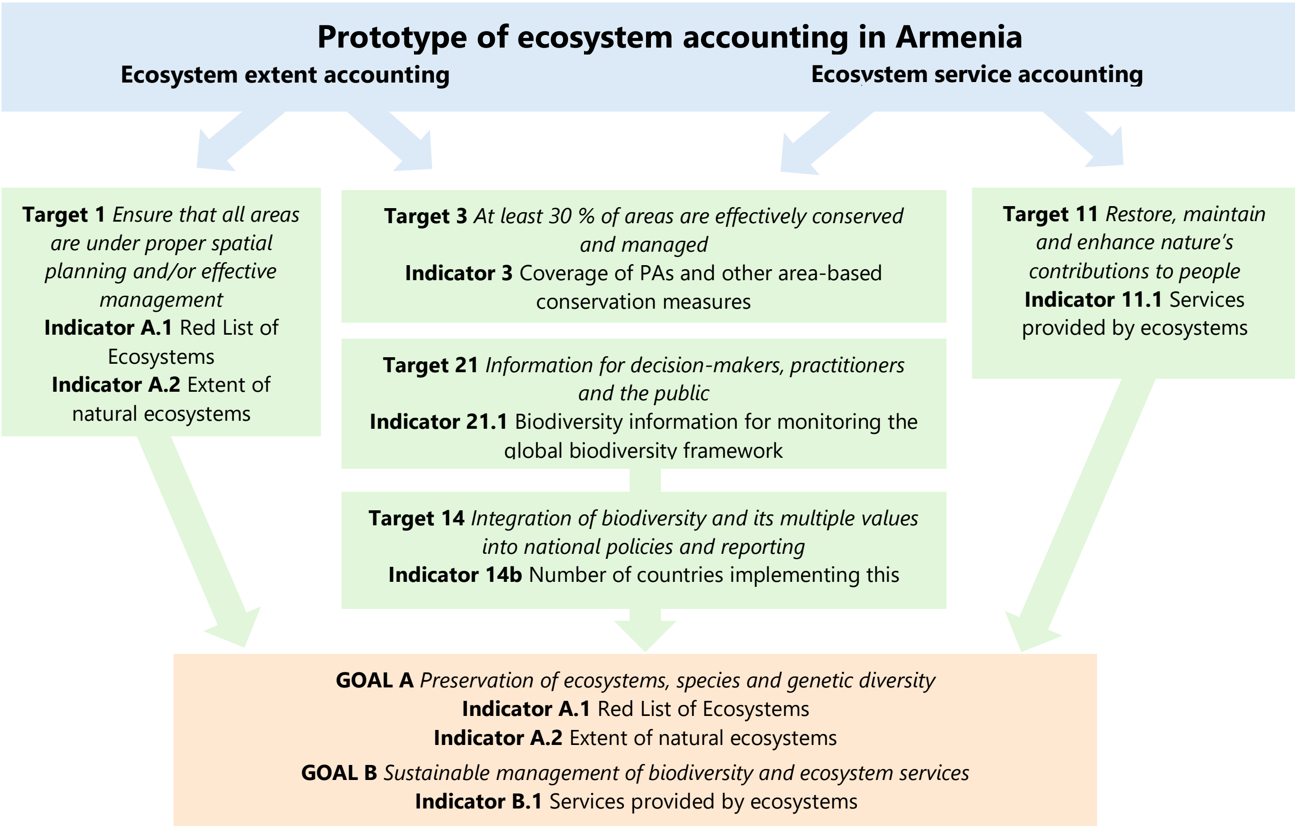
Figure 28. Changes in avoided erosion across ecosystem types and marzes (left) and total changes across marzes (right).

International Reporting and Integration

EA Prototype V1 is aligned with the overarching principles and supports Armenia's integration into the main global and international processes in the fields of ecosystem accounting and biodiversity protection.

