HRL 2018 verification report for Grassland Change 2015-2018 (GRAC1518)

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*
	Finnish Land Parcel Identification System LPIS *- individual years 2009 - 2018 (2017 partial, 2016 missing)* *- classification of LPIS to managed agricultural grasslands, 2015 and 2018*
Reporting done by (name, position and e-mail)	Markus Törmä, Senior Research Scientist, markus.torma@syke.fi
Date and place of writing the report	16th July, 2021, Helsinki

II. General overview of the verified data

HRL Grassland Change 2015-2018 (GRAC1518) consists of seven classes; two describing grassland gain, two for grassland loss, one for non-grassland areas, one for unchanged grassland and one for unclassified areas. Most of the country is covered by non-grassland areas (about 93%) and unchanged grasslands (about 1%). The area of total grassland gain is 4.5% and total loss a bit more than 1%. Table 1 presents the overall statistics of the HRL GRAC1518 data and Figure 1 shows the HRL GRAC1518 areas in Finland.

Finland do not have specific grassland data describing the extent and changes of natural and managed grasslands, therefore GRAC1518 was compared to the HR CLC changes 2012 – 2018 and locally combined grassland data based on various sources. HR CLC changes has 0.5 – 1 ha minimum mapping unit, smaller MMU for artificial and agricultural areas and larger for seminatural areas. Table 2 presents the areas of grassland change classes of GRAC-product (gain: GRAC01 & GRAC11, loss: GRAC02 & GRAC22), the proportion of unchanged area of GRAC-class according to HR CLC change and the most common HR CLC-change classes and their proportions from GRAC-class area. GRAC1518 changes are quite different than HR CLC-changes, because the proportion of unchanged area based on HR CLC-changes is very high, over 95% from the area of all GRAC-change classes. The most common HR CLC-changes are related to forests, 310-324 are forest clear-cuts and 324-310 forest re-growth. Possible grassland gain changes of HR CLC could be xxx-211 if the agricultural plant belongs to grasses, or 2yy-xxx when the areas is converted from agricultural use to other use. Possible grassland loss changes could be 2yy-xxx if the agricultural area has been pasture or used for fodder production, or xxx-310 due to forest regrowth.

Table1. Overall statistics. Sea areas are removed from statistics.

HRL GRAC1518 Finland	Value	Km²	%
All non-grassland areas	0	314301,0	92,8
GRAC01: Grassland gain	1	17,3	0,005
GRAC02: Grassland loss	2	10,1	0,003
GRAC10: Unchanged grassland in both years	10	3836,0	1,13
GRAC11: Unverified grassland gain	11	15356,5	4,54
GRAC22: Unverified grassland loss	22	4554,8	1,35
Unclassifiable	254	531,0	0,16
SUM (Non-GRAC & GRAC)		**338606,7**	**100**
Total changed surface[1]		**19938,7**	**5,89 %**

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

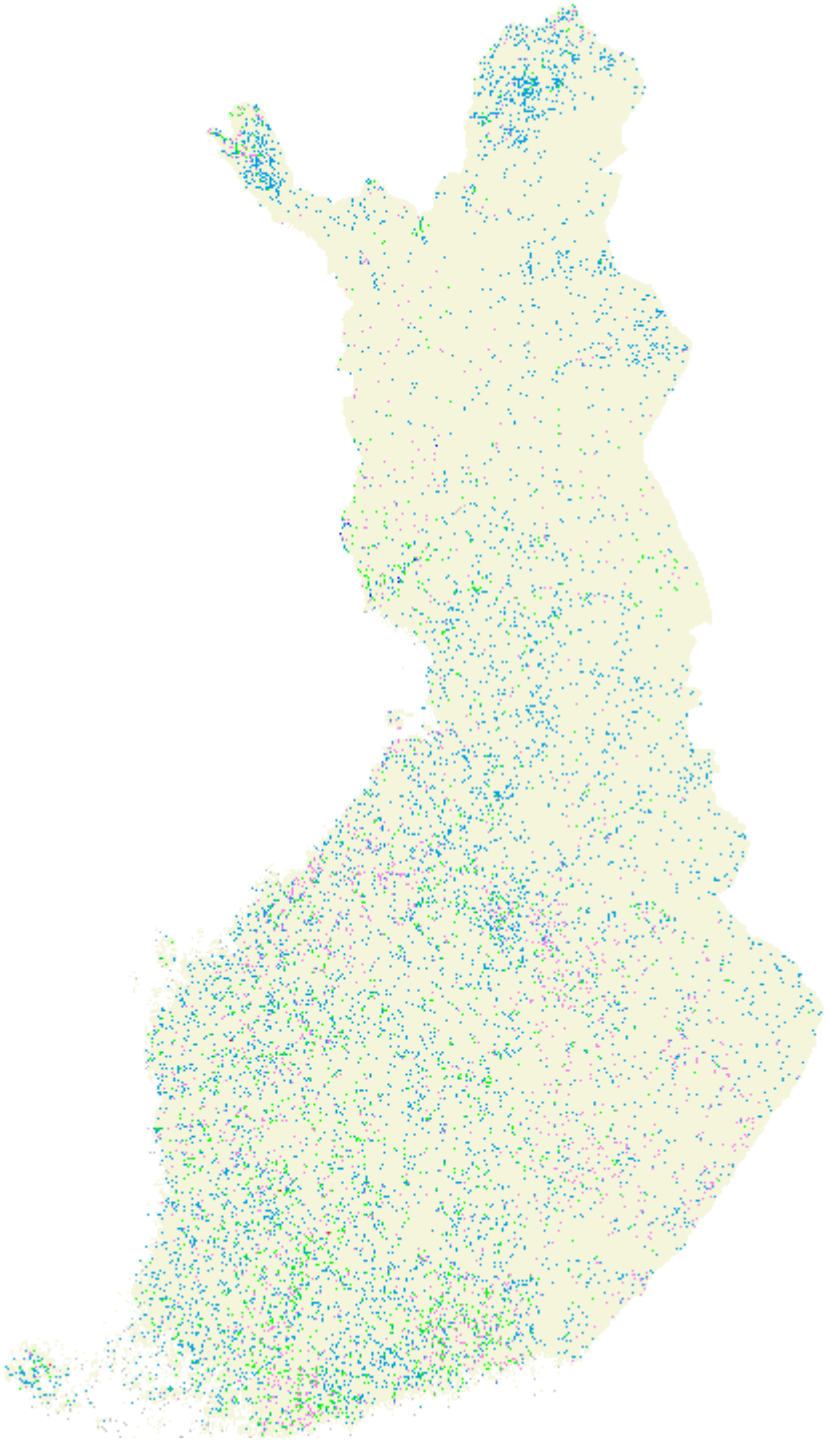

Figure 1. Overview map. Non-grassland areas light beige, Grassland gain blue, Grassland loss red, Unchanged grassland in both years green, Unverified grassland gain light blue, Unverified grassland loss purple and Unclassified grey. NOTE: sea areas are removed from image.

