HRL 2018 verification report for Imperviousness change classified 2015-2018 (IMCC1518)

I. Administrative part

HRL IMCC1518	
Verified area, region	Finland
Institution carrying out the work	Finnish Environment Institute (SYKE)
Overall visual checking done by (name, position and e-mail)	Markus Törmä, Senior Research Scientist, markus.torma@syke.fi
Look & feel verification done by (name, position and e-mail)	Markus Törmä, Senior Research Scientist, markus.torma@syke.fi
Statistical verification done by (name, position and e-mail)	Markus Törmä, Senior Research Scientist, markus.torma@syke.fi
In situ data used.	*National Ortho photo database/The National Land Survey* *Natural color/black and white ortho photos* *Spatial resolution: 0.25-0.5m* *Reference years: 2014, 2015, 2016 (partial coverages)*
	National High Resolution Corine Land Cover 2018 (HR CLC2018) *National Corine raster dataset* *Spatial resolution 20x20m* *Reference year: 2018*
	National High Resolution Corine Land Cover changes 2012 – 2018 *National Corine change raster dataset* *Spatial resolution 20m, MMU 0.5 – 1 ha depending on change* *Reference year: 2012 – 2018 (in practice 2017)*
	Topographic Database/The National Land Survey *Raster* *Spatial resolution 1m* *Reference year: 2018*
	The Finnish Land Parcel Information System (FLPIS) *Based on farming subsidy reports* *Vector data* *Reference year: 2018*
	Image2018 VHR Satellite image mosaic *Planet / Pleiades / Spot-6/7* *Spatial resolution: 4m / 2m / 4m* *Reference year: 2018 / 2018 / 2018*
	Image2017 HR Satellite image mosaic *Sentinel-2* *Spatial resolution: 10m*

	Reference year: 2017
	Image2012 HR Satellite image mosaic *IRS P6 LISS, Spot-4, RapidEye* *Spatial resolution: 20m* *Reference year: 2011-2013*
	Image2012 VHR Satellite image mosaic *RapidEye / Spot-5 / Spot-6 2013* *Spatial resolution: 5m / 2.5m / 1.5m* *Reference year: 2012 / 2011-2013 / 2013 (partial cover-ages)*
	Image2006 HR Satellite image mosaic *IRS P6 LISS / Spot-4* *Spatial resolution: 20m* *Reference year: 2005-2007*
Reporting done by (name, position and e-mail)	Markus Törmä, Senior Research Scientist, markus.torma@syke.fi
Date and place of writing the report	24th June, 2021, Helsinki Corrected version 13th July, 2021, Lahti

II. General overview of the verified data

HRL Impervious change classified 2015-2018 (IMCC1518) consists of eight classes; two describing unchanged areas, two for increased impervious area, two for decreased impervious area, unclassified areas and areas outside Finland. Most of the country is covered by unchanged areas (about 98%) consisting of areas of impervious degree 0% (about 33614 km^2, 96%) and areas with impervious degree greater than 0% (about 6410 km^2, 1,8%), the area of increased impervious is about 106 km^2 and decreased about 1 km^2. Unclassified area is about 2%. Table 1 presents the IMCC1518 classes and their areal statistics. Figure 1 shows the HRL IMC1518 areas in Finland.

In order to give some perspective, the built-up area according to the National High Resolution Corine Land Cover 2018 data (20x20m) (later HR CLC18) is 7423 km^2 compared to 6516 km^2 of IMCC. IMCC1518 was compared to the HR CLC changes 2012 – 2018. HR CLC changes has 0.5 – 1 ha minimum mapping unit, smaller MMU for artificial and agricultural areas and larger for seminatural areas. HR CLC changes was recoded to areas of no change, changed area but not involving artificial surfaces (classes CLC11 and CLC12), decreased artificial surfaces and increased artificial surfaces.

