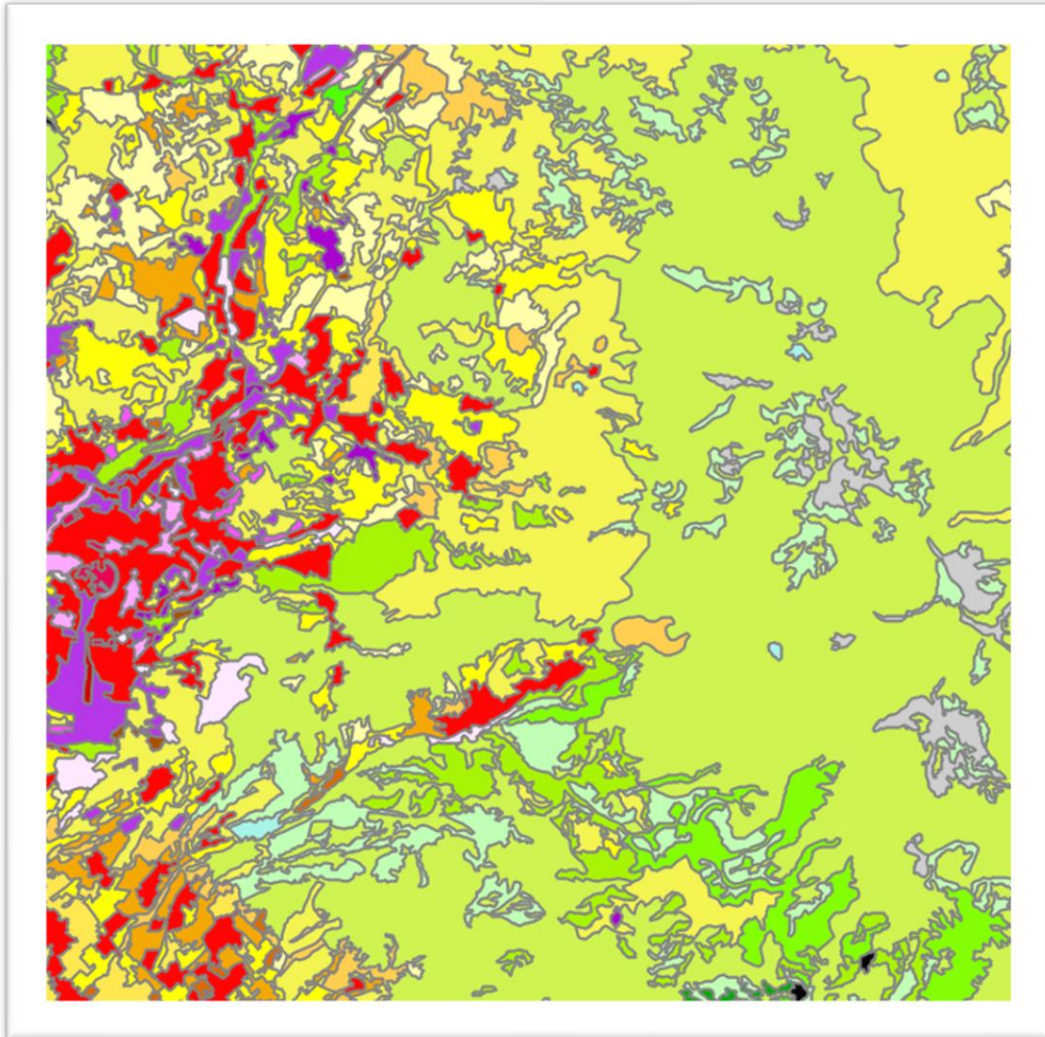# Implementation of the pilot project extending the CORINE Land Cover (CLC) methodology in Republic of Armenia
Final Report
Armenia

"Geoinfo" LLC

Project manager: Samvel Nahapetyan

June, 2020

Yerevan, Armenia

Table of contents

1. Background

This report represents a detailed overview of the outcomes of the **CORINE Land Cover** pilot project carried out in Armenia. This initiative was launched in 2017, when Armenia became a part of the EU-funded "Implementation of the Shared Environmental Information System principles and practices in the Eastern Partnership countries" (the ENI SEIS II East) regional project, nonetheless, to our great regret, the main technical part of the work started only at the end of 2019. Armenia is one of the six Eastern Partnership countries (Armenia, Azerbaijan, Belarus, Georgia, Republic of Moldova and Ukraine) where the CLC pilot project (2017-2020) is implemented.

The **CLC2018** and **CLC-change$_{2000-2018}$** layers were produced by "Geoinfo" LLC, which is a specialized scientific-research centre in Armenia. Mapping has been conducted according to "CLC2018 Technical Guidelines" (10/25/2017) and "Updated CLC illustrated nomenclature guidelines" (09/30/2017). Detailed information about the content of the mentioned guidelines were introduced to the Armenian national technical team during the trainings by ETC-ULS experts.

