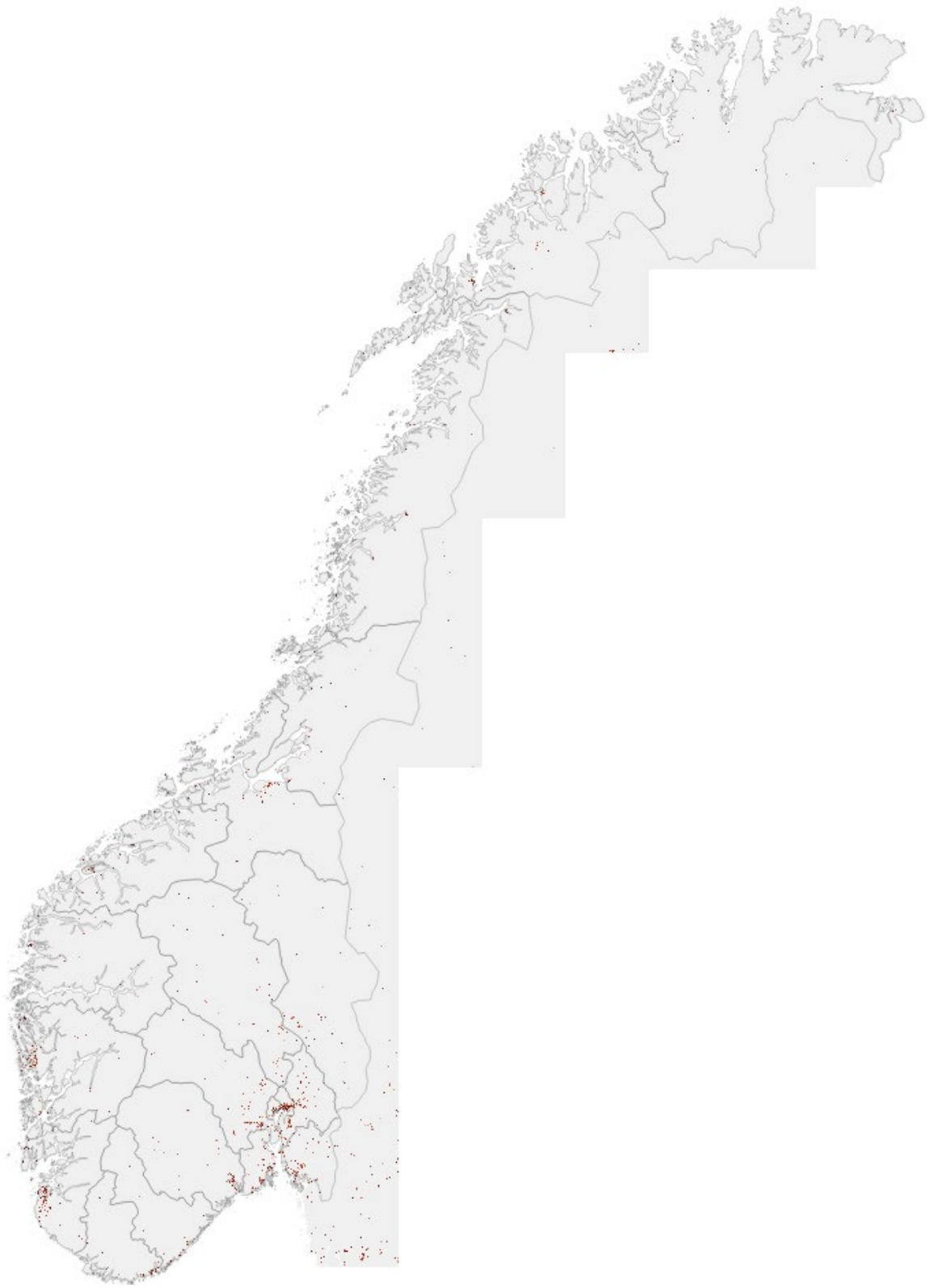
HRL 2018 look & feel verification report for Imperviousness (2018) Norway

I. Administrative part

HRL	*Imperviousness 2018*
Verified area, region	*Norway*
Institution carrying out the work	*NIBIO Survey and statistics*
Overall visual checking done by (name, position and e-mail)	*Karsten Dax, Senior Engineer* *Karsten.Dax@nibio.no*
Look & feel verification done by (name, position and e-mail)	*Karsten Dax, Senior Engineer* *Karsten.Dax@nibio.no*
In situ data used..	*National ortophoto database Norge-i-bilder* *Ref: http://www.norgeibilder.no*
	National spatial data infrastructure *Ref: http://kilden.nibio.no*
	Ortophoto, topographic and thematic maps available as wms services were integrated with the HRL data using qGIS
Reporting done by (name, position and e-mail)	*Karsten Dax, Senior Engineer, Karsten.Dax@nibio.no* *Geir-H Strand, Director R&D, ghs@nibio.no*
Date and place of writing the report	*Ås 26.03.2021*

II. General overview of the verified data



IMD2018 Norway. The delivery is organized as tiles partly extending into Sweden and Finland. The verification is limited to areas inside Norway.