Table 2. The comparison between GRAC-change classes and national CLC-changes. The areas of grassland change classes of GRAC-product (gain: GRAC01 & GRAC11, loss: GRAC02 & GRAC22), the proportion of unchanged area of GRAC-class according to HR CLC change and the most common HR CLC-change classes and their proportions from GRAC-class area.

	GRAC01	GRAC02	GRAC11	GRAC22
Area (km2)	17,3	10,1	15356,5	4554,8
Proportion (%) of no-change area of class according to HR CLC-changes	98,0	98,71	92,18	95,51
The most common HR CLC-changes within area of GRAC-class and their proportions (%)	412-211 0,82 243-412 0,48 211-324 0,25	310-324 0,99 324-211 0,30	310-324 6,67 324-310 0,30 412-324 0,22 324-211 0,16	310-324 3,06 324-310 0,86 324-211 0,23 310-211 0,15

It should be noted that the time periods of the two change products are not the same, for GRAC 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, natural grasslands are rare in Finland, and most of the grasslands are managed agricultural grasslands.

Another national grassland data describing the occurrence of mostly managed agricultural grasslands at years 2015 and 2018 was combined at SYKE by combining suitable classes from national Corine Land Cover classifications 2006, 2012 and 2018, relevant themes from Topographic database of Finnish National Land Survey, and relevant classes from yearly LPIS data 2009 - 2018. This data was created because national CLC-changes do not represent the changes within agricultural areas well because managed agricultural grassland can be classified as arable land in CLC. Figure 2 presents an example how national grassland data and GRAC look like on agricultural area.

Table 3 represents the proportions of national grasslands 2015, 2018 and both times for grassland gain (classes GRAC01 & GRAC11) and loss (GRAC02 & GRAC22) of GRAC-product. For all GRAC-classes, the proportion of non-grassland area based on national data is quite large, from 52% (GRAC01) to 81-18% for rest of the GRAC-classes. For both grassland gain-classes (GRAC01 & GRAC11), the proportion of national grassland 2018 but not 2015 is bigger than the proportion of national grassland 2015 but not 2018. This is showing some ability to indicate grassland gain, but in both cases the proportion of grassland both 2015 and 2018 is even bigger indication that there are more classification mistakes than successes. For grassland loss-classes (GRAC02 & GRAC22) the degree of success is worse. The GRAC02 is better, the proportion of national grassland 2015 but not 2018 is larger than the proportion of national grassland 2018 but not 2015 as well as the proportion of grassland both 2015 and 2018 indicating that the class describes grassland loss at least to at some degree. The GRAC22 is worse, the proportion of national grassland 2015 but not 2018 is the smallest proportion indicating that the class described grassland loss quite badly. It should be remembered that this national data mainly consists of managed agricultural grasslands.

Table 3. The comparison between GRAC-change classes and combined national grassland data describing grassland extent 2015 and 2018.

	GRAC01	GRAC02	GRAC11	GRAC22
Area (km2)	17,3	10,1	15356,5	4554,8
Proportion (%) of non-grassland area of GRAC-class according to national grassland data	52,4	81,8	85,4	81,7
The proportion (%) of grassland extent 2015 but not 2018 within GRAC-class	0,8	8,2	1,1	2,9
The proportion (%) of grassland extent 2018 but not 2015 within GRAC-class	20,3	3,0	4,0	5,1
The proportion (%) of grassland extent both 2015 and 2018 within GRAC-class	26,5	7,0	9,4	10,3