Within the framework of the project tasks mentioned below have been fulfilled by the national technical team:

- Selection of the pilot area
- Mapping (photo interpretation) of the CLC2018 status layer over the pilot area
- Internal quality control of the CLC2018 status layer
- Revision of the CLC2018 layer
- Mapping (photo interpretation) of the CLC-change$_{2000-2018}$ layer for the pilot area
- Creation of final versions of the layers
- Technical report writing

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

## 2.	Databases used in the project

2.1 CLC 2018

CLC 2018 status layer over the pilot area was based on interpretation of Sentinel-2 imagery (table 1) provided by ETC-ULS. Multi-seasonal satellite imagery was acquired during the period between March 2018 and October 2019, containing satellite images from spring, summer and autumn. The digital forestry maps and digital maps of specially protected areas of the Republic of Armenia (RA) were also used as reference data (Figure 1). The topographic maps of Armenia have not been updated since 1980's, hence, due to the lack of new maps they could not be used by the national team. New data is exclusively available in cadastral maps, however the problem with using those maps is that they contain extremely detailed information, which in turn causes a number of difficulties while working on this project. Nonetheless, some cadastral maps were also used on different levels of this project wherever appropriate and/or manageable.
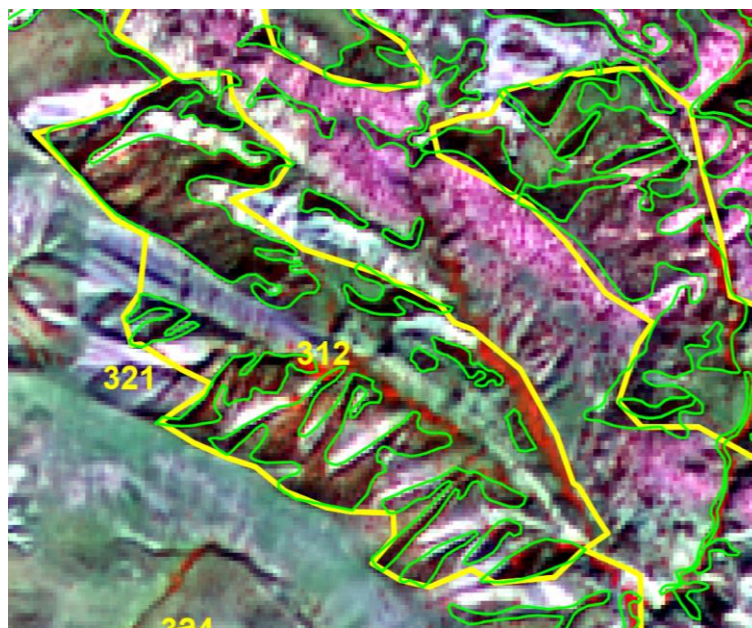
Figure 1- Using forestry maps as a reference data

Table 1 Sentinel 2 Satellite images

IMAGE2018 used to map CLC2018 status layer	
Sensor	Acquisition date (m/d/y)
Sentinel 2-A	04/07/2018
Sentinel 2-A	05/17/2018
Sentinel 2-B	07/11/2018
Sentinel 2-B	04/27/2019
Sentinel 2-A	07/31/2019
Sentinel 2-B	09/24/2018
Sentinel 2-B	09/29/2019
Sentinel 2-B	10/14/2019

Satellite images have been selected by national team members with the support of ETC-ULS experts (preprocessing of the satellite images were done by ETC-ULS experts).
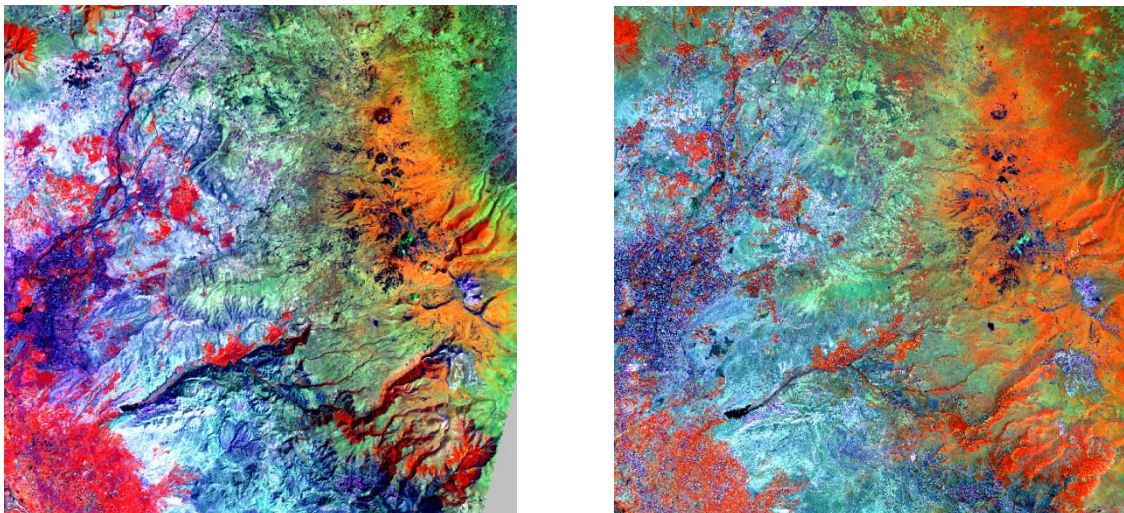
Figure 2 - Landsat-7 ETM (2000/08/13) and Sentinel-2 (2019/07/31) satellite images

2.2 CLC-change₂₀₀₀₋₂₀₁₈

To create a CLC-change₂₀₀₀₋₂₀₁₈ layer of the pilot area Landsat-7 imagery (table 2) were used. Selecting and preprocessed satellite images were provided by the ETC-ULS.

