

## Ministry of Energy and Environmental Protection of Ukraine

EU-funded regional project “Implementation of the Shared Environmental Information System principles and practices in the Eastern Partnership countries” (the ENI SEIS II East Project).

Activity 2.3 of the ENI SEIS II East Description of Action “Pilots on extending CORINE Land Cover (CLC) methodology to areas of the partner countries”

### Report

on the results of application of CORINE Land Cover (CLC) methodology  
on pilot area in Ukraine for 2019

#### Task executed by:

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Agroresurssystemy

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## 1. Background

Cooperation between the European Environment Agency (EEA) and the six Eastern Partnership countries (Armenia, Azerbaijan, Belarus, Georgia, Republic of Moldova and Ukraine) is established through the EU-funded regional project “Implementation of the Shared Environmental Information System principles and practices in the Eastern Partnership countries” (the ENI SEIS II East Project). The period of implementation of the ENI SEIS II East project is 48 months, 1 February 2016 - 31 January 2020.

Coordination of country-level activities is ensured by two formally appointed National Focal Points (NFPs), from the Ministry of Ecology and Natural Resources and the State Statistics Service in the case of Ukraine.

Activity 2.3 of the ENI SEIS II East Description of Action “Pilots on extending CORINE Land Cover (CLC) methodology to areas of the partner countries” is a step to facilitate the access to, and use of, some spatial data required for SEIS implementation at national level. This activity also allows direct links to related initiatives and programmes at the European level; namely the on-going work to produce the 2018 update of the CLC layers in the EEA39 countries, and services provided through the Copernicus Programme (activities are to be implemented in close dialogue and cooperation with the Copernicus activities led by the EEA).

The Ministry of Ecology and Natural Resources of Ukraine (MENR) does not currently have remote sensing experts, needed for some of the tasks under the CLC activity. For these services in remote sensing, MENR relies on the National University of Life and Environmental Sciences of Ukraine and Agrosurssystemy enterprise – the institutions selected during the feasibility visit.

## 2. Databases used in the project

### 2.1. IMAGE2018

The used data from Sentinel-2 satellites: 03 May 2017, 20 July 2017, 8 October 2017, 08 April 2018, 02 June 2018. Good quality cloud-free multi-temporal imagery. Full coverage for all scenes.

### 2.2. IMAGE2005

The used data from Landsat-5 TM satellites: 10 Apr 2005, 31 July 2005, 03 May 2005, 08 & 25 Sept 2005. July good quality cloud-free, April slightly hazy, May and 08 Sept partial coverage, 25 Sept striped, not usable.

### 2.3. Reference (in-situ) data

Reference data included topographic map of Ukraine scale 1:50000, time series images on Google Earth App and local geo-tagged photos.

### 3. Organization of the work at national level

#### 3.1. Milestones

All work consists of the following successive stages:

- 1) Selection of the image and its date to create the status layer, discussion of its characteristics with the European topic centre experts, creation of a composite image for decryption;
- 2) Decryption of an image and creation of a status layer, joint work of the photo interpreter with other experts for unambiguous selection of classes;
- 3) Checking the status layer and elimination of the errors, transferring it to ETC experts for external verification;
- 4) Selection of the image and its date to create the CLC-change layer discussing its characteristics with European topic centre experts creation of a composite image for decrypting;
- 5) Revision of the status layer based on verification and creation of the CLC-change layer;
- 6) Check for errors and transfer of CLC-change layer to the ETC experts for verification;
- 7) Creation of the final version of status layer and CLC-Change layer based on verification
- 8) Creation of a status layer of the past period;
- 9) Writing a report on the performed work.

