EU4Environment in Eastern Partner Countries:
Water Resources and Environmental Data (ENI/2021/425-550)

IMPLEMENTATION OF CORINE LAND COVER (CLC) OF LORI AND TAVUSH REGIONS IN THE REPUBLIC OF ARMENIA

Final Report

Funded by the European Union

EU4Environment
Water and Data in Eastern Partner Countries

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Water Resources and Environmental Data (ENI/2021/425-550)

ABOUT THIS REPORT

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June 2024

ABOUT EU4ENVIRONMENT – WATER RESOURCES AND ENVIRONMENTAL DATA

This Programme aims at improving people's wellbeing in EU's Eastern Partner Countries and enabling their green transformation in line with the European Green Deal and the Sustainable Development Goals (SDGs). The programme's activities are clustered around two specific objectives: 1) support a more sustainable use of water resources and 2) improve the use of sound environmental data and their availability for policy-makers and citizens. It ensures continuity of the Shared Environmental Information System Phase II and the EU Water Initiative Plus for Eastern Partnership programmes.

The Programme is implemented by five Partner organisations: Environment Agency Austria (UBA), Austrian Development Agency (ADA), International Office for Water (OiEau) (France), Organisation for Economic Co-operation and Development (OECD), United Nations Economic Commission for Europe (UNECE). The action is co-funded by the European Union, the Austrian Development Cooperation and the French Artois-Picardie Water Agency based on a budget of EUR 12,75 million (EUR 12 million EU contribution). The implementation period is 2021-2024.

https://eu4waterdata.eu

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List of abbreviations

ADA: Austrian Development Agency

CLC: CORINE Land Cover

EEA: European Environment Agency

ENI: European Neighbourhood Instrument

EU: European Union

EU4Environment: European Union for Environment

ETC-DI: European Topic Centre on Data Integration

HR-VPP: High-Resolution Vegetation Phenology and Productivity

IOW: Office International de l'Eau (International Office for Water)

MMU: Minimum Mapping Unit

MMW: Minimum Mapping Width

OECD: Organisation for Economic Co-operation and Development

OiEau: Office International de l'Eau

RA: Republic of Armenia

SDGs: Sustainable Development Goals

UNECE: United Nations Economic Commission for Europe

UBA: Umweltbundesamt GmbH (Environment Agency Austria)

Key messages

The "Implementation of CORINE Land Cover (CLC) of Lori and Tavush Regions in the Republic of Armenia" project, under the EU4Environment Water Resources and Environmental Data programme, has successfully mapped the CLC 2024 status layer and CLC-Change (2018-2024) layer over the pilot areas. This initiative marks a significant step in advancing land and agriculture monitoring in Armenia. The project also facilitated three workshops, fostering knowledge exchange and capacity building in land cover mapping and high-resolution vegetation monitoring. The outcomes of this project provide a robust foundation for future land monitoring and water accounting efforts, contributing to sustainable environmental management and cross-sectoral collaboration in Armenia and beyond.

Executive Summary

The primary objective of the “Implementation of CORINE land cover (CLC) of Lori and Tavush regions in the Republic of Armenia'' project is to contribute the Output 2.2 - Land and agriculture monitoring of the EU4ENVIRONMENT WATER RESOURCES AND ENVIRONMENTAL DATA programme. During the implementation of ENI SEIS II East, 2016-2020 by the EEA, the CORINE land-cover (CLC) approach was introduced to pilot areas in the capital regions of the participating countries, including Armenia. This project envisions the continuation and expansion of the mentioned initiative, ensuring the implementation of a national CLC mapping in the Republic of Armenia.

Planned undertakings within the framework of this project include:

- Mapping the CLC 2024 status layer over the pilot area that mainly covers the Lori and Tavush regions of the Republic of Armenia
- Mapping the CLC-Change (2018-2024) layer by backdating
- Generating CLC2018 status layer by combining CLC 2024 and CLC-Change (2018-2024).
- Technical report writing

The objective of this final report is to present the process and outcomes of mapping the CLC 2024 status layer across the designated mapping area.

Furthermore, two workshops were already conducted as part of this project. The initial workshop, focusing on land monitoring, took place from November 30 to December 1, 2022. The second workshop, titled "Training Workshop: High-resolution monitoring of inter-annual changes in vegetation productivity in Armenia," occurred on November 28-29, 2023. The third regional workshop, titled "Regional Workshop on Land Monitoring and Water Accounting," was held on May 21-22, 2024, in Tbilisi.

The first workshop's agenda encompassed the presentation of project objectives, detailed exploration of land cover mapping through the "Corine" methodology, additional technical discussions pertaining to the Pilot area, and a comprehensive review of the work plan.

The agenda of the second workshop included an introduction to Earth Observation and Copernicus products, an overview of the Copernicus Data Space Ecosystem with guidance on locating Copernicus products, insights into the use of satellite data in Armenia with a focus on CLC mapping in Lori and Tavush marzes, an introduction to case studies covering land cover classification using HR-VPP data, agricultural productivity insights from satellite observations, and the examination of vegetation productivity in response to inter-annual changes in climate. The session concluded with a Q&A session, discussions, and feedback.

The agenda of the third workshop included an overview of Programme Outputs 2.1 and 2.2, the presentation of main results, case studies, and application examples, a technical session on water accounting and land monitoring, and discussions on water accounting and remote sensing. The meeting objectives were to present the main achievements obtained within the land monitoring and water accounting tasks, offer a platform for identifying common objectives and establishing frameworks for cooperation beyond the "EU4Environment – Water Resources and Environmental Data" programme, and provide an unprecedented opportunity for discussion and collaboration among different countries and experts from various sectors and domains, such as water management, statistics, and land use monitoring.

This report also contains relevant details concerning databases, processing methodology, main difficulties and results of the CLC pilot mapping process.

1. Databases used in the project

1.1. Data used for creating CLC 2024

The CLC 2024 status layer for the test area is based on the interpretation of Sentinel-2 images pre-processed by the national technical team (Table 1). The multi-seasonal satellite images were acquired between April 2022 and October 2023, containing satellite images in spring, summer, and autumn. Digital forest maps and digital maps of specially protected nature areas of the Republic of Armenia (RA) were also used as reference data (Figure 1).