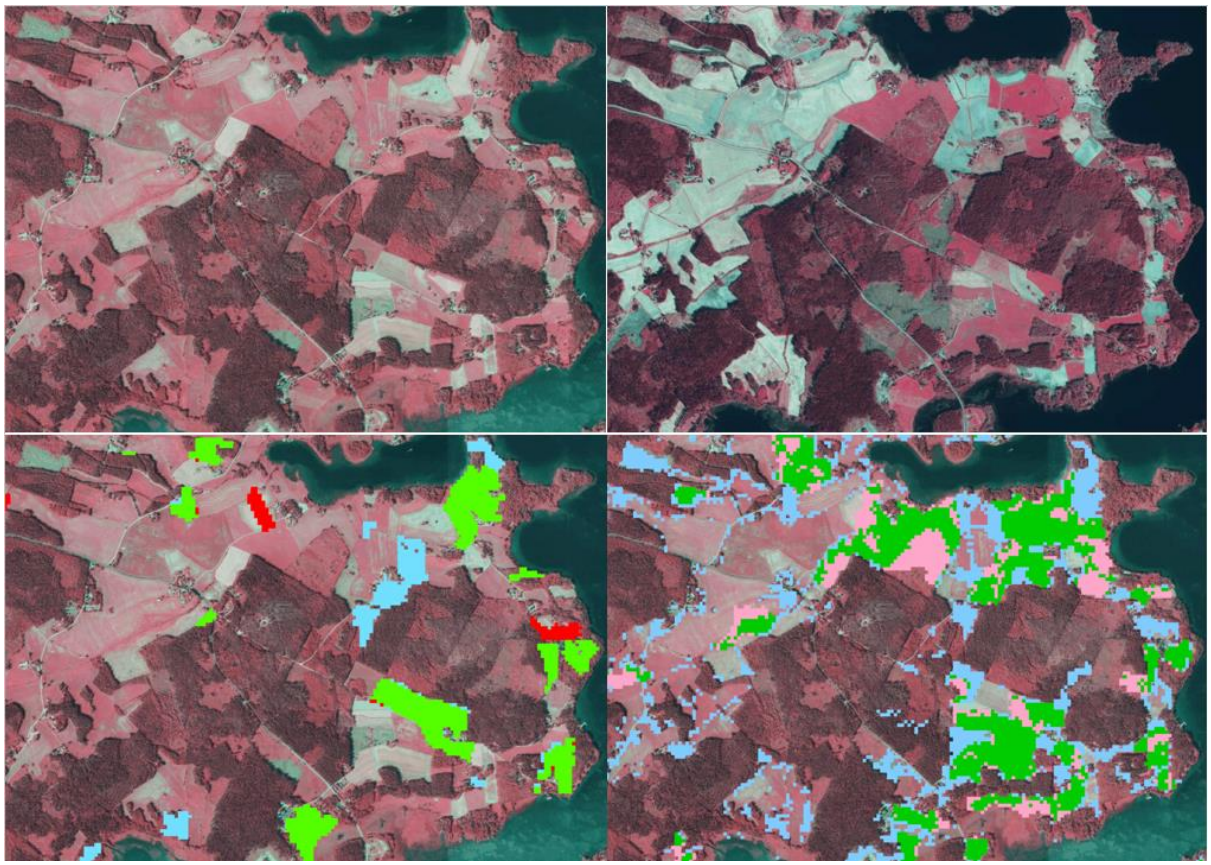

Figure 2. False-color aerial image 2015 on the top left, 2018 on the top right, national grassland data (green: grassland both 2015 and 2018, blue: grassland gain, red: grassland loss) on the bottom left and GRAC1518 (green: no change grassland, blue: unverified grassland gain, pink: unverified grassland loss) in the bottom right. 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)	Not OK	The quick visual comparison of the HRL GRAC1518 data with national ortophoto images, satellite image mosaics, topographic maps and Land Parcel Identification System polygons indicate that the HRL GRAC1518 represent the changes of grasslands badly. On the other hand, the natural grasslands are rare in Finland, most of the grasslands are agricultural grasslands. The best class is Grassland gain. The main problem with all classes is that natural grassland areas are rare in Finland. Most of the detected grassland changes are related with agricultural areas and their changes, detected changes do not belong to grassland (e.g. forest clear-cuts, peat forming wetlands) or there are no changes according to reference material.

IV. Look & feel verification results

Look & feel verification was done for classes

- GRAC class 1: grassland gain
- GRAC class 2: grassland loss
- GRAC class 11: unverified grassland gain
- GRAC class 22: unverified grassland loss

In all cases, contiguous areas were formed from GRAC1518 raster by vectorizing data to polygons. This was done using Erdas Imagine. Polygons were sorted from largest to smallest and 100 largest were studied in look & feel verification. The later part was done using ArcMap. Table 4 presents the statistics of polygons, number of polygons formed in vectorization process and statistics of polygon size (maximum, minimum and mean) of 100 largest polygons.

Table 4. Statistics of polygons of GRAC1518 classes. Statistics concerning size are computed using 100 largest polygons used in look & feel verification.

Class	Nr of polygons	Maximum size (ha)	Minimum size (ha)	Mean size (ha)
GRAC class 1: grassland gain	710	21,5	4,0	6,4
GRAC class 2: grassland loss	469	22,9	2,6	4,4
GRAC class 11: unverified grassland gain	4638036	3891,9	144,7	378,9
GRAC class 22: unverified grassland loss	730132	292,9	59,9	86,5

V. Documentation of errors and critical findings

GRAC class 1: grassland gain was the best class of GRAC1518 product, NRL_NOTE was 3 or more for 23 polygons, 2 for 14 polygons and 1 for 63 polygons. The mean HRL_NOTE was 1,73. Figure 3 presents one change area which is rather well mapped, area has not been agricultural grassland year 2015, but turned agricultural grassland 2018 according to LPIS. Change areas with HRL_NOTE 2 or 3 are typically areas that have changes, but polygons have considerable unchanged areas or areas of change have been omitted, or changed areas are delineated badly. Change areas with HRL_NOTE 1 are mostly areas where there are grasslands at both times according to LPIS (Figure 4, 25% from studied polygons), old or new forest clear-cuts (Figure 5, 21%), there are cereal or some other agricultural plant according to LPIS indicating tilling or ploughing so that the definition of grassland is not fulfilled (Figure 6, 12%) or change area is open wetland or peat production area with no change or change do not belong to grassland category (Figure 7, 3%). One reason for low HRL_NOTE can be that the change area has been delineated badly.

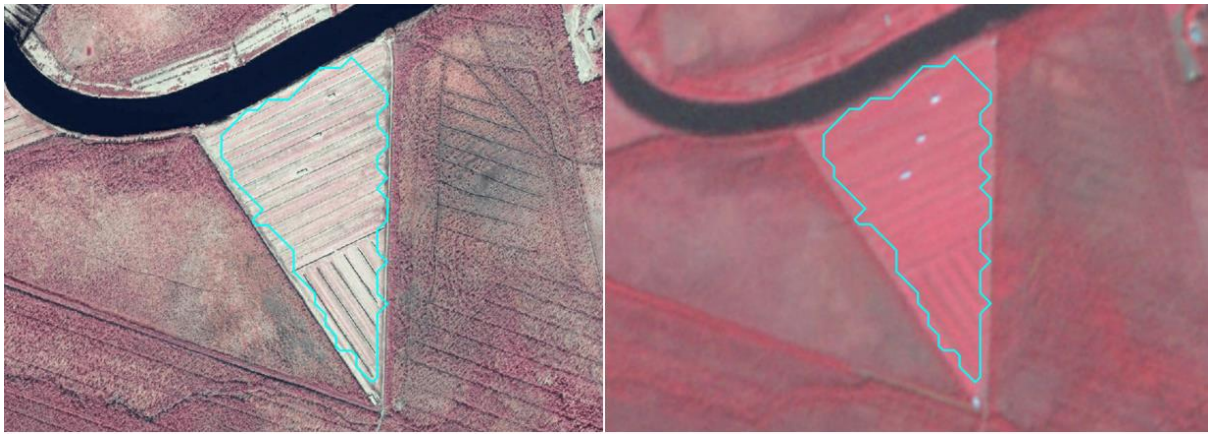

Figure 3. The gain of grassland; not agricultural grassland 2015, agricultural grassland 2018 according to LPIS. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 1006, coordinates ETRS_1989_LAEA N: 4866598, E: 4936443, size of polygon 11,0 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

Figure 4. The area has been managed agricultural grassland according to LPIS at both 2015 and 2018. Aerial image 2016 on the left, Pleiades image of Image2018 VHR on the right. SAMPLE_ID 1074, coordinates ETRS_1989_LAEA N: 4838387, E: 5040416, size of polygon 8,1 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

