

Mapping of lichen coverage using optical satellite data and the NFI, over the Swedish reindeer husbandry area



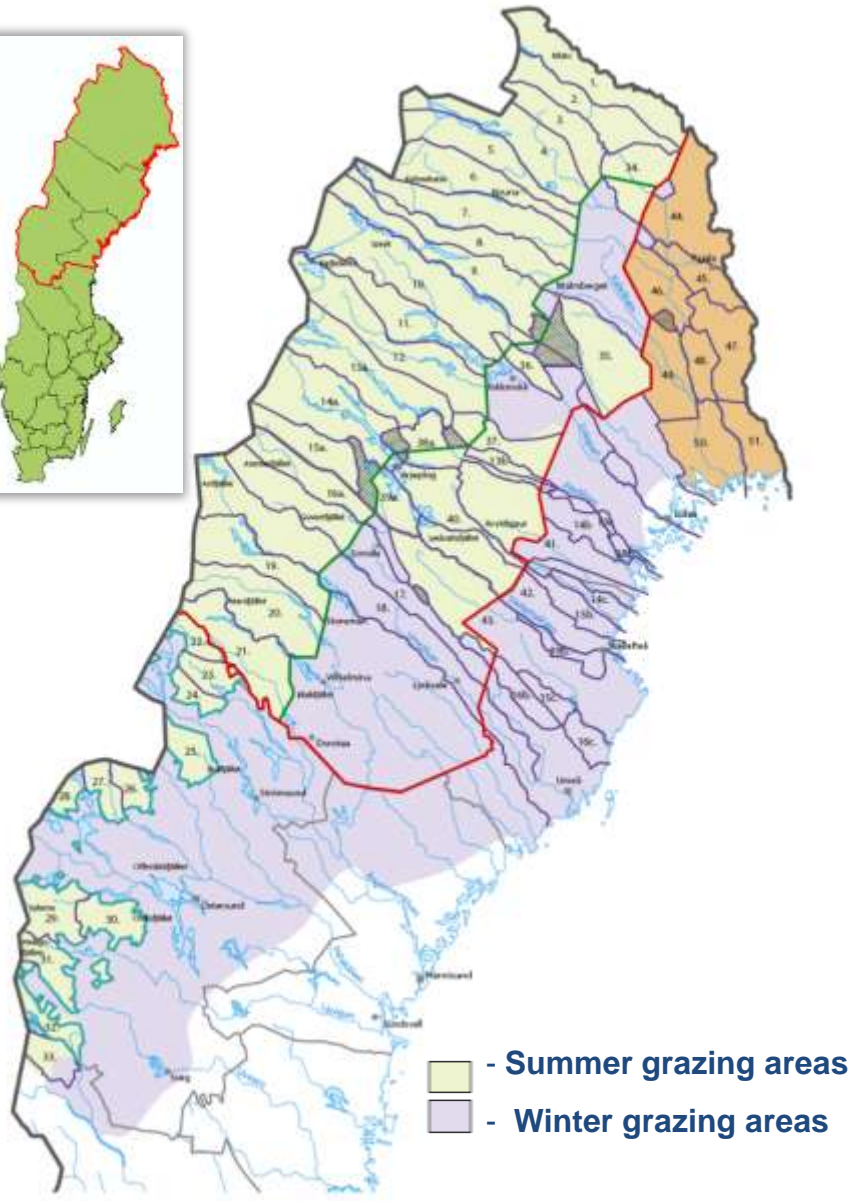
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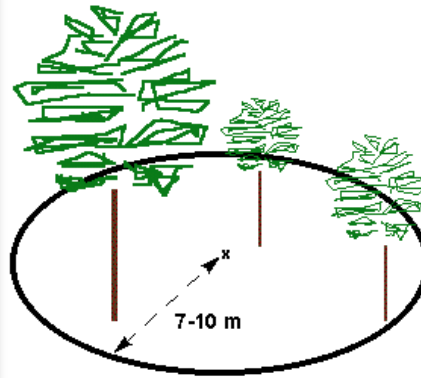
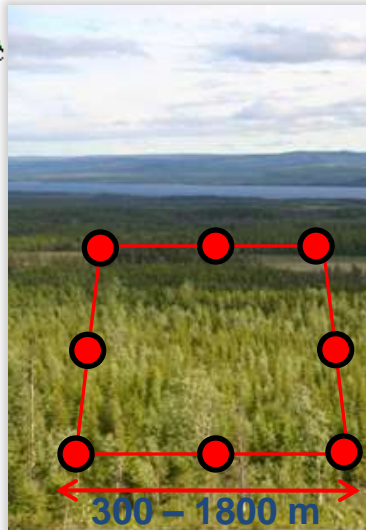
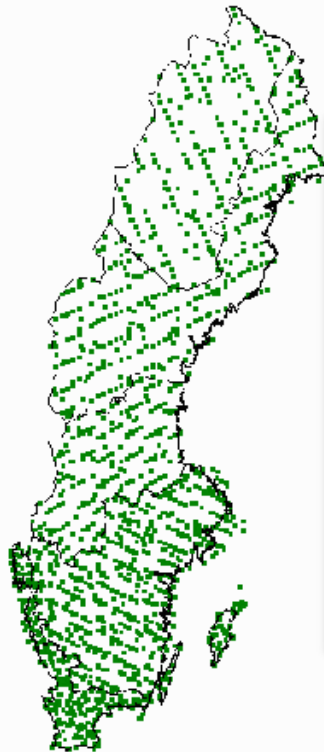


Lichen and reindeer husbandry



- There are about ~230,000 reindeer in Sweden
- Herding area in Sweden is about 160,000 km² divided by 51 herding communities (Saami villages)
- About 80% of reindeer's winter diet is ground lichen
- Lichen have a slow (about 10 percent) annual growth and affected by forest management operations e.g. fertilization, scarification etc
- Historical and continuous conflict between reindeer and forest owners