The topographical maps of Armenia have not been completely updated since the 1980s, so due to the partial absence of new maps, they were partially used by the national team. New data is exclusively available in cadastral maps, but the problem with using these maps is that they contain too much detailed information, which in turn causes a number of difficulties when working on this project. However, some cadastral maps were also used at different levels of this project where necessary and/or manageable. The project also used high-resolution orthophotos and satellite images that partially cover the mapped area. Orthophotos and satellite images were also used to develop the CLC 2024 status layer.

This diverse collection of reference data provided a detailed and accurate representation of the land cover of the Lori and Tavush marzes of Armenia.

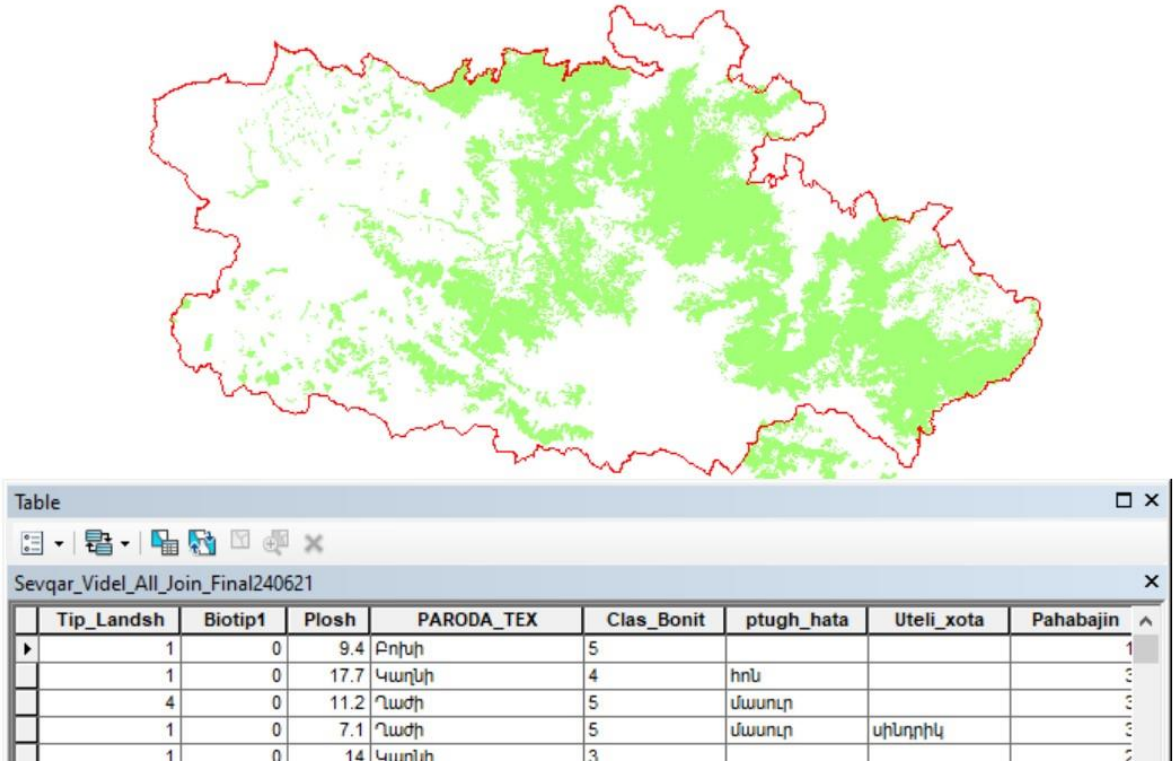

Figure 1- Using forestry maps as a reference data

Table 1 - Sentinel 2 Satellite images (CLC2024)

IMAGE2022-23 used to map CLC202024 status layer		
Sensor	**Acquisition date (m/d/y)**	**Tile Number**
Sentinel-2A	26/04/2022	T38TML
Sentinel-2A	26/04/2022	T38TNL
Sentinel-2A	05/06/2022	T38TML
Sentinel-2A	05/06/2022	T38TNL
Sentinel-2B	10/07/2022	T38TML
Sentinel-2A	15/07/2022	T38TNL
Sentinel-2A	14/08/2022	T38TML
Sentinel-2A	14/08/2022	T38TNL
Sentinel-2B	29/08/2022	T38TML
Sentinel-2B	29/08/2022	T38TNL
Sentinel-2B	18/09/2022	T38TML
Sentinel-2B	18/09/2022	T38TNL
Sentinel-2B	28/09/2022	T38TML
Sentinel-2B	28/09/2022	T38TNL
Sentinel-2A	06/05/2023	T38TNL
Sentinel-2A	20/07/2023	T38TML
Sentinel-2A	20/07/2023	T38TNL
Sentinel-2B	14/08/2023	T38TML
Sentinel-2B	14/08/2023	T38TNL
Sentinel-2A	08/10/2023	T38TML
Sentinel-2A	08/10/2023	T38TNL

The CLC2024 layer was based on more than 20 Sentinel-2 images from the years of 2022-2023, incorporating both Sentinel 2A and 2B. Retrieving two images was necessary to encompass the entire pilot area, which is situated between two grid tiles (T38TML, T38TNL).