Table 2 presents the results, which show that most of the CLC changes have happened in areas where IMCC1518 shows no change of impervious area. Green color shows the areas which are similar in both products. The proportion of changed area to the whole area is very small in both change products. IMCC1518 seems to have more changes, impervious area has increased about 90 km^2 and decreased about 1 km^2. The density of impervious has increased in about 15 km^2 area. The national data shows that artificial surfaces have increased about 30 km^2 and decreased less than 3 km^2 during longer time period of HR CLC changes. Figure 2 presents an example from Oulu city in which IMCC1518 seems to correspond area better than HR CLC changes.

Table1. Overall statistics

HRL IMCC1518 Finland	Value	Km^2	%
Unchanged areas with imperviousness degree of 0	0	333614,4	96,12
New cover - increased imperviousness density, zero IMD at first reference date	1	90,74	0,03
Loss of cover - decreasing imperviousness density, zero IMD at second reference date	2	0,97	>0,01
Unchanged areas, IMD>0 at both reference date	10	6410,3	1,85
Increased imperviousness density, IMD>0 at both reference date	11	15,00	>0,01
Decreased imperviousness density, IMD>0 at both reference date	12	0	0
Unclassifiable in any of parent status layers	254	6962,27	2,01
Outside area	255	-	-
SUM (Non-IMCC & IMCC)		347093,7	**100,00 %**
Total changed surface[1]		**106,7**	**0,03 %**

[1] The areas are calculated as the arithmetical product of the number of pixels of class and the area of the pixel.