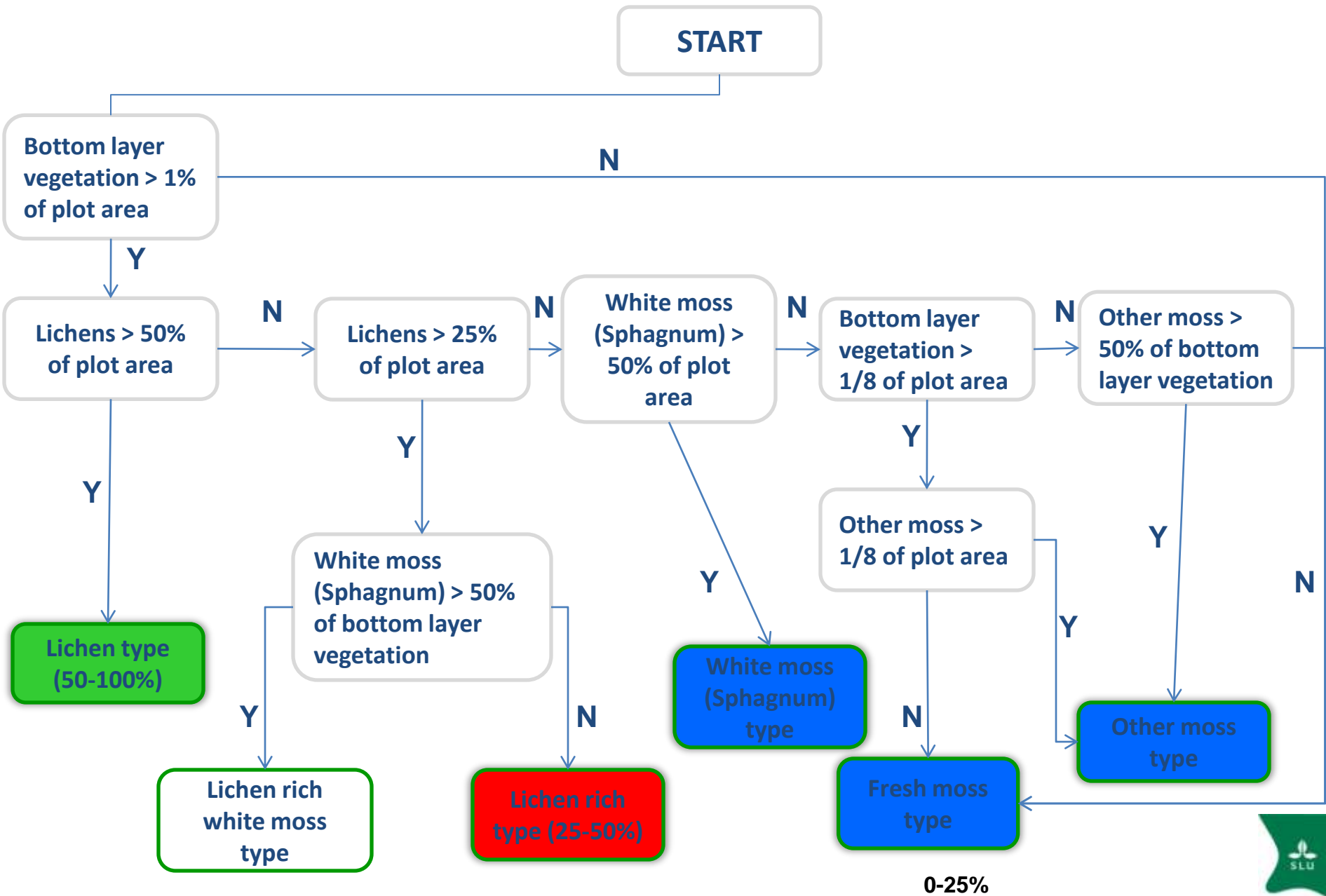
The Swedish National Forest Inventory



VOLGRAN	VOLBJORK	VOLOLOV	Lichen Type	Lichen rich type	Moss type	FURTIGH	TALLAND
1528.00000	450.00000	0.00000			1	3.00000	0.00000
85.00000	92.00000	0.00000			1	4.00000	0.00000
898.00000	0.00000	0.00000			1	3.00000	0.00000
2104.00000	261.00000	0.00000			1	4.00000	0.00000
127.00000	174.00000	0.00000			1	3.00000	0.00000
382.00000	460.00000	0.00000			1	2.00000	0.00000
1907.00000	999.00000	0.00000			1	2.00000	1.00000
1588.00000	0.00000	0.00000			1	2.00000	2.00000
1732.00000	767.00000	0.00000			1	2.00000	2.00000
257.00000	442.00000	0.00000			1	2.00000	2.00000
257.00000	68.00000	0.00000			1	3.00000	1.00000
51.00000	0.00000	0.00000			1	2.00000	9.00000
147.00000	419.00000	0.00000			1	2.00000	1.00000
111.00000	0.00000	0.00000			1	2.00000	9.00000
0.00000	0.00000	0.00000			1	2.00000	0.00000
1339.00000	1.00000	0.00000			1	3.00000	0.00000
413.00000	34.00000	0.00000			1	3.00000	4.00000
0.00000	0.00000	0.00000	1			1.00000	10.00000
0.00000	0.00000	0.00000	1			2.00000	10.00000
0.00000	0.00000	0.00000	1			1.00000	10.00000
0.00000	1.00000	0.00000			1	2.00000	0.00000
1298.00000	12.00000	0.00000			1	3.00000	0.00000
1030.00000	2.00000	0.00000			1	2.00000	4.00000
3.00000	71.00000	2.00000			1	2.00000	4.00000
8.00000	0.00000	0.00000	1			1.00000	9.00000
0.00000	17.00000	0.00000	1			1.00000	9.00000
0.00000	0.00000	0.00000			1	1.00000	10.00000
0.00000	1.00000	0.00000			1	3.00000	10.00000
17.00000	4.00000	0.00000			1	2.00000	9.00000
0.00000	0.00000	0.00000			1	2.00000	10.00000
2252.00000	6.00000	39.00000			1	2.00000	4.00000

- is a part of the Official Statistics of Sweden
- has been undertaken since 1923
- includes annually inventoried 13,500 sample plots, clustered into 1,450 tracts (GPS locations since 1996)
- gathers various vegetation characteristics (e.g. lichen coverage) concerning all land cover types with an emphasis on forest land

The NFI classification scheme of bottom layer vegetation (bottenskikt)