The key dates for work

Table 1

1	Mapping the CLC status layer for the pilot area;	15.07. 2019
2	Mapping the CLC-change layer for the pilot area	15.09. 2019
3	Generating the backdated status layer for the pilot area;	15.10. 2019
4	A report about the process	30.11. 2019

### 3.2. CLC training

There were 2 training activities during the project:

- 1) 25 - 27 September 2018 – experts György BÜTTNER, Stefan KLEESCHULTE, Christopher PHILIPSEN together with Ukrainian National Team members agreed the area in the West and South suburbs of the capital as the pilot area. Time series of high-resolution satellite images taken by the ESA Sentinel-2 satellite in 2017 and 2018 chosen by the NT was made available for the project to cover the pilot area (called as IMAGE2018). The satellite images were optimized (pre-processed) for photointerpretation by ETC-ULS partner BFKH. InterChange software was adapted to map the CLC Pilot area and the InterChange project file was prepared to be demonstrated during the training programme and offered to implement the mapping exercise. A SEIS National Assistant in Ukraine facilitated logistical support to organise the training.
- 2) 17 - 19 September 2019 – experts György BÜTTNER, Barbara KOSZTRA together with Ukrainian National Team members discussed the deliverables after 1 training session: multi-seasonal set of Landsat TM satellite images taken in the past (2004-2005, and referred to as IMAGE2005), has been provided by the NT to support mapping CLC changes over a 13-year long period; the first draft of the CLC status layer (CLC2018) has been produced by NT and sent for remote verification to ETC-ULS in July 2019.  
The ENI/CLC National Team in Ukraine prepared to implement the 2nd phase of the CLC pilot project. This included the following major steps:
  - photointerpretation: revision of the status layer (CLC2018) and mapping the layer of CLC-Changes (between 2005 and 2018);
  - GIS-based generation of backdated CLC2005;
  - writing a Technical Report.

## 3.3. Participating experts

Table 2

<b>Name</b>	<b>Organization</b>	<b>Position in project</b>
Dmytro Bulyka	Ministry of Energy and Environmental Protection <sup>1</sup>	project_manager, National Team (NT)
Sergiy Zibtsev	National University of Life and Environmental Sciences of Ukraine	member of NT, forestry expert
Iryna Melnyk	Agroresurssystems LLC	member of NT, GIS expert
Iryna Zibtseva	National University of Life and Environmental Sciences of Ukraine	photo interpreter
Oleksii Petrov	Agroresurssystems LLC	remote sensing expert, quality control

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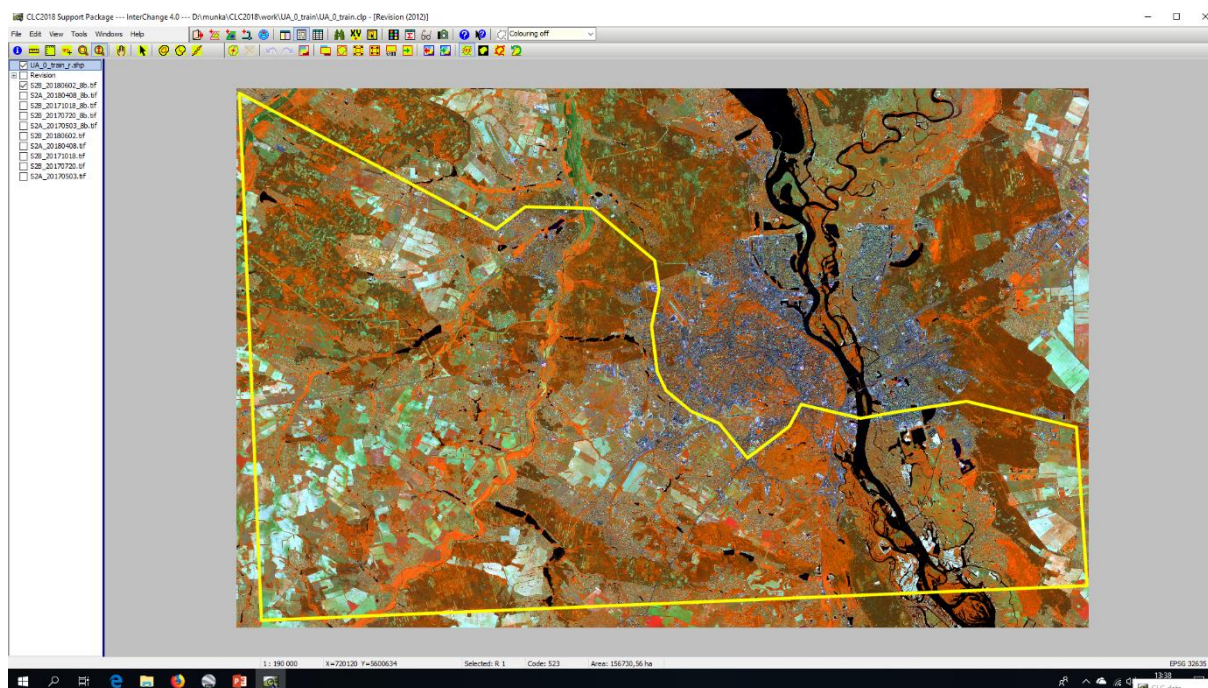
<sup>1</sup> New name of the former Ministry of Ecology and Natural Resources of Ukraine