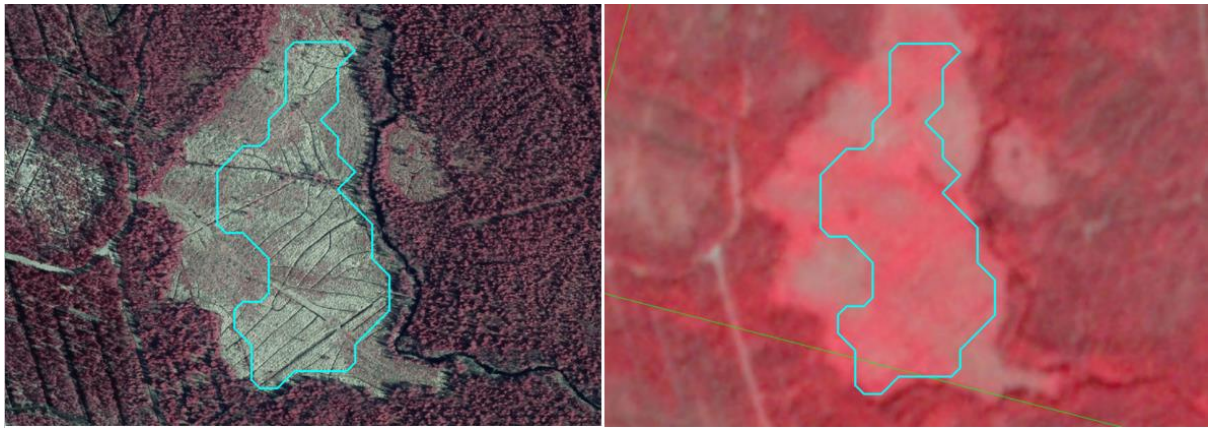

Figure 5. Forest clear-cut that has been interpreted as grassland gain. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 1015, coordinates ETRS_1989_LAEA N: 4865397, E: 4982150, size of polygon 4,6 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

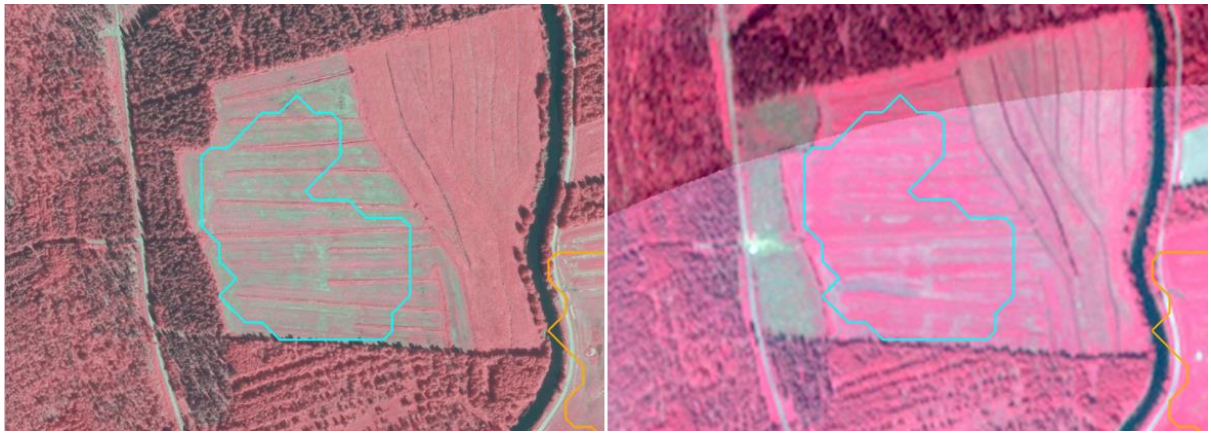

Figure 6. The plant on this agricultural area has been barley during year 2018 according to LPIS. Aerial image 2016 on the left, Pleiades image of Image2018 VHR on the right. SAMPLE_ID 1085, coordinates ETRS_1989_LAEA N: 4818110, E: 4971420, size of polygon 4,5 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

Figure 7. Open wetland with no change has been interpreted as grassland gain. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 1032, coordinates ETRS_1989_LAEA N: 4843304, E: 4953994, size of polygon 4,0 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

GRAC class 2: grassland loss was interpreted badly, NRL_NOTE was 3 or better for 3 polygons, 2 for 8 polygon and 1 for 89 polygons. The mean HRL_NOTE was 1,16. Figure 8 presents one change area which is rather well mapped, area that has been agricultural grassland year 2015, but not 2018 according to LPIS. Change areas with HRL_NOTE 1 are mostly areas where there was no grassland 2015 because there have been other agricultural plants according to LPIS (Figure 9, 63% from studied polygons), there has been grassland on both times according to LPIS (Figure 10, 6%), there has not been grassland on both times according to LPIS (Figure 11, 6%), increase of grassland (Figure 12, 4%), or some forest clear-cuts or unchanged mountain area.

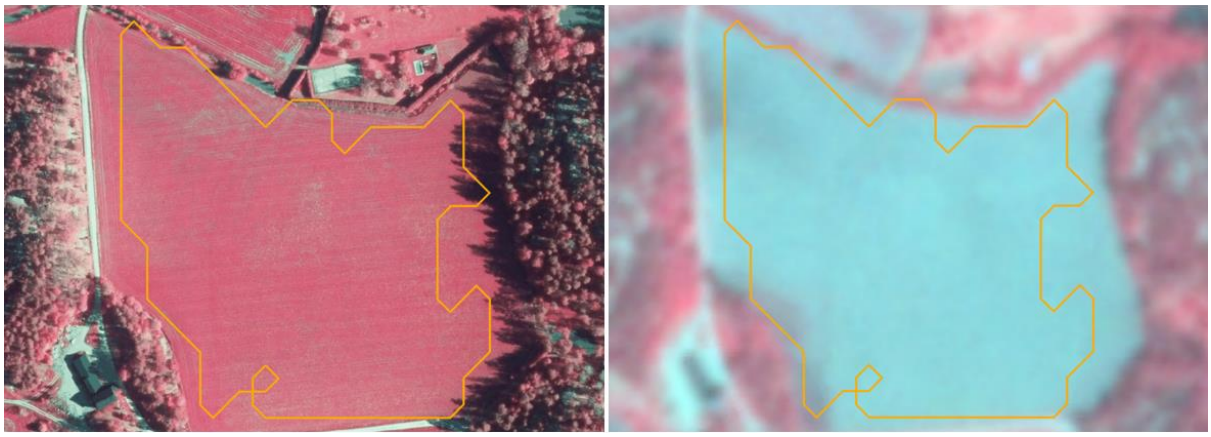

Figure 8. The loss of grassland; area has been managed agricultural grassland 2015 but not 2018 according to LPIS. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 2038, coordinates ETRS_1989_LAEA N: 4201834, E: 5014612, size of polygon 3,2 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