Figure 3 - An example of conversion of urban green (141) to different built-up classes (111, 112, 121)
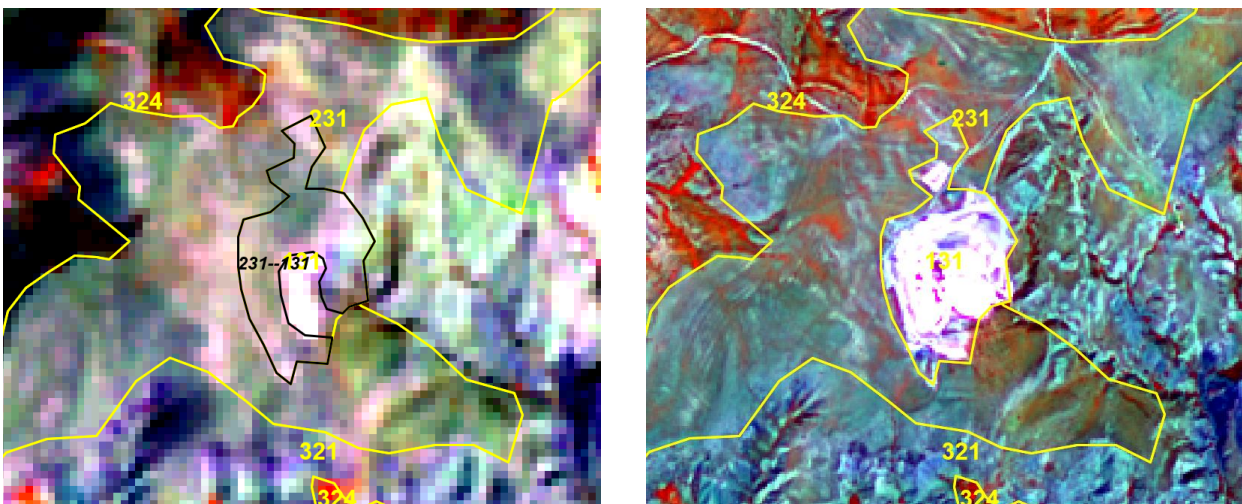
Figure 4 - An example of conversion of pasture (231) to mining site (131)
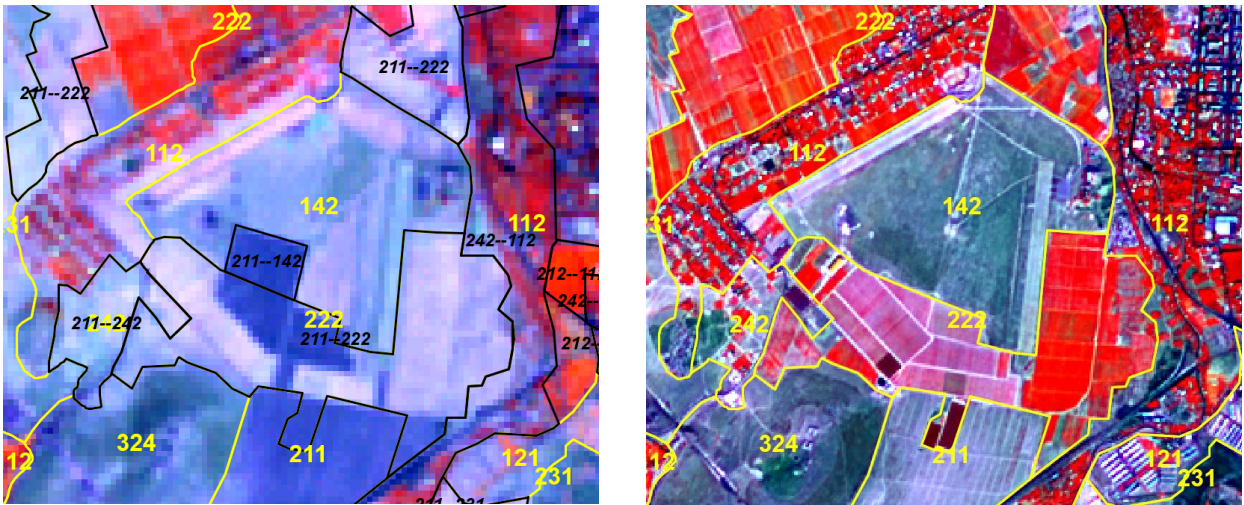
Figure 5 - An example of conversion of arable land **(211)** to fruit trees **(222)**
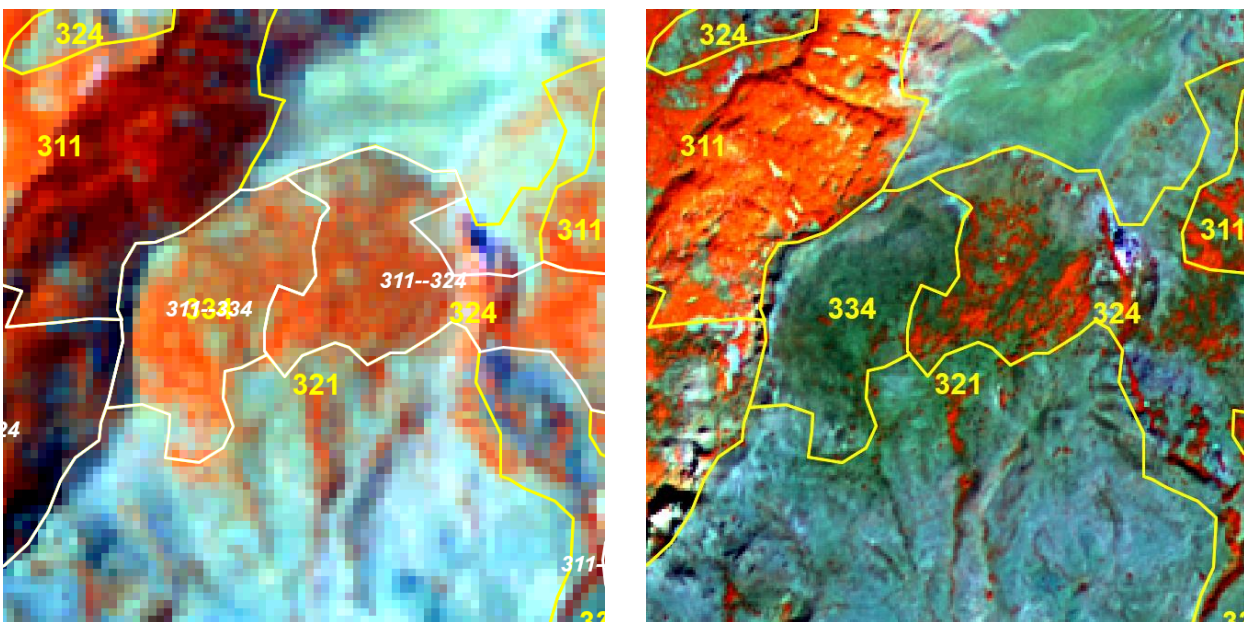
Figure 6- An example of conversion of deciduous forest **(311)** to burnt areas (**334**)