### 3.4. Processing methodology, software

#### 3.4.1. Methodology of mapping

Mapping methodology based on main principals of Corine Land Cover project. The methodology is in conformity with the Technical Guidelines issued by the ETC.

The territory of pilot area chosen, because of predicted many changes over the period. (Figure1).



**Figure 1:** Sentinel-2 satellite image taken in June 2018 covering the region of Kiev. The pilot area selected by the Ukrainian National Team is overlaid in yellow

The methodology consists of the following main steps:

- Preparing databases to support mapping CLC2018;
- Producing seamless CLC2018 layer;
- Pilot area quality control with feedback to interpreters;
- Preparing databases to support mapping CLC2005;
- Delineation of land cover changes between 2018 and 2005, using satellite images and ancillary data in pilot area;
- Correction (revision) of CLC2018 in pilot area;
- Producing backdated seamless CLC2005 by means of semiautomatic generalisation;
- Final quality control of deliverables: CLC-Changes, CLC2005, CLC2018.

#### 3.4.2. Photointerpretation

Like in many other participating countries, National team used InterChange CLC Support Package (V4.0.5.3) for creation and revision of CLC2018 and CLC2005 and mapping of changes.



InterChange software (module of the CLC2018 Support Package) has been designed to support the CLC2018 project of the EEA, which included revision of CLC2012 and mapping of CLC changes between 2012 and 2018. The software has been modified to support mapping changes between any two years (not just 2012 and 2018) and provide possibility for backward mapping in time (i.e. starting with mapping a recent status layer and mapping changes back in time). In addition, ArcGIS Desktop software were used for quality control and semiautomatic generalization.

According to the European methodology, all changes larger than 5 ha have been delineated, not depending on their location and 25 ha areas were delineated in core layers.

#### 3.4.3. Field checking

For field checking NT used backdated images from Google Earth App and aerial orthophotos, also some geotagged photos were useful while delineation.

#### 3.4.4. Generating the CLC2005 database

Having the CLC-Change database completed, CLC2005 is generated in a semi-automated process:

CLC2005 = CLC2018revised (-) CLC-Change2018-2005

Where CLC2005 means the CLC database for 2005 (MMU=25 ha, width of linear elements=100 m);

CLC2018 revised means the controlled / revised CLC2018 database (MMU=25 ha, width of linear elements=100 m);

CLC-Change2018-2005 means the CLC changes between 2018 and 2005, delineated by the mapping process (MMU=5 ha, width of linear elements=100 m);

(-) means an operation having GIS components and photointerpretation components.