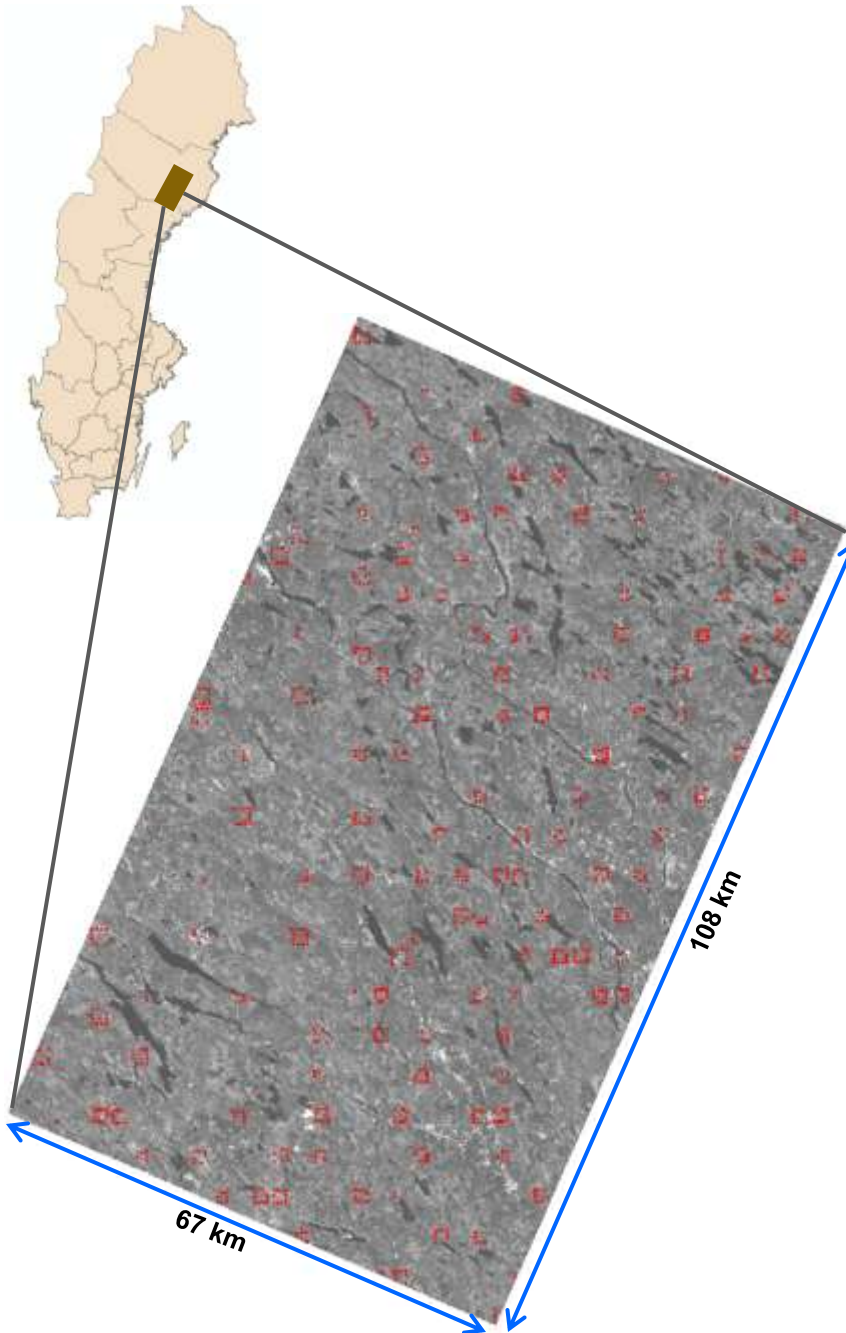
0-25%

Remote sensing and NFI data

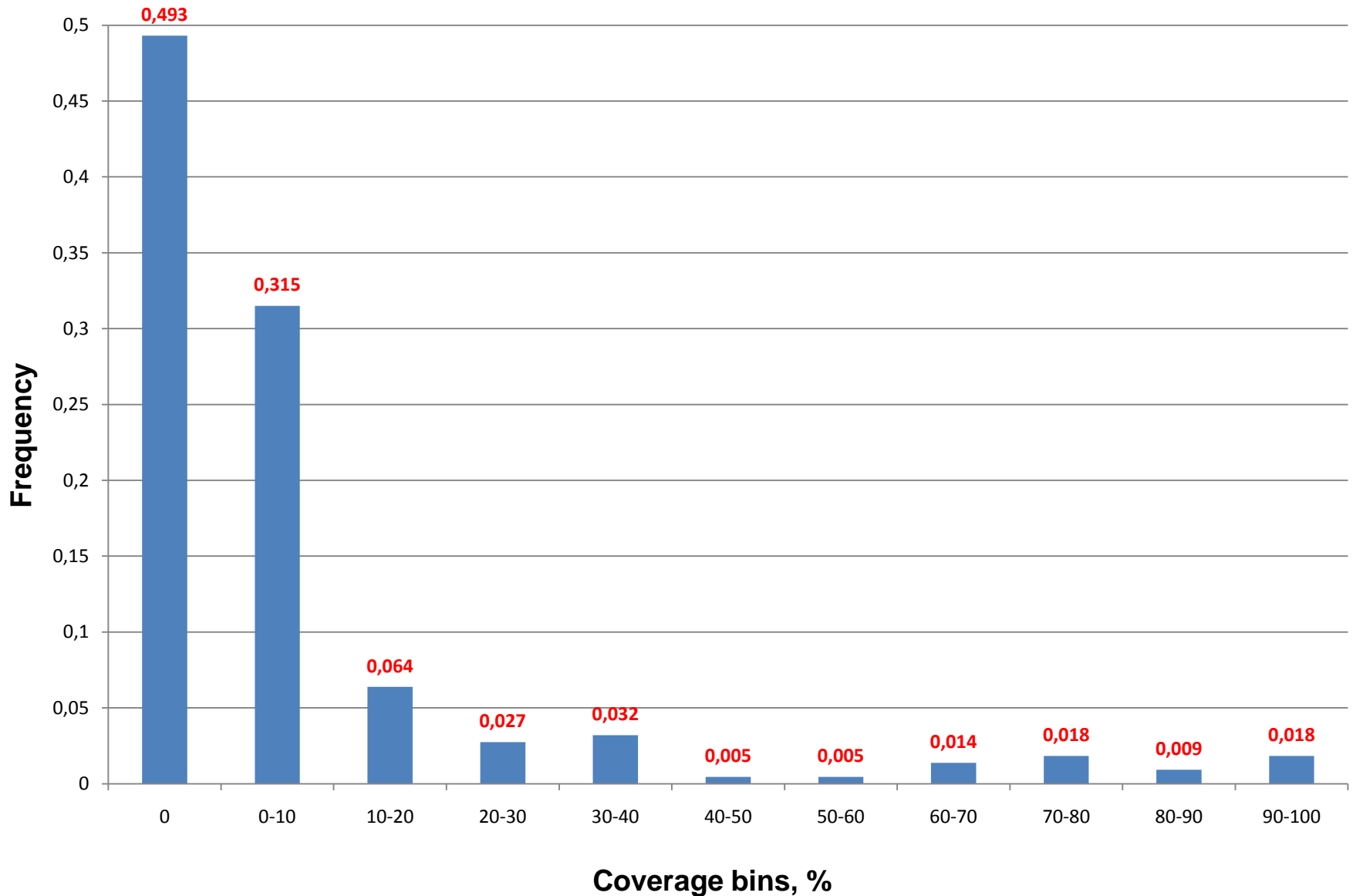
The study area ($\sim 7,100 \text{ km}^2$) - geometrically precision corrected SPOT5 (4 bands, 10m resolution) (from June 2005) covering the winter grazing lands in Vilhelmina Norra, Northern Sweden

All images were haze- and topographically corrected using a highly automated production line (MUNIN) primarily developed for the CORINE/SMD forest classification.