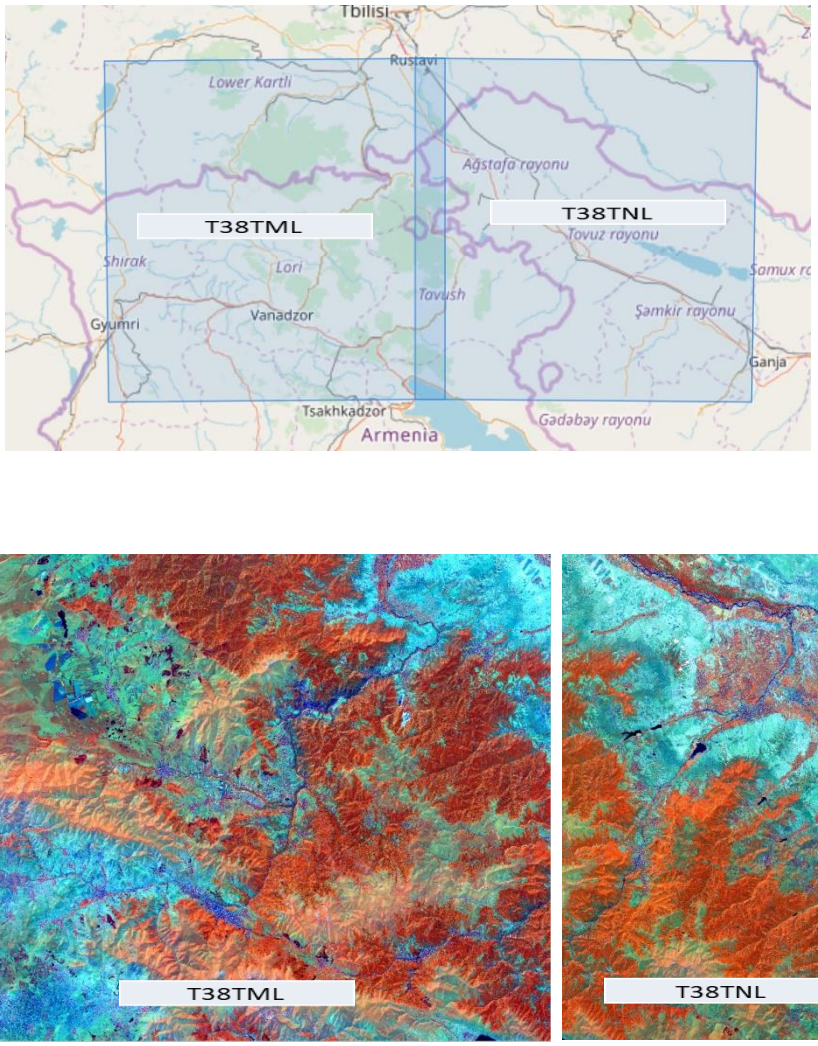

Figure 2 – Sentinel 2B (14/08/2023) satellite images (grid tiles T38TML, T38TNL)

1.2. Data used for creating CLC-Change$_{2018\text{-}2024}$

Sentinel-2 images from 2017-2018 were used to create the CLC-Change2018-2024 layer for the mapping area (Table 2). The satellite images were selected and pre-processed by the national technical team.