Statistical overview

Class	Value	Haa	%
Non impervious area	*0*	*32 179 200*	*99,37%*
Imperviousness 1-29 %	*1-29*	*50 700*	*0,16%*
Imperviousness 30-100 %	*30-199*	*151 000*	*0,47%*
Total		***32 380 900***	***100,00%***
Impervious surface		*201 700*	*0,63%*

National and regional maps of recoded imperviousness closely resemble small-scale thematic maps of settlements and the main road infrastructure in Norway. The overall assessment is that this reclassified map of imperviousness is meaningful at small cartographic scales and show the areas expected to be included in the map when inspected at these scales.

The impervious area in Norway in 2018 according to official statistics (Statistics Norway Table 10781) was

Class	Haa	%
Area covered by buildings	*54 866*	*0,17%*
Area covered by roads	*112 952*	*0,35%*
Total	***167 818***	***0,52%***

III. Overall visual checking

Positional accuracy			
Relative positional accuracy	Quick visual comparison of HRL data with available EO imagery (identifying large positional errors)	*OK / correct,*	*The positional accuracy was checked by comparing the HRL and orthophoto for large roads and industrial areas with crisp outlines. Checks were carried out at several latitudes and the positional accuracy is OK (also in the far northern part of the country)*
Thematic accuracy			
Classification correctness	Simple look & feel thematic check (identifying basic thematic mistakes)	*OK / correct,* *NOK / not correct*	*The overall impression is that the accuracy is high in densely built-up or developed areas, variable in discontinuously built-up areas (single family housing) and low (due to omission errors) in rural areas.*

IV. Look & feel verification results

1.Included elements, possible OMISSIONS

Stratum	Name of the stratum	Number of samples verified	Results of the verification by strata (using qualitative evaluation as: Excellent, good, acceptable, insufficient, very poor).
4	Construction sites (checked for omissions and commissions)	10	*Excellent.* *Verification was carried out on known construction sites along roads and railways as well as in some housing development areas.* *Paved parts (existing roads, buildings) were rendered as impervious, while the non-sealed parts of the construction sites (also alongside existing roads) were rendered correctly as "non-impervious".*
8	Greenhouses	10	*Insufficient.* *Half of the greenhouse sites checked were correctly classified as impervious, some were wrongly classified as non-impervious, and some were in between. It seems the detection rate is depending on whether the roof material is glass or plastic, and how much is being grown inside. We mainly checked sites with several greenhouses, not single houses.*
9	Sports fields covered by artificial material	12	*Insufficient.* *Many sports fields are nowadays covered with artificial grass or green rubber granulate instead of sand or gravel. While any of these surface materials may be non-impervious, the underlying base may not.*
10	Major cities	9	*Excellent.* *"Downtown" area of major cities, including the five largest cities in Norway, was scanned. The city cores are correctly rendered as impervious. Occasional parks or open spaces are correctly rendered as "non-impervious" gaps.*
11	Highways	10	*Excellent.* *The major highways are well represented and appear as strings of impervious pixels. Intersections and occasional pixels are also rendered as impervious along other highways. The result is as expected, keeping in mind that many Norwegian highways are narrow compared to the standard in other European countries.*
12	Ports	14	*Excellent.* *Most of almost all ports are correctly rendered as impervious, though smaller parts of the port may be missing.*
13	Airports	14	*Excellent* *Runways and other concrete surfaces were represented as impervious.*
14	Industrial areas	14	*Acceptable.* *Major industrial sites were correctly represented as impervious, but storage areas, piles of sawdust and clay*

			and timber storage areas were also frequently mapped as impervious
15	Commercial areas	12	*Excellent.* *Larger commercial areas, shopping malls, etc., (including paved parking lots) were correctly represented as impervious.*
20	Farmsteads	57	*Insufficient* *Farnsteads with large buildings are partly impervious. The results range across the entire scale from poor to excellent.*
Overall evaluation (based on look-and-feel)			*(excellent, good, acceptable, insufficient, very poor)* *Excellent if attention is mainly on the most intensively used areas (urban, industrial, commercial, transport, quarries, mines)* *Acceptable if all areas are considered..* *Detailed explanation:* *Excellent for most intensively used areas (urban, industrial, commercial, transport, quarries, mines)* *Inexact but acceptable for roads and single-family housing residential areas (which constitute large parts of the Norwegian settlements). Commission and omission errors seem (look-and-feel) to cancel each other out.* *Insufficient for farmsteads and camping sites with permanent caravans. There are occasional commission errors in urban fringe and rural areas. Also greenhouses and sports fields may be insufficiently correct supposedly depending on the material of the surface.*
Comments			*Areas with single-family houses are shown as a speckle of impervious and non-impervious pixels, due to the frequent change between buildings and gardens, often with trees. We consider this to be fairly accurate in a "look-and-feel" sense, but statistical examination is needed in order to understand exactly how these areas are represented.* *Farmsteads are randomly shown as impervious, although the barns and production building can be quite large.* *This represents an underestimation of imperviousness in rural areas. Again, a statistical examination is needed in order to estimate the magnitude.*