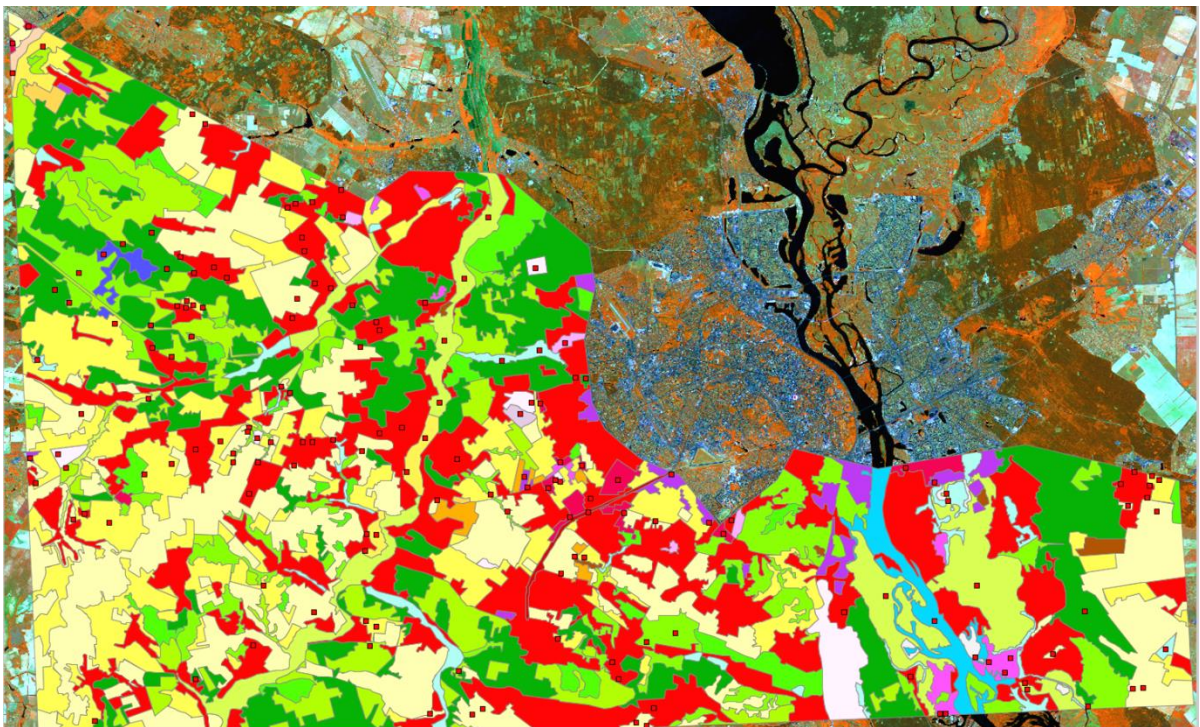
The automated component was implemented in an ArcGIS Add-on by ETC. The programme integrates the CLC2018revised and CLC-Change2018-2005 databases, then the small (<25 ha) polygons are generalised according to a priority table. As an option polygons “almost” reaching the 25 ha limit (e.g. larger than 23.5 ha) can be generalised by a photo interpreter, as was the method in Ukraine too.

### 3.5. Internal quality control, results

The revised CLC2018 and CLC-Change (2018-2005) databases were 100% quality controlled by the leading photo-interpreter. In case mistakes had been discovered, the interpretation with written comments on polygon level was sent back to the interpreter for correction.

### 3.6. External quality control (verification), results

The CLC Technical Team of the ETC verified the results of the photo-interpretation, the revised CLC2018 and CLC-Change databases. The results of mapping CLC2018 over the pilot area (Figure 2) was acceptable for continuation of work with mapping CLC change. The overall evaluation was well mapped in general, however, thematic detail of the interpretation is not sufficient. Non-relevant CLC classes found: 111 (continuous urban fabric), 212 (permanently irrigated arable land) and 244 (agroforestry). Especially the following improvements are expected: reclassify 111 (continuous urban fabric); provide more detail to 112 polygons (discontinuous urban fabric) by excluding non-built-up areas; improve agriculture classes by better separating 211 (non-irrigated arable land), pasture (231) and fruit trees (222) classes and applying the mixed agriculture classes (242, 243). Reclassify permanently irrigated arable land (212) and agroforestry (244) polygons. Reduce the coverage of the 321 class (natural grassland) by excluding areas with strong human influence.



**Figure 2** Draft CLC2018 map of the pilot area submitted for 1<sup>st</sup> verification by the Ukrainian National Team

According to the verification report, pilot's area delineation was accepted. Some remarks were given on technical quality during the 1st verification mission, and some other remarks were given concerning specific and systematic thematic mistakes (misinterpretation). CLC2018 subsequently re-checked and both specific and systematic mistakes were corrected.