Table 2 Landsat 7 Satellite images

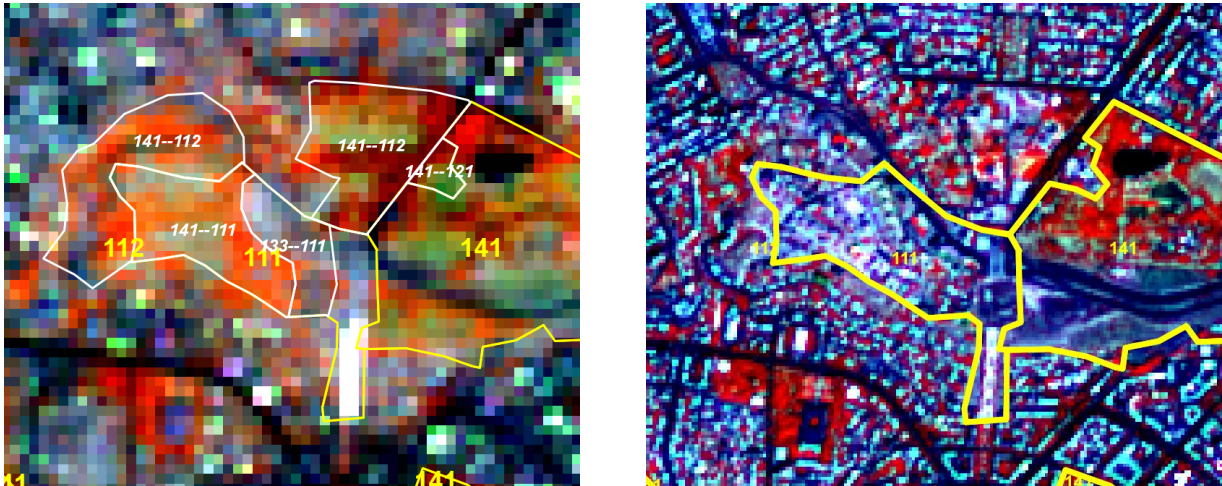| IMAGE2000 used to map CLC-change$_{2000\text{-}2018}$ layer	
Sensor	Acquisition date (m/d/y)
Landsat-7 ETM	05/09/2000
Landsat-7 ETM	06/03/2000
Landsat-7 ETM	08/13/2000
Landsat-7 ETM	08/22/2000
Landsat-7 ETM	09/23/2000
Landsat-7 ETM	10/16/2000

Google Earth imagery available for the pilot area were also used as ancillary data to support the visual interpretation.

2.3 Backdated CLC2000

Backdated CLC2000 (CLC2000 = CLC2018 - CLC-change$_{2000\text{-}2018}$) layer for the pilot area was generated by ETC-ULS partner using technical error free, topologically correct final CLC2018 and CLC-change$_{2000\text{-}2018}$ layers provided by the national technical team.

3. Organization of the work at national level.

3.1 General

As it was mentioned previously, the project in Armenia started in 2017, but the main technical processes for the CLC pilot project implementation commenced only at the end of 2019. Because of the shortage of time national technical team worked for only 4 months (February-June 2020) to create the CLC2018 and CLC-change$_{2000-2018}$ layers. Working process started right after the first CLC training. Table 3 shows the list of the Armenian national technical team members:

Table 3 List of the Armenian national technical team members:

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

3.2 Milestones

Milestones of the Armenian CLC pilot project implementation are presented in **Table 4**.

Table 4. Actions and chronology

No	Date (m/d/y)	Description
1.	1/21/2019	Selection of the pilot area
2.	1/26/2019	Selection of satellite images (participation to that process)
3.	2/12/2020	First CLC training in Armenia (day 1)
4.	2/13/2020	First CLC training in Armenia (day 2)
5.	2/14/2020	Start of the visual interpretation to create the CLC2018
6.	3/30/2020	Internal quality checking by the National Technical Team
7.	4/15/2020	External verification of the CLC 2018 layer
8.	4/23/2020	Corrections based on the external verification
9.	5/08/2020	CLC2018 layer completed for the pilot area
10.	5/15/2020	Second CLC remote (on-line) training (day 1)
11.	5/18/2020	Second CLC remote (on-line) training (day 2)
12.	5/19/2020	Change mapping
13.	5/30/2020	External verification of CLC-change$_{2000-2018}$ layer
14.	6/05/2020	Corrections based on the external verification
15.	6/10/2020	Revised CLC2018 and CLC-change$_{2000-2018}$ layers completed
16.	6/10/2020	Generation of the backdated CLC2000 layer of the pilot area
17.	6/15/2020	Delivery of final results to ETC-ULS

Regrettably, few field-checking activities were carried out during the working process due to the time pressure and the situation over COVID-19. Few point objects were checked for finding out the right code of the object (e.g. if it is mineral extraction site (131) or dumpsite (132)).

