HRL 2018 look & feel verification report for Dominant leaf type status 2018

I. Administrative part

HRL	*Dominant leaf type status*
Verified area, region	*Finland*
Institution carrying out the work	Natural Resources Institute Finland (Luke)
Overall visual checking done by (name, position and e-mail)	Hanna Huitu, researcher, hanna.huitu@luke.fi Matti Katila, researcher, matti.katila@luke.fi
Look & feel verification done by (name, position and e-mail)	Hanna Huitu, researcher, hanna.huitu@luke.fi
Statistical verification done by	Matti Katila, researcher, matti.katila@luke.fi
In situ data used.	National Forest Inventory (NFI) field plots, from systematic cluster sampling with NFI field plots 2017- 2019 except for northern Lapland (see Fig. 5 for sampling regions) 2012-2013. Data set covers national forestry land (larger than FAO forest, n=13496)
	Finnish multisource-NFI thematic maps of canopy cover (broadleaved, coniferous) Resolution: 16 m, Reference years:2015, 2017, 2019
	National Ortho photo database Natural color/black and white ortho photos Resolution: 0.25-0.5m Reference years: 2017 - 2019 (partial coverages)
	Polygon database of forest stands/ Finnish Forest Center Reference year 2021(partial coverage)
	CORINE Land Cover 2018, resolution: 20 m
	Topographic database of National Land Survey
Reporting done by (name, position and e-mail)	Hanna Huitu, researcher, hanna.huitu@luke.fi Matti Katila, researcher, matti.katila@luke.fi
Date and place of writing the report	Helsinki 28.6.2021

II. General overview of the verified data

General overview of the verified data	*Statistical information chart about the verified data.*

General information

High Resolution Layer for Dominant Leaf Type (2018) is a raster layer in 10 m resolution, a status product that separates broadleaved and coniferous cover for all tree covered (TCD > 0 %) areas. Main aim of this verification exercise is identification of systematic classification errors, which are eligible for improvement in future product updates.

Statistical information charts, overview image and comparison to national statistics

Total area covered by values in HRL Dominant leaf type layer is 211 056 km^2. Shares of broadleaved and coniferous trees are shown in Table 1.

Table 1: Overview statistics – Dominant leaf type 2018 Finland

HRL TCD18 Finland	Value	Km2	%
1	Broadleaved trees	41 389.8	19.6
2	Coniferous trees	169 666.3	80.4
-	***Total area of tree cover***	***211 056.0***	***100***
0	No tree cover	135 973.7	-
255	Outside area (no data)	428 904.3	-

Total area covered by values in HRL Dominant Leaf Type 2018 layer is 211 056 km^2. This is less than estimated by the thematic layers in national data, where total area of above-zero canopy cover is 261 586 km$^{2.}$ (See report for HRL TCD 2018 for more information).

Overview image (Fig.1) shows division of values in HRL Dominant Leaf Type 2018 layer within Finland. Coniferous tree cover dominates most of the area, with exceptions being found in northern Finland, and for instance in some densely populated urban areas in southern or central Finland.