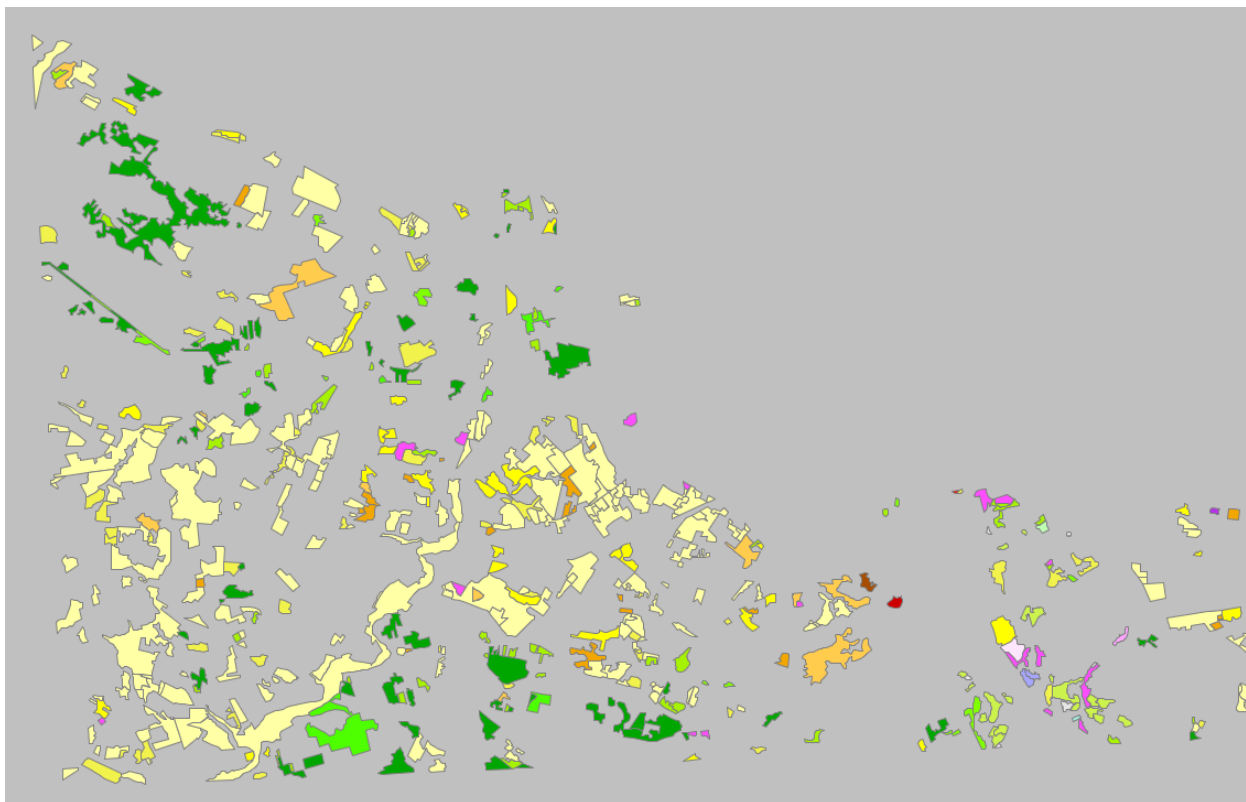
### 3.7. Main difficulties and their solutions

The main difficulty was that it was the first experience of NT in preparing CLC layers. Also NT had lack of fresh orthophotos over the territory of Ukraine, nevertheless it could be solved with more extensive implementation of CLC methodology in National plans of the Government's institutions.

## 4. Results

### 4.1. CLC-changes

The map of CLC-changes (2018-2005) is shown on Figure 3. Altogether 523 CLC change polygons, representing 92 different change types were delineated. 18.82 percent of total area of the pilot area changed between 2005 and 2018.



**Figure 3** CLC-changes (2018-2005) map of pilot area

Based on detailed CLC change statistics, table including exits, entries and their balance, and dynamics for each class have been produced (Table 6). This summarizes the evolution of land cover in Ukraine between 2005 and 2018.