3.3 Training

CLC trainings for Armenia

In order to carry out the project in Armenia, two training courses were provided by the ETC-ULS experts.

3.3.1 First training course

During the first, two-days long training course, which was held on 12-13 February 2020 in Yerevan, the following topics were thoroughly introduced to the national technical team members:

- **CORINE Land Cover introduction**

    Definition of land cover

    What is CORINE Land Cover?

    CORINE land cover basics

    Methodology of mapping

- **The standard European CLC nomenclature introduction**

    Details and examples on:

    1. Artificial surfaces

    2. Agriculture

    3. Forests and semi-natural areas

    4. Wetlands

    5. Water

- **CLC2018 Support Package introduction**

    National technical team got acquainted with the InterChange photo-interpretation software. Practical CLC mapping exercise was carried out during the training (using the InterChange tool for the pilot area).

3.3.2 Second training course

The second training for Armenia was held remotely (via Skype) on 15 and 18 of May 2020. On the first day CLC change mapping principles were introduced by ETC experts.

The second day was dedicated to the practical introduction (important functionalities, steps of change delineation…) of CLC-change mapping tool - InterChange. The training also had a practical part (second day of training), during which CLC change mapping exercises were conducted.

3.4 Processing methodology, software

3.4.1 Methodology of mapping, software

Mapping has been conducted on the approved pilot area (50km x 50km, total area- 250197 ha) according to all principles described in "CLC2018 Technical Guidelines" (10/25/2017) taking into account definitions of the CLC nomenclature. 25 ha minimum mapping unit (MMU) and 100 m minimum mapping width (MMW) were applied while mapping the CLC2018 status layer.

Due to the lack of time the pilot area was divided into two equal parts. Two specialists were working on photo interpretation of the CLC2018 layer, whereas the photo interpretation of the CLC change layer was conducted by a single expert (according to the required methodology, all changes larger than 5 ha with 100 m minimum width have been delineated).

InterChange software has been used to map both of the layers.

3.4.2 Internal quality control

Internal checking of the CLC2018 layer has been carried out by an independent photo interpreter (using InterCheck software provided by ETC-ULS), 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.

3.4.3 External validation

Two external verifications were carried out by ETC-ULS experts. Comments were evaluated by national technical team and the databases were improved accordingly.

3.4.4 Main difficulties and their solutions

1. The first difficulty for the national technical team was the shortage of time and the situation regarding COVID-19. Because of the mentioned issues few field checking activities had been carried out.

2. Moreover, at the beginning of the working process photo interpreters faced several difficulties while adapting to the InterChange software without the usage of ArcMap. During the first stage of mapping process, the ArcMap software was used in parallel, which caused numerous topologic errors, which were duly noted. Much time and effort was spent to eliminate these errors.

3. While mapping pastures, the need of extending the CLC nomenclature for Armenia with higher level classes in order to reflect the real situation in the country has been revealed. Instead of having one class for pastures, three level-4 classes are needed to describe all the existing land classes (below mentioned lands are managed separately in Armenia).

- Grass covered areas around settlements without any use

- Pasture, hayfield used for agricultural purposes

- Pasture, permanent grassland for hay harvesting

4. Results

4.1 CLC2018

The CLC2018 map of the pilot area is shown in **Figure 7**. CLC2018 layer consists of **743** polygons. The total area of the CLC2018 layer is **250197 ha.**

Detailed information about land cover types over the pilot area of Armenia (as of 2018) can be found in **Table 5**.