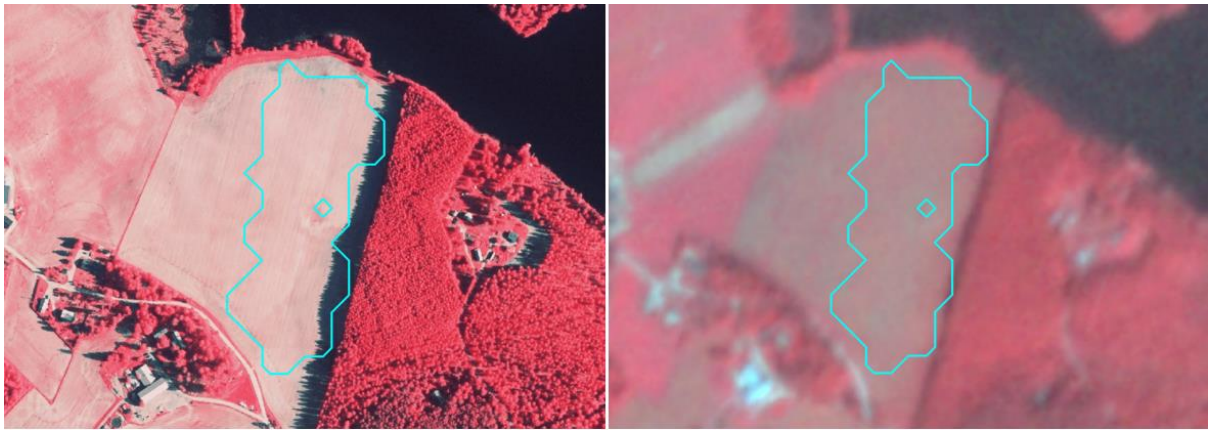

Figure 9. The agricultural plant has been barley 2015 and oats 2018 according to LPIS, so the area has not been grassland. Also, agricultural parcel is delineated quite badly covering only half of the parcel. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 2044, coordinates ETRS_1989_LAEA N: 4478183, E: 5115446, size of polygon 3,8 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

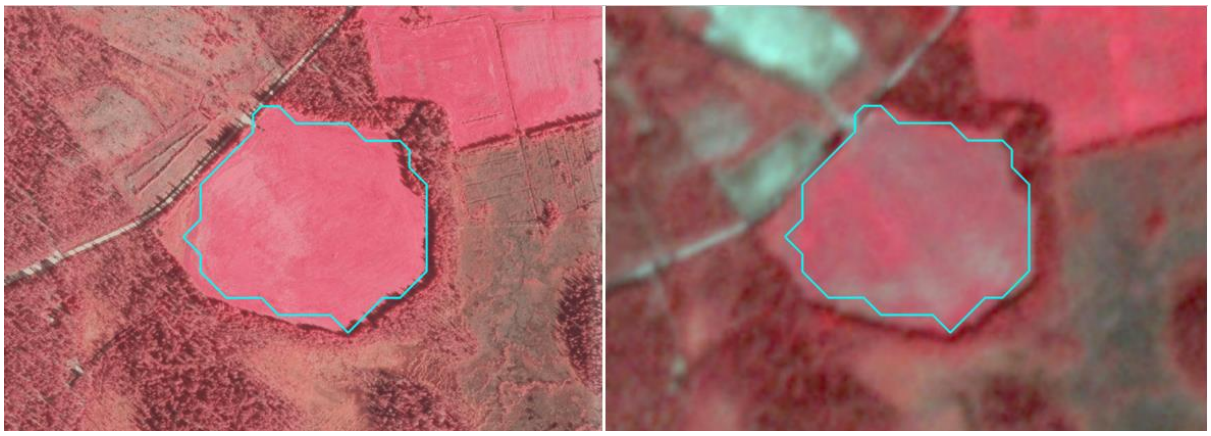

Figure 10. The area has been managed agricultural grassland at both times according to LPIS, therefore no change. Aerial image 2015 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 2008, coordinates ETRS_1989_LAEA N: 4901304, E: 5140124, size of polygon 5,0 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

Figure 11. The area has not been managed agricultural grassland at either of times according to LPIS, therefore no change. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 2059, coordinates ETRS_1989_LAEA N: 4333587, E: 5086160, size of polygon 7,5 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

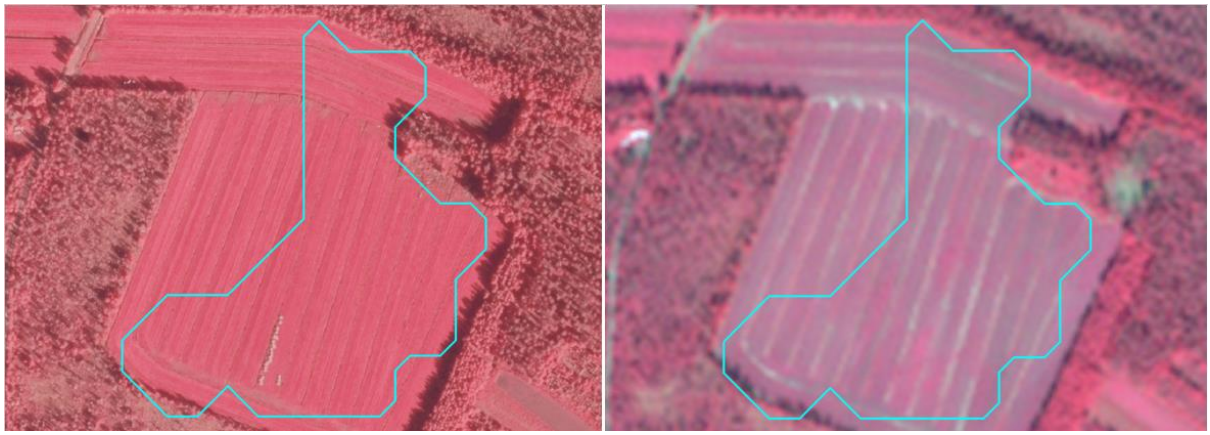

Figure 12. The proportion of managed agricultural grassland has increased, 2015 there was some grassland area on the upper part of polygon, and 2018 whole polygon was grassland according to LPIS. Aerial image 2015 on the left, Pleiades image of Image2018 VHR on the right. SAMPLE_ID 2006, coordinates ETRS_1989_LAEA N: 4917213, E: 5132966, size of polygon 3,0 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

GRAC class 11: unverified grassland gain was interpreted quite badly, NRL_NOTE was 3 or better for 2 polygons, 2 for 2 polygon and 1 for 96 polygons. The mean HRL_NOTE was 1,06. Polygons were very large, the largest one studied was 3892 ha and smallest 145 ha. Typically, these large areas are mixtures of different kinds of land covers and do not represent Finnish landscape well. Figure 13 presents one change area which is reasonably well mapped, old peat production site is mostly converted to agricultural area. Change areas with HRL_NOTE 1 are mostly very large polygons at Upper Lapland (Figure 14, 72% from studied polygons) which are low-vegetated areas with Mountain birch, brush, heathland, grass-like plants, mosses and lichens mixed with different kind of wetlands, open rock and boulder fields. These

have been defined as no-change areas because reference material do not indicate change, and because at the moment I am not convinced that the time series of high resolution satellite imagery would be that good that the slow changes that are possibly happening in this area would be visible in three year time-frame. I expect that longer time series of Sentinel-2 data, for example in the form of CLMS HR-VPP product should be useful in this sense. Other polygons with HRL_NOTE 1 are more or less wet wetlands (Figure 15, 17%), peat production sites (Figure 16, 3%) or forest clear-cuts (Figure 17, 2%).