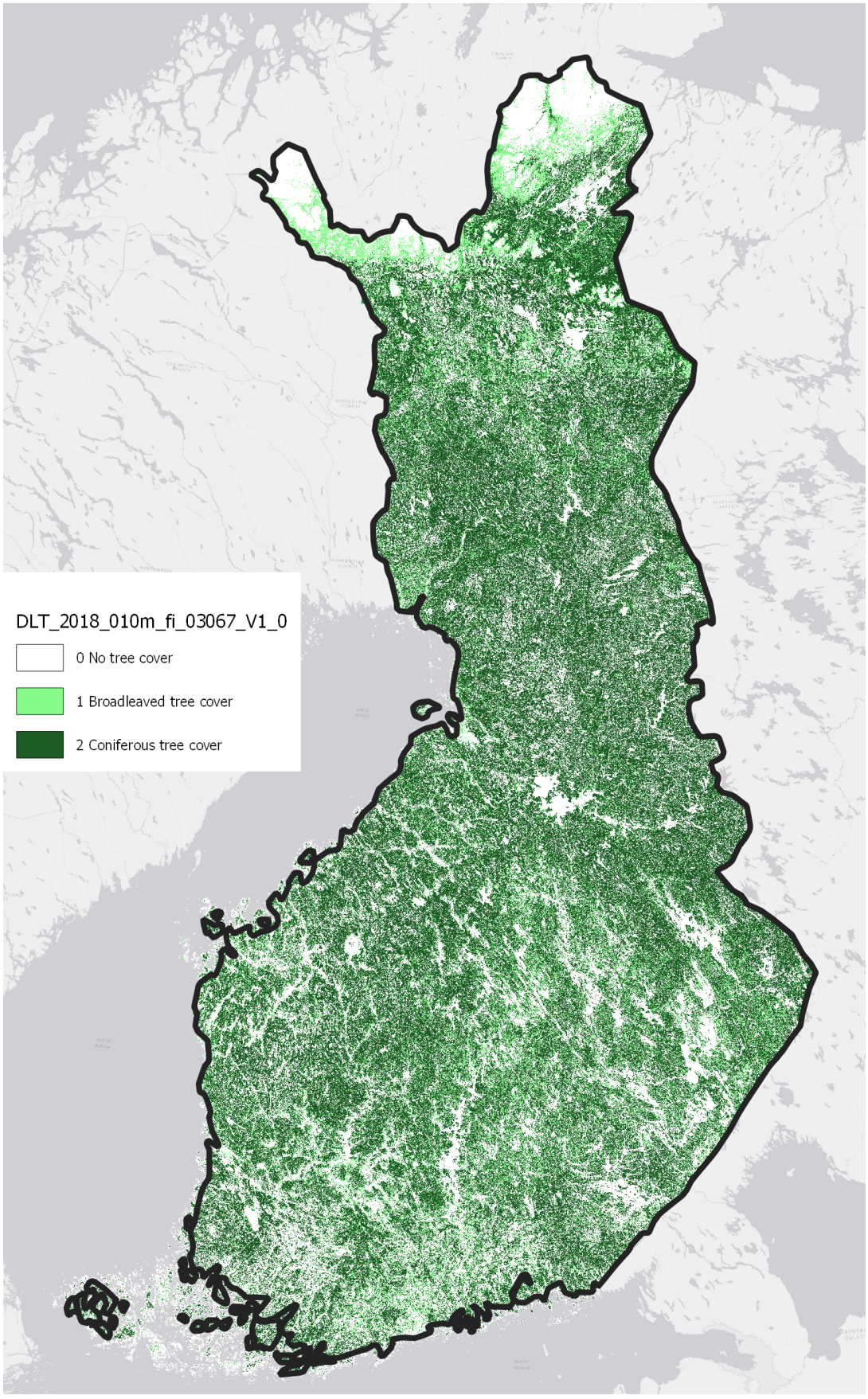

Fig. 1: Overview image, HRL DLT 2018

To assess dominance of coniferous and broadleaved cover on different land cover and land use, HRL DLT 2018 layer was overlaid with the national Corine 2018 Land cover / Land use product HR CLC 2018, which is raster layer at 20 m resolution. Main point drawn from this comparison was that leaf type dominance seems reasonable for most land use classes, and that prevalence of HRL DLT - coniferous forests in CLC class broadleaved forests suggests omission error for broadleaved leaf type, and respective commission error for coniferous leaf type.

Most Level 1 Urban classes had broad leaved dominated tree cover. Urban fabric and green urban areas were clearly dominated by broad-leaved leaf types. Summer cottages were the only urban CLC class showing coniferous dominance, presumably as many cottages are situated in remote areas dominated by coniferous forests
Level 1 Agricultural land is dominated by the broadleaved. These results are as anticipated. Pastures and borders of fields often contain individual broadleaved trees, and for lay or abandoned fields broadleaved trees are often first in succession.
For forest classes, HR CLC 2018 distinguishes broadleaved, coniferous, and mixed forests. Forests that are coniferous by CLC classification, are almost all (> 90 %) dominated by coniferous also by the HRL DLT layer. Broadleaved class in HR CLC shows more disagreement. About 20 % of the broadleaved forests on peatland were classified by HRL DLT as being coniferous dominated. Transitional woodlands on mineral soil were equally divided to broadleaved and coniferous by HRL DLT, but on rocky soils and peatlands HRL DLT classified them as broadleaved. This seems reasonable. Further for wetland and water body classes, there was no clear dominance of either leaf type. Detailed comparison is given as Table 2.