2. Excluded elements, possible COMMISSIONS

Stratum	Name of the stratum	Number of samples verified	Results of the verification by strata (using qualitative evaluation as: Excellent, good, acceptable, insufficient, very poor).
1	Mineral extraction sites (including quarries and open pit mines)	11	*Excellent.* *Rarely misclassified (impervious) pixels inside extraction sites, except one sand/gravel quarry that was entirely misclassified.*
2	Dump sites	12	*Good* *Dump sites outside mines and dump sites used for rock deposits from tunnel construction are mostly, but not always, correctly rendered as not impervious.* *Rock-fill dams used for hydro-power production constitute a special kind of "dump site" in Norway. These are sometimes incorrectly rendered as impervious.*
3	Gravel and sand	15	*Excellent.* *Gravel and sand areas are mainly rendered correctly as not impervious, though some beaches and extraction sites were misclassified.* *The verification samples in this look-and-feel stratum include sand and gravel extraction sites, natural gravel areas and sand dunes.*
4	Construction sites checked for omissions and commissions)	10	*Excellent.* *Verification was carried out on known construction sites along roads and railways.* *Paved parts (existing roads, buildings) were rendered as impervious, while the non-sealed parts of the construction sites (also alongside existing roads) were rendered correctly as "non-impervious".*
5	Bare rock	10	*Excellent.* *We scanned large areas of bare rock in high mountains and on oceanic islands. Bare rock wrongly classified as impervious has not been observed.*
6	Sparsely vegetated areas	19	*Excellent.* *We scanned large areas of sparsely vegetated heath in mountains and on oceanic islands. Sparsely vegetated area wrongly classified as impervious has not been observed.*
7	Agriculture	25	*Excellent.* *We scanned agricultural areas, in particular around built-up areas. Agricultural area wrongly classified as impervious has not been observed.*
16	Sports areas (natural grass)	19	*Insufficient (variable),* *Several sand or gravel covered sports fields were mapped as impervious.*
17	Marinas	18	*Insufficient.* *Large areas of marinas mapped as impervious, probably because of the boats*
18	Camping sites & Caravan parks	9	*Good.* *Meadowed camping sites with seasonal tents, caravans and motorhomes are mainly rendered correctly as*

			non-impervious. Service areas and access (gravel) roads may be rendered as impervious. Caravan parks and camping sites with cabins were aceptable, in the light of their inhomogeneous appearance. *Sites with (semi-)permanent caravans with attached annex are scattered, depending on the density of caravans, their access roads and availability of green areas. Service areas are more likely to be marked as impervious. Holiday cabin areas: Correctly shown as "non-impervious", but some dense areas may be rendered impervious though access roads are gravel.* *Railway lines are occasionally shown as impervious.*
19	Various	12	*Excellent.* *Downhill ski tracks: Correctly shown as non-impervious.*
Overall evaluation (based on look-and-feel)			*Excellent* *The result is "automatically" excellent since most (99%) of Norway is non-impervious natural areas (where no impervious pixels should occur)* *Good if more weight is given to details in the partly built-up areas.* *Inexact but acceptable for roads and single-family housing residential areas (which constitute large parts of the Norwegian settlements). Commission and omission errors seem (look-and-feel) to cancel each other out.*
Comments			*Bare rock is never misclassified in the mountains, but occasionally in areas close to settlements.*

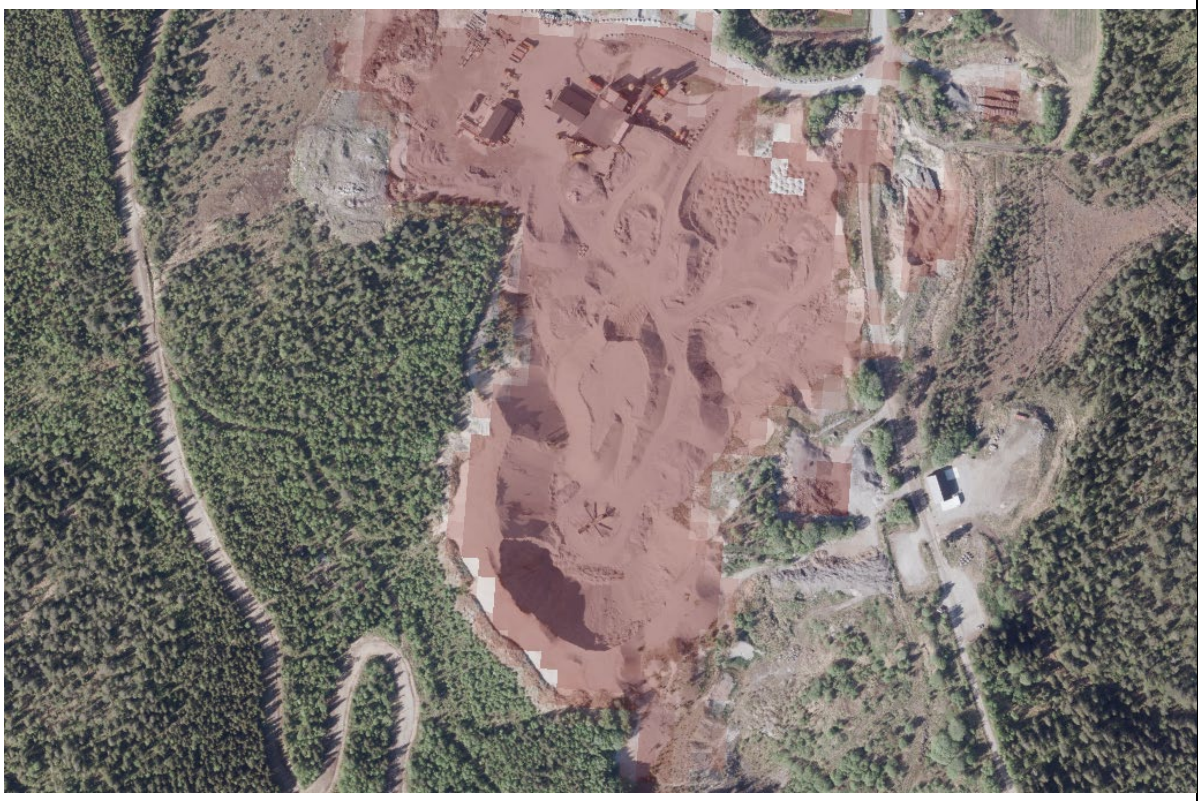
V. Documentation of errors and critical findings

Please include detailed descriptions, meaningful examples and screenshots of errors, critical findings. Please make sure the nature, location and frequency of the issue is described in some detail. Screenshots should contain ETRS1989 LAEA coordinates.