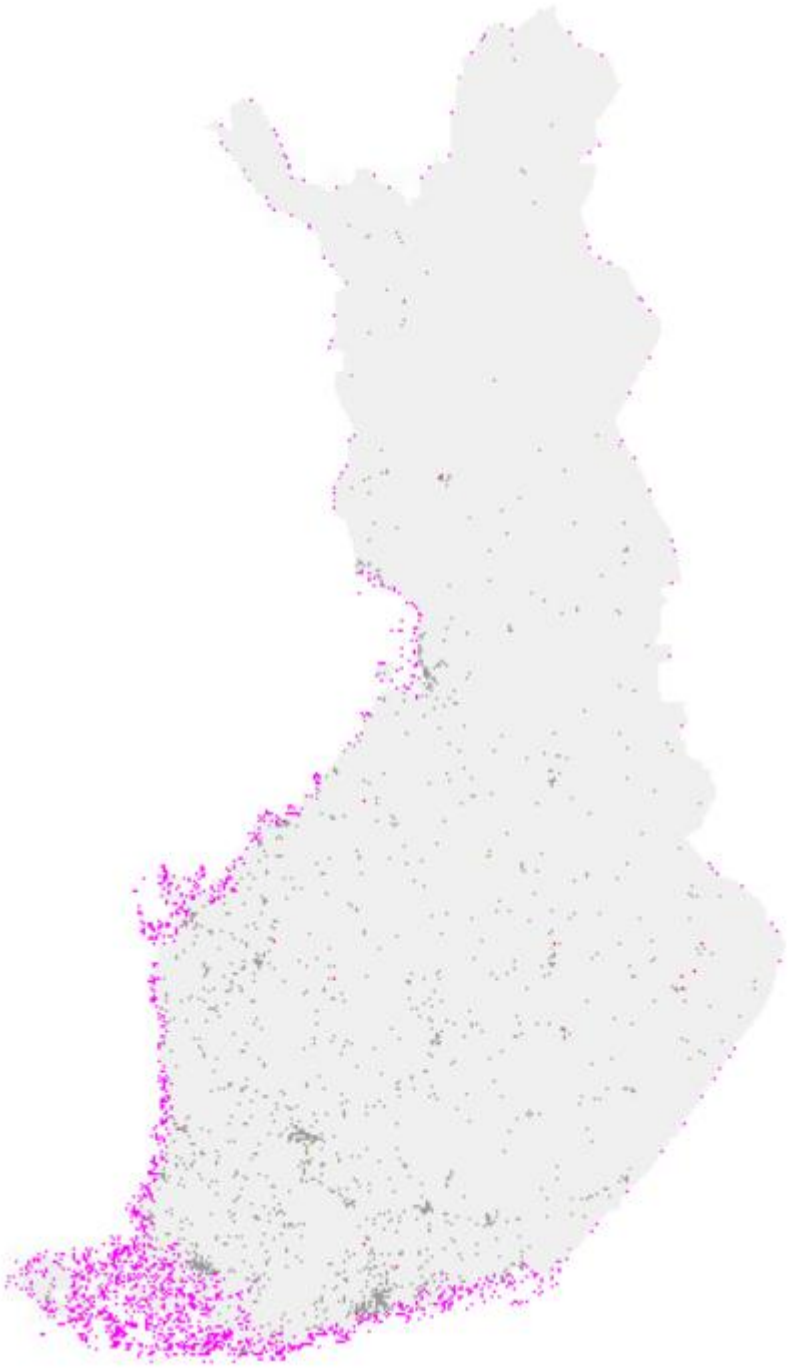

Figure 1. Overview map. Unchanged classes 0 (light grey) and 10 (grey), and Unclassified areas (purple) are the largest areas, changed areas are so small that they are not visible in the overview map.

It should be noted that the time periods of the two change products are not the same, for IMCC this is 2015 – 2018 and for HR CLC changes 2012 – 2017 in practice because the end of the period describes the situation at the start of the year 2018. Also, the definitions of artificial CLC-classes do not directly correspond to impervious areas and these CLC-classes can have also other areas than impervious surfaces like vegetation.

Table 2. Comparison of IMCC1518 changes to HR CLC changes 2012 – 2018.

IMCC1518	No CLC-change (km^2)	CLC-change, no artificial surface (km^2)	CLC-change, artificial surface decreases (km^2)	CLC-change, artificial surface increases (km^2)	SUM
Unchanged areas with imperviousness degree of 0	322808,0	10521,8	1,38	7,74	333338,9
New cover - increased imperviousness density, zero IMD at first reference date	73,8	15,5	0,10	1,34	90,7
Loss of cover - decreasing imperviousness density, zero IMD at second reference date	0,95	>0,01	>0,01	0,01	0,98
Unchanged areas, IMD>0 at both reference date	6333,3	54,7	1,11	20,8	6409,9
Increased imperviousness density, IMD>0 at both reference date	14,1	0,71	0,01	0,15	15,0
SUM	329230,1	10592,7	2,59	30,0	