**Table 3** CLC-changes between 2005 and 2018

Table 3

CODE 2005	CODE 2018	PIECES	AREA	% of total changes	R
211	112	31	1187	3.98	1
231	112	15	306	1.03	1
133	112	12	369	1.24	1
142	112	2	96	0.32	1
312	112	7	154	0.52	1
242	112	19	1009	3.38	1
243	112	1	73	0.24	1
222	112	4	94	0.31	1
141	112	1	27	0.09	1
512	112	1	9	0.03	2

CODE 2005	CODE 2018	PIECES	AREA	% of total changes	R
321	112	2	59	0.20	1
311	112	5	57	0.19	1
324	112	3	59	0.20	1
222	121	2	51	0.17	1
231	121	2	48	0.16	1
211	121	11	220	0.74	1
133	121	3	79	0.26	1
324	121	5	67	0.22	1
122	121	1	38	0.13	1
243	121	1	26	0.09	1
242	121	1	8	0.03	1
211	132	2	43	0.14	1
333	132	1	26	0.09	1
324	132	1	18	0.06	1
231	132	1	6	0.02	1
321	133	3	111	0.37	1
324	133	3	64	0.21	1
231	133	6	166	0.56	1
211	133	14	299	1.00	1
311	133	2	17	0.06	1
242	133	2	40	0.13	1
331	133	1	24	0.08	1
112	133	1	5	0.02	1
312	133	1	7	0.02	1
231	142	4	91	0.30	1
313	142	1	24	0.08	1
211	142	5	227	0.76	1
321	142	2	23	0.08	1
311	142	1	59	0.20	1
222	211	1	9	0.03	1
231	211	1	10	0.03	1
231	222	1	56	0.19	1
121	222	1	13	0.04	1
211	231	100	10506	35.20	1
242	231	11	406	1.36	1
222	231	6	187	0.63	1
324	231	1	10	0.03	1
243	231	3	973	3.26	1
312	231	1	18	0.06	1
211	242	20	1102	3.69	1
231	242	3	320	1.07	1
222	242	3	132	0.44	1
321	242	1	35	0.12	1
231	243	1	124	0.42	1
242	243	3	136	0.46	1

CODE 2005	CODE 2018	PIECES	AREA	% of total changes	R
211	243	2	62	0.21	1
321	243	1	71	0.24	1
324	243	1	67	0.22	1
132	311	1	47	0.16	1
324	311	17	328	1.10	1
321	311	1	30	0.10	1
211	311	2	20	0.07	1
231	311	2	88	0.29	1
312	311	3	94	0.31	1
324	312	10	165	0.55	1
231	312	3	78	0.26	1
312	313	5	556	1.86	1
324	313	4	104	0.35	1
211	321	5	1758	5.89	1
324	321	1	75	0.25	1
231	321	2	90	0.30	1
242	321	1	59	0.20	1
331	321	1	6	0.02	1
311	321	1	35	0.12	1
211	324	16	697	2.34	1
222	324	4	122	0.41	1
411	324	1	23	0.08	1
133	324	2	45	0.15	2
312	324	49	3623	12.14	1
231	324	18	675	2.26	1
243	324	5	288	0.96	1
331	324	1	5	0.02	1
311	324	5	148	0.50	1
313	324	7	732	2.45	1
242	324	1	76	0.25	1
411	331	1	34	0.11	3
324	331	1	27	0.09	1
321	331	7	222	0.74	1
243	411	1	8	0.03	1
231	512	1	44	0.15	1
331	512	2	12	0.04	1
321	512	1	11	0.04	1

Table shows that two counteracting land cover change pairs provide almost half of all land cover changes in Ukraine, namely the restoration of arable lands and growth of coniferous forests.