Table 2: Corine Land Cover 2018 compared to tree covered area in HRL DLT18.

HR CLC18 code (Level 4)	HR CLC18 class name	Total area (km2)	Broadleaved tree cover (HRL DLT2018)	Coniferous tree cover (HRL DLT2018)
1.1.1.1	Continuous urban fabric	171.0	**16.5 %**	**8.7 %**
1.1.2.1	Discontinuous urban fabric	3 176.1	**23.3 %**	**16.1 %**
1.2.1.1	Commercial units	956.6	**12.7 %**	**13.5 %**
1.2.1.2	Industrial units	623.9	**12.9 %**	**14.5 %**
1.2.2.1	Road and rail networks and associated land	2 378.1	**10.1 %**	**14.8 %**
1.2.3.1	Port areas	39.9	**4.6 %**	**1.2 %**
1.2.4.1	Airports	77.0	**4.9 %**	**6.4 %**
1.3.1.1	Mineral extraction sites	421.9	**3.2 %**	**13.5 %**
1.3.1.2	Open cast mines	28.9	**2.6 %**	**2.2 %**
1.3.2.1	Dump sites	134.0	**6.1 %**	**2.5 %**
1.3.3.1	Construction sites	27.5	**2.6 %**	**10.4 %**
1.4.1.1.	Green urban areas	33.8	**22.6 %**	**6.1 %**

1.4.2.1	Summer cottages	1 367.2	**17.6 %**	**52.9 %**
1.4.2.2	Sport and leisure areas	134.9	**9.3 %**	**10.0 %**
1.4.2.3	Golf courses	87.1	**10.2 %**	**12.5 %**
1.4.2.4	Racecourses	9.9	**3.2 %**	**5.9 %**
2.1.1.1	Non-irrigated arable land	21 774.7	**2.2 %**	**0.6 %**
2.2.2.1	Fruit trees and berry plantations	62.6	**4.6 %**	**0.8 %**
2.3.1.1	Pastures	39.7	**7.6 %**	**1.7 %**
2.3.1.2	Natural pastures	93.9	**20.4 %**	**15.9 %**
2.4.3.1	Arable land outside farming subsidies	2 125.2	**9.6 %**	**1.6 %**
2.4.4.1	Agro-forestry areas	35.3	**18.0 %**	**6.6 %**
3.1.1.1	Broad-leaved forest on mineral soil	9 795.5	**81.3 %**	**10.1 %**
3.1.1.2	Broad-leaved forest on peatland	562.7	**70.2 %**	**17.2 %**
3.1.2.1	Coniferous forest on mineral soil	114 100.1	**4.4 %**	**89.0 %**
3.1.2.2.	Coniferous forest on peatland	32 643.2	**3.9 %**	**82.8 %**
3.1.2.3	Coniferous forest on rocky soil	3 060.2	**0.9 %**	**89.2 %**
3.1.3.1	Mixed forest on mineral soil	36 411.7	**37.8 %**	**54.6 %**
3.1.3.2	Mixed forest on peatland	8 723.2	**28.2 %**	**62.9 %**
3.1.3.3.	Mixed forest on rocky soil	227.7	**17.5 %**	**71.9 %**
3.2.1.1	Natural grassland	107.9	**0.1 %**	**0.0 %**
3.2.2.1	Moors and heathland	7 382.0	**16.8 %**	**1.4 %**
3.2.4.1	Transitional woodland/shrub cc <10%	8 477.9	**8.2 %**	**10.1 %**
3.2.4.2	Transitional woodland/shrub, cc 10-30%,on mineral soil	14 768.9	**26.5 %**	**24.5 %**
3.2.4.3	Transitional woodland/shrub, cc 10-30%, on peatland	8 623.5	**9.8 %**	**22.9 %**
3.2.4.4	Transitional woodland/shrub, cc 10-30%, on rocky soil	1 542.9	**5.6 %**	**57.2 %**
3.2.4.6	Transitional woodland/shrub under power lines	384.3	**13.5 %**	**12.2 %**
3.3.1.1	Beaches, dunes, and sand plains	64.1	**4.4 %**	**5.9 %**
3.3.2.1	Bare rock	1 779.9	**6.3 %**	**8.8 %**
3.3.3.1	Sparsely vegetated areas	541.7	**2.0 %**	**0.3 %**
4.1.1.1	Inland marshes, terrestrial	373.6	**20.2 %**	**10.5 %**
4.1.1.2	Inland marshes, aquatic	1 066.2	**2.4 %**	**4.4 %**
4.1.2.1	Peatbogs	19 087.9	**4.5 %**	**5.4 %**
4.1.2.2	Peat production sites	1 026.2	**1.6 %**	**2.4 %**
4.2.1.1	Salt marshes, terrestrial	300.6	**16.1 %**	**4.1 %**
4.2.1.2	Salt marshes, aquatic	292.2	**1.5 %**	**0.7 %**
5.1.1.1	Water courses	1 168.5	**6.5 %**	**11.3 %**
5.1.2.1	Water bodies	32 299.1	**0.1 %**	**1.3 %**
5.2.3.1	Sea and ocean	52 197.4	**0.0 %**	**0.0 %**