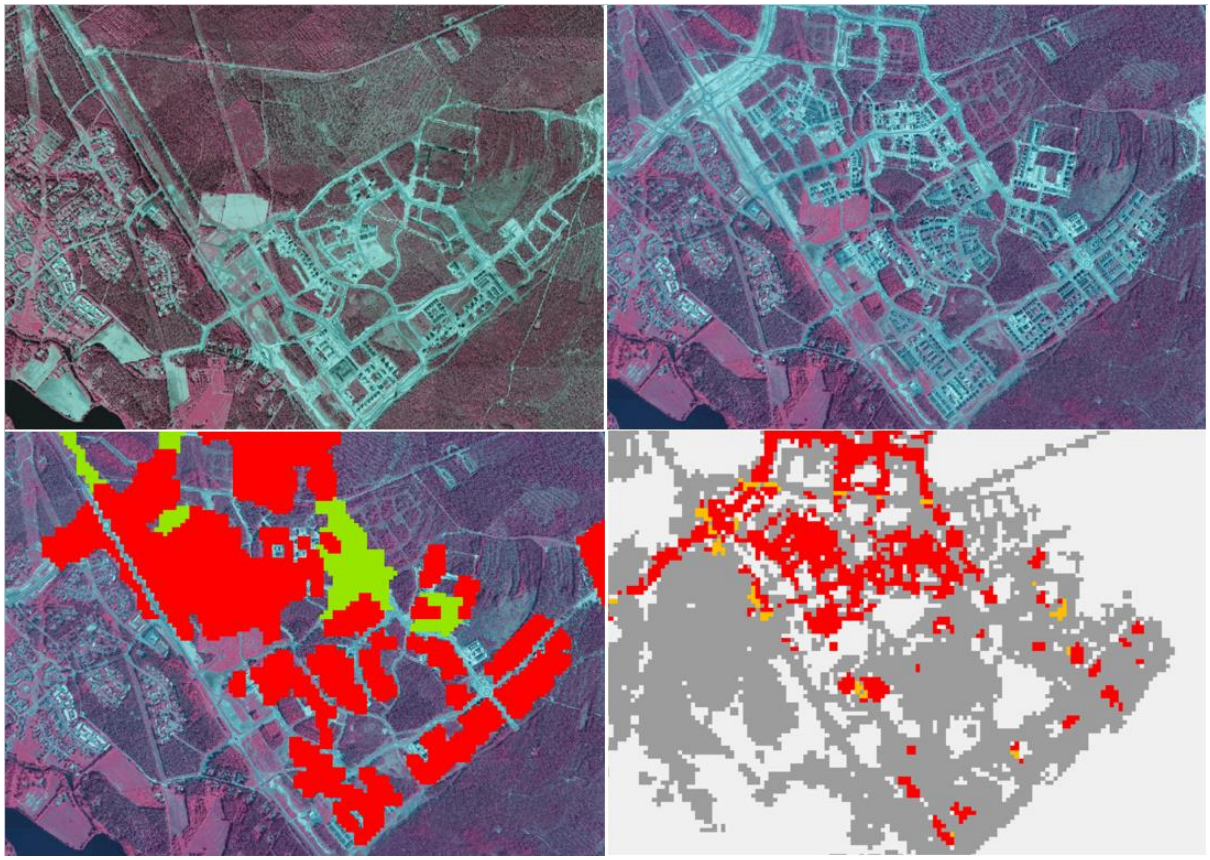

Figure 2. Top left: Aerial image 2014 of National Land Survey. Top right: Aerial image 2017 of National Land Survey. Bottom left: HR CLC changes, red increased artificial surfaces, light green forest clear-cut. Bottom right: IMCC1518, white no impervious, grey impervious has not changed, red new impervious cover, orange impervious cover has increased. Area: Oulu city / Hiukkavaara. Orthophoto (MML/WMTS 06/2021).

III. Overall visual checking

Positional accuracy			
Relative positional accuracy	Quick visual comparison of HRL data with available EO imagery (identifying large positional errors)	OK	Large positional errors were not detected in the data.
Thematic accuracy			
Classification correctness	Simple look & feel thematic check (identifying basic thematic mistakes)	Mostly OK	The quick visual comparison of the HRL IMCC1518 data with national ortophoto images indicate that the HRL IMCC1518 represents the changes of impervious areas quite well. There are some difficulties with bare areas like sand, rocks, non-vegetated agricultural fields.

IV. Look & feel verification results

Look & feel verification was done for classes

- IMCC class 1: New impervious cover, meaning increased imperviousness density, zero IMD at the first reference date.
- IMCC class 2: Loss of impervious cover, meaning decreasing imperviousness density, zero IMD at the second reference date.

In both cases, contiguous areas were formed from IMCC1518 raster by vectorizing data to polygons, resulting 40205 polygons for class 1 and 1500 for class 2. This was done using Erdas Imagine. Polygons were sorted from the largest to smallest and the 100 largest were studied in look & feel verification. The later part was done using ArcMap. The largest area of class 1 polygons was 232 ha, the smallest 5 ha and the mean was 12,8 ha. The largest area of class 2 polygons was 1,8 ha, the smallest 0,14 ha and the mean was 0,3 ha.

V. Documentation of errors and critical findings

IMCC class 1 was interpreted reasonably well, NRL_NOTE was 3 or more for 58 polygons, 2 for 10 polygons and 1 for 32 polygons. The mean HRL_NOTE was 2,56. Figure 3 presents one change area which is mapped well, industrial building has been built on forest clear-cut. Change areas with HRL_NOTE 2 are typically areas that have changes, but polygons have considerable unchanged areas (Figure 4), or areas of change have been omitted (Figure 5). Change areas with HRL_NOTE 1 are mostly no change areas like wood storage area in Figure 6 or change do not belong to impervious like forest clear-cut in Figure 7. About half of polygons with NRL_NOTE 1 were industrial and/or storage areas mostly concerned with wood industry, then construction areas where construction seems to have ended 2015 and areas where there was no sign of change according to reference material.