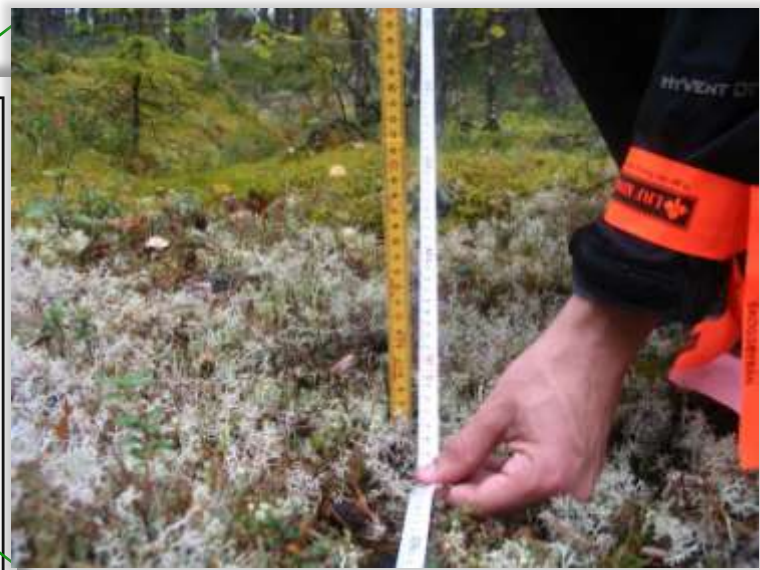
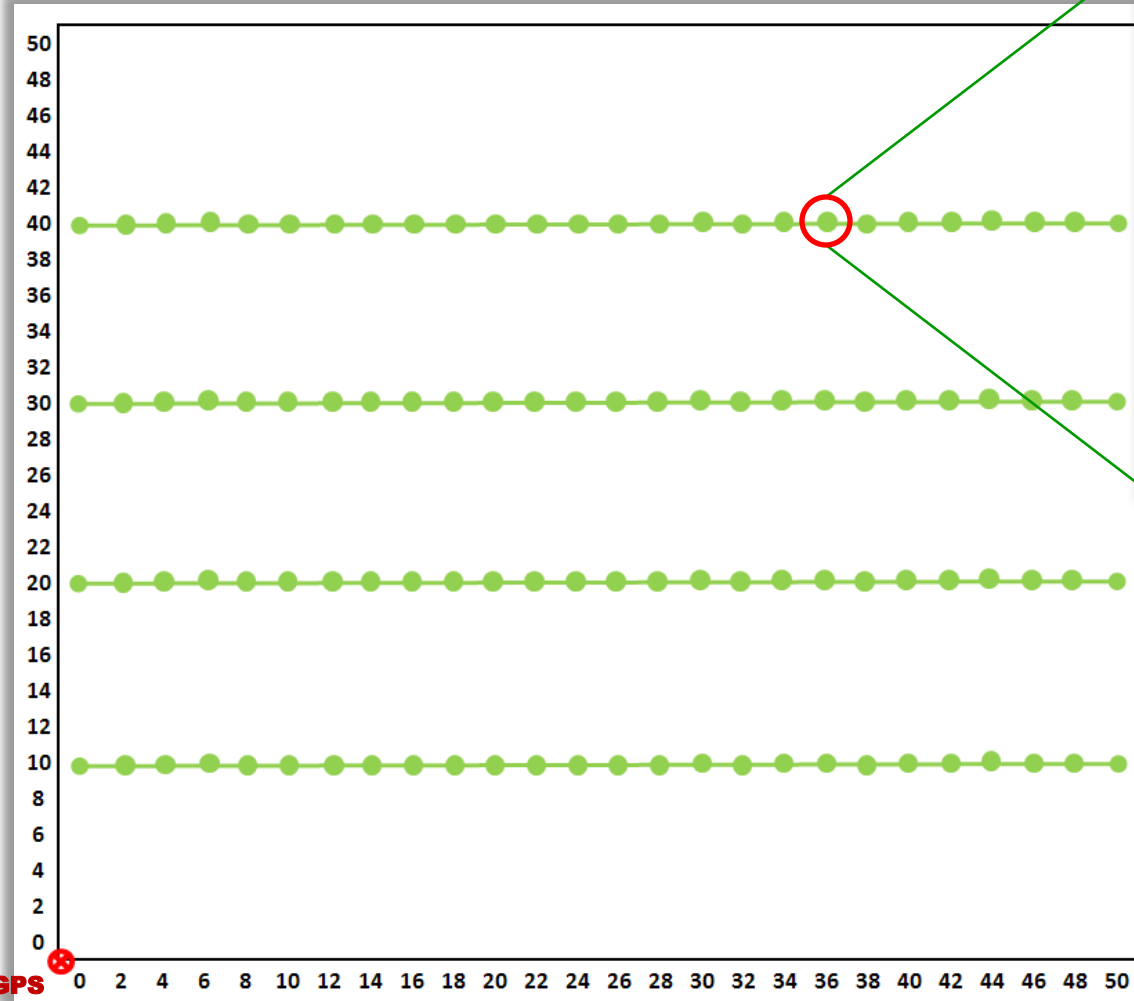
- Time period: last decade (1996-2005)
- 943 NFI plots have been chosen within the study area
- All chosen plots have a radius of 10 meters
- 63 plots of lichen type (6.7%),
- 72 plots of lichen rich type (7.6%)
- 808 plots of moss type (85.7%).



Frequency distribution of lichens coverage in the study area (Soil Inventory)

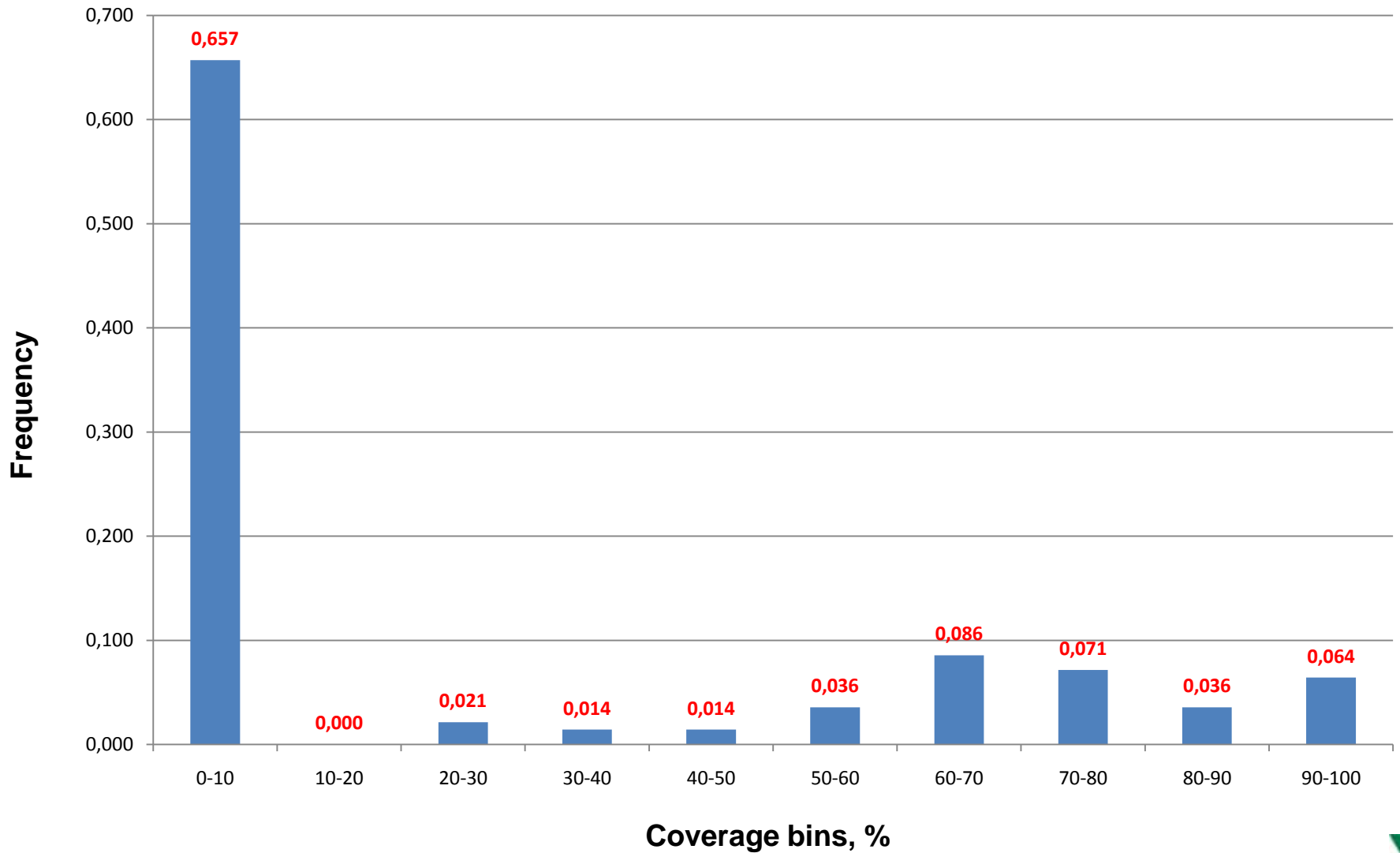


Field lichens inventory (2006 - 2007)