Table 5. CLC 2018 statistics

| CODE2018	CLC classes	PIECE	AREA	AVERAGE	%
111	Continuous urban fabric	6	346	58	0.14
112	Discontinuous urban fabric	67	17117	255	6.84
121	Industrial or commercial units	42	4839	115	1.93
122	Road and rail networks and associated land	3	264	88	0.11
124	Airports	1	39	39	0.02
131	Mineral extraction sites	16	1172	73	0.47
132	Dump sites	4	204	51	0.08
133	Construction sites	12	571	48	0.23
141	Green urban areas	20	1512	76	0.60
142	Sport and leisure facilities	13	1863	143	0.74
211	Non-irrigated arable land	70	11159	159	4.46
212	Permanently irrigated land	13	3496	269	1.40
221	Vineyards	9	751	83	0.30
222	Fruit trees and berry plantations	41	5130	125	2.05
231	Pastures	83	48202	581	19.27
242	Complex cultivation patterns	103	15856	154	6.34
243	Land principally occupied by agriculture, with significant areas of natural vegetation	26	4720	182	1.89
311	Broad-leaved forest	13	6682	514	2.67
312	Coniferous forest	4	290	72	0.12
313	Mixed forest	4	355	89	0.14
321	Natural grassland	26	96381	3707	38.52
324	Transitional woodland-scrub	53	10557	199	4.22
332	Bare rocks	18	3918	218	1.57
333	Sparsely vegetated areas	87	14160	163	5.66
334	Burnt areas	3	146	49	0.06
411	Inland marshes	1	47	47	0.02
512	Water bodies	5	418	84	0.17
			250195		**100**
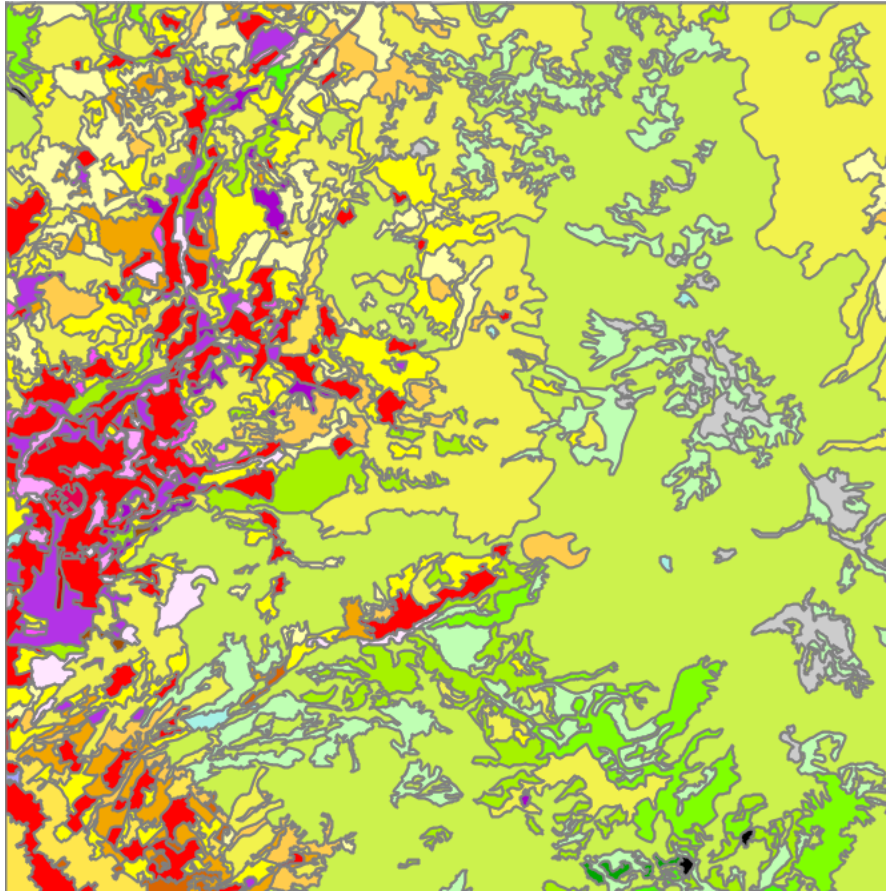
Figure 7 – CLC2018

As we can see the most dominant land cover type over the pilot area is 321- Natural grasslands (38,52%, light green on Figure 7.). **Table 6** shows 8 main land cover types of the pilot area.

Table 6 Dominant land cover types in CLC2018 (covering 88% of the pilot area)

CODE2018	CLC land cover class	%
321	Natural grassland	38.52
231	Pastures	19.27
112	Discontinuous urban fabric	6.84
242	Complex cultivation patterns	6.34
333	Sparsely vegetated areas	5.66
211	Non-irrigated arable land	4.46
324	Transitional woodland-shrub	4.22
311	Broad-leaved forest	2.67

4.2 CLC-change₂₀₀₀₋₂₀₁₈

The CLC-change₂₀₀₀₋₂₀₁₈ map of the pilot area is shown on **Figure 8**. **437** changes were detected during the 18-year long period. Altogether **88** different change types have been mapped covering **4.94 %** of the total pilot area. **Table 7** describes dominant changes between 2000 and 2018.

Table 7 Dominant changes (57 % of total change) between 2000 and 2018

Change (2000-2018)	Process	Area	%
242-231	Complex cultivation patterns turned into pastures (associated to abandonment of agriculture)	1541	12.47
211-222	Non-irrigated arable land turned into fruit trees and berry plantations (increase of fruit tree and berry plantations)	1304	10.55
211-231	Non-irrigated arable land turned into pastures (associated to abandonment of agriculture)	1296	10.48
212-242	Permanently irrigated land turned into complex cultivation patterns (partial abandonment of irrigation)	685	5.54
211-242	Fruit and berry plantations turned into complex cultivation patterns (change in agriculture practice)	685	5.54
242-112	Complex cultivation patterns turned into discontinuous urban fabric (urban sprawl, loss of agricultural land)	558	4.51
221-242	Vineyards turned into complex cultivation patterns (decrease of vineyards)	462	3.74
242-222	Complex cultivation patterns turned into fruit trees and berry plantations (increase of fruit tree and berry plantations)	462	3.74

Table 8 Size distribution of change polygons

N	INTERVAL	PIECE	AREA	%
1	0 - 5 ha	13	39	0.32
2	5 - 10 ha	99	737	5.96
3	10 - 15 ha	75	916	7.41
4	15 - 20 ha	54	930	7.52
5	20 - 25 ha	39	863	6.98
6	25 - 30 ha	41	1124	9.09
7	30 - 35 ha	21	685	5.54
8	35 - 40 ha	16	599	4.84
9	40 - 45 ha	10	419	3.39
10	45 - 50 ha	9	428	3.46
11	> 50 ha	60	5627	45.50
			12367	**100**