Figure 3. Well mapped change, new industrial building with its associated parking areas. Aerial image 2014 on the left and 2016 on the right. SAMPLE_ID 1078, coordinates ETRS_1989_LAEA N: 4279973, E: 4944288, size of polygon 9,4 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

Figure 4. Change area has partly buildings and roads under construction, partly buildings that have been made before year 2015. Aerial image 2015 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 1055, coordinates ETRS_1989_LAEA N: 4527381, E: 5214943, size of polygon 7,0 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

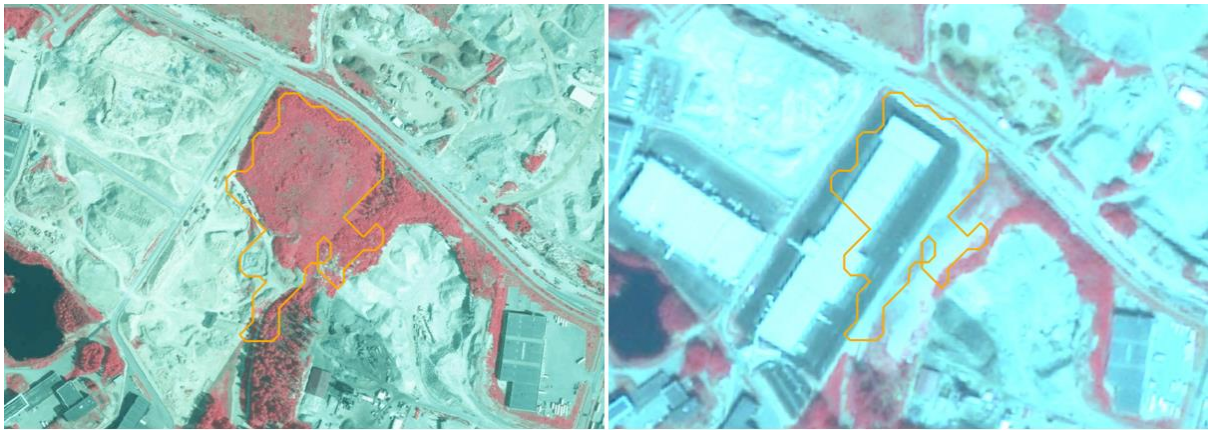

Figure 5. New industrial building construction. The change polygon omits part of the building. Aerial image 2015 on the left, Spot image of Image2018 VHR on the right. SAMPLE_ID 1095, coordinates ETRS_1989_LAEA N: 4220434, E: 5139728, size of polygon 11,4 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

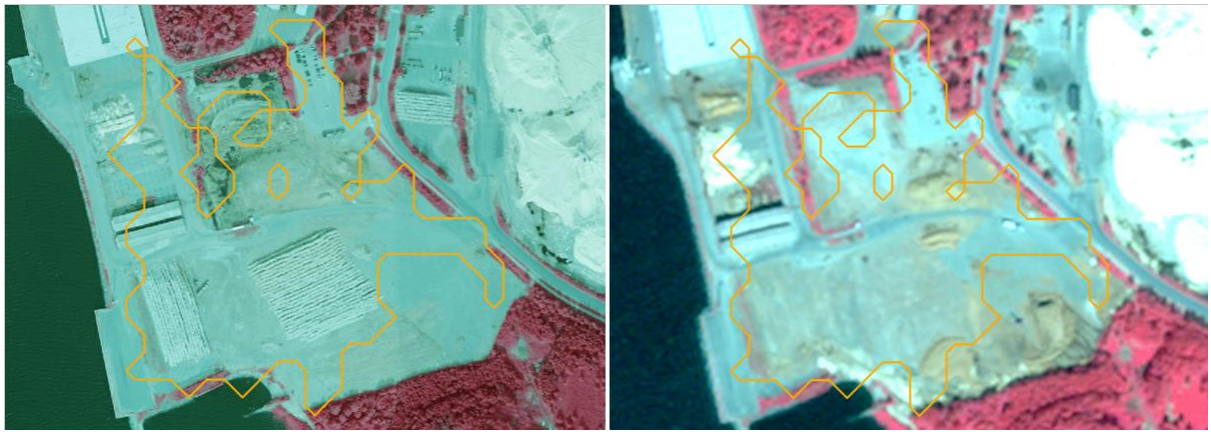

Figure 6. Wood storage area of Veitsiluoto paper mill, no change. Aerial image 2015 on the left, Pleiades image of Image2018 VHR on the right. SAMPLE_ID 1014, coordinates ETRS_1989_LAEA N: 4801617, E: 4992366, size of polygon 9,1 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