- Precise location of south west point of the plot (GPS)
- Estimation of forest parameters (dominating tree species, last clear cut, vegetation layers etc)
- Systematic measurements of lichens height (cm)
- Moss presence (Yes/No)

Frequency distribution of lichens coverage (Field data, 2007)



Field data survey (2007)

Lichen type (>50% of plot coverage), 40 plots



Moss type (<25% of plot coverage), 93 plots

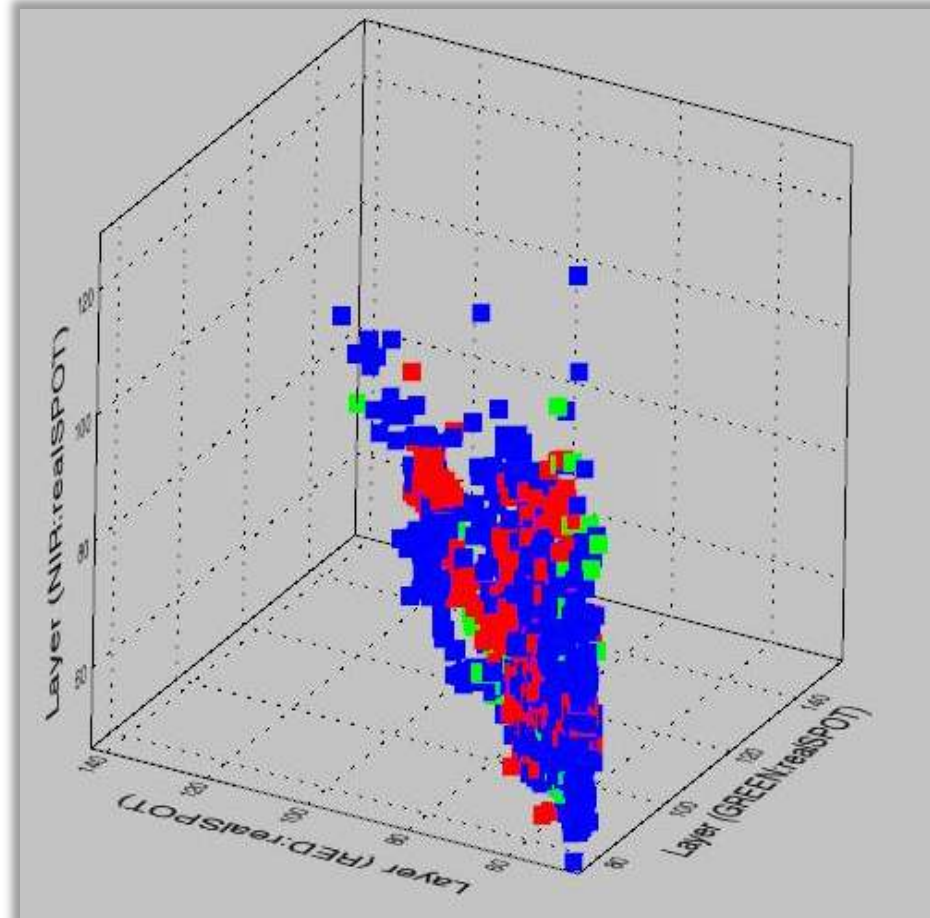
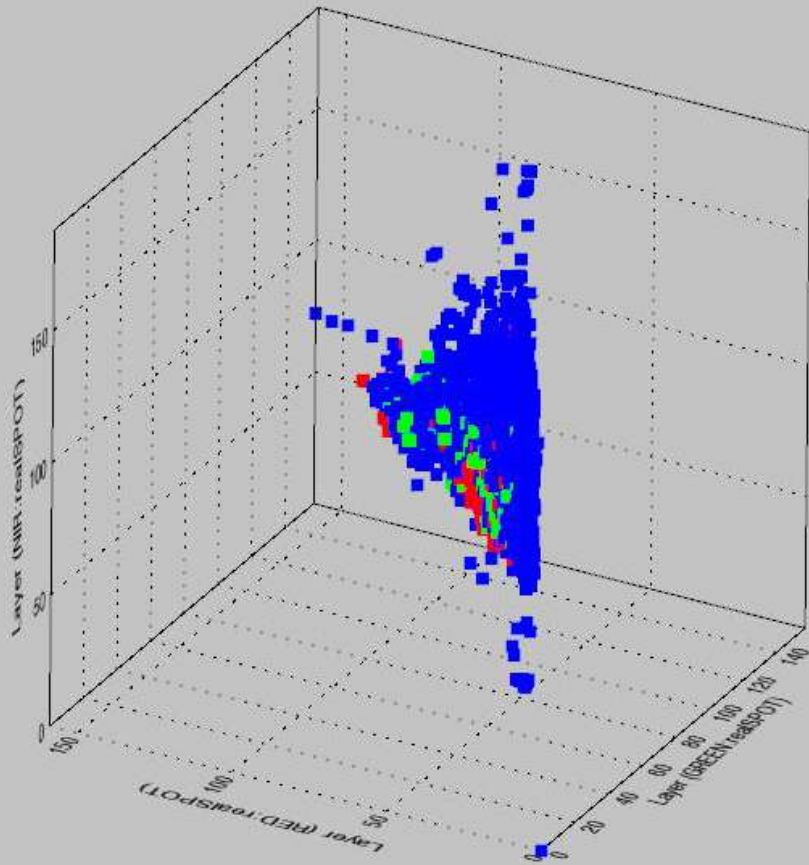


Lichen rich type (25%-50% of plot coverage), 7 plots (!!!)

The visualization of lichen training data in 3D image space

NFI (1996 - 2006)

Field data (2007)

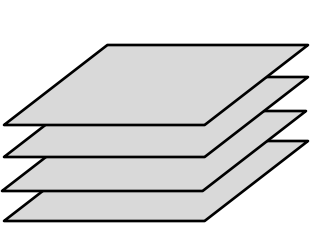


■ Lichen type

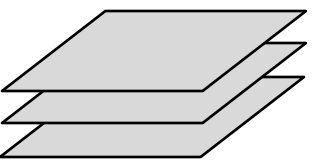
■ Lichen rich type

■ Moss type

Transformation of spectral data and separability test of training sets



Original SPOT5 bands:
 Green [1],
 Red [2],
 NIR [3],
 SWIR [4]



Processed bands:
 PC1 [5]
 PC2 [6]
 NDVI [7]

Number of combinations:

$$C = \frac{B!}{N!(B-N)!}$$

$$\frac{7!}{2!(7-2)!} = \frac{5040}{2 * 120} = 21$$

C is possible bands combination,
 B is a number of all available input bands
 N is a number of bands in the combination