Summary of experiences about data quality

- Visual scanning of the HRL DLT 2018 layer over MS-NFI thematic layer and ortho-photos showed good consistency in the detailed spatial forest stand structure. Positional errors were not encountered.
- Comparison of HRL DLT 2018 layer to national HR Corine land cover statistics showed that leaf type dominance of the tree cover was in line with what was expected for different land cover types (table 2).
- For the field measured reference sites where HRL DLT 2018 value was Coniferous, 96.7 % of the sites were coniferous dominated. Where HRL DLT 2018 value was Broadleaved, 62.0 % of the reference sites were broadleaved dominated (See part V Statistical verification for full statistics)
- For coniferous dominated, field measured reference sites, classification accuracy improved as the forest matured (table 3).

Users accuracy of “Non-forest” class was low (21 %). This was due to many seedling stands and regeneration areas being classified as zero tree cover density in the HRL TCD 2018.

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)	*OK*	*Quick visual comparison of the DLT2018 over MS-NFI respective thematic layers shows good agreement.*

IV. Look & feel verification results

Details of look & feel verification

1.Included elements, possible OMISSIONS

DLT-Misclassification, coniferous misclassified as broadleaved

Stratum	Name of the stratum (see proposed strata in Tables 5.2.2.x.b)	Number of samples verified	*Results of the verification by strata (excellent, good, acceptable, insufficient, very poor): see chapter 5.2 of the guidelines*
1	Coniferous tree cover class in national forest type dataset containing broadleaved cover	10	**Acceptable** (3.0)
2	Young mixed forests dominated by coniferous	11	**Good** (3.8)
3	Clearing areas or young coniferous plantations inside coniferous forests	10	**Good** (3.7)
4	Patches of coniferous forest within broadleaved forests	10	**Excellent** (4.7)
N		41	
Overall evaluation			**Good** (4)
Comments, overview of results			All strata recommended in 5.2.2.4.b was covered, except “Coniferous (pinus and cypress) within graveyards or urban areas at Mediterranean”, which does not exist in area.

2. Excluded elements, possible COMMISSIONS

CONIFEROUS-COMMISSION, broadleaved classified as coniferous

Stratum	Name of the stratum (see proposed strata in Tables 5.2.2.x.c)	Number of samples verified	*Results of the verification by strata (excellent, good, acceptable, insufficient, very poor): see chapter 6.3 of the guidelines*
1	Broadleaved tree class in national forest type dataset containing coniferous cover	11	**Good** (4.0)
2	Broadleaved tree cover on wetland	10	**Good** (4.0)
3	Broadleaved tree cover on the bank of a river or lake	11	**Good** (4.0)
4	Young tree plantations (fruit, energy, or broadleaved trees	10	**Excellent** (4.6)
5	Shadows of tall broadleaved trees	10	**Good** (4.3)
N		52	
Overall evaluation			***Good** (4)*
Comments, overview of results			Strata recommended in 5.2.2.4.c was covered, except Poplar, Willow, Alder and Eucaluptus plantations, Evergreen sclerophyllous vegetation and Topographic shadows in mountain area. These do not exist in the area.