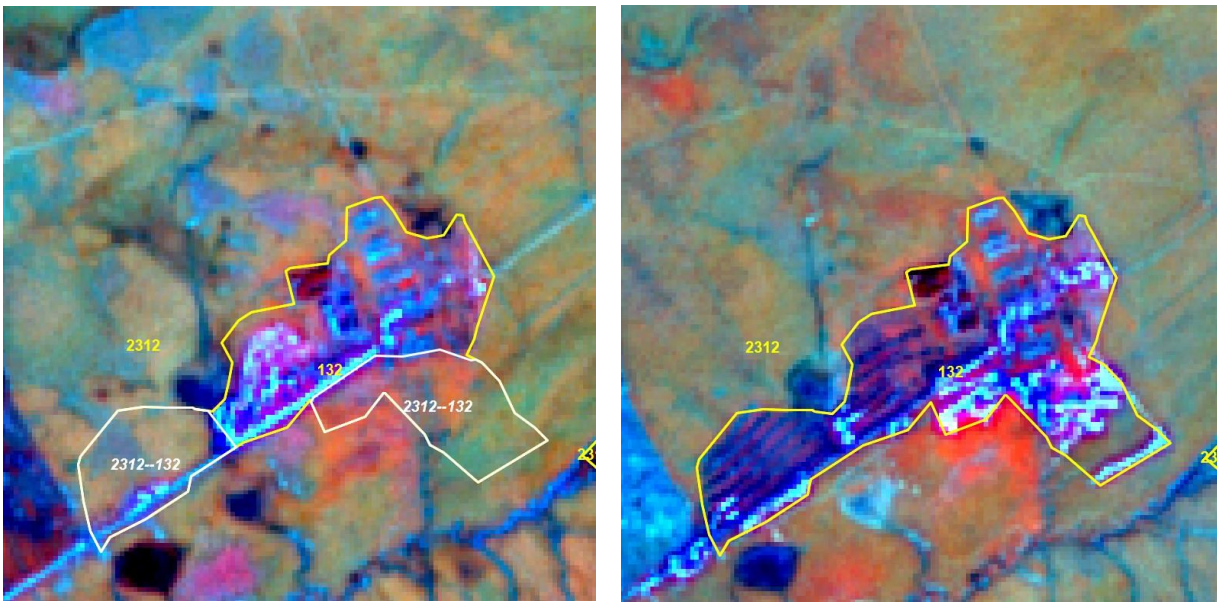

Figure 3 - An example of conversion of pasture **(2312)**
dump sites **(132)**

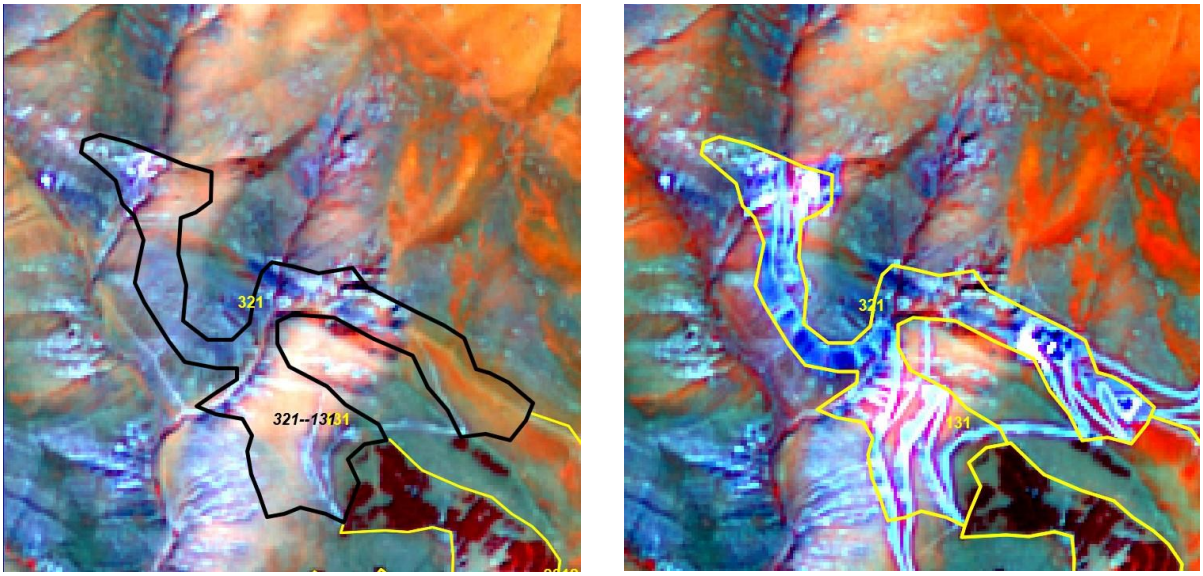

Figure 4 - An example of conversion of pasture **(231)** to mining site **(131)**

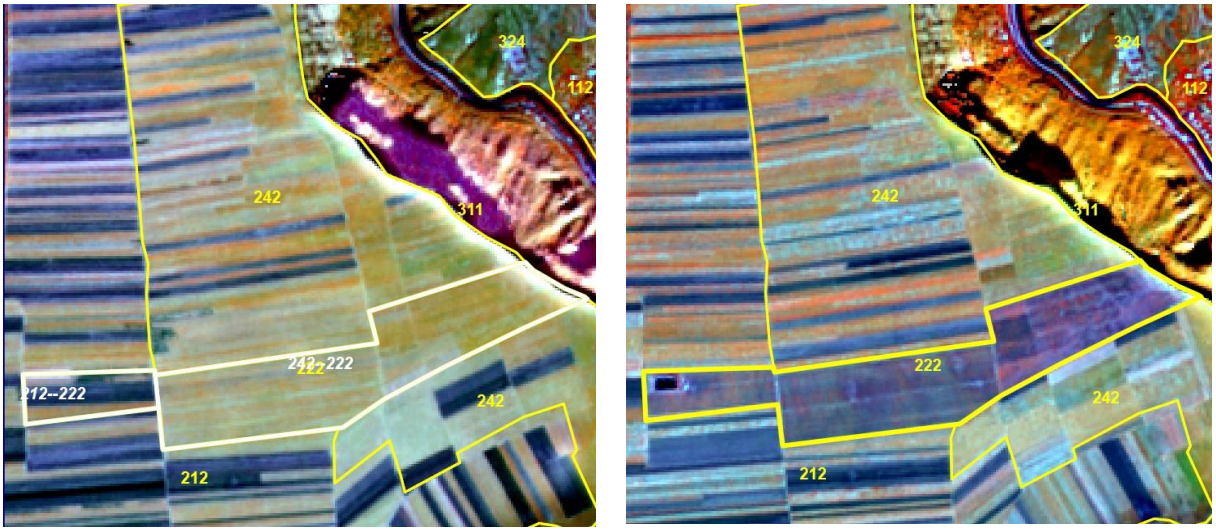

Figure 5 - An example of conversion of arable land and complex cultivation **(211, 242)** to fruit trees **(222)**

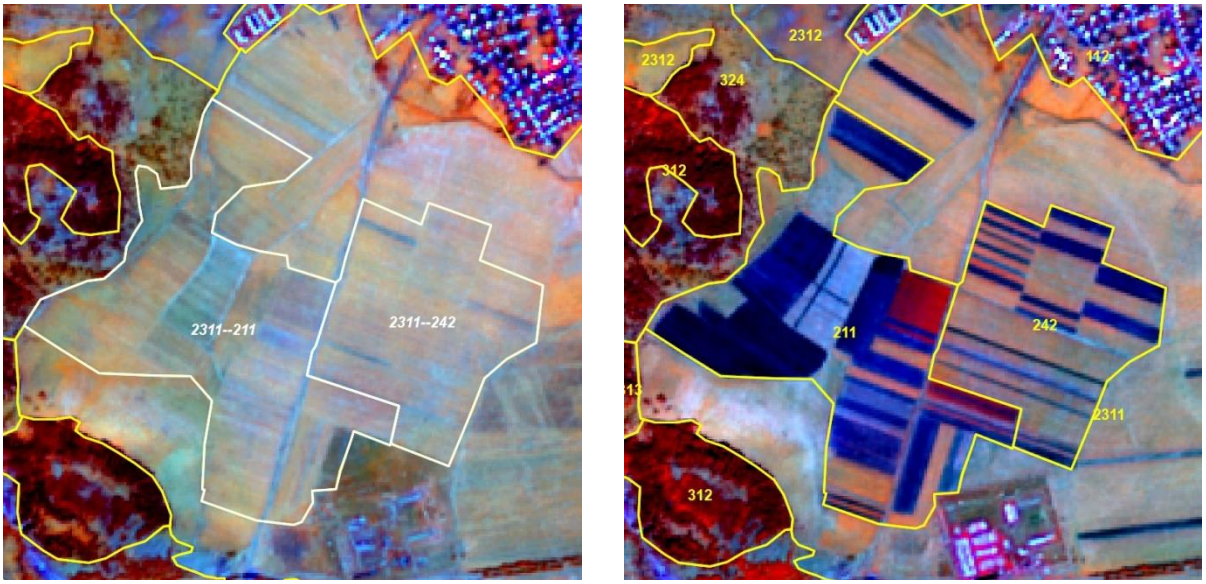

Figure 6 - An example of conversion of pasture **(2311)** to arable land and complex cultivation **(211, 242)**

Table 2 - Sentinel 2 Satellite images (CLC-Change$_{2018\text{-}2024}$)