	2-Bands Combinations	JM distance	3-Bands Combinations	JM distance	4-Bands Combinations	JM distance	5-Bands Combinations	JM distance
1	12	0.21	123	0.40	1234	0.49	12346	1.73
2	13	0.36	124	0.37	1235	0.48	23456	1.75
3	14	0.24	125	0.36	1236	0.50	23467	1.78
4	15	0.23	126	0.38	1237	0.69		
5	16	0.32	127	0.39	1245	1.00		
6	17	0.35	134	0.37	1246	0.49		
7	23	0.35	135	0.45	1247	0.51		
8	24	0.29	136	0.44	1256	0.49		
9	25	0.29	137	0.58	1257	0.50		
10	26	0.32	145	0.86	1267	0.54		
11	27	0.35	146	0.45	1345	1.00		
12	34	0.32	147	0.46	1346	0.49		
13	35	0.31	156	0.44	1347	0.70		
14	36	0.34	157	0.46	1356	0.50		
15	37	0.40	167	0.47	1357	0.70		
16	45	0.17	234	0.44	1367	0.72		
17	46	0.34	235	0.44	1456	0.99		
18	47	0.36	236	0.45	1457	1.00		
19	56	0.34	237	0.65	1467	0.76		
20	57	0.35	245	0.53	1567	0.76		
21	67	0.42	246	0.45	2345	0.71		
22			247	0.46	2346	1.72		
23			256	0.45	2347	0.74		
24			257	0.46	2356	0.96		
25			267	0.46	2357	0.73		
26			345	0.39	2367	0.74		
27			346	0.44	2456	0.72		
28			347	0.42	2457	0.71		
29			356	0.42	2467	0.75		
30			357	0.43	2567	0.76		
31			367	0.50	3456	0.68		
32			456	0.40	3457	0.78		
33			457	0.45	3467	0.75		
34			467	0.54	3567	0.72		
35			567	0.56	4567	0.80		

The Jeffries-Matusita (JM) distance have been calculated for every pair of spectral classes and most lichens-sensitive 5-bands combination [23467] have been selected for classification



Separability of training data

SPOT

Separability test of continuously estimated training classes (from Soil Inventory)

	Lichen type	Lichen rich type	Moss type
Lichen type			
Lichen rich type	0.811		
Moss type	1.913	1.909	

Separability test of discrete estimated training classes (from NFI)

	Lichen type	Lichen rich type	Moss type
Lichen type			
Lichen rich type	0.589		
Moss type	1.778	1.737	

Separability test of continuously estimated training classes (Field data)

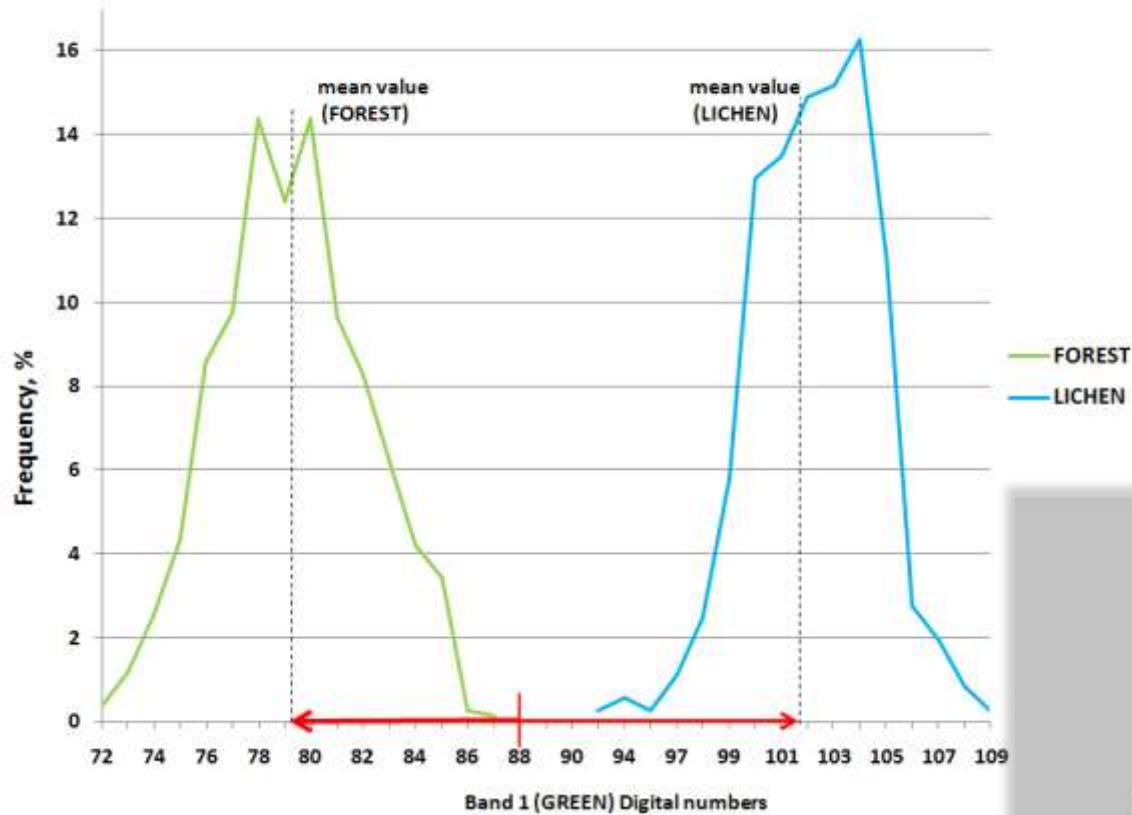
	Lichen type	Lichen rich type	Moss type
Lichen type			
Lichen rich type	1.962		
Moss type	1.967	1.316	

Classification of remotely sensed data

- **Using NFI lichen classification scheme: moss type, lichen rich type and lichen type**
- **Using parametric (maximum likelihood, mahalanobis distance) and non-parametric classifiers (decision trees)**
- **Accuracy assesment by field data (confusion matrix)**

Parametric classification (maximum likelihood, mahalanobis distance)

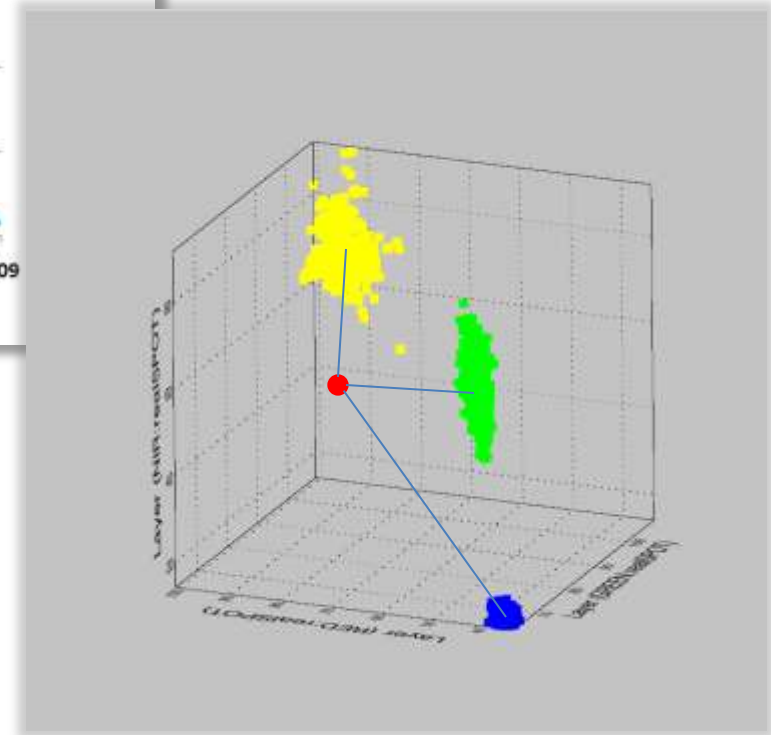
Simplified maximum likelihood



The Mahalanobis distance classification is a direction-sensitive distance classifier that uses statistics for each class and assumes all class covariances are equal