Almost half of the changed area consists in polygons covering large (>50 ha) areas.
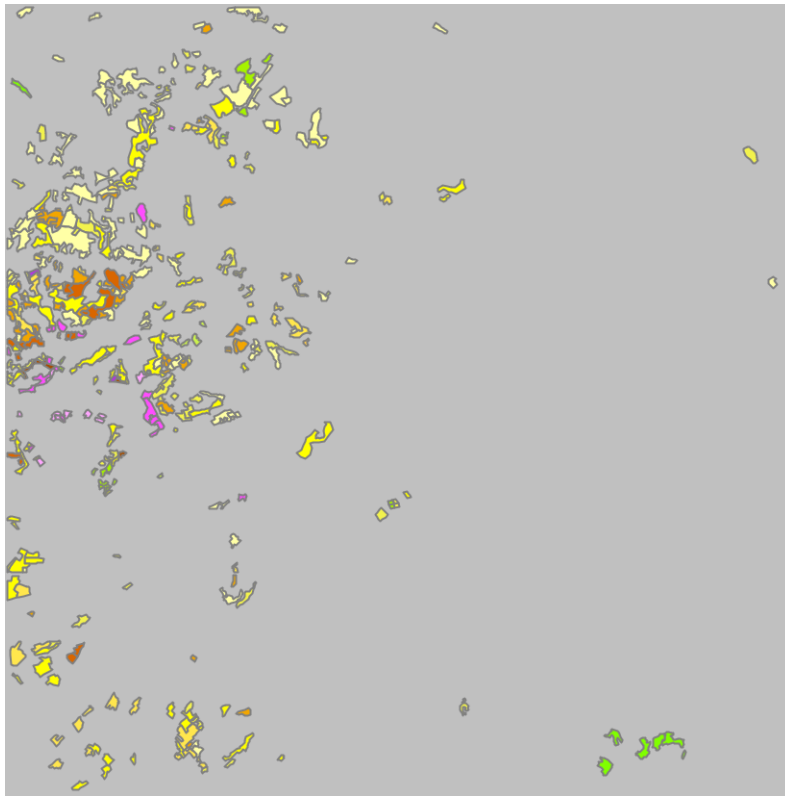
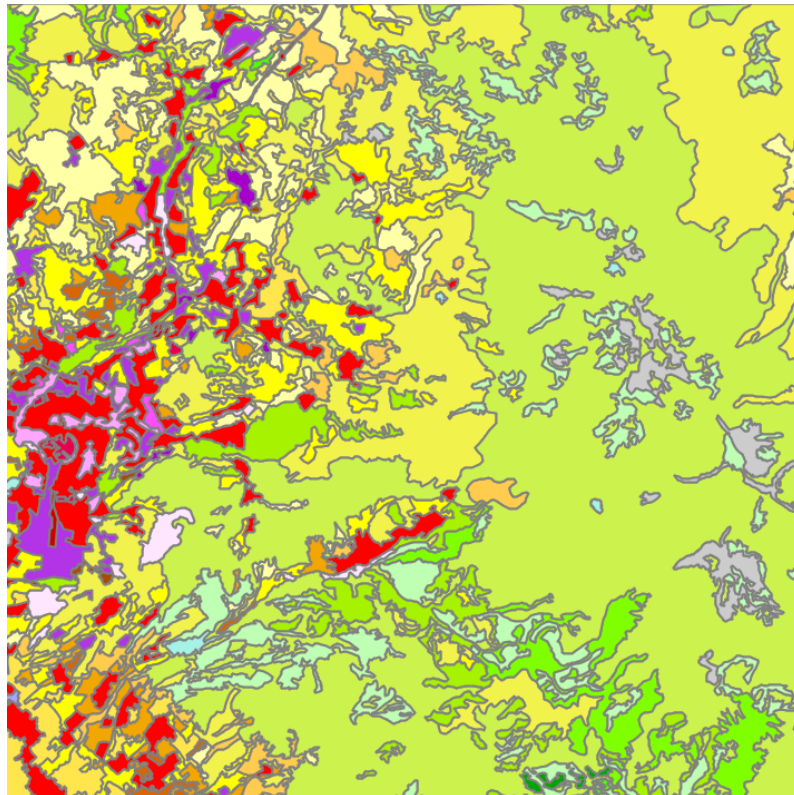**Figure 8-** CLC-change2000-2018

Figure 9- CLC2000 (backdated)

4.3 CLC2000

As it was mentioned previously, backdated CLC2000 layer was generated by ETC-ULS, on the basis of already corrected CLC2018 and CLC-change$_{2000\text{-}2018}$ layers. CLC2000 map is shown in **Figure 9**. The detailed table with statistical information about CLC2000 layer can be found in **Table 10**. CLC2000 layer consists of **759** polygons. The total area of the CLC200 layer is **250196 ha.**

Table 10. CLC 2000 statistics

CODE2000	PIECE	AREA	AVERAGE	%
111	4	313	78	0,13
112	73	15898	218	6,35
121	42	4350	104	1,74
122	3	279	93	0,11
124	1	39	39	0,02
131	7	672	96	0,27
132	4	275	69	0,11
133	8	399	50	0,16
141	17	1535	90	0,61
142	12	1806	150	0,72
211	79	14023	178	5,60
212	23	4330	188	1,73
221	14	1295	92	0,52
222	42	3896	93	1,56
231	86	46525	541	18,60
242	106	16732	158	6,69
243	25	4754	190	1,90
311	13	7010	539	2,80
312	4	290	72	0,12
313	4	247	62	0,10
321	26	96468	3710	38,56
324	55	10517	191	4,20
332	18	3918	218	1,57
333	87	14160	163	5,66
411	1	47	47	0,02
512	5	418	84	0,17
		250196		**100**

Table 11 shows 8 main land cover types of the pilot area in 2000.