IMAGE2017-18 used to map CLC-Change2018-2024 layer		
Sensor	**Acquisition date (m/d/y)**	**Tile Number**
Sentinel-2B	02/05/2018	T38TML
Sentinel-2B	02/05/2018	T38TNL
Sentinel-2A	06/06/2018	T38TML
Sentinel-2A	06/06/2018	T38TNL
Sentinel-2B	01/07/2028	T38TML
Sentinel-2B	01/07/2028	T38TNL
Sentinel-2B	30/08/2028	T38TML
Sentinel-2B	30/08/2028	T38TNL
Sentinel-2A	24/09/2018	T38TML
Sentinel-2A	24/09/2018	T38TNL
Sentinel-2B	19/10/2018	T38TML
Sentinel-2B	19/10/2018	T38TNL
Sentinel-2A	21/07/2017	T38TML
Sentinel-2A	21/07/2017	T38TNL
Sentinel-2A	09/09/2017	T38TML
Sentinel-2A	09/09/2017	T38TNL
Sentinel-2A	19/09/2017	T38TML
Sentinel-2A	19/09/2017	T38TNL

Google Earth multi-time imagery available for the mapping area were also used as ancillary data to support the visual interpretation.

1.3. Backdated CLC2018

The backdated CLC2018 (CLC2018 = CLC2024 - CLC-change$_{2018-2024}$) layer for the mapping area was created using the methodology given in the CLC2018 Technical Guidelines, using the technically error-free, topologically correct final CLC2024 and CLC-Change2018-2024 layers.

2.1. General

The main technical processes for the implementation of the Lori and Tavush CLC project began at the end of 2022. The layers CLC2024 and CLC-Change 2018-2024 were created. The work process started immediately after the signing of the contract. Table 3 shows the composition of the national technical team of Armenia.

Table 3 - List of the Armenian national technical team members:

Experts	Position	Tasks
Samvel Nahapetyan	National project manager, senior	• Project management • Photo-interpretation for CLC2024 • Photo-interpretation of changes • Backdating CLC2018 • Evaluation of the results, reporting
Gevorg Azgaldyan	Photo interpreter, junior	• Photo-interpretation for CLC2024 • Corrections / revision after verifications
Yeva Danielyan	Forestry expert, junior	• Internal quality control of CLC2024 • Reporting

2.2. Processing methodology, software

2.2.1. Methodology of mapping, software

Mapping was carried out in the Lori and Tavush regions (total area: 652,346 ha) according to all the principles described in the "CLC2018 Technical Guidelines" (10/25/2017), taking into account the definitions of the CLC nomenclature. A minimum mapping unit (MMU) of 25 ha and a minimum mapping width (MMW) of 100 m were used when mapping the CLC2024 status layer.

The territory was divided into two parts, corresponding to the Lori and Tavush regions. Two experts worked on the photo-interpretation of the CLC2024 layer, while the photo-interpretation of the CLC change layer was carried out by one expert. According to the required methodology, all changes larger than 5 ha with a minimum width of 100 m were delineated.

InterChange software[1] was used to map the two layers.

2.2.2. Internal quality control

Internal checking of the CLC2024 layer has been carried out by an independent photo interpreter (using InterCheck), who was not participating in main mapping process. In case mistakes had been discovered, independent photo interpreter made comments on the polygons and sent them back for problem elimination.

2.2.3. External validation

External verifications were carried out by ETC-DI experts. Comments were evaluated by national technical team and the databases were improved accordingly.

2.2.4. Main difficulties and their solutions

The first problem the National Technical Team faced was the preprocessing methodology for the Sentinel-2 satellite images. The images were processed according to the "Task 2: Draft Technical Requirements for Image Processing and Preparation Needed for the 2018 Exercise" (15/05/2016) guide with the virtual pan-band creation methodology. This work took a lot of time from the technical team.

During the mapping of pastures, the need to expand the CLC nomenclature for Armenia with higher-level classes was revealed to reflect the real situation of the country. Instead of having one class for grasslands, two level 4 classes were mapped. The following lands are managed separately in Armenia:

In the CLC nomenclature, 231 class was subdivided to the following two subclasses:

- 2311: Permanent grasslands (not part of the crop rotation) used for harvesting the grass.
- 2312: The rest of the pastures.

As a result, the volume of work increased by about 25 percent.

[1] CLC2018 Support Package https://clc2018.taracsak.hu/

3. Results

3.1. CLC2024

The CLC2024 map of the Lori and Tavush region is shown in **Figure 7**. CLC2024 layer consists of **2554** polygons. The total area of the CLC2024 layer is **652346 ha.**

Detailed information about land cover types over the Lori and Tavush region of Armenia (as of 2024) can be found in **Table 5.**

Table 5 - CLC 2024 statistics

CODE2024	CLC classes	PIECE	AREA	AVERAGE	%
111	Continuous urban fabric	3	137	46	0.02
112	Discontinuous urban fabric	186	19693	106	3.02
121	Industrial or commercial units	40	2302	58	0.35
122	Road and rail networks and associated land	7	260	37	0.04
124	Airports	2	137	69	0.02
131	Mineral extraction sites	11	831	76	0.13
132	Dump sites	5	212	42	0.03
133	Construction sites	5	198	40	0.03
141	Green urban areas	7	243	35	0.04
142	Sport and leisure facilities	17	738	43	0.11
211	Non-irrigated arable land	137	21904	160	3.36
212	Permanently irrigated land	67	13397	200	2.05
221	Vineyards	20	1392	70	0.21
222	Fruit trees and berry plantations	30	3672	122	0.56
223	Olive groves	1	62	62	0.01

2311	Pastures harvesting the grass	401	63017	157	9.66
2312	Pastures	321	104847	327	16.07
242	Complex cultivation patterns	218	13510	62	2.07
243	Land principally occupied by agriculture, with significant areas of natural vegetation	148	10523	71	1.61
311	Broad-leaved forest	153	231377	1512	35.47
312	Coniferous forest	58	4918	85	0.75
313	Mixed forest	33	1833	56	0.28
321	Natural grassland	86	112766	1311	17.29
322	Moors and heathland	27	2189	81	0.34
324	Transitional woodland-scrub	368	36260	99	5.56
332	Bare rocks	16	1336	84	0.20
333	Sparsely vegetated areas	69	3536	51	0.54
511	Water courses	3	75	25	0.01
5121	Water bodies-natural	8	313	39	0.05
5122	Water bodies-artificial	7	671	96	0.10
		2454	**652346**		**100**