Soccer fields and tennis court confirmed as artificial grass partly rendered as impervious [ETRS1989 LAEA: 43477200, 4190000]

Gravel extraction site. Part of this extraction site was wrongly mapped as impervious in 2015. The entire (and enlarged) site is correctly mapped as not impervious in 2018. [ETRS1989 LAEA: 4404900, 4519325]

The quarry to the left is correctly not classified as impervious while the post-processing to the right is partially not correctly classified as imperivous. [ETRS1989 LAEA: 4372900, 4097900]

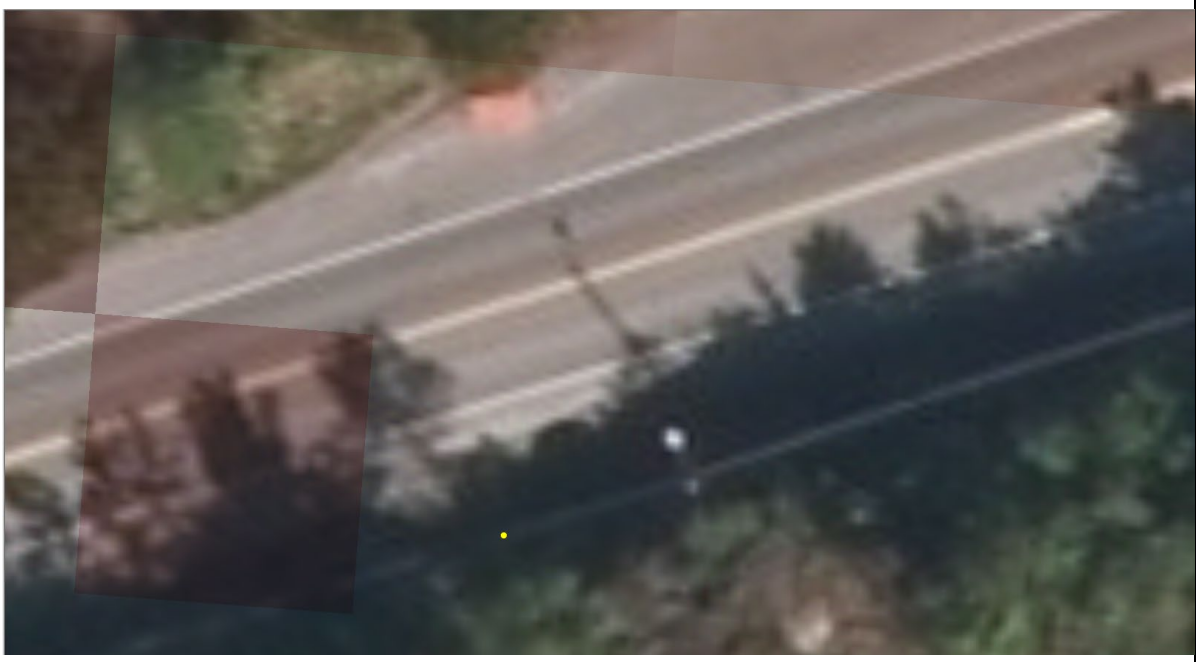


Sand/gravel quarry mistakenly classified as impervious. [ETRS1989 LAEA: 4397800, 4639300]

Gravel of a parking lot and the shore of a lake mistakenly classified as impervious. [ETRS1989 LAEA: 4391483, 4063727]

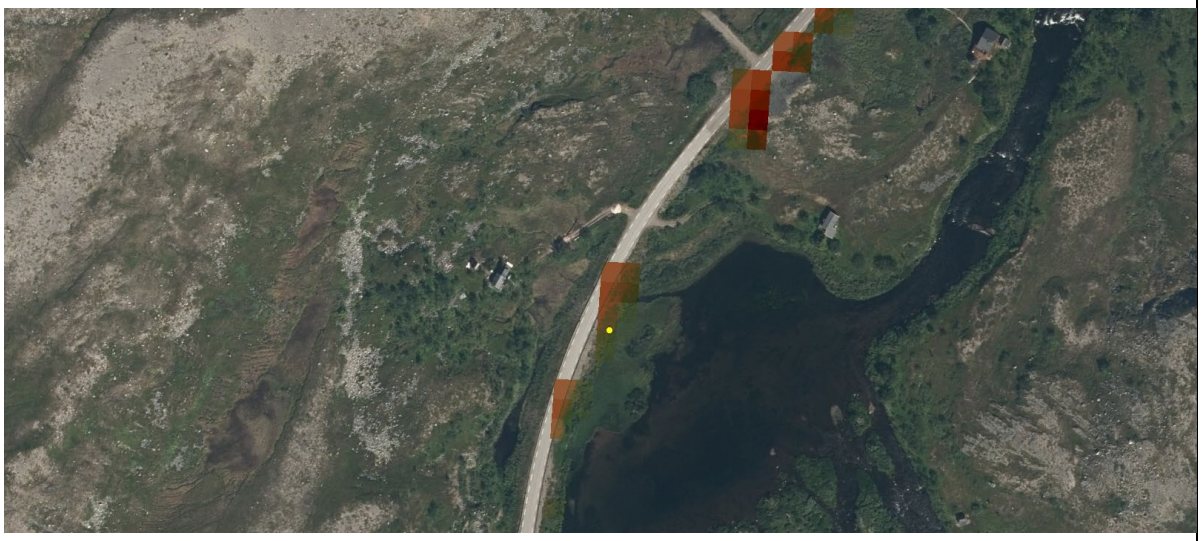
Sand beach partially classified as impervious. [ETRS1989 LAEA: 4070220, 3944800]