Table 11. Dominant land cover types in CLC2018

CODE2000	CLC land cover class	%
321	Natural grassland	38.56
231	Pastures	18.60
242	Complex cultivation patterns	6.69
112	Discontinuous urban fabric	6.35
333	Sparsely vegetated areas	5.66
211	Non-irrigated arable land	5.60
324	Transitional woodland-shrub	4.20
311	Broad-leaved forest	2,80

While comparing tables 5 and 10, it become clear that there is some increase in 222 class area (fruit trees and berry plantations)- as in 2000 the area of 222 was 3896 ha (1.56%) and in 2018 it became 5130 ha (2.05%). The same situation is noted for 231 class (pastures)- in 2000 the area of pastures was 46525 ha (18.6%), and in 2018 the area increased till 48202 ha (19.27%).
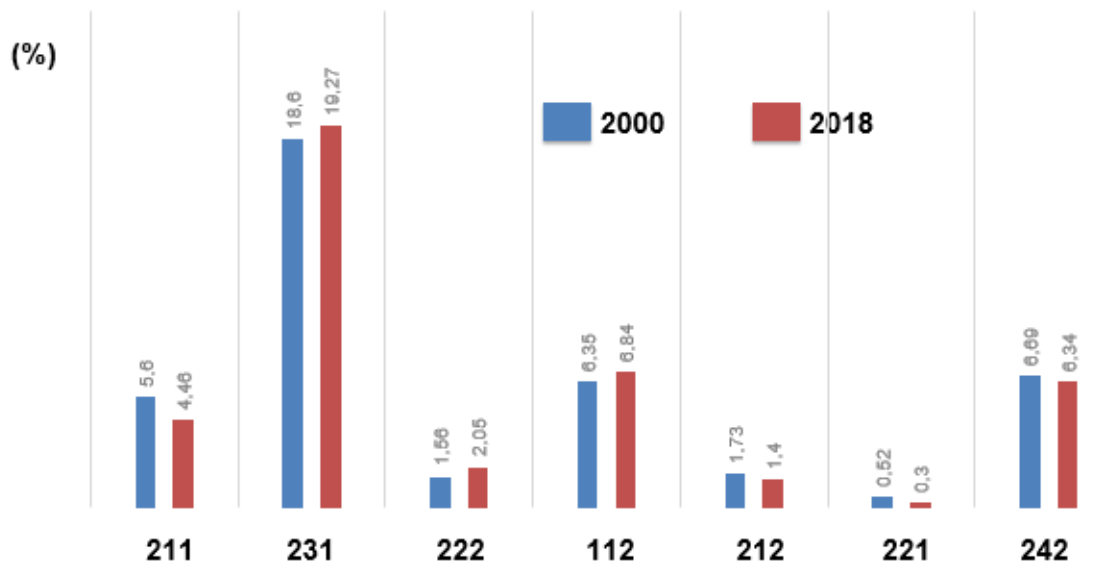

Figure 10- Comparison of dominant changes between 2000 and 2018

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.

- There is some increase in Discontinuous urban fabric (112), Pastures (231) and Fruit trees and berry plantations (222) classes.

- Decreasing trends has been noted in Non-irrigated arable land (211), Permanently irrigated land (212), Vineyards (221) and Complex cultivation patterns (242).

- Road and rail networks and associated land (122), Airports (124), Bare rocks (332), Sparsely vegetated areas (333), Inland marshes (411) and Water bodies (512) classes are stable.

5 Conclusions

CLC2018 and CLC-change layers were derived by visual photo-interpretation of satellite imagery (Sentinel-2, Landsat-7) according to "CLC2018 Technical Guidelines" (10/25/2017) and "Updated CLC illustrated nomenclature guidelines" (09/30/2017).

CLC mapping technology has been learnt; the national technical team is ready to use this knowledge to extend the project for the whole area of the Republic of Armenia.

The European (level-3) CLC nomenclature was easily applicable for Armenia, except the pasture (231) class, which needs more thematic details for national applications.

CLC-changes show the main processes that have taken place over the pilot area.

Taking into account the opportunities and advantages of the program, the national technical team proposes to extend it for the whole area of Armenia.

Deliverables

CLC2018

Format: shapefile, polygon topology

Number of polygons: 743

Area: 250197 ha

Dominant land cover types over the pilot area:

1. Artificial surfaces: 112, **Discontinuous urban fabric** (6.84% of total area)
2. Agriculture area: 231, **Pastures** (19.27% of total area)
3. Forests and seminatural area: 321, **Natural grasslands** (38,52% of total area)
4. Wetland (only a single class): 411, **Inland marshes** (0.02% of total area)
5. Water (only a single class): 512, **Water bodies** (0.17% of total area)

27 of the 44 CLC classes are present in the pilot area.

CLC-change_{2000-2018}

Format: shapefile, polygon topology

Number of polygons: 437

Area: 12362 ha

Dominant change of the pilot area (2000-2018): 242-231 - Complex cultivation patterns turned to pasture (12.47%, 6993 ha). The reason for that major change was the abandonment of arable lands during the years of economic and energy crisis (1990s) in Armenia.
88 different change types have been mapped covering **4.94 %** of the total pilot area.

Backdated CLC2000 layer

Format: shapefile, polygon topology

Number of polygons: 759

Area: 250197 ha

26 of the 44 CLC classes were present in the pilot area.

References

1. Büttner G., Kosztra B. "CLC2018 Technical Guidelines", 10/25/2017

2. Kosztra B., Büttner, G., Hazeu, G, Arnold, S. "Updated CLC illustrated nomenclature guidelines", 09/30/2017 (updated by Büttner G., Kosztra B., 10/05/2019).

3. Kosztra, B. 2020. CLC2018 first verification report, Armenia ETC-ULS report, 21-22.04.2020, Budapest

4. Kosztra, B. CLC2018 second verification report, Armenia ETC-ULS report, 04-05.06.2020, Budapest