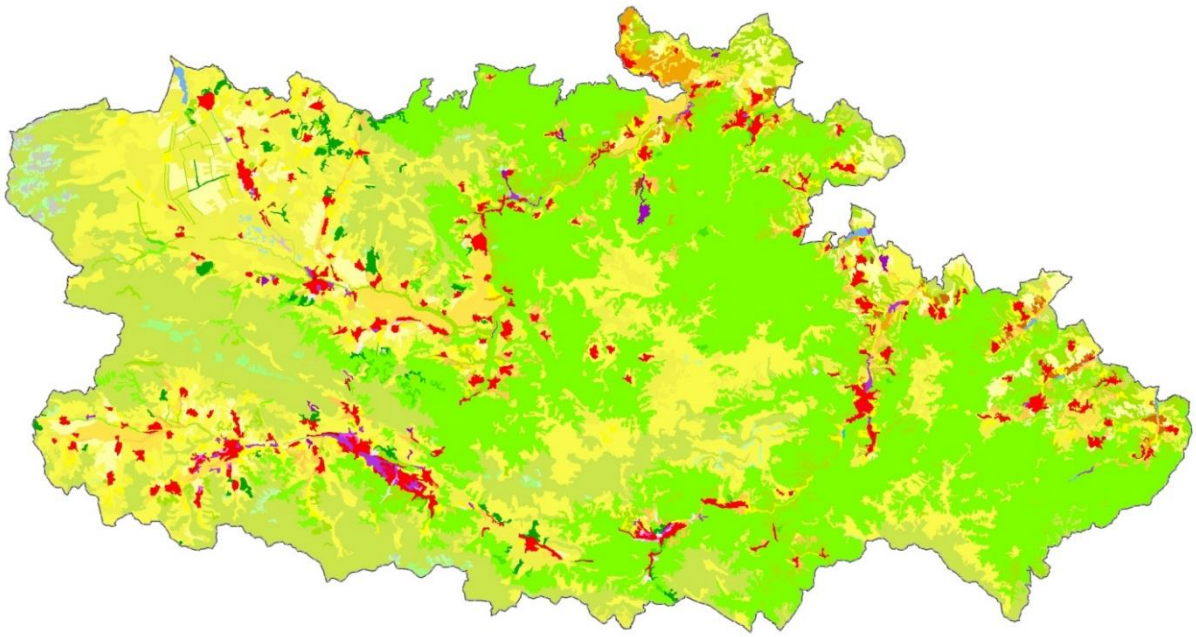

Figure 7 – CLC2024

As we can see the most dominant land cover type over the pilot area is 311- Broad-leaved forest (35,47%). **Table 6** shows 10 main land cover types of the pilot area.

Table 6 - Dominant land cover types in CLC2024 (covering 96.16% of the mapped area)

CODE2024	CLC land cover class	%
311	Broad-leaved forest	35.47
321	Natural grassland	17.29
2312	Pastures	16.07
2311	Pastures harvesting the grass	9.66
324	Transitional woodland-scrub	5.56
211	Non-irrigated arable land	3.36
112	Discontinuous urban fabric	3.02
242	Complex cultivation patterns	2.07
212	Permanently irrigated land	2.05

243	Land principally occupied by agriculture, with significant areas of natural vegetation	1.61

3.2. CLC-Change$_{2018-2024}$

The CLC-Change2018-2024 map of the pilot area is shown on **Figure 8. 102** changes were detected during the 6-year period. Altogether 38 different change types have been mapped covering **0.69%** of the total area. **Table 7** describes dominant changes between 2018 and 2024.

Table 7 - Dominant changes (86 % of total change) between 2018 and 2024

Change (2018-2024)	Process	Area	%
2311--211	Pastures harvesting the grass turned into Non-irrigated arable land **(associated with the reuse of non-irrigated arable land)**	1710	38.09
2311--242	Pastures harvesting the grass turned into complex cultivation patterns **(associated with the partial reuse of non-irrigated arable land)**	1523	33.92
242--222	Complex cultivation patterns turned into fruit trees and berry plantations **(increase of fruit tree and berry plantations)**	127	2.83
211--222	Non-irrigated arable land turned into fruit trees and berry plantations **(increase of fruit tree and berry plantations)**	121	2.69
211--212	Non-irrigated arable land turned into Permanently irrigated land **(associated with the restoration of the irrigation network)**	119	2.65
242--211	Complex cultivation patterns turned into Non-irrigated arable land **(associated with the reuse of non-irrigated arable land)**	103	2.29
212--222	Permanently irrigated land turned into fruit trees and berry plantations **(increase of fruit tree and berry plantations)**	84	1.86
2312--324	Pastures turned into Transitional woodland-scrub **(associated with afforestation)**	68	1.51

Table 8 - Size distribution of change polygons

N	INTERVAL	PIECE	AREA	%
1	0 - 5 ha	3	7	0.16
2	5 - 10 ha	15	110	2.45
3	10 - 15 ha	8	96	2.14
4	15 - 20 ha	7	121	2.70
5	20 - 25 ha	3	64	1.43
6	25 - 30 ha	15	406	9.05
7	30 - 35 ha	9	290	6.47
8	35 - 40 ha	5	190	4.24
9	40 - 45 ha	4	172	3.84
10	45 - 50 ha	6	285	6.36
11	> 50 ha	27	2753	61.40
		102	4494	100

Almost more then half of the changed area consists of polygons covering large (>50 ha) areas.