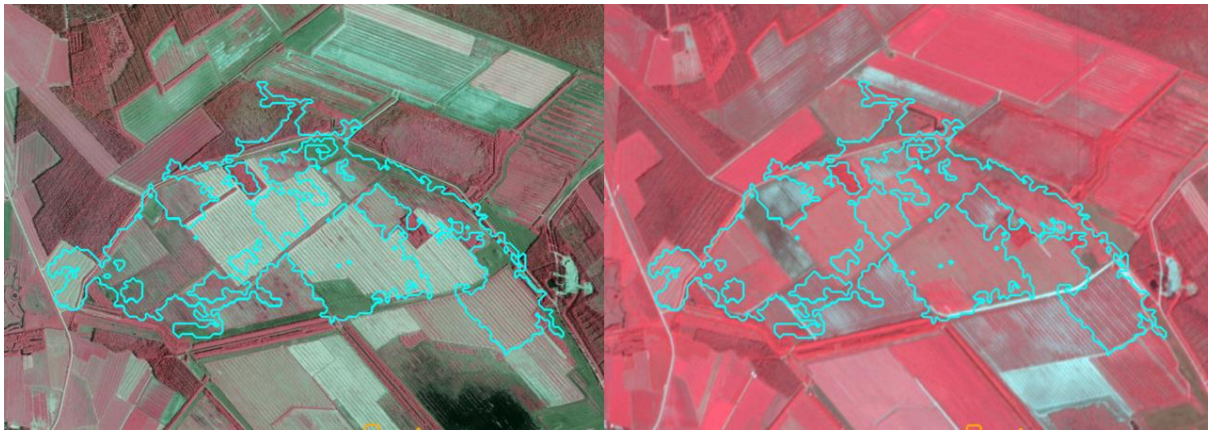

Figure 13. Old peat production site is mostly converted to agricultural area, including grassland. Aerial image 2014 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 11088, coordinates ETRS_1989_LAEA N: 4645488, E: 5076149, size of polygon 146,1 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

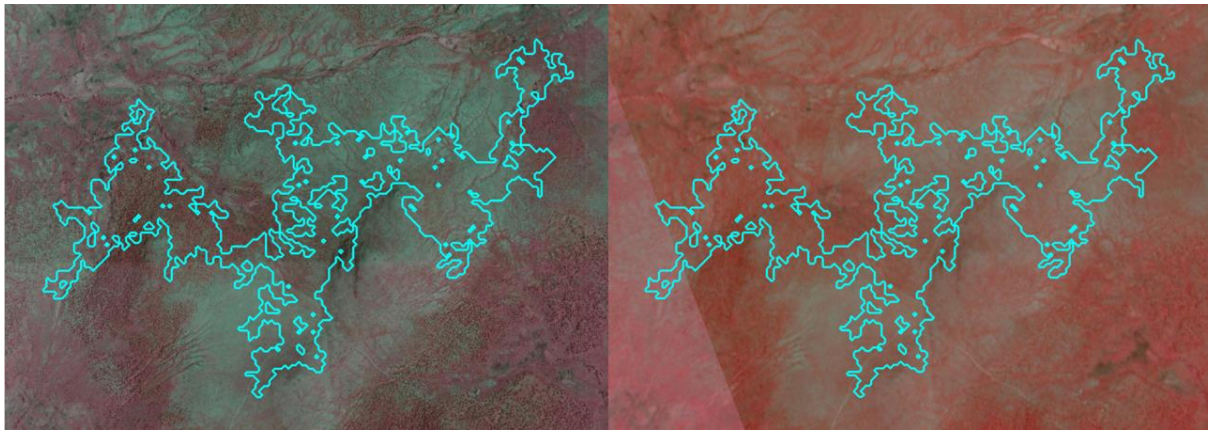

Figure 14. Mountain area in Upper Lapland, consisting on mostly brush areas with some mountain birch areas and boulder field and open bedrock as minority. Aerial image 2014 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 11022, coordinates ETRS_1989_LAEA N: 5223660, E: 4956575, size of polygon 145,2 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

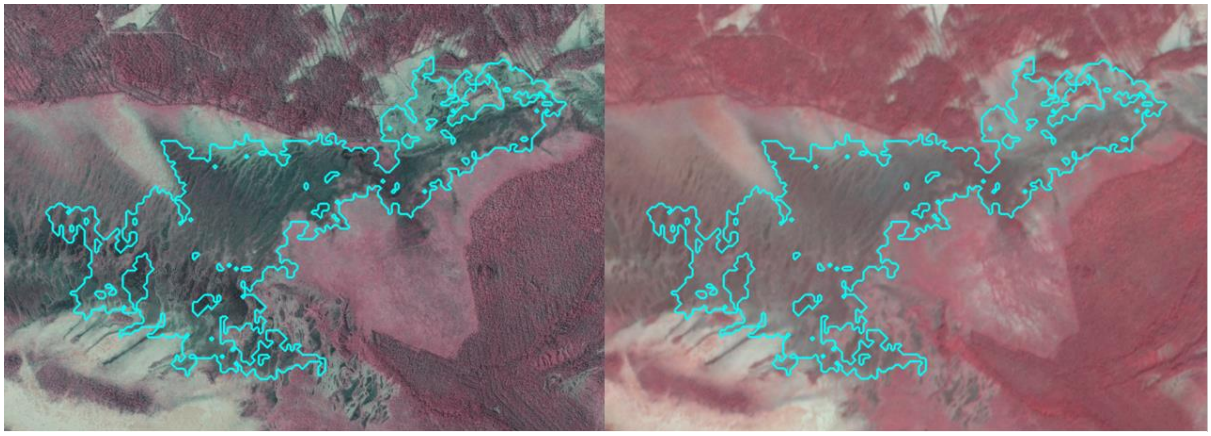

Figure 15. Open wet, mostly difficult to travel with foot due to wetness wetland. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 11078, coordinates ETRS_1989_LAEA N: 4763608, E: 5086866, size of polygon 164,4 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