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.

Classification errors were searched for DLT misclassification and Coniferous-comission. Look and feel verification was based on the recommendations in the Guidelines document (Tables 5.2.2.4.b and 5.2.2.4.c).

Generally, the HRL DLT 2018 layer was in good agreement with the national data, and errors found in these strata were mainly resulting from misclassification between broadleaved/coniferous and no crown cover, not between misclassification of the two leaf types. This error type (between tree cover and no tree cover) is assessed in verification report for HRL TCD 2018 and focus of this report is in classification errors between broadleaved and coniferous leaf type dominances.

Young coniferous dominated forest classes had more classification errors than older coniferous stages. This observation from Look and Feel verification was confirmed using field measured data set (Table 3.)

Homogeneity of the forest stand in terms of tree species affected the abundance of errors. Pure coniferous forests (with >90 % of the trees on the stand coniferous) showed almost no misclassifications. Classification errors on mixed forests are more common, but they are difficult to verify, as the spatial detail of data set in question affects the outcome. Figures 2. and 3. show examples, where type of a young growing forest (02 in national classification) has been misclassified.

Fig. 2: Spruce-dominated young growing forest misclassified as broadleaved (green) in HRL DLT. Stand is delineated with white polygon. Only the western part of the stand is classified coniferous (red).

Fig. 3: Spruce-dominated young growing forest partly misclassified as broadleaved (green) in HRL DLT. Stand is delineated with white polygon.

Commission errors listed in the Guidelines (Table 5.2.2.4.c) were rare. Coniferous-commission was found on isolated cases, one example given in Figure 4.

Fig. 4. Commission error on coniferous. HRL DLT overlaid over aerial imagery. River and broadleaved (birch) trees classified as coniferous (red). Surrounding area is correctly classified broadleaved (green).

VI. **Statistical verification** (optional)

Description of methodology and software	*Describe shortly the methodology and software used for quantitative verification* For statistical verification of the HRL forest layers, there is an extensive field sample available based on systematic cluster sampling. The field sample was NFI12 and NFI13 data from years 2017-2019, for which the crown cover (cc) was available only for the national forest land field plots. The northernmost Lapland (Ylä-Lappi) was an exception (Fig. 5), the field sample was selected based on double sampling with stratification and originated from the year 2012-2013 (NFI11). The data set contained 13496 field plots on forestry land selected for quantitative verification. All the field plots on land and inland water were included. In addition for the plots selected the minimum distance to the nearest stand boundary was 20 m on national forestry land. The radius of the of the NFI12 and NFI13 field plot is 9 m. The forestry land is defined according to national definition, see Tomppo, E., Heikkinen, J., Henttonen, H.M., Ihalainen, A., Katila, M., Mäkelä, H.,Tuomainen, T. & Vainikainen, N. 2011. Designing and conducting a forest inventory - case: 9th National Forest Inventory of Finland. Springer, Managing Forest Eco-systems. Field plots where a drastic change of land cover or a clearcut of forest had occurred between the field measurement date and assumed image acquisition date (30.6.2018 was assumed for the HRL product) were removed using MS-NFI2019 satellite images and land use change monitoring data from Greenhouse gas reporting project. The canopy cover percentage was readily modeled for the field plots on the forest, poorly productive forest land and unproductive land (national land classes) plots (Mäkisara K., Katila M., Peräsaari J. (2019). The multi-source national forest inventory of Finland – methods and results 2015. Natural resources and bioeconomy studies 8/2019. Natural Resources Institute Finland (Luke). http://urn.fi/URN:ISBN:978-952-326-711-4, sect. 3.2.1).). For more details about estimating the canopy cover for the NFI field plots see the Tree Cover Density verification report section V. The broadleaved-coniferous dominance was derived from the proportion between cc of broadleaved trees and total cc.
Stratification	*'no stratification'*
Comments	Field measurements from the national forest inventory (NFI) were used as ground truth data in this verification. NFI is based on systematic cluster sampling over all land use classes and ownership types, although only plots on forestry land were used for verification of HRL2018. Number of field plots per area decreases towards north. The country is divided into six inventory areas (Fig.5.), and results are presented also for these sub-regions. In Finland, over 78 % of the land area is covered by forestry land. Due to sampling methodology, no stratification was used. Note that a subset of field plots within forest stands was selected for validation set; selected the minimum distance to the nearest stand boundary was 20 m.