Considering all 25 possible level-1 changes (including internal changes) three change types provide more than 90 % of all changes:

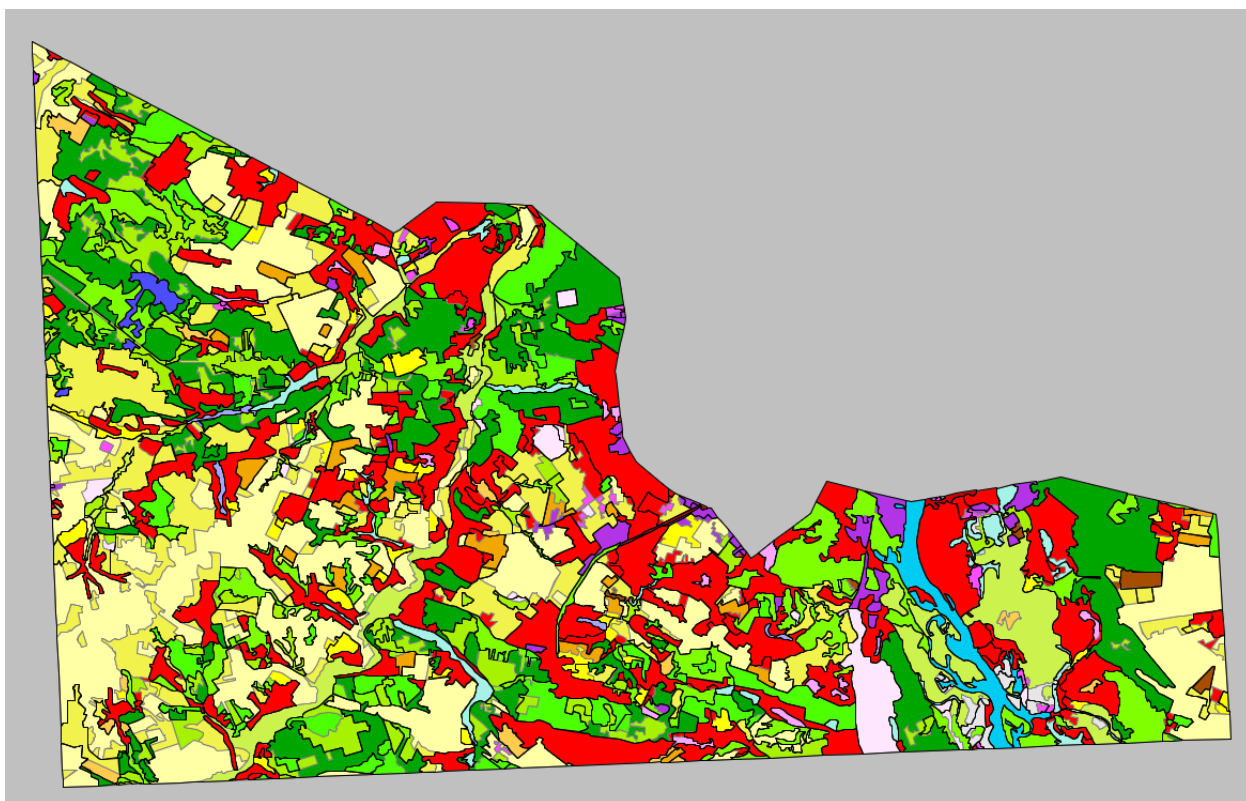
- internal changes between semi-natural classes;
- internal changes between agriculture classes;
- increase of the area of semi-natural classes at the expense of agricultural classes.

Seven additional level-1 changes (together with the three largest ones) provide 99% of all changes:

- loss of agricultural land to artificial surfaces;
- conversion of semi-natural areas to agricultural land;
- conversion of wetlands to water;
- new wetlands on former agricultural land ;
- conversion of semi-natural areas to wetlands.

#### 4.2. CLC2018

The CLC2018 map of the project area is presented on Figure 9. The associated statistics are shown in Table 9. Discontinuous urban fabric (112) is the largest category (21.5 % of total area), followed by arable lands (18.02%) and coniferous forests (14.16 %). Pastures include the largest number of polygons (109), followed by Discontinuous urban fabric (104) and coniferous forests (87).