A horse racecourse. Not sure what it is covered with, but sand or fine gravel might be. Classification was a bit indecisive. [ETRS1989 LAEA: 4066800, 4162200]

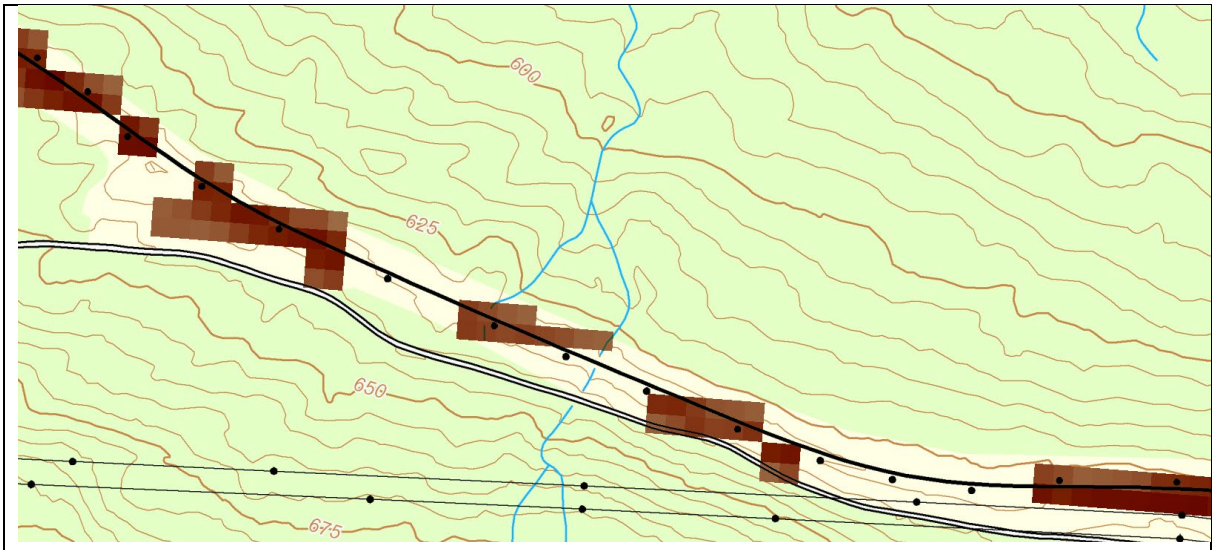


Hard surface road. Only parts are mapped as imperviousness > 0. [ETRS1989 LAEA: 4303100, 3993700]

Highway and, farms and rural buildings. Most of the impervious areas are mapped with imperviousness = 0. [ETRS1989 LAEA: 4357100, 4077300]



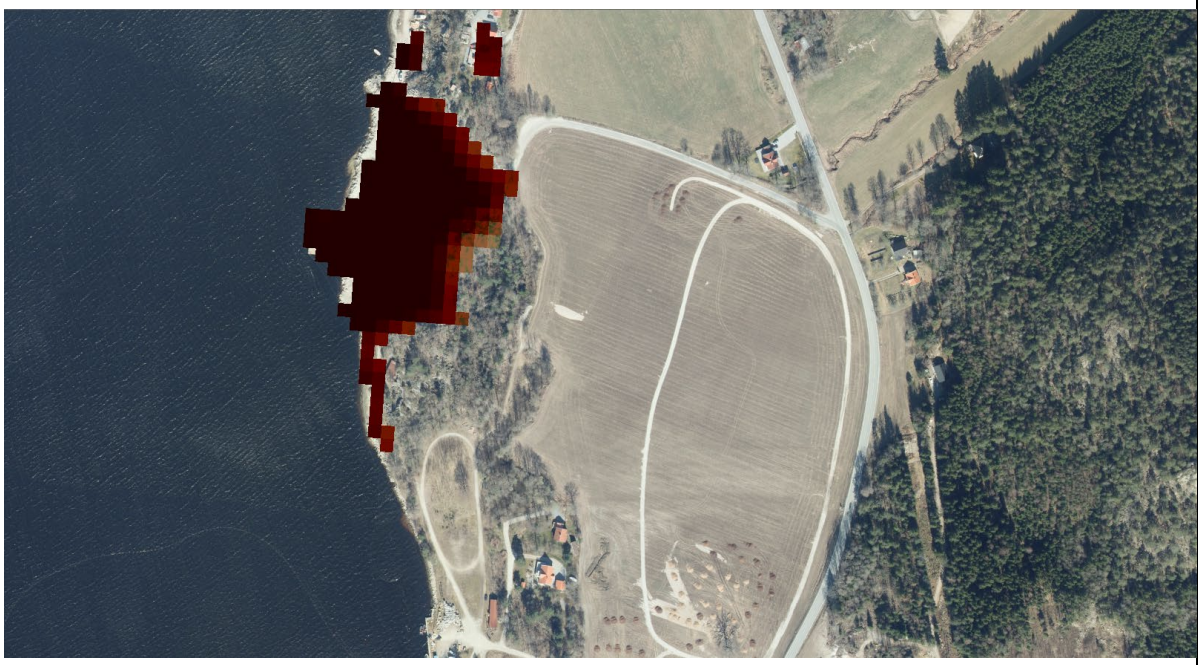
Highway. Only patches are mapped as imperviousness > 0. These patches are also mapped slightly off the actual road (geometrical inaccuracies). The pixel with the yellow dot at the centre of the image has imperviousness = 22 % (Class = 1) but is outside the road. It is still evaluated as “correct” since the distance to the road is short and there are pixels in the immediate vicinity where Class = 1 is a correct label