Global and international Initiatives	Related sections of EA Prototype V1
System of Environmental-Economic Accounting — Ecosystem Accounting **(SEEA EA)**	Ecosystem extent accounting (Section 2) Ecosystem service accounting (Section 3)
Integrated Natural Capital Accounting in the European Union (EU INCA)	Ecosystem service accounting (Section 3), subsections about ES potential-use balance
International Union for Conservation of Nature (IUCN) Red List of Ecosystems (RLE)	Extent of ecosystems (Section 2.3)
Global Ecosystem Atlas (GEA)	Section 2.7
Convention on Biological Diversity (CBD) and Global Biodiversity Framework (GBF)	Section 4

The EA PV1 makes a direct informational contribution to Targets 1, 3, 11, 14 and 21, as well as Goals A and B of the Global Biodiversity Framework (https://www.gbf-indicators.org/) and indirectly contributes to other GBF targets by providing an informational basis for management and educational efforts.



Data Gaps Identified

Absence of an accurate regularly updated land-cover dataset

Currently, Armenia does not have a refined national land-cover dataset that is regularly updated. Therefore, for the methodological demonstration of ES, we had to rely on one of the publicly available global datasets. Their testing showed that, for the four datasets that most closely represent Armenia's land cover (Dynamic World; ESRI; ESA; GLAD), the total discrepancy with Government-reported land-cover class areas across marzes ranges from 19.4% to 20.9% of Armenia's total area (Section 2.1). For use in EA Prototype V1, the ESRI dataset was selected, as it is sufficiently accurate and allows us to demonstrate changes in EE and ES between 2017 and 2023. However, global land-cover datasets inevitably contain errors. Among the most evident land-cover errors are the misclassification of croplands and built-up areas in high-elevation regions. Such errors have the strongest impact on EA results for small EEA units, such as PAs and natural monuments. Examples are provided in Sections 2.6 and 3.1.I

Accounting by land-cover classes delineated in accordance with Government of RA Decision on land-cover classification can be carried out on the basis of Government-reported data (Section 2.2.A). However, these data do not include digital land-cover maps, so they cannot be used for ES modelling and mapping. The absence of maps also prevents the construction of a land-cover transition matrix and the assessment of additions and reductions by land-cover classes over the reporting period, as recommended by the SEEA EA.

Ecosystem map

A national ecosystem map is essential for biodiversity conservation, as it provides a consistent spatial basis for identifying rare, threatened and priority ecosystems. EA Prototype V1 uses a generalized vegetation map developed by the project experts on the basis of previous long-term studies by Armenian geobotanists. To enable more accurate ecosystem accounting for biodiversity conservation purposes, as well as a more precise assessment of the role of ecosystems in providing ES, we need detailed ecosystem map based on the conceptual approach Ecological Land Units (ELU), defining the correspondence between vegetation community types and environmental factors – topography, climate (precipitation, temperature, seasonality), soils, and geology.

Lack and inaccuracy of data for ES assessments

In the scoping phase certain data for ES assessment were obtained from global databases which accuracy at the national scale may vary. We recommend that ES modeling for national ecosystem accounting be based on data verified using *in situ* measurements from Armenia's hydrometeorological, geodesy, and cartography services.

The absence of publicly available data on forestry and hunting management did not allow us to assess the corresponding ES. The use of the recreation ES was assessed based on data provided by the project's experts. The lack of recent scientific studies on the productivity and exploitable stocks of wild edible and medicinal plants, as well as the absence of data on harvesting intensity, did not allow us to assess the level of use of the corresponding ES.

Use of scoping-level ES models

At the scoping stage, the InVEST models used for water-related ES modelling proved useful for demonstrating general approaches to integrating ES assessments and maps into Armenia's ecosystem accounting. However, InVEST tool does not reflect the diversity of natural conditions in Armenia.

Main initial steps for launching ecosystem accounting in Armenia

The launch of the first phase of ecosystem accounting requires only standard, commonly available hardware and software. The first data-related steps for accounting for terrestrial natural ecosystems are as follows (Section 5 of TR):

- Develop the national land cover dataset, verified using Armenian data and harmonized with the official land-cover area statistics.
- Develop a detailed national ecosystem map using GIS-based methods and Ecological Land Units (ELU) approach.
- Develop a framework for integrating scoping-stage ES models (InVEST and others) with advanced hydrological and meteorological models to account for the high diversity of natural conditions in Armenia.
- Use nationally verified data for ES modelling based on *in situ* measurements in Armenia. Develop national and regional databases of ES modeling coefficients.

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