**Figure 4** CLC2005 map of Ukraine Pilot

**Table 4** CLC2018 statistics

Table 4

code	No of polygons	Area ha	%
112	104	34189	21.56055
121	25	2097	1.322428
122	2	156	0.098378
132	6	453	0.285675
133	19	666	0.419998
141	15	734	0.462881
142	12	2279	1.437202



211	68	28576	18.02084
222	23	2424	1.528643
231	109	17077	10.76924
242	40	3064	1.932245
243	16	1131	0.713241
311	75	11453	7.222587
312	87	22454	14.16013
313	50	8328	5.251873
321	18	7402	4.667911
324	73	10144	6.397094
331	7	725	0.457206
333	1	31	0.019549
411	5	310	0.195495
412	3	479	0.302071
511	2	2041	1.287112
512	28	2359	1.487652
<b>Sum</b>	<b>788</b>	<b>158572</b>	<b>100</b>

### 4.3. Backdated CLC2005

Table 5 shows comparison of CLC 2005 and CLC 2018

Table 5

CODE2005	PIECE	AREA	AVERAGE	CODE2018	PIECE2	AREA3	AVERA	area 2018-2015	% chang	remark
112	101	30502	302	112	104	34189	329	3687	12.1%	
121	19	1619	85	121	25	2097	84	478	29.5%	
122	3	194	65	122	2	156	78	-38	-19.6%	see 122(2005)-121(2018) change
132	4	396	99	132	6	453	75	57	14.4%	
133	14	522	37	133	19	666	35	144	27.6%	
141	15	795	53	141	15	734	49	-61	-7.7%	
142	8	1960	245	142	12	2279	190	319	16.3%	
211	51	45170	886	211	68	28576	420	-16594	-36.7%	
222	23	2925	127	222	23	2424	105	-501	-17.1%	
231	64	6812	106	231	109	17077	157	10265	150.7%	
242	46	3239	70	242	40	3064	77	-175	-5.4%	
243	17	1986	117	243	16	1131	71	-855	-43.1%	
311	67	11141	166	311	75	11453	153	312	2.8%	
312	65	26989	415	312	87	22454	258	-4535	-16.8%	
313	48	8366	174	313	50	8328	167	-38	-0.5%	
321	12	5942	495	321	18	7402	411	1460	24.6%	
324	54	4430	82	324	73	10144	139	5714	129.0%	
331	5	369	74	331	7	725	104	356	96.5%	
333	2	51	26	333	1	31	31	-20	-39.2%	
411	6	359	60	411	5	310	62	-49	-13.6%	
412	3	479	160	412	3	479	160	0	0.0%	
511	2	2043	1022	511	2	2041	1020	-2	-0.1%	
512	27	2285	85	512	28	2359	84	74	3.2%	
	<b>656</b>	<b>158574</b>			<b>788</b>	<b>158572</b>				
								<b>-2</b>	<b>rounding up</b>	

Comparing % changes of class areas, the largest increase is observed in Pastures class (231) followed by transitional woodland-shrub (324) and discontinuous urban fabric (112). The largest decrease is observed in arable land class (211), followed by coniferous forests (312). Most dynamic classes are transitional woodland-shrub (324), pastures (231) and arable land (211). On the other end, rivers (511), Road and rail networks and associated land (122) and mixed forests (313) did not show any change.

Considering changes normalised to class areas in revised CLC2018, the two largest relative increases are observed in pastures (231: 150.7 %), followed by transitional woodland-shrub (324: 129%).

## 5. Deliverables

After pilot project CLC2018, CLC2005 and Change layers were done. In addition, interactive map with two status layers were published in Internet. National team learned a lot about CLC Programme and ready to delineate the whole country using this methodology.

## 6. Conclusions

CLC-Changes2018-2005 database was derived by visual comparison of IMAGE2018 and IMAGE2005 based on CLC2018. All changes fulfilling the mapping criteria (> 5 ha, > 100 m boundary displacement) were delineated.

Dominant changes (evolution processes) in pilot area are:

- Agricultural areas have decreased;
- Semi-natural areas have increased;
- Built-up areas have increased;

The CLC2005 database was produced by combining the CLC2018revised and CLC-changes2018-2005 databases in GIS, followed by a semi-automated process to eliminate polygons smaller than 25 ha.

## References

György BÜTTNER, Stefan KLEESCHULTE, Christopher PHILIPSEN CLC Training mission report, ENI SEIS II East Project / Ukraine, 25-27 September 2018.

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