Railway line partially classified as impervious. Same situation as in IMD-2015, where the line also was represented as patches of impervious land. Notice that the road south of the railway line is a gravel road, and correctly mapped as not impervious. [ETRS1989 LAEA: 4229600, 4165250]

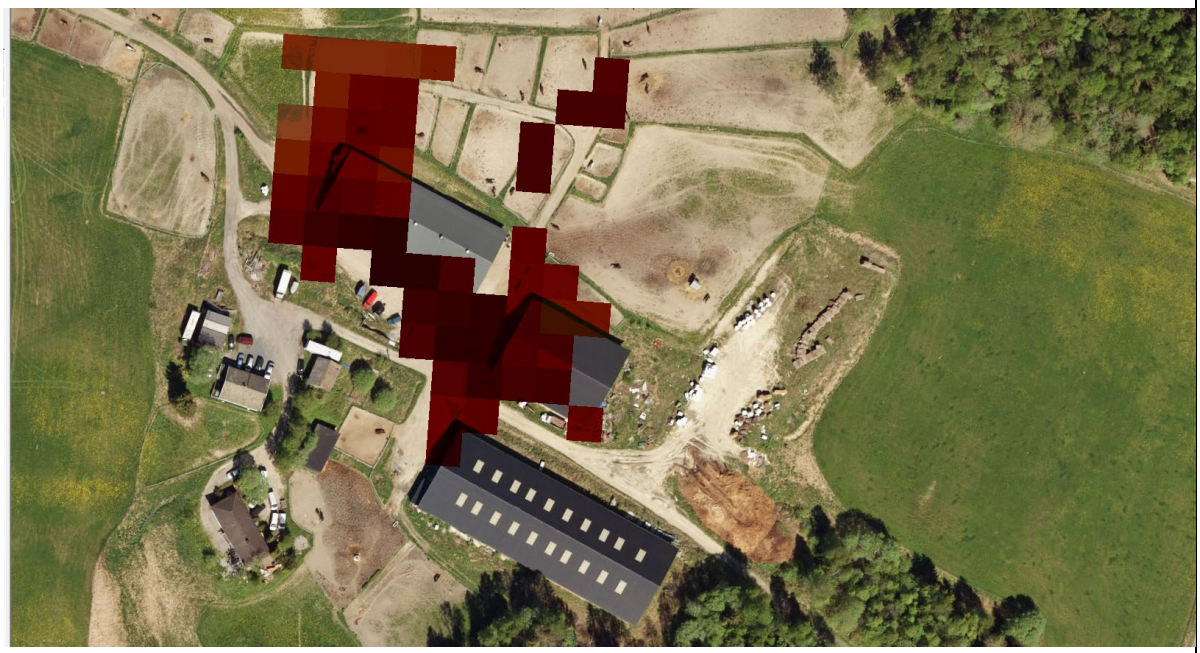
A large rock and gravel deposit (from tunnel dug as part of a hydropower development in 1955) at [ETRS1989 LAEA: 4171900,] that was wrongly mapped as impervious in IMD-2015 is now corrected. The entire dumpsite is mapped as IMD=0 in 2018. Another rock deposit from the same hydropower development, but 1,5 km further east, is still mapped as impervious (aerial photo with and without IMD-layer superimposed) [ETRS1989 LAEA:4219550, 4171700]

Agricultural field planted with row culture and mapped as impervious. Could have been covered with plastic in the satellite image? [ETRS1989 LAEA: 4403850, 3990400]