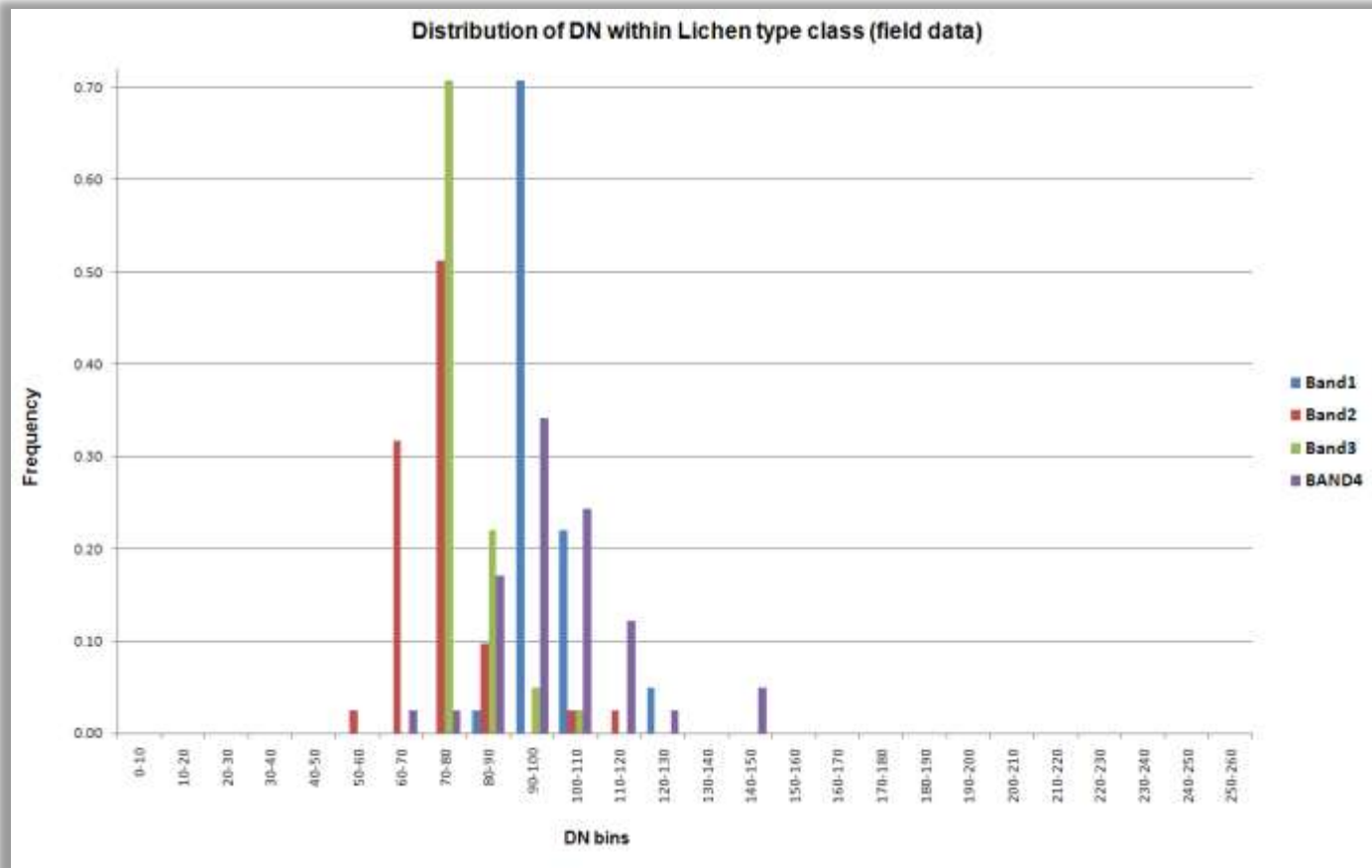


Simplified mahalanobis distance

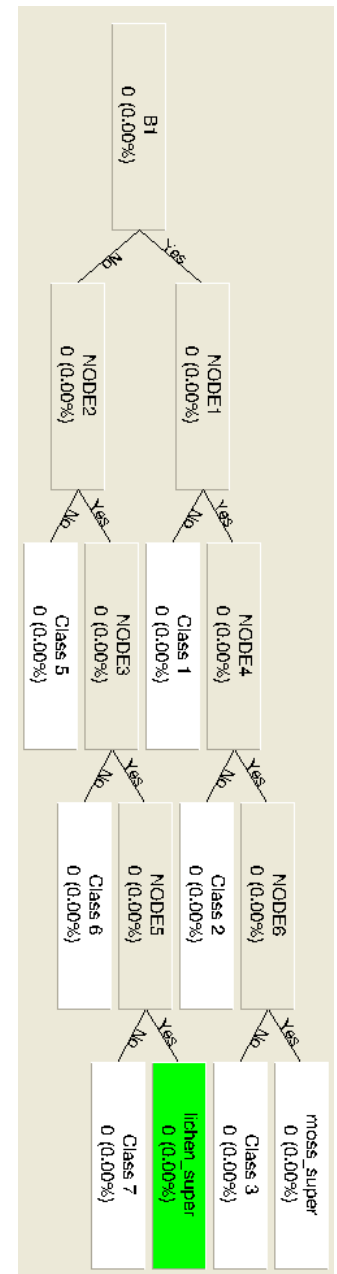


Maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class.

Non-parametric classification (decision trees)



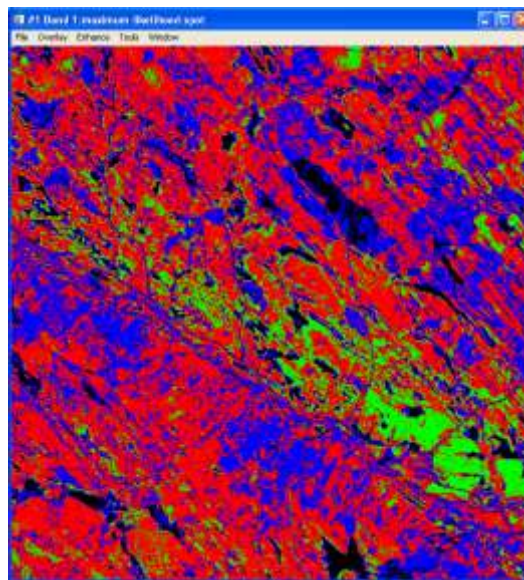
	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140
Band1									
Band2									
Band3									
Band4									