Figure 7. Forest clear-cut, possibly for building construction or agricultural use but there are no clear signs of construction or agriculture. Aerial image 2014 on the left, Pleiades image of Image2018 VHR on the right. SAMPLE_ID 1017, coordinates ETRS_1989_LAEA N: 4744708, E: 5042891, size of polygon 7,3 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

IMCC class 2 was interpreted badly, NRL_NOTE was 3 for 4 polygons, 2 for 1 polygon and 1 for 95 polygons. The mean HRL_NOTE was 1,09. On the other hand, these kinds of changes are very rare in Finland. There were two cases of road construction (removal of temporary road), one case of bridge removal (Figure 8) and one change in green house area. Typical errors of IMCC class 2 are cases where there are no impervious surface at year 2015, these can be areas like agricultural areas (21% from studied cases, Figure 9), water or shore areas (20%, Figure 10), sand pits (12%, Figure 11), land fills (6%, Figure 12) or quarries or storage areas.

Figure 8. Removal of road bridge. Low HRL_NOTE 3 is due to poor delineation of changed area. Aerial image 2014 on the left, Pleiades image of Image2018 VHR on the right. SAMPLE_ID 2002, coordinates ETRS_1989_LAEA N: 4998251, E: 4958677, size of polygon 0,2 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

Figure 9. Agricultural area that has been classified to IMCC class 2: Loss of impervious surface. Aerial image 2014 on the left, Pleiades image of Image2018 VHR on the right. SAMPLE_ID 2024, coordinates ETRS_1989_LAEA N: 4491818, E: 4933726, size of polygon 0,7 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

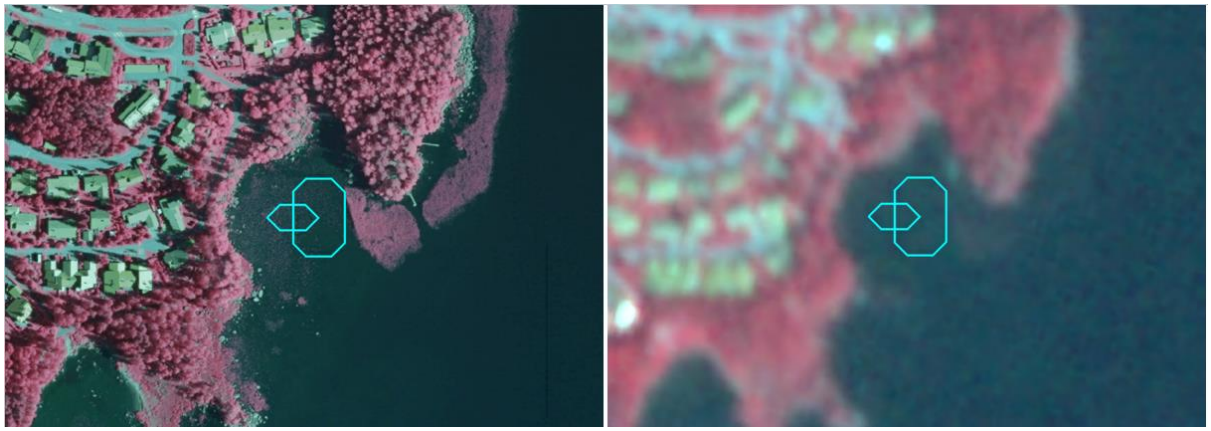

Figure 10. Water area that has been classified to IMCC class 2: Loss of impervious surface. Aerial image 2014 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 2056, coordinates ETRS_1989_LAEA N: 4436847, E: 5137858, size of polygon 0,2 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