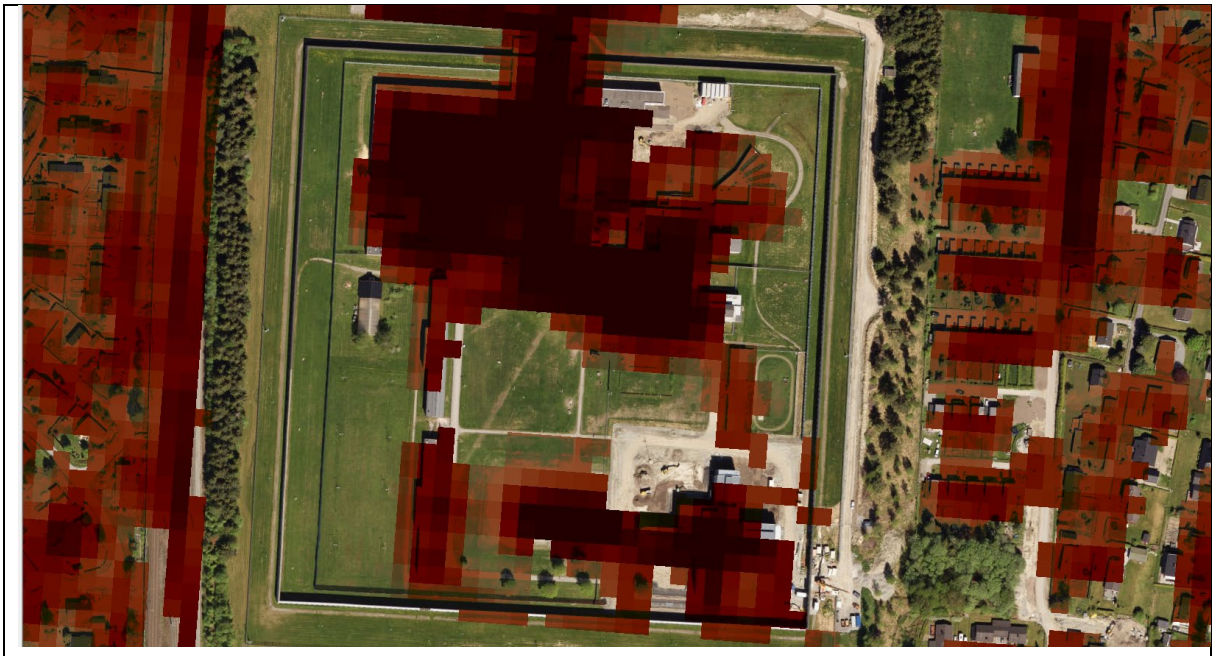


Quarry wrongly mapped as impervious [ETRS1989 LAEA: 4404070, 3991940]

Buildings in an otherwise agricultural area, not classified as impervious. [ETRS1989 LAEA: 4381275, 4071243]



Stables with paddocks. In 2015, the upper left stable and some of the paddocks were classified at impervious. These still classified as impervious in 2018, and the second stable (center of the image) is added to the impervious area. The large riding house at the bottom is not classified as impervious (and was not in 2015 either). It is present on aerial imagery from 2011 and was probably built in 2009 or 2010. [ETRS1989 LAEA: 4388915, 4104625]



Prison. The representation of the impervious buildings surrounded by open green areas is quite accurate. Also notice the fairly accurate representation of the town houses in the neighbourhood on the left. [ETRS1989 LAEA: 4384906, 4108267]

Highway and scattered settlements along Isfjorden. Only a few pixels are shown as partly impervious. [ETRS1989 LAEA: 4201257, 4388284]

Farmstead with house, garage and a large barn mapped as impervious. Farm equipment parked around the barn may have been interpreted as additional imperviousness? [ETRS1989 LAEA: 4372652, 4069653]

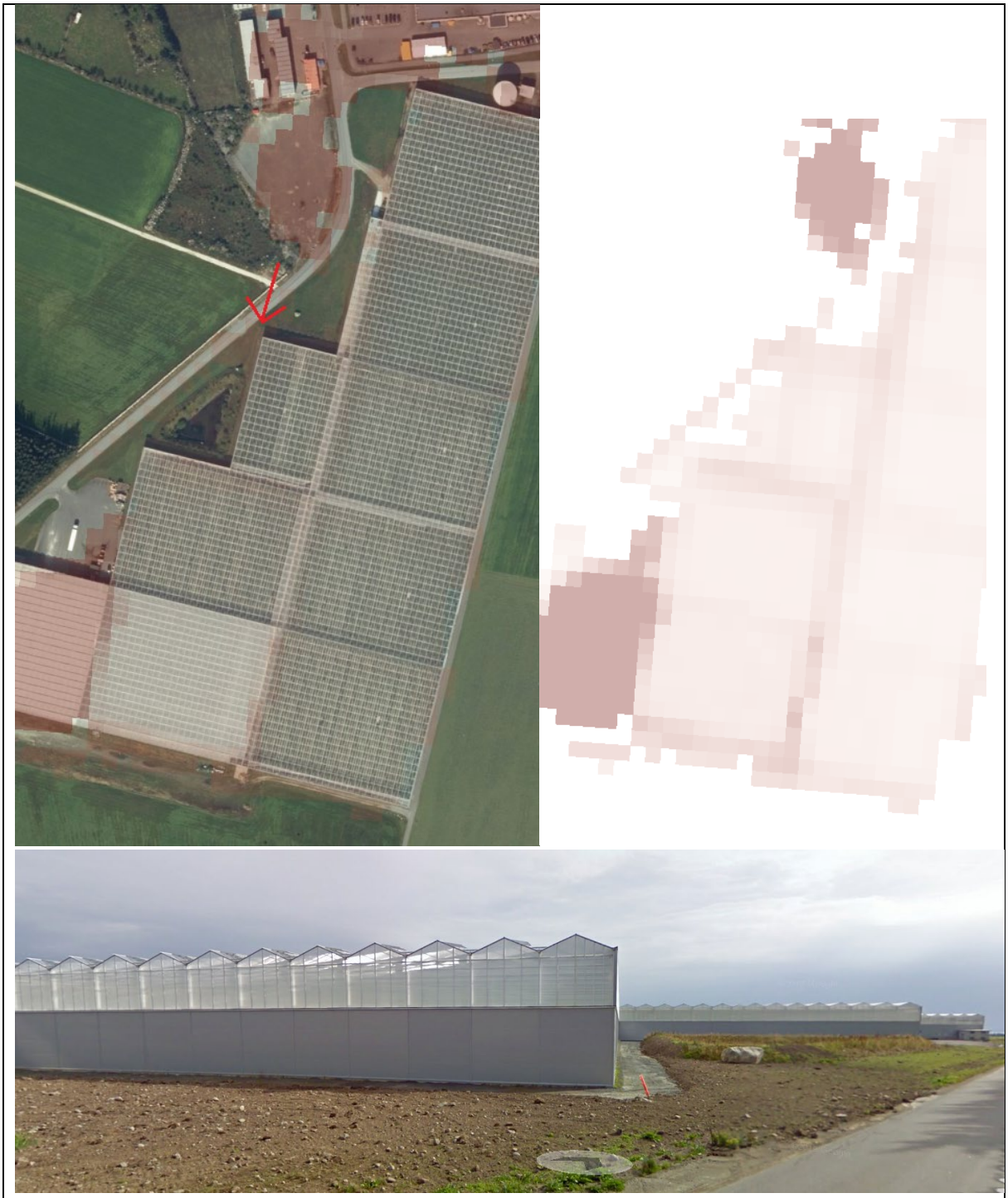
Fun fact: leisure boats in a marina classified as impervious. While technically indeed man-made blocking rainwater from drainage, problably not the first thing that comes into your mind. [ETRS1989 LAEA: -4075869, 3991697]