Sample results of lichen coverage in Vilhelmina Norra herding community, accordingly to NFI training data

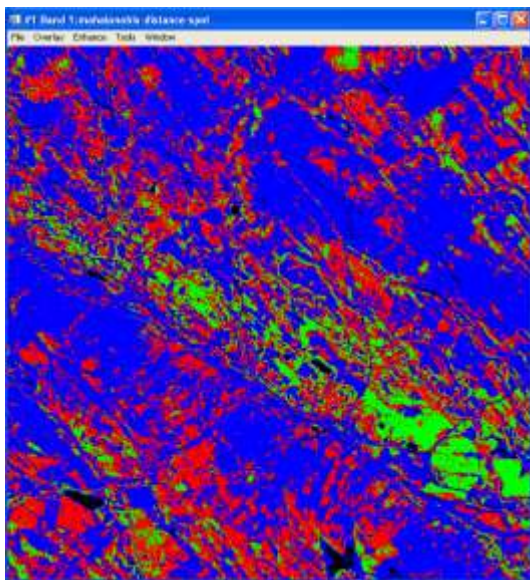


Original Image:
Red, NIR, MIR



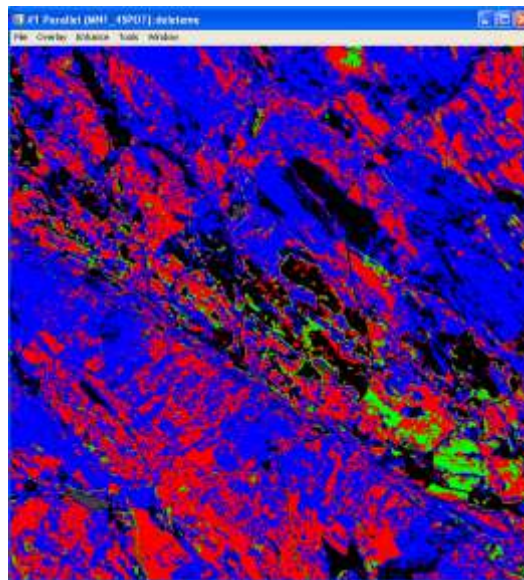
Decision tree
classification

Overall
accuracy:71%



Mahalanobis
distance
classification

Overall
accuracy:78%



Maximum
likelihood
classification

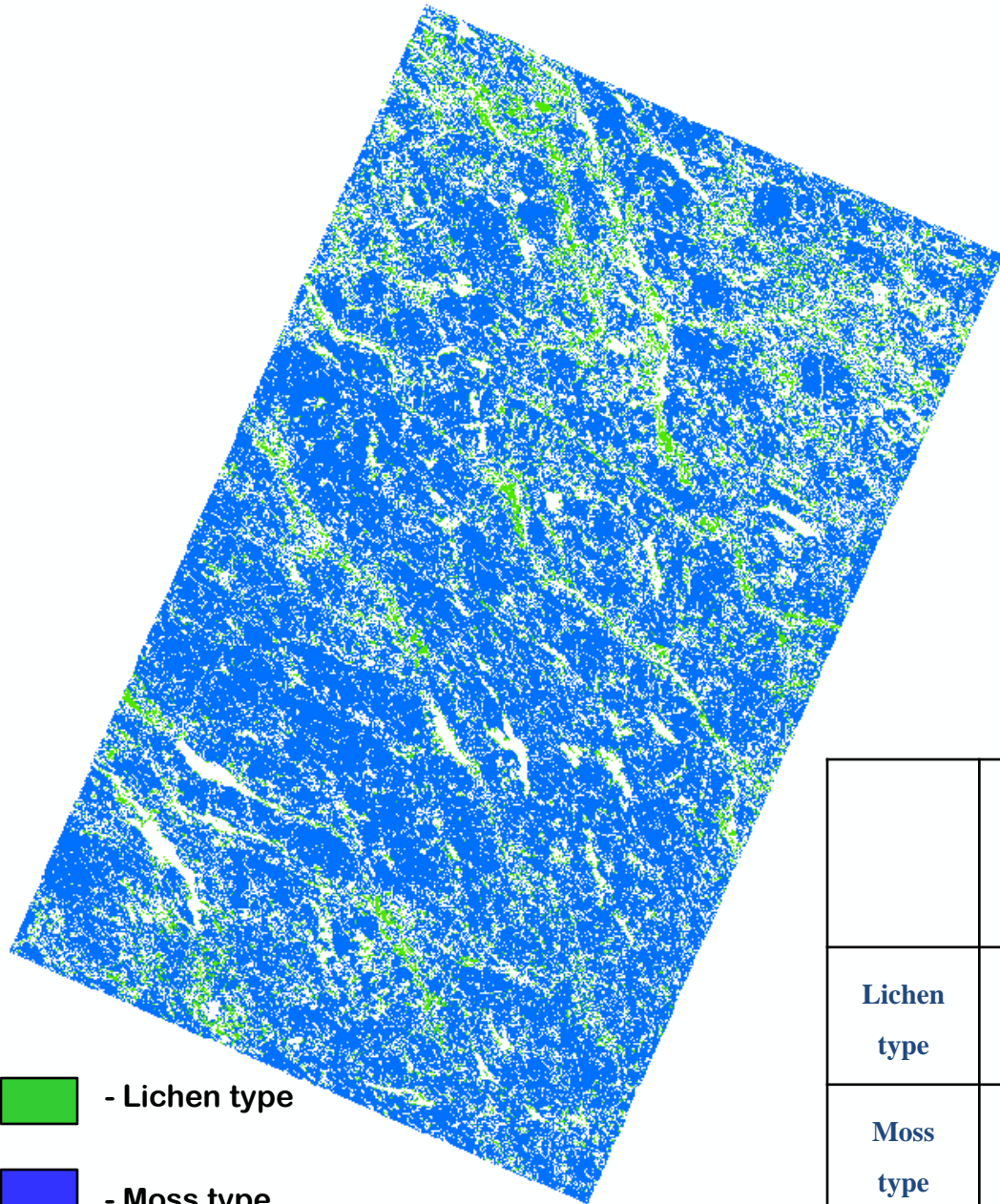
Overall
accuracy:73%

 - Lichen type

 - Lychen rich type

 - Moss type

Mahalanobis distance discriminating of lichen type and moss type areas



Overall accuracy: 81.4%

Kappa=0.73

	Commission, %	Omission, %	Producer accuracy, %	User accuracy, %
Lichen type	20.66	16.27	83.73	79.34
Moss type	12.54	21.82	78.18	87.46

Conclusion and further research

- The study has approved the effectiveness of lichen-related data from NFI database for estimating fraction of lichen coverage in large boreal areas
- The NFI-based approach to lichens classification provides realistic results for practical issues of reindeer management than spectrally-based methods
- Only areas with lichens coverage more than 50% of bottom layer vegetation, gave the reliable classification results
- Heterogeneity and insignificant amount of the field data not allows to provide the reliable classification for lichen rich type class.
- Exploitation of additional NFI embedded data might contribute to improve the classification accuracy of lichen sub-classes. The most possible sources of ancillary data that might be useful are: soil maps, digital elevation models, and additional thematic data from the NFI.
- Test of additional available sources of multispectral information
- Modelling of lichen coverage and biomass by environmental parameters