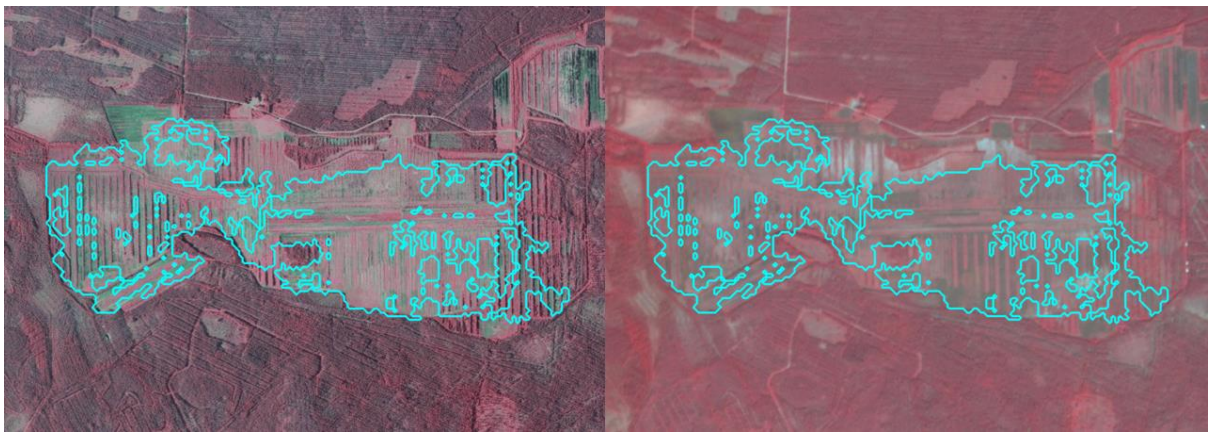

Figure 16. Peat production area that has been classified as grassland gain area. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 11080, coordinates ETRS_1989_LAEA N: 4757834, E: 5101199, size of polygon 168,0 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

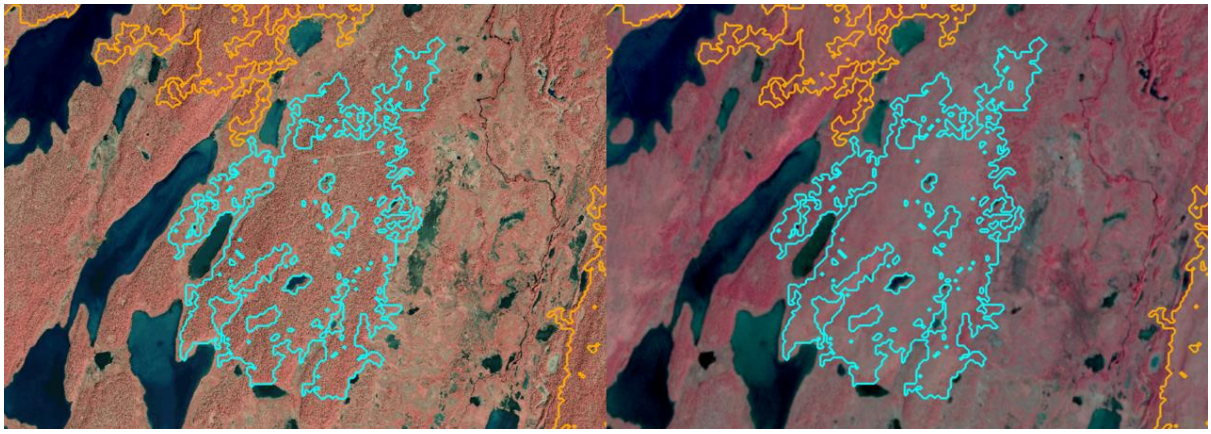

Figure 17. Forest clear-cut in Upper Lapland which has happened between 2016 and 2018 that has been classified as grassland gain. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 11018, coordinates ETRS_1989_LAEA N: 5243465, E: 5004984, size of polygon 200,0 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

GRAC class 22: unverified grassland loss was interpreted very badly, the HRL_NOTE was evaluated to be 1 for all polygons. Again, polygons were large but not as large as with GRAC class 11, the largest one studied was 293 ha and smallest 60 ha. Typically, these large areas are mixtures of different kinds of land covers and do not represent Finnish landscape well. Change areas are typically large agricultural areas with many parcels with many different kinds of agricultural plants, where the proportion of managed agricultural grassland as increased (Figure 18, 36% from studied polygons) or is same at both times (Figure 19, 36%). Other change areas consist of change polygons from Upper Lapland (Figure 20, 9%) which have been defined as no-change areas because reference material does not indicate change, or forest clear-cuts (Figure 21, 3%)

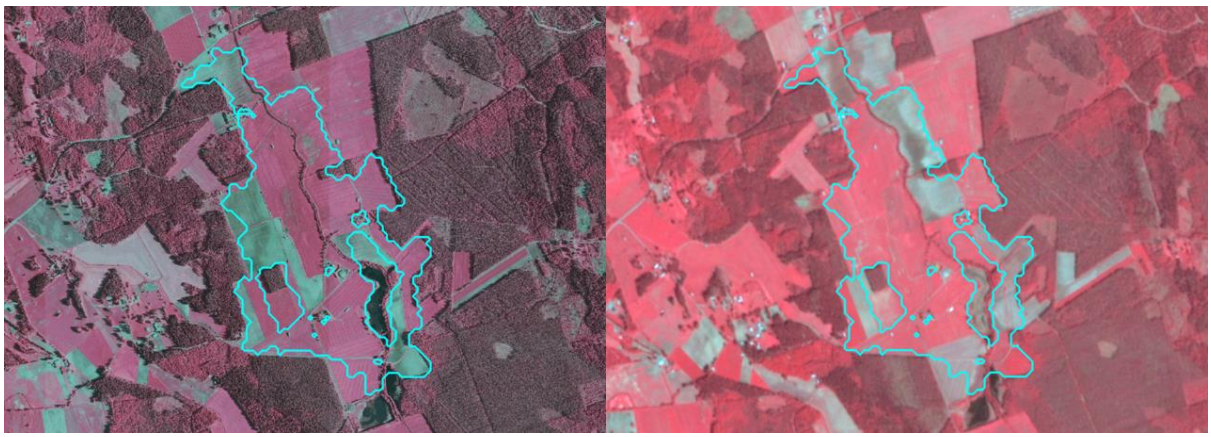

Figure 18. Agricultural area with many parcels, where the proportion of managed agricultural grassland as increased from approximately 30% to 50% according to LPIS. Aerial image 2014 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 22085, coordinates ETRS_1989_LAEA N: 4523179, E: 5341515, size of polygon 74,6 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

Figure 19. Agricultural area with several parcels, where the proportion of managed agricultural grassland has stayed at the same (about 10%) at both times. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 22039, coordinates ETRS_1989_LAEA N: 4580667, E: 4971030, size of polygon 69,9 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