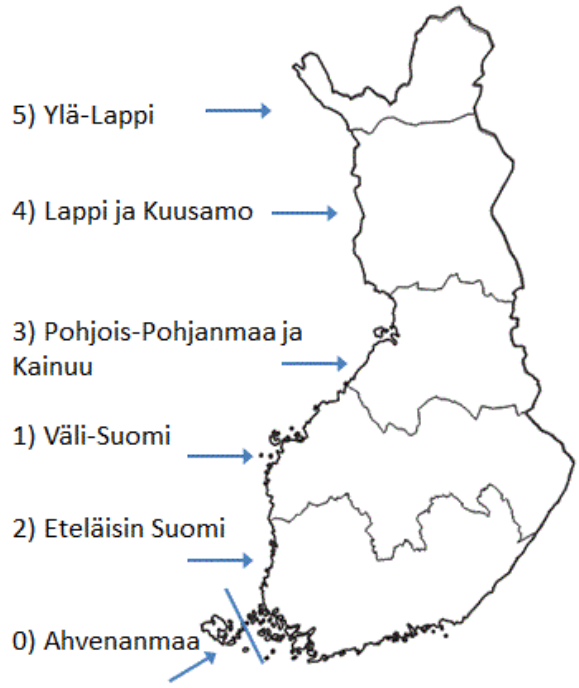

Fig. 5. Sampling region for the Finnish National Forest Inventory.

Leaf type information from HRL DLT 2018 was checked against the ground truth leaf types recorded on-site (NFI field plots). Classification error matrix is given in Table 4.
For coniferous stands, classification improved along the aging of the stand. This comparison is presented as table 3.

Table 3. Correctly classified broadleaved and coniferous dominated reference sites (NFI field plots) by forest development stages. Reference sites with HRL Tree cover density value 0 are not included.

Development stage	Broadleaved	Coniferous
2: Young seedling stand	76.5 % (n=34)	62.5 % (n=64)
3: Advanced seedling stand	79.3 % (n=222)	69.5 % (n=558)
4: Young thinning stand	81.1 % (n=530)	91.7 % (n=2 722)
5: Advanced thinning stand	70.8 % (n=243)	97.9 % (n=3 609)
6: Mature stand	58.8 % (n=80)	97.7 % (n=1 596)

Table 4 Classification error matrix for dominant leaf type using field sample plots of NFI on forestry land (national definition) from years 2017-2019 (except 2012-2013 the northernmost Lapland, Ylä-Lappi).

Confusion Matrix

		Reference Data				
		non-forest	broadleaved	coniferous	UserAccuracy	UserAccuracyVariance
Classification Data	non-forest	638	611	1810	20,86 %	0,0144
	broadleaved	34	1001	644	59,62 %	0,023477
	coniferous	8	286	8464	96,64 %	0,003773
	Weights	3059	1679	8758		
	ProducerAccuracy	93,82 %	52,74 %	77,52 %		
	ProducerAccuracyVariance	0,017839	0,017986	0,004741		
	PortmanteauAccuracy	81,75 %	88,33 %	79,64 %		
	PortmanteauAccuracyPartial	20,57 %	38,86 %	75,49 %		

OverallAccuracy	**0,748592**
OverallAccuracyVariance	**0,005018**
AllocationDisagreement	**0,075133**
Shift	**0,026526**
Exchange	**0,048607**
QuantityDisagreement	**0,176274**
AMI	**0,271981**
AMIAdjusted	**0,249065**
AMIVariance	**0,01412**
Kappa	**0,436444**
KappaVariance	**0,014984**