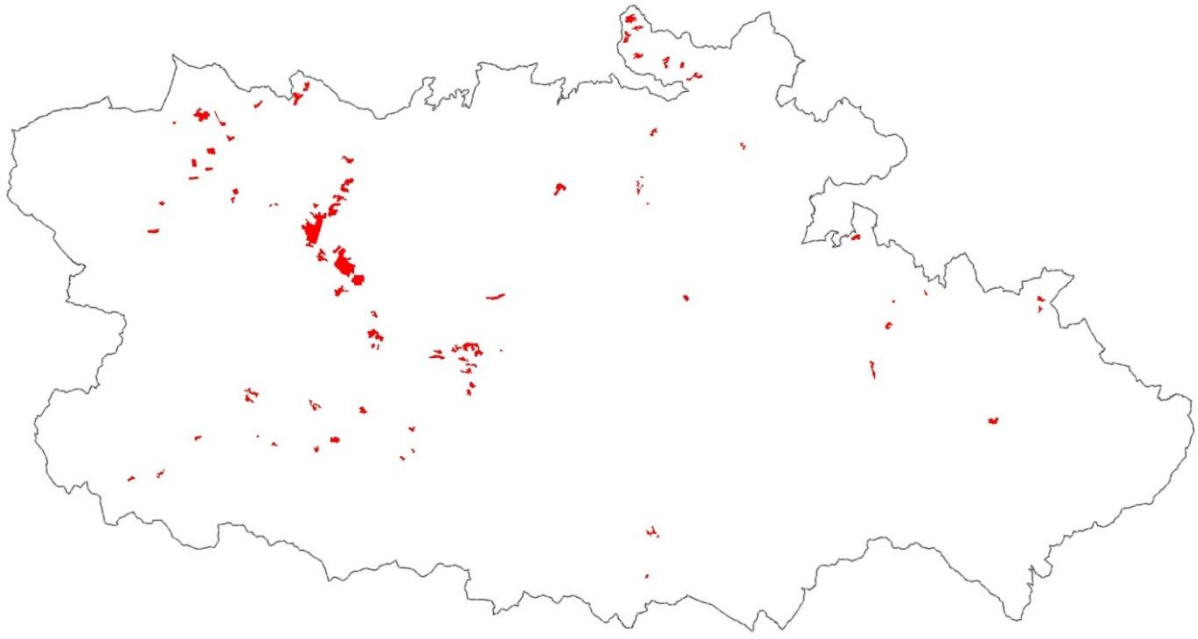

Figure 8 - CLC-Change2018-2024

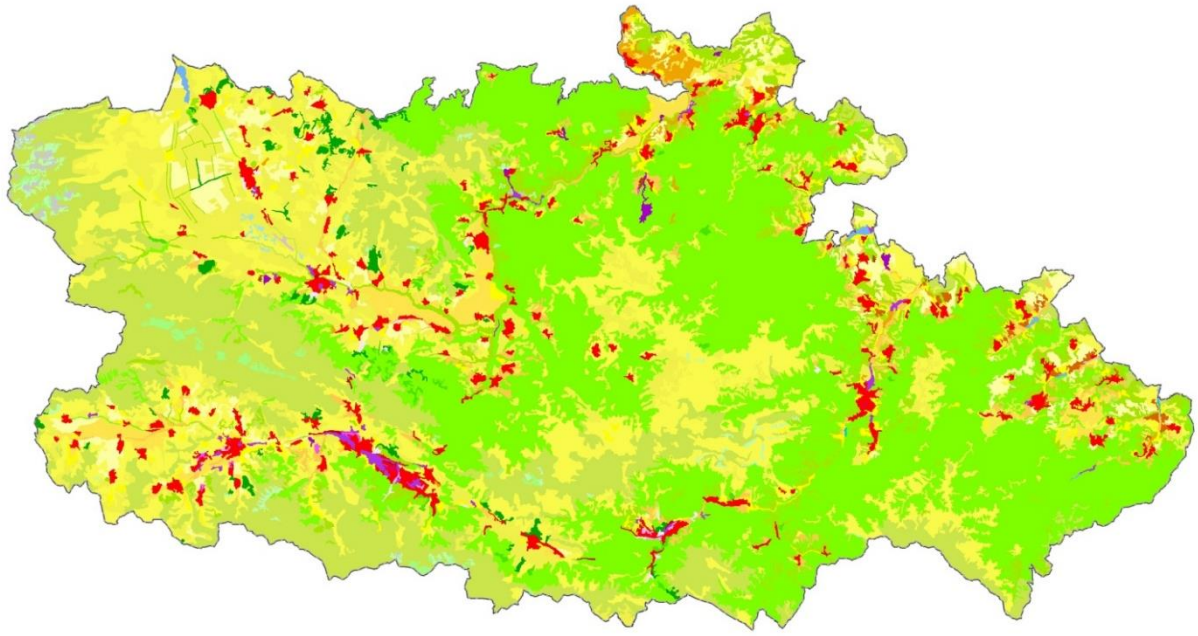

Figure 9 - CLC2018 (backdated)

3.3. CLC2018

CLC2018 generated on the basis of already corrected CLC2024 and CLC-Change2018-2024 layers. CLC2018 map is shown in **Figure 9**. The detailed table with statistical information about CLC2018 layer can be found in **Table 10**. CLC2018 layer consists of **2421** polygons. The total area of the CLC2018 layer is **652 346 ha.**

Table 10 - CLC 2018 statistics

CODE2018	PIECE	AREA	AVERAGE	%
111	3	137	46	0.02
112	185	19666	106	3.01
121	38	2205	58	0.34
122	7	260	37	0.04
124	2	137	69	0.02
131	8	723	90	0.11
132	4	135	34	0.02
133	6	253	42	0.04

141	7	269	38	0.04
142	17	731	43	0.11
211	132	20414	155	3.13
212	68	13338	196	2.04
221	20	1398	70	0.21
222	26	3269	126	0.50
223	1	62	62	0.01
2311	407	66369	163	10.17
2312	323	105064	325	16.11
242	192	12061	63	1.85
243	148	10606	72	1.63
311	153	231382	1512	35.47
312	58	4918	85	0.75
313	33	1833	56	0.28
321	86	112815	1312	17.29
322	27	2189	81	0.34
324	367	36182	99	5.55
332	16	1336	84	0.20
333	69	3536	51	0.54
511	3	75	25	0.01
5121	8	313	39	0.05
5122	7	671	96	0.10
	2421	652346		100.00

Table 11 shows 10 main land cover types of the pilot area in 2018.