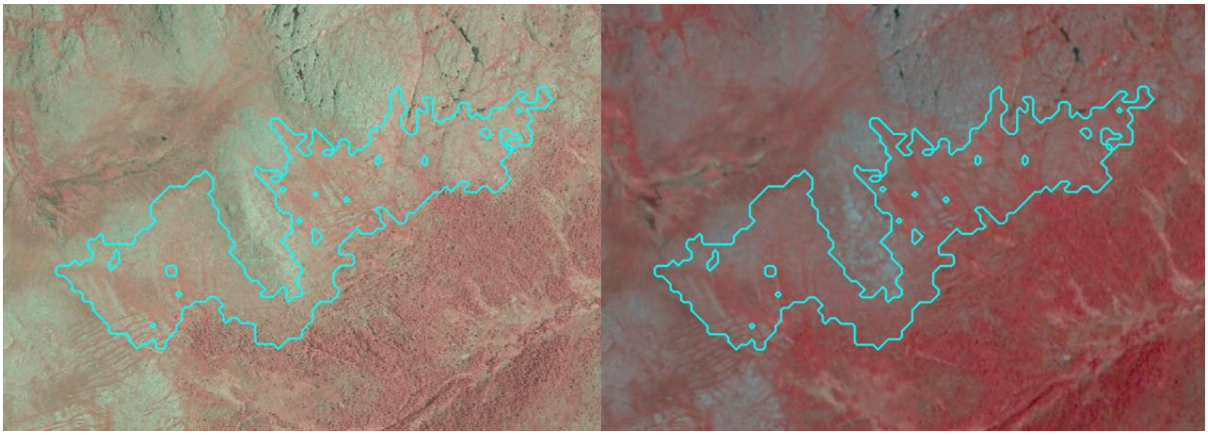

Figure 20. The area in Upper Lapland, consisting on mostly brush and heathland. The area has been classified as grassland loss but reference material does not indicate change. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 22007, coordinates ETRS_1989_LAEA N: 5138156, E: 4994661, size of polygon 64,6 ha. Orthophoto (MML/WMTS 06/2021), VHR_IMAGE_2018 ©CCME(2018), provided under COPERNICUS by the European Union and ESA, all rights reserved.

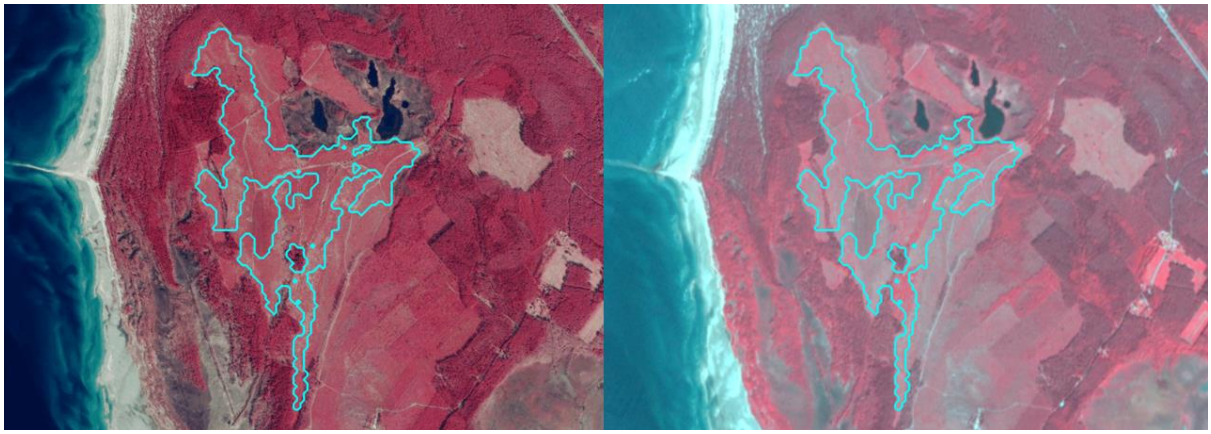

Figure 21. Old forest clear-cut which has been made between 2006 and 2012 that as been classified as grassland loss. Aerial image 2016 on the left, Planet image of Image2018 VHR on the right. SAMPLE_ID 22088, coordinates ETRS_1989_LAEA N: 4322052, E: 4934033, size of polygon 68,1 ha. Orthophoto (MML/WMTS 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

- GRAC class 1: grassland gain
- GRAC class 2: grassland loss
- GRAC class 11: unverified grassland gain
- GRAC class 22: unverified grassland loss

For all classes, samples were selected, then samples were compared to reference data (LPIS, 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 validated against national in-situ datasets using ArcMap 10.8. Samples were selected as following: • GRAC class 1: First, systematic sampling with 100 m spacing in E- and N-direction was done. Then, samples with 2015 and 2016 aerial image coverage were selected. Finally, every seventh sample was selected systematically resulting 308 samples • GRAC class 2: First, systematic sampling with 100 m spacing in E- and N-direction was done. Then, samples with 2015 and 2016 aerial image coverage were selected. Finally, every fourth sample was selected systematically, resulting 302 samples • GRAC class 11: First, systematic sampling with 100 m spacing in E- and N-direction was done. Then, samples with 2015 aerial image coverage were selected. Finally, 300 sample random sampling (Matlab, rand-function) was performed. • GRAC class 22: First, systematic sampling with 100 m spacing in E- and N-direction was done. Then, samples with 2015 aerial image coverage were selected. 300 sample random sampling (Matlab, rand-function) was performed. These sample pixels were 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 GRAC-classes and availability of aerial images, see “Description of methodology and software ”
Comments	Classification accuracies are low. It is hoped that the quality of GRAC-product would increase due to longer Sentinel-2 time series and better phenology products like HR-VPP.

The accuracies of classes were based on used sample:

- GRAC class 1: There were 308 samples, 50 samples were correctly classified which gives sample-based probability of correct classification of class 16,2%. The area of class was 17,3 km^2 and its proportion from whole Finland 0,005%
- GRAC class 2: There were 302 samples, 23 samples were correctly classified which gives sample-based probability of correct classification of class 7,6%. The area of class was 10,1 km^2 and its proportion from whole Finland 0,003%
- GRAC class 11: There were 300 samples, 12 samples were correctly classified which gives sample-based probability of correct classification of class 4,0%. The area of class was 15356,5 km^2 and its proportion from whole Finland 4,5%
- GRAC class 22: There were 300 samples, 11 samples were correctly classified which gives sample-based probability of correct classification of class 3,7%. The area of class was 4554,8 km^2 and its proportion from whole Finland 1,4%