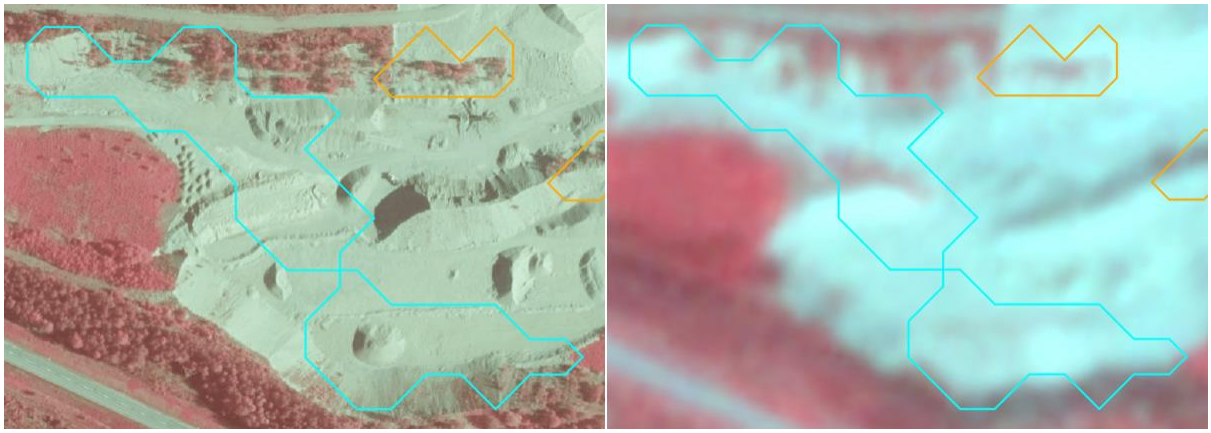

Figure 11. Area of sand pit that has been classified to IMCC class 2: Loss of impervious surface. Aerial image 2015 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 2028, coordinates ETRS_1989_LAEA N: 4300540, E: 5149396, size of polygon 0,2 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

Figure 12. Areas of landfill that has been classified to IMCC class 2: Loss of impervious surface. Aerial image 2014 on the left, Pleiades image of Image2018 VHR on the right. SAMPLE_ID 2018, 2019, 2020, 2021, 2022, coordinates ETRS_1989_LAEA N: 4489931, E: 4911126, size of polygons 0,1 – 0,5 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

VI. **Statistical verification** (optional)

Statistical verification was performed for classes

- IMCC class 1: New impervious cover, meaning increased imperviousness density, zero IMD at the first reference date.
- IMCC class 2: Loss of impervious cover, meaning decreasing imperviousness density, zero IMD at the second reference date.

For both classes, samples were selected, then samples were compared to reference data (mostly aerial and satellite imagery) and assessed as correct or incorrect and finally the proportion of correctly classified samples were computed.

Description of methodology and software	Statistical verification was performed using GIS-software. Samples were selected and they were visually validated against national in-situ datasets using ArcMap 10.8. Samples were selected as following: • IMCC class 1 - New impervious cover: First, systematic sampling with 100 m sample spacing in E- and N-direction was done and then 300 samples belonging to IMCC class 1 and having aerial image 2015 coverage were selected from this group of samples using random sampling (MatLab, rand-function). • IMCC class 2 - Loss of impervious cover: Systematic sampling with 40 m sample spacing in E- and N-direction was done and samples belonging to IMCC 2 and having aerial image 2015 coverage were selected resulting 296 samples. These sample pixels were visually checked against relevant in-situ datasets and assessed as correct/incorrect. Finally, the proportion of correctly classified samples was computed.
Stratification	Stratification was based on the area of IMCC-classes and availability of aerial images, see “Description of methodology and software ”
Comments	

The accuracies of classes were based on used sample:

- IMCC class 1: There were 300 samples, 78 samples were correctly classified which gives sample-based probability of correct classification 26%. The area of class was 90,74 km^2 and its proportion from whole Finland 0,026%.
- IMCC class 2: There were 296 samples, 5 samples were correctly classified which gives sample-based probability of correct classification 1,7%. The area of class was 0,97 km^2 and its proportion from whole Finland 0,0003%