Table 11 - Dominant land cover types in CLC2018

CODE2018	CLC land cover class	%
311	Broad-leaved forest	35.47
321	Natural grassland	17.29
2312	Pastures	16.11
2311	Pastures harvesting the grass	10.17
324	Transitional woodland-scrub	5.55
211	Non-irrigated arable land	3.13
112	Discontinuous urban fabric	3.01
242	Complex cultivation patterns	2.04
212	Permanently irrigated land	1.85
243	Land principally occupied by agriculture, with significant areas of natural vegetation	1.63

While comparing tables 5 and 10, it become clear that there is some increase in 211 class area (Non-irrigated arable land)- as in 2018 the area of 211 was 20414 ha (3.13%) and in 2024 it became 21904 ha (3.36%). The opposite situation is for 2311 class (Pastures harvesting the grass)- in 2018 the area of pastures harvesting the grass was 66369 ha (10,17%), and in 2024 the area decreased till 63017 ha (9.66%).

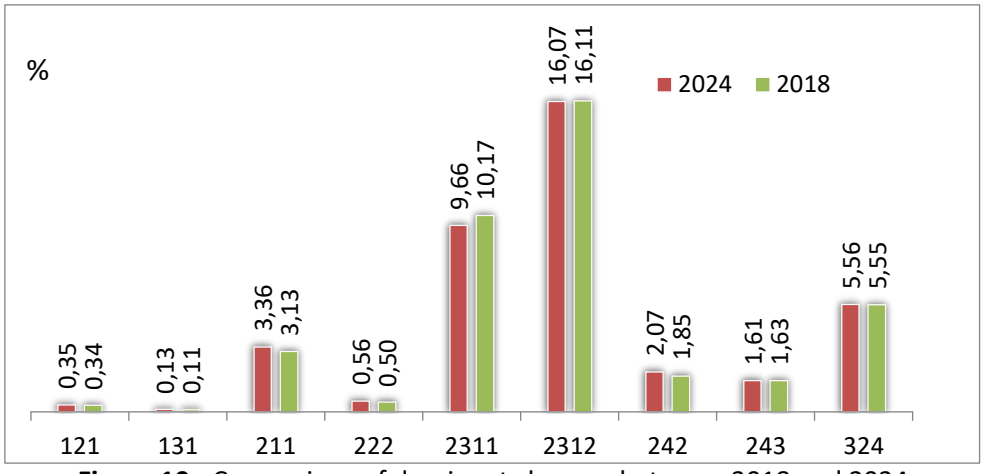

Figure 10 - Comparison of dominant changes between 2018 and 2024

Also it became clear that:

- Major changes has been noted especially in agricultural areas regarding changes in agriculture practices or associated to abandonment of agricultural lands.
- Increasing trends has been noted in Non-irrigated arable land (211), Permanently irrigated land (212), Vineyards (221) and Complex cultivation patterns (242).
- As a result of afforestation, transitional woodland (324) has also increased

4. Conclusions

CLC2024 and CLC-Change layers were obtained by visual photointerpretation of satellite imagery (Sentinel-2) according to the "CLC2018 Technical Guidelines" (10/25/2017) and the "Updated CLC Illustrated Nomenclature Guidelines" (09/30/2017).

The European (level 3) CLC nomenclature was readily applicable to Armenia, except for the pastureland class (231), which was further elaborated for national applications.

CLC-changes show the main processes that took place in Lori and Tavush regions.

Considering the possibilities and advantages of the program, the national technical team proposes to extend it throughout the territory of Armenia.

Deliverables

CLC2024

Format: shapefile, polygon topology

Number of polygons: 2454

Area: 652346 ha

30 of the 44 CLC classes are present in the mapped area, including 2 added subclasses.

Attributes:

CODE2024: The status layer code for the year 2024.

AREA: The area of objects, measured in hectares.

CLC-Change$_{2018\text{-}2024}$

Format: shapefile, polygon topology

Number of polygons: 102

Area: 4494 ha

38 different change types have been mapped covering 0.69 % of the total pilot area.

Attributes:

CLC2024: The status layer code representing the current land covers classification for the year 2024.

CODE2024: The code indicating changes in land cover for the year 2024.

CODE2018: The code representing the state of land covers as of 2018.

AREA: The area affected by the changes, measured in hectares.

LABEL: The descriptive label assigned to the type of change observed between 2018 and 2024.

Backdated CLC2018 layer

Format: shapefile, polygon topology

Number of polygons: 2420

Area: 652346 ha

30 of the 44 CLC classes are present in the mapped area, including 2 added subclasses

Attributes:

CODE2018: The CLC (Corine Land Cover) layer code for the year 2018.

AREA: The area of objects, measured in hectares.

5. References

1. György Büttner and Barbara Kosztra (2017). CLC2018 Technical Guidelines. Final report. Service Contract No 3436/R0-Copernicus/EEA.56665. Environment Agency Austria; EAA Spittelauer Lände 5 1090 Wien, Austria.
2. Barbara Kosztra, György Büttner, Gerard Hazeu, Stephan Arnold (2017). Updated CLC illustrated nomenclature guidelines. Final report. Service Contract No 3436/R0-pernicus/EEA.56586 Task 7, D7.2 – Part 1. Environment Agency Austria; EAA Spittelauer Lände 5 1090 Wien, Austria.
3. Kosztra, B. 2024. Armenia CLC2023 1st (status layer) verification report ETC-ULS report, 07.03.2024, Budapest
4. Barbara Kosztra, Róbert Lehoczki, Róbert Pataki, Ottó Petrik, Mátyás Rada (2017). Task 2: draft technical requirements for image processing and preparation needed for the 2018 exercise. Draft Report V2. Service Contract No 3436/R0-Copernicus/EEA.56872. Environment Agency Austria; EAA Spittelauer Lände 5 1090 Wien, Austria.