Two Marinas in Narvik, four kilometers from each other. While in one boats were classified as non-impervious, in the other they were not. In both marinas boats are visible on 28.7.2018-Sentinel-2-scenes. Left: [ETRS1989 LAEA: 4625550, 5049688] – right: [ETRS1989 LAEA: 4628300, 5052470]

Marina and caravan park with paved access roads and few greens at a lake, both considered impervious. [ETRS1989 LAEA: 4378390, 4171820]

Shadows may impact the quality of detecting highways or other impervious surfaces. [ETRS1989 LAEA: 4340777, 4080251]

To the right, the middle part of a field suspected to be covered with plastic, and correctly not classified as imperveous as they are seasonal. Right: Sentinel-2, 8.7.2018; left: Ortophoto 29.5.2020 used for control. [ETRS1989 LAEA: 4184130]



A greenhouse in southern Norway that has vaguely been detected as impervious. [ETRS1989 LAEA: 4066850, 3956400]

VI. **Statistical verification** (optional)

Description of methodology and software	*The HRL was classified into three classes. Samples were obtained by stratified random sampling using the reclassified HRL as strata. The sampling sizes is found in the table below. Each sample point was examined on topographic maps and recent orthophoto using qGIS. Accuracy was calculated following standard methodology using SPSS*
Stratification	*The HRL was classified into three classes* *0: Not impervious* *1: Imperviousness 1-29 %* *2: Imperviousness 30-100 %*
Comments	*The interpretation of ground truth was conservative. The HRL was accepted as correct when the analyst was in doubt. Misclassification was only recorded when the analyst was confident that an error was present.*

Please copy here the (weighted) confusion matrix and main accuracy parameters and provide the corresponding Excel file in attachment.

IMD2018 Verification strata sizes			
		Haa	**%**
HRL	**0**	32 179 200	99,38
	1	50 700	0,16
	2	151 000	0,47
	Total	**32 380 900**	**100,00**

IMD2018 Verification raw data confusion matrix

		Ground truth			
		0	**1**	**2**	**Total**
HRL	**0**	1 049	3	0	**1 052**
	1	11	87	7	**105**
	2	11	6	87	**104**
	Total	**1 071**	**96**	**94**	**1 261**

IMD2018 Verification weighted confusion matrix

		Ground truth			
		0	**1**	**2**	**Total**
HRL	**0**	0,990936	0,002834	0,000000	**0,993770**
	1	0,000164	0,001298	0,000104	**0,001566**
	2	0,000493	0,000269	0,003900	**0,004662**
	Total	**0,991593**	**0,004401**	**0,004004**	**0,999998**

IMD2018 Verification Overall accuracy

		Accuracy	**95% CI**	**Lower**	**Upper**
		99,6 %	0,3 %	99,3 %	99,9 %

IMD2018 Verification User's accuracy

		Accuracy	**95% CI**	**Lower**	**Upper**
HRL	**0**	99,7 %	0,3 %	99,3 %	99,9 %
	1	82,9 %	7,2 %	75,7 %	91,1 %
	2	83.7 %	7,1 %	76.6 %	90,8 %

IMD2018 Verification Producer's accuracy

		Accuracy	**95% CI**	**Lower**	**Upper**
HRL	**0**	99,9 %	< 0,1 %	99,9 %	99,9 %
	1	29,5 %	21,6 %	7,9 %	51,1 %
	2	97.3 %	1,8 %	95,5